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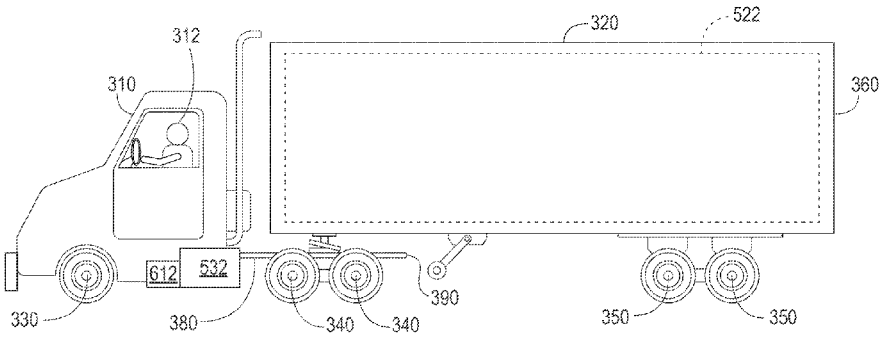

FIG. 3

(57) **Abstract:** According to one aspect, generating axle weight and load distribution value estimates may include receiving a pressure associated with an air-ride suspension of a drive axle of a vehicle or a trailer axle of the vehicle, receiving vehicle information associated with a characteristic of the vehicle, receiving load information associated with a load of the vehicle, and calculating a weight value estimate including at least one of a gross weight of the vehicle, a single-axle weight for the vehicle, or a tandem-axle weight for the vehicle or a load distribution value estimate based on the pressure, the vehicle information, and the load information.

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LOAD DISTRIBUTION IN TRUCKING TRANSPORTATION AND CONTROL OF PARAMETERS OF CARGO INSIDE TRAILERS

CROSS-REFERENCE TO RELATED APPLICATIONS

[0001] This application claims priority to U.S. Provisional Pat. App. Ser. No. 63/519,442, filed on August 14, 2023, entitled "SYSTEM AND METHOD FOR CALCULATING THE WEIGHT ON ALL AXLES OF A TRUCK AND TRAILER PROVIDED WITH AN AIR SUSPENSION, THE WEIGHT OF CARGO IN THE TRAILER, AND FOR PREDICTING CHANGES IN LOAD DISTRIBUTION WHEN MOVING THE FIFTH WHEEL, TRAILER TANDEM, OR POSSIBLE REFUELING", the entirety of which is hereby incorporated by reference.

BACKGROUND OF INVENTION

[0002] In the United States and in other countries, there are regulations that limit the amount of weight that can be transported by a truck and/or trailer over roadways. The limits are typically measured as a function of the weight born by each axle. Some trucks and most trailers do not have onboard equipment for accurately determining and managing axle weight. Thus, it is customary in the United States and in other countries for truck drivers to travel to certified scales to measure the axle weight of typical loads. This takes time, and there is a fee associated with the axle weight measurement service. Further, measurements of this type must be done, on average, about once per week.

[0003] Due in part, to the risk of fines for hauling loads in excess of the axle weight limits and, in part, to the lack of accurate real-time axle weight information due to time and cost, trucks and trailers frequently haul less freight than the maximum lawful capacity. This adversely affects profit margins for shippers, drivers, and carriers. It also results in an unnecessary waste of fuel to make additional trips. It is estimated that at least 700,000 tons of diesel fuel are wasted each year in the United States for trips to certified scales to verify this information.

BRIEF SUMMARY OF THE INVENTION

[0004] According to one aspect, a system for generating axle weight and load distribution value estimates may include a memory and a processor. The memory may store one or more instructions and the processor may execute one or more of the instructions stored on the memory to perform one or more acts, actions, and/or steps. For example, the processor may receive load information, pressure or weight associated with an air-ride suspension of a drive axle of a vehicle or a trailer axle of the vehicle, receive vehicle information associated with a characteristic of the vehicle, calculate load information associated with a load of the vehicle, and calculate a weight value estimate including at least one of a gross weight of the vehicle (e.g., with and/or without the trailer), a single-axle weight for the vehicle, or a tandem-axle weight for the vehicle based on the pressure, the vehicle information, and the load information. According to one aspect, a method for generating axle weight and load distribution value estimates may include receiving load information, pressure or weight associated with an air-ride suspension of a drive axle of a vehicle or a trailer axle of the vehicle, receiving vehicle information associated with a characteristic of the vehicle, calculating load information associated with a load of the vehicle, and calculating a weight value estimate including at least one of a gross weight of the vehicle, a single-axle weight for the vehicle, or a tandem-axle weight for the vehicle based on the pressure, the vehicle information, and the load information.

[0005] According to one aspect, a system for generating axle weight and load distribution value estimates may include a memory and a processor. The memory may store one or more instructions and the processor may execute one or more of the instructions stored on the memory to perform one or more acts, actions, and/or steps. For example, the processor may receive a pressure value associated with an air-ride suspension of a drive axle of a vehicle or a trailer axle of the vehicle, receive vehicle information associated with a characteristic of the vehicle, calculate load information associated with a load of the vehicle, and generate a suggested action pertaining to the load or a vehicle configuration based on the pressure value, the vehicle information, and the load information.

[0006] The foregoing and other features of the invention are hereinafter more fully described below, the following description setting forth in detail certain illustrative embodiments of the invention, these being indicative, however, of but a few of the various ways in which the principles of the present invention may be employed.

BRIEF DESCRIPTION OF THE DRAWINGS

[0007] FIG. 1 is an exemplary component diagram of a system for generating axle weight and load distribution value estimates, according to one aspect.

[0008] FIG. 2 is an exemplary flow diagram of a method for generating axle weight and load distribution value estimates, according to one aspect.

[0009] FIG. 3 is an exemplary schematic side view of a vehicle and a semi-trailer on which the system and method for generating axle weight and load distribution value estimates may be implemented, according to one aspect.

[0010] FIG. 4 is an exemplary schematic bottom plan view of the vehicle and the semi-trailer of FIG. 3, according to one aspect.

[0011] FIG. 5 is an illustration of an example computing environment where one or more of the provisions set forth herein are implemented, according to one aspect.

[0012] FIG. 6 is an illustration of an example computer-readable medium or computer-readable device including processor-executable instructions configured to embody one or more of the provisions set forth herein, according to one aspect.

DETAILED DESCRIPTION OF THE INVENTION

[0013] The present invention advantageously unites seven important variable parameters and constants of trucks and trailers. All existing scales using not more than three variable parameters and are thus only able to provide up to four simple results about the weight. With the use of the present invention and the electronic devices disclosed herein, it is possible to obtain twenty-five results regarding weight of truck, trailer and cargo. This application explains how the information is acquired and the calculations that are made to obtain this information, and provides a preferred implementation.

[0014] U.S. Pat. No. 8,424,892 B2 is hereby incorporated by reference in its entirety. U.S. Pat. No. 8,424,892 B2 discloses and teaches the use of air fittings such as Schrader valves in the air-ride suspension system of a vehicle. Schrader valves are usually covered with a cap, which must be removed before a hand-held pressure gauge is used to measure the pressure at the valve. The installation may include use of valves in the air-ride suspension of a vehicle, which do not require removal of a cap in order to permit measurement of air pressures using a hand-held gauge. Suitable valves include, but are not limited to, double seal valve caps under the DS-1 designation. Use of a valve that permits a pressure measurement to be rapidly made without removal of a cap provides the benefit of quick access while still protecting the valve from snow, ice, and salt.

[0015] This disclosure provides improvements in the technical field of determining axle weight and load distribution for vehicles, such as a tractor towing a semi-trailer, for example. Information associated with a pressure associated with an air-ride suspension of an axle of a vehicle, vehicle information, and load information may be received by a software application operating on a smartphone, tablet, electronic plug-in device, GPS navigator, on-board truck computer or computer (e.g., the system for generating axle weight and load distribution value estimates) and processed to provide approximate axle weight information to drivers or operators of the vehicle when needed. This enables drivers to pick up additional loads, which improves profit margins and saves fuel and energy. It is no longer necessary for drivers to drive a vehicle or pull a trailer that has available space and is below the maximum axle weight limits. Additionally, the disclosure reduces the need of a driver to visit a certified scale to determine whether the weight on the axles of a loaded trailer permits or prohibits picking up additional loads without exceeding legal limits. Furthermore, the disclosure provides drivers with additional information including, but not limited to, explanations, media, video lessons, or text, which shows the driver exactly how to manage axle weight for a particular load and achieve maximum lawful capacity.

[0016] There are many factors that affect the weight on an axle (e.g., the amount of fuel in the tanks, the location of the fuel tanks relative to the axles, the amount and location of diesel emission fluid (DEF), the weight of a fifth wheel, if present, and the

weight of the front portion of the trailer that is supported by the fifth wheel of the vehicle, the location of the fifth wheel and trailer tandems and the distance they can be adjusted, the weight of the driver and any passengers, the weight and location of additional equipment, and the weight and center of gravity of the load(s), etc.). These factors are unique to each vehicle (e.g., there is no standard that applies to every vehicle).

[0017] In accordance with the disclosure, after performing a calibration, the software application operating on the smartphone, tablet, or computer , may determine the weight of various physical objects and their respective position/location on the particular vehicle and/or trailer with reasonably sufficient accuracy. The software application may calculate coefficients of weight distribution for such physical objects and locations. Furthermore, measurements of distances between physical objects on or associated with the vehicle or trailer allow for more useful real-time information for drivers and carriers.

[0018] It may be more cost-effective to measure the pressure in an air-ride suspension and calculate weight, as opposed to spending the money to install an onboard scale on each vehicle and trailer or as opposed to spending the money to travel to a scale and pay for a weight determination. The use of the system for generating axle weight and load distribution value estimates is advantageous because it allows a driver to make far fewer periodic controlled weightings, but instead may update the parameters associated with the air-ride suspension for the system to improve accuracy.

[0019] Further, a smartphone, tablet, electronic log-in device ("ELD"), global positioning system ("GPS") navigator, on-board truck computer and/or computer may store and share information via an internet connection regarding various vehicle parameters and trailer parameters. This allows for machine learning, where a wide range of users contribute to an improving accuracy in parameters used to make the calculations. It will be appreciated that it may be desired to perform controlled weightings and pressure measurements (e.g., recalibration) after repair work is conducted on the air-ride suspension to correct/adjust the parameters of linear dependence between pressure and weight.

[0020] The following includes definitions of selected terms employed herein. The definitions include various examples and/or forms of components that fall within the scope of a term and that may be used for implementation. The examples are not intended to be limiting. Further, one having ordinary skill in the art will appreciate that the components discussed herein, may be combined, omitted, or organized with other components or organized into different architectures.

[0021] A "processor", as used herein, processes signals and performs general computing and arithmetic functions. Signals processed by the processor may include digital signals, data signals, computer instructions, processor instructions, messages, a bit, a bit stream, or other means that may be received, transmitted, and/or detected. Generally, the processor may be a variety of various processors including multiple single and multicore processors and co-processors and other multiple single and multicore processor and co-processor architectures. The processor may include various modules to execute various functions.

[0022] A "memory", as used herein, may include volatile memory and/or non-volatile memory. Non-volatile memory may include, for example, ROM (read only memory), PROM (programmable read only memory), EPROM (erasable PROM), and EEPROM (electrically erasable PROM). Volatile memory may include, for example, RAM (random access memory), synchronous RAM (SRAM), dynamic RAM (DRAM), synchronous DRAM (SDRAM), double data rate SDRAM (DDRSDRAM), and direct RAM bus RAM (DRRAM). The memory may store an operating system that controls or allocates resources of a computing device.

[0023] A "drive" or "disk", as used herein, may be a magnetic disk drive, a solid-state disk drive, a floppy disk drive, a tape drive, a Zip drive, a flash memory card, and/or a memory stick. Furthermore, the disk may be a CD-ROM (compact disk ROM), a CD recordable drive (CD-R drive), a CD rewritable drive (CD-RW drive), and/or a digital video ROM drive (DVD-ROM). The disk may store an operating system that controls or allocates resources of a computing device.

[0024] A "bus", as used herein, refers to an interconnected architecture that is operably connected to other computer components inside a computer or between computers. The bus may transfer data between the computer components. The bus

may be a memory bus, a memory controller, a peripheral bus, an external bus, a crossbar switch, and/or a local bus, among others. The bus may also be a vehicle bus that interconnects components inside a vehicle using protocols such as Media Oriented Systems Transport (MOST), Controller Area network (CAN), Local Interconnect Network (LIN), among others.

[0025] An "operable connection", or a connection by which entities are "operably connected", is one in which signals, physical communications, and/or logical communications may be sent and/or received. An operable connection may include a wireless interface, a physical interface, a data interface, and/or an electrical interface.

[0026] A "computer communication", as used herein, refers to a communication between two or more computing devices (e.g., computer, personal digital assistant, cellular telephone, network device) and may be, for example, a network transfer, a file transfer, an applet transfer, an email, a hypertext transfer protocol (HTTP) transfer, and so on. A computer communication may occur across, for example, a wireless system (e.g., IEEE 802.11), an Ethernet system (e.g., IEEE 802.3), a token ring system (e.g., IEEE 802.5), a local area network (LAN), a wide area network (WAN), a point-to-point system, a circuit switching system, a packet switching system, among others.

[0027] A “mobile device”, as used herein, may be a computing device typically having a display screen with a user input (e.g., touch, keyboard) and a processor for computing. Mobile devices include handheld devices, portable electronic devices, smart phones, laptops, tablets, and e-readers.

[0028] A “vehicle”, as used herein, refers to any motor vehicle that is capable of towing a trailer.

[0029] Unless otherwise noted, a line of vehicle movement in a straight direction is an imaginary line on the ground where the vehicle is located, which is perpendicular to the drive axles of the vehicle and is parallel to the direction of movement of the vehicle when driven in a straight line on the wheels of the vehicle. A location of an object on the vehicle is a perpendicular projection of the center of gravity of the object or other described point relative to the line of vehicle movement in a straight up-down direction (e.g., the z-axis). A distance between the two locations on the vehicle is a linear

distance between their projections on the line of vehicle movement (e.g., on the ground plane associated with the x-axis and the y-axis) in the straight direction.

[0030] FIG. 1 is an exemplary component diagram of a system 100 for generating axle weight and load distribution value estimates, according to one aspect. The system 100 for generating axle weight and load distribution value estimates may include a processor 102, a memory 104, a storage drive 106, a communication interface 108, an output device (e.g., including a display, a speaker, etc.), and a bus 112. The bus 112 communicatively couples respective components (e.g., processor 102, memory 104, storage drive 106, communication interface 108) of the system and enables computer communication between respective components (e.g., processor 102, memory 104, storage drive 106, communication interface 108) of the system and external components (e.g., sensors 152). The system 100 for generating axle weight and load distribution value estimates may receive measurements from a vehicle 310 (e.g., either by manual input or automatically, via sensors 152 and wired and/or wireless communication). In any event, the vehicle 310 may include one or more sensors 152, one or more axles, such as a steering axle 330, a drive axle 340, etc. Additionally, the vehicle 310 may be coupled to a trailer 320. The trailer 320 may include one or more trailer axle(s) 350 and be utilized to carry a load 522 (e.g., cargo, object, etc.).

AIR-RIDE SUSPENSION PRESSURE

[0031] The pressure associated with the air-ride suspension of an axle (e.g., the drive axle 340 of the vehicle 310 or the trailer axle 350 of the vehicle 310) is generally considered to be correlated to a weight on the axle. For example, it is known from Hapyuk et al., U.S. Patent No. 8,424,892 B2, that there is a relationship between the pressure in an air-ride suspension of a truck or trailer and the weight on the axles. Air pressure measurements may be made at various locations within the air-ride suspension of a truck or trailer using handheld pressure gauges, built-in pressure gauges (particularly for the drive axle 340) and/or pressure sensors (wired and/or wireless). In addition, wireless onboard scales may obtain this information.

[0032] According to one aspect, one or more of the sensors 152 may measure the pressure associated with the air-ride suspension of the drive axle 340 or the trailer axle

350 of the vehicle 310, the height of the suspension, etc. and the communication interface 108 may, by wire, or more preferably, wirelessly (e.g., via a wireless network, Bluetooth ®, short range communication, etc.) receive the pressure associated with the air-ride suspension of the drive axle 340 or the trailer axle 350 of the vehicle 310 and pass the pressure value to the processor 102. The sensors 152 may also detect other data, such as the fuel level, the DEF level, etc. Additionally, the sensors 152 may transmit any sensed information to an electronic logging device (ELD).

[0033] A driver may use various methods to get the weight of the axle or the pressure associated with the air-ride suspension to be used by the processor 102 to calculate results set forth herein based on the formulas described herein. According to one aspect, drivers may use hand-held pressure gauges, built-in pressure gauges, wired and/or wireless pressure sensors, on-board scales, on ground scales and combinations of the foregoing. According to one aspect, the driver may use a hand-held gauge, and take the air pressure measurements in the air-ride suspension via valves that do not require the removal of a cap and input these pressures manually onto the system 100 for generating axle weight and load distribution value estimates via the communication interface 108 (e.g., which may include a touchscreen display, a keypad, etc.).

[0034] Further, the markings on the hand-held pressure gauge may measure the height of components of the air-ride suspension, which may help determine whether recalibration is necessary or whether the working level of the air-ride suspension is too high or too low.

[0035] The memory 104 may store one or more instructions and the processor 102 may execute one or more of the instructions stored on the memory 104 to perform one or more acts, actions, and/or steps. For example, the processor 102 may receive a pressure associated with an air-ride suspension of an axle of the vehicle 310, such as the drive axle 340 or the trailer axle 350 of the vehicle 310. The processor 102 may receive vehicle information associated with a characteristic of the vehicle 310. The processor 102 may receive load information associated with a load of the vehicle 310.

VEHICLE INFORMATION

[0036] The vehicle information associated with the characteristic of the vehicle 310 may include at least one of a dimension associated with the vehicle 310, a dimension associated with a component of the vehicle 310, a dimension associated with the trailer 320 coupled to the vehicle 310, or a position associated with the component of the vehicle 310 (e.g., the position and dimensions of the axles of the vehicle 310 and/or the trailer 320, position and dimensions of fuel tanks, DEF tanks, etc., a height of the air-ride suspension, etc.). Examples of components of the vehicle 310 may include a fuel tank, a DEF tank, a fifth wheel, a volume of fuel in the fuel tank, etc.

LOAD INFORMATION

[0037] The load information may include at least one of a position of a load (e.g., which may be cargo, a passenger, fuel in the fuel tank, DEF in the DEF tank, a component of the vehicle such as the fifth wheel, etc.), a weight of the load, a dimension associated with the load, or a distance from a portion of the vehicle 310 to a center of mass of the load. The load may include at least one of a fuel tank, fuel in the fuel tank, an additive to the fuel in the fuel tank, a passenger, a fifth wheel, or cargo.

COEFFICIENT OF WEIGHT DISTRIBUTION

[0038] The processor 102 may calculate one or more coefficient of weight distributions for one or more objects, loads, or components associated with the vehicle 310. In one implementation, during calibration, weighing with an empty trailer, it is best to put its tandems in the front position so that in the future it is possible to more easily determine the position of the center of mass of the cargo. It is also appropriate to measure the distance between the positions of the fifth wheel pin and the middle between the axles of the tandem trailer, which is in the frontmost position. This measurement can be used to determine the position of the center of mass of the cargo in the trailer. If the trailer is not fully loaded and there is an opportunity to add one or more slots to the driver, it is appropriate to put the trailer tandems in the front position to evenly distribute the load and determine the position of the center of mass of the load in the trailer. In this case, the processor can calculate the weight resting on the fifth wheel

and the weight of the tandem trailer in the forward position. Knowing these parameters for an empty trailer, it is easy to program how much their weight increased under the influence of the weight distribution of the cargo in the trailer. In the latter, the distance between the positions of the fifth wheel and the tandems in the forward position will be preserved, then the processor can easily calculate the position of the center of mass of the cargo in the trailer. This can be very useful for the successful developing of associated transportation when approximate mass of partials and the location of the center of mass are known.

[0039] For example, the coefficient of weight distribution for an object relative to the drive axle 340 of the vehicle 310 may be calculated as:

$$K = \frac{dist}{base}$$

where $dist$ is the distance between a location of a center of a tire or wheel on the steering axle 330 (in a straight orientation or position) and a location of a center of gravity of an object (e.g., a load) or described point measured on the line of vehicle movement in a straight direction; and

where $base$ is a length of the base of the vehicle 310 (not including the trailer 320). The projection of a distance between the center of the front wheel and the middle between the drive axle(s) 340 to the line of vehicle movement in the straight direction.

[0040] A distance from the center of the tire or wheel on the steering axle 330 to the center of gravity of the fuel in fuel tanks of the vehicle 310 may be calculated by the processor 102 as:

$$x = (ca + eb)/(a + b)$$

where:

a is a length of a fuel tank on a driver side of the vehicle 310;

b is a length of the fuel tank on a passenger side of the vehicle 310;

c is a projection of distance between the center of the front wheel and the middle of the length of the fuel tank located on the driver side of the vehicle 310 to the line of vehicle movement in the straight direction; and

e is a projection of distance between the center of the front wheel and the middle of the length of the fuel tank located on the passenger side to the line of vehicle movement in the straight direction.

[0041] The coefficient for the fuel weight distribution for the vehicle 310 may be calculated by the processor 102 as:

$$K(fuel) = \frac{x}{base}$$

[0042] The coefficient for the distribution of weight of DEF, when present, may be calculated by the processor 102 as:

$$K(DEF) = \frac{y}{base}$$

where y is a projection of a distance between a center of the front wheel and a center of gravity of the DEF (e.g., middle of the length of the DEF tank) to the line of vehicle movement in the straight direction.

[0043] The coefficients for passengers are calculated by the processor 102 as:

$$K(passengers) = \frac{z}{base}$$

where z is the distance between a center of the front wheel and a center of gravity of the person or passenger in the driver seat on the line of vehicle movement in the straight direction.

[0044] The coefficient of weight distributed for the fifth wheel in a position n of a number of positions may be calculated by the processor 102 as:

$$K(n) = \frac{p(n)}{base}$$

where n is a number of available holes or positions for sliding of the fifth wheel between a cab and the first sliding pin of the corresponding position; and

where $p(n)$ is a distance between the locations of the center of the front wheel and a center of the pin that holding of the weight of the fifth wheel in the nth-position of the fifth wheel measured on the line of vehicle movement in the straight direction.

[0045] In this regard, all numbers $p(n)$ form an arithmetic sequence because $p(n) = p(0) + n * d$, where d is the shortest step (e.g., distance) for sliding of the fifth wheel. Thus, the following formula is derived:

$$K(n) = \frac{p(n)}{base} = \frac{(p(0) + n * d)}{base} = K(0) + n * \frac{d}{base}$$

[0046] Thus, $K(n)$ is also a member of other arithmetic sequences with a step of $\frac{d}{base}$. If a user measures the distance d and $base$ and the user estimates any of the coefficients $K(n)$, the system 100 for generating axle weight and load distribution value estimates may determine the coefficient of weight distribution for any and/or all positions of the fifth wheel. This enables an easy calculation for the coefficient of weight distribution for any position of the fifth wheel. The coefficient of the weight distribution for the particular position of the fifth wheel may be estimated by measuring of the axle weight by the processor 102 as:

$$K(n) = (m1 - m2)/(M1 - M2)$$

where $(M1 - M2)$ is the difference in weight placed on (e.g., borne by) the fifth wheel during two weighing operations, and $(m1 - m2)$ is the difference of the weight measured on the drive axle for the two different weights (different

loads or removed partial loads) during the two different weighing operations (all parameters - fuel load, weight of driver etc. being the same).

CALIBRATION

[0047] According to one aspect, a first weighing operation may be done with an empty trailer (e.g., the weight of the vehicle 310 with full tanks of fuel (and DEF, if appropriate) with an empty trailer 320. The trailer tandems need to be in the front position. A second weighing operation may be done shortly thereafter with a loaded trailer (e.g., with a heavy load) to determine the coefficients of the weight distribution for one or more positions of the fifth wheel. A third weighing operation may be done for the vehicle 310 without a trailer 320 with full tanks of fuel (and DEF, if appropriate). As discussed herein, the first weighing operation may be referred to as a calibration and any results associated with the calibration may be stored on the storage drive 106 for easy or quick access and computation of any of the weight value estimates, load distribution value estimates, suggested actions, etc. For accurate results, other weight factors may be held the same or maintained (e.g., the top level of DEF, the top level of fuel in the fuel tanks of the vehicle 310, the top level of fuel in a fuel tank on the trailer, the weight of the driver and the passenger, etc.) when the three weighing operations are conducted.

[0048] During calibration, distances may be measured to facilitate computation of the weight value estimate or load distribution value estimate, such as a length of the $base, a, b, c, e, d, y, z, dist$ and distances between pins for fifth wheel and middle of trailer tandems in front position. Additionally, axle weight measurements obtained at a certified scale, first with the vehicle 310, second with the vehicle 310 and an empty trailer, and third with the vehicle 310 and the loaded trailer may be utilized as a ground truth or a reference in any of the equations discussed herein. Further, the configuration or position of the fifth wheel, weights of passengers and/or drivers, total capacity of fuel tanks on the vehicle 310, DEF tank capacity, base length, the length and position of the fuel tank(s) on the vehicle 310, the length and position of the DEF tank(s), distances between fifth wheel positions, the distance between holes to move the tandem of the trailer 320, the coefficient of distribution of the weight that leaning on the fifth wheel for a

single position of the fifth wheel, the ideal weight of the front axle and drive axle(s) 340 with full fuel tanks and DEF may be calculated by the processor 102 by subtraction influence of the load on the fifth wheel, trailer weight without load, etc. may be provided as an input during the calibration.

WEIGHT VALUE ESTIMATE

[0049] According to one aspect, the processor 102 may calculate a weight value including at least one of a gross weight of the vehicle 310, a single-axle weight for the vehicle 310, or a tandem-axle weight for the vehicle 310 based on the pressure, the vehicle information, the load information, and/or corresponding coefficient of weight distributions. The processor 102 may determine a legal limit determination of whether the weight value is in accordance with a legal limit and notify a user of the legal limit determination. For example, the processor 102 may receive a GPS location of the vehicle's current location, destination information, etc. to determine the legal limits applicable to the vehicle 310 and ensure compliance with all legal limits associated with the route. The processor 102 may generate different types of suggested actions based on the legal limit determination and/or the pressure, the vehicle information, and the load information.

[0050] The suggestions or suggested actions may be determined by the processor 102 based on the legal limit (e.g., as a given or as an input), one or more inputs (e.g., the pressure associated with the air-ride suspension at one of the axles, the vehicle information, and the load information), and solving one or more of the equations described herein based on a change in position for one of the loads, a change in configuration for the vehicle fifth wheel positioning, etc. According to one aspect, inputs may be provided automatically or manually via a software application or "app" on a mobile device (e.g., smartphone or other portable device) and outputs may be provided by an output device (e.g., which may be the same mobile device).

[0051] Further, the processor 102 may summarize the influence of each weight factor utilized in the calculation to the axle weight of the vehicle 310 and present (e.g., display notification, text message, email, notify, audio notification, text notification, etc.) useful information about these factors to the driver via the output device. For example,

the processor 102 may calculate the weight that is bearing on the fifth wheel and provide additional information or suggestions (e.g., an estimate of the weight on the steering axle 330 with any type of suspension or weight of the cargo in trailer). Further, the processor 102 may generate or render video guides for the driver of the vehicle 310 demonstrating the suggested actions.

[0052] When the vehicle 310 (e.g., bobtail vehicle or the vehicle 310 without the trailer 320) is weighed on a scale, the weight of each of the drive axles is not equal because of the manner in which the vehicle 310 is constructed. This imbalance also has an influence on the weight attributed to the steering axle 330. Thus, for convenience, the processor 102 may use hypothetical ideal numbers of the base weight for the steering axle 330 and drive axle 340, which predict the equal weight of the drive axle(s) 340 to each other.

[0053] To estimate such parameters, it may be desired to measure an axle weight of the loaded vehicle 310 with full tanks of fuel and DEF (if applicable), and subtract the influence of the weight that is borne on the fifth wheel to the steering axle 330 ($M(steering\ base)$ and drive axle 340 ($M(drive\ base)$) because the coefficient of weight distribution is used for such positions.

[0054] The weight of the front part of the trailer 320 that is bearing on the fifth wheel may be calculated by the processor 102 as:

$$M(front) = (M(dr) - (m(dr.base) - dM(passengers) * K(passengers) - dm(fuel) * K(fuel) - dm(DEF) * K(DEF) + M(fifth) * (n-k) * d/base))/K(n)$$

where:

$M(dr)$ is the weight of the loaded drive axle 340 that may be estimated by linear dependence from pressure readings taken in the air-ride suspension;

$dM(passengers)$ is the difference of the weight of the driver and passenger between calibration (e.g., the first weighing operation) and a current or second weighing operation;

$dm(fuel)$ is the difference of the weight of fuel during the calibration and the second weighing operation;

$dm(DEF)$ is the difference of the weight of DEF during the calibration and the second weighing operation;

$M(fifth)$ is the average weight of the fifth wheel (typically about 300lb);

k is the number for position of the fifth wheel during the calibration; and

n is the number for the current position of the fifth wheel.

[0055] The weight of the steering axle 330 may be estimated by the processor 102 as:

$$M(steering) = M(St.base) + M(front) * (1 - K(n)) - dM(passengers) * (1 - K(passengers)) - dm(fuel) * (1 - K(fuel)) - dm(DEF) * (1 - K(DEF)) - M(fifth) * (n - k) * d/base)$$

[0056] The weight of the drive axle 340 and the trailer axle 350 $M(tr)$ may be estimated by measuring pressure (e.g., from sensors 152) and its correlation with weight.

[0057] The gross weight of the vehicle 310 and trailer may be calculated by the processor 102 as:

$$M(gross) = M(steering) + M(dr) + M(tr)$$

[0058] The calculations performed by the processor 102 may be reported in pounds, kilograms, tons, or any other unit, as desired by the user.

[0059] The processor 102 may calculate the weight of the empty trailer as $M(empty.tr)$.

[0060] The processor 102 may calculate the weight of the vehicle 310 (e.g., bobtail) with any level of fuel, weight of the passengers and position of the fifth wheel as:

$$M(bob) = (m(dr.base) + M(St.base) - dM(passengers) - dm(fuel) - dm(DEF)$$

[0061] The processor 102 may determine the weight of the freight inside the trailer 320 as:

$$M(cargo) = M(gross) - M(bob) - M(empty.tr)$$

[0062] Since the weight of the steering axle 330 may be calculated at any position of the fifth wheel, the processor 102 may determine the optimal front position for the fifth wheel (e.g., by performing calculations for each position and taking the optimal calculation). This information may be utilized to make adjustments (e.g., via the processor 102) in order to distribute the weight of the front part of the trailer 320 so steering axle 330 will be legal even if the fuel tanks are full of fuel and the weight of the drive axle 340 is equal to the legal maximum legal limit. For example, given a load and a set of inputs (e.g., the pressure associated with the air-ride suspension, the vehicle information and the load information), the processor 102 may calculate the weight value estimate and/or the load distribution value estimate based on an assumption that the vehicle fuels from a current fuel level to a full fuel level and/or adds additional DEF, for example. If the weight value estimate and/or the load distribution value estimate is not in accordance with a legal limit, the processor 102 may perform additional calculations based on moving the load around to determine a configuration of the weight value estimate and/or the load distribution value estimate that meets the legal limit. The processor 102 may calculate partial amounts of fuel that may be added to the fuel tanks without causing the vehicle 310 to exceed legal road limits.

[0063] The processor 102 may determine the legal weight capacity of the loaded vehicle 310 and trailer without moving the fifth wheel and adding fuel as:

$$M(cap) = (M(dr.max) - M(dr))/K(fifth) + M(tr.max) - M(tr)$$

where $M(dr.max)$ is the maximum legal weight of the drive axle 340 of the vehicle 310 and $M(tr.max)$ is the maximum legal weight of the trailer axle 350. This formula is particularly suitable when the position of the fifth wheel is not closer to the cab than its optimal position.

[0064] The processor 102 may calculate the portion of the weight of one gallon of fuel is distributed to the drive axle 340 and to steering axle 330 (approximately) using the formulas:

$$Mdr(1\ gallon\ of\ fuel) = 7.1lb * K(fuel)$$
$$Mst(1\ gallon\ of\ fuel) = 7.1lb * (1 - K(fuel))$$

[0065] The processor 102 may provide information to the driver that explains how the weight of the drive axle 340 will change if fuel is added to the fuel tanks as:

$$7.1lb * K(fuel) * r$$

[0066] The processor 102 may provide information to the driver that explains how the weight on the steering axle 330 will be affected if fuel is added to the fuel tanks as:

$$7.1lb * (1 - K(fuel)) * r$$

where r is the number of gallons of fuel that the driver may add to the fuel tank.

[0067] The processor 102 may provide information to the driver that explains how many gallons of fuel (r) may be added to the fuel tanks when the weight reserve $M(dr.reserve)$ is known on the drive axle 340 and how this value may change the weight of steering axle 330 using the formulas:

$$r = M(dr.reserve)/(7.1lb * K(fuel))$$
$$dM(st.reserve) = r * 7.1lb * (1 - K(fuel))$$

[0068] The processor 102 may provide information to the driver that explains how much it will change the weight of the vehicle axles if the fifth wheel will be moved to the distance:

$$dm = \text{distance} * ((M(front) + (\frac{M(fifth)}{base})$$

[0069] The processor 102 may provide information to the driver that regarding the weight of the loaded trailer as:

$$M(loaded\ trailer) = M(gross) - M(bob)$$

[0070] It may be useful for driver to know how many gallons of fuel (r) the driver may add to fill the fuel tanks to the top. The driver may mark on the processor 102 the current level of fuel ($Q\%$) during the weight diagnostic and level during calibration with full tanks $Z\%$. The processor 102 may calculate the total volume of the fuel tanks V, and thus may easily estimate (r) as:

$$R = (Z\% - Q\%) * V$$

[0071] If the driver adds r gallons of fuel to the fuel tanks, the weight of steering axle 330 may be calculated by the processor 102 as:

$$M(\text{steering}\ with\ full\ fuel\ tanks) = M(steering) + r * 7.1lb * (1 - K(fuel)$$

and for drive axle 340:

$$M(drive\ with\ full\ tanks\ of\ fuel) = M(drive) + r * 7.1lb * K(fuel)$$

[0072] The gross weight of the vehicle 310 with trailer may be determined by the processor 102 as:

$$M(gross\ with\ full\ tanks\ of\ fuel) = M(gross) + r * 7.1lb$$

[0073] Since the weight of the front part of the trailer 320 that is bearing on the fifth wheel may be estimated, it may be useful to calculate/determine the maximum weight of the front part of the trailer that the driver may attach to the fifth wheel without exceeding the weight limit for the drive axle 340. The processor 102 may calculate this information as:

$$M(front\ max) = (M(dr.max) - M(dr))/K(n) + M(front)$$

[0074] Moving the axles of the vehicle 310 and trailer improve fuel efficiency by distributing the weight between the drive and trailer axle(s) 350 more evenly. Most vehicle drivers know how much it may change the weight on the axles if they slide the trailer axle 350 to the nearest position. According to one aspect, the processor 102 may provide an estimate of the weight of the drive axle 340 and trailer axle 350 for the user, and provide information to the user indicative of how many holes to rearrange the trailer axle 350 to make the weight thereon closer to the weight on the drive axle 340 based on one or more of the formulas described herein. Weight adjustments of this nature improve the vehicle fuel efficiency during the trip.

[0075] The processor 102 may determine the weight of the rear part of a trailer box that is supported on the trailer tandem axles. The position of the axles of the trailer 320 and/or the vehicle 310 may be provided as an input and the processor 102 may calculate the weight of the trailer box with cargo and the location of its center of mass based on this input. The processor 102 may be programmed to estimate the weight of the trailer tandem axles without the trailer box in order to calculate a predicted distribution with any position of the tandem axles and the fifth wheel of the vehicle 310. In this way, the driver may use the system 100 for generating axle weight and load distribution value estimates to calculate the optimum weight distribution (e.g., when there is approximately equal weight on the drive axle(s) 340 and trailer axle(s) 350).

[0076] Thereafter, the driver may use a trailer axle stop device to slide trailer tandems to the calculated optimal position. Measuring the distance between adjacent tandem tapping holes will allow the processor 102 to roughly calculate its optimal position. This will help predict the load distribution before the axles of the trailer 320 move and thus reduce the number of extra vehicle maneuvers and graft wear. This may be achieved by providing the value of the pressure in the suspension or the weight of the drive axle(s) 340 of the vehicle 310 and trailer axle(s) 350 to the system 100 for generating axle weight and load distribution value estimates via the communication interface 108 or via the software application, for example. Further, the processor 102 may calculate the target pressure in the drive axle suspension system, which may

correspond to an equal weight distribution between the drive axle(s) 340 and the trailer axle(s) 350 for control by the driver. According to one aspect, it is possible to use a small number of input parameters to calculate in advance the optimum position of tandems and change in weight of the drive axle(s) 340 of the vehicle 310 as well as a dry van trailer or refrigerator trailer. The change in weight of typical axes may be calculated by the processor 102 as:

$$dM/in = ((M(dr) + M(tr))/2 - 11000lb) * 0.0022058 + 12.6lb$$

where:

$M(dr)$ is the weight of loaded drive axle 340 that may be estimated by linear dependence from pressure readings taken in the air-ride suspension; and

$M(tr)$ is the weight of loaded trailer axle 350 that may be estimated by linear dependence from pressure readings taken in the air-ride suspension.

[0077] For example, this may be the weight of the drive axle(s) 340 and axles of the trailer 320 (e.g., which may have two axles and eight wheels). In this regard, the processor 102 may calculate how many holes it takes to move the trailer tandem to get an approximately even load distribution between the axles. Also, if desired, the driver may choose an optimal load distribution between the axles to increase the safety of transportation by changing the appropriate number of holes in the settings for the movement of tandems. Knowing the desired position for tandems from the system 100 for generating axle weight and load distribution value estimates, the driver may quickly move them with a metal stopper that stops the axles in the correct position.

[0078] Most well-equipped vehicles have pressure gauges for the drive axles suspension. However, some vehicles do not have such equipment and do not have space to install such gauges. A pressure gauge may be placed in front of the driver behind the wheel because it allows the driver to notice the change in weight of the drive axle(s) 340 if the freight in the trailer 320 has shifted significantly. Therefore, it is appropriate to utilize a smartphone stand in which a pressure gauge for the suspension

may be placed. Placing such equipment in the driver's field of vision will solve the problem efficiently without large expenses.

[0079] The processor 102 may determine the legal and/or optimal placement of tandem trailers based on the weight value estimate, the center of mass of the load or cargo, and a predicted position of the center of mass of additional cargo to be transported. Typical distances for tandem travel are 4 or 6 inches between holes. This means that the centers of the two tandem travel holes on most American trailers are 12 inches apart.

[0080] After the trailer axle(s) 350 have been slidingly moved to the calculated optimum position, the processor 102 may perform a confirmation regarding the difference in weight between the drive axle(s) 340 and the trailer axle(s) 350. For example, this may be achieved because a suspension pressure difference of 1 PSI between a real reading and a suggested target reading generally corresponds to about a 1000 pound difference in weight between drive axle(s) 340 and trailer axle(s) 350. It is possible to use a handheld pressure gauge with wireless communication capacity to verify a suspension pressure in the trailer axle(s) 350 after sliding tandems to confirm that the driver has distributed the weight evenly to improve safety and to save resources such as time, money, and fuel.

[0081] The weight of the trailer axle 350 may be calculated by the processor 102 based upon a linear dependence suspension pressure from the axle weight. In one embodiment, the processor 102 may estimate the weight of the trailer tandems without the trailer box, and use this estimate to further estimate the amount of weight the rear part of the trailer 320 leans on the trailer tandems. To do this, the processor 102 may perform calibration weightings to find out the weight of the trailer 320, the weight and location of the trailer axle(s) 350 in the front position, and the weight and location of the trailer axle(s) in the rear position. The calculations performed by the processor 102 are set forth below:

$$Mr1 = Mtr - Mf1 - Mtd$$

$$Mr2 = Mtr - Mf2 - Mtd$$

$$Mtr * x = Mr1 * l1 = Mr2 * l2$$

$$(Mtr - Mf1 - Mtd) * l1 = (Mtr - Mf2 - Mtd) * l2$$
$$(Mtr - Mf1) * l1 - (Mtr - Mf2) * l2 = Mtd(l1 - l2)$$
$$Mtd = ((Mtr - Mf1) * l1 - (Mtr - Mf2) * l2)/(l1 - l2)$$

where:

$Mr1$ is the weight of the rear part of the trailer 320 that leans on the trailer tandems during the first weighing with the front position of the tandems;

$Mf1$ is the weight of the front part of the trailer 320 that leans on the fifth wheel during the first weighing with the front position of the tandems;

$Mr2$ is the weight of the rear part of the trailer 320 that leans on the trailer tandems during the second weighing with the rear position of the tandems;

$Mf2$ is the weight of the front part of the trailer 320 that leans on the fifth wheel during the second weighing with the rear position of the trailer tandems;

Mtr is the weight of the trailer 320 during calibration;

x is the distance between kingpins of the fifth wheel and location of the center of mass of the trailer box without tandems;

$l1$ is the distance between kingpins of the fifth wheel and location of the center between axles of trailer tandems during the first weighing;

$l2$ is the distance between kingpins of the fifth wheel and location of the center between axles of the trailer tandems during the second weighing; and

Mtd is the weight of the trailer tandems without the trailer box.

[0082] In this way, the processor 102 may estimate the weight of cargo inside the trailer 320, the weight of the front part of the weight of the trailer 320 that rests on the fifth wheel of the vehicle 310, or the weight of the front axle by inputting variable parameters of the vehicle 310 including volume of fuel in tanks, volume of DEF, or position of the fifth wheel on the vehicle 310 based on the inputs discussed herein.

TRANSPORTATION NETWORK

[0083] The processor 102, via the communication interface 108, may search for accompanying transportation, such as when the vehicle 310 is over or underloaded. For example, after obtaining qualitative results about the weight of the cargo in the trailer 320, the position of its center of mass, and additional carrying capacity, the processor 102 may track the movement of other vehicles and their destinations to find transit cargo for the ego-vehicle or vehicle. According to one aspect, requestors may be able to enter the desired parameters of their parcel in the search, such as weight, dimensions, and the place of pickup and delivery in order to see a list of vehicles with available capacity are travelling in the desired direction and may perform such a transport task legally and safely.

[0084] Most flatbed and step deck trailers are characterized by the use of two spread axles with independent pneumatic suspensions. For drivers, it may be desired to know how to place several loads while observing all weight limits and transportation safety. The weight of each such axles may be determined by weighing or by the pneumatic method, knowing the dependence of pressure on the load. Knowing what the weight of these axles was without load and after placing the load, the processor 102 may determine how much the weight of each of them increased. It is also worth measuring the distance between these axes. This will allow the processor 102 to calculate where the point of application of the weight of the load that falls on the axle of the trailer 320 is located. $DM1/l2 = DM2/L1;\ L1 + L2 = L.$ Knowing the point of application of such a force and by how much the weight of the load on the spread axles of the trailer 320 has increased and the weight by how much the load on the fifth wheel has increased, the processor 102 may determine the total weight of the load on the trailer 320 and the position of its center of mass as:

$$(DM1 + DM2)/Lfifth = DMfifth/Lspread;\ lfifth + lspread = base + L1$$

where:

$DM1$ is by how much the weight of the front axle of the axle spread increased after loading;

$l2$ is the distance from the rear of the spread axles to its imaginary point of application of the weight of the load distributed between the axles of the trailer 320 and the fifth wheel;

$DM2$ is by how much the weight of the rear axle of the axle spread increased after loading;

$L1$ is the distance from the rear axle of the axle spread to the imaginary point of application of the weight of the load distributed between the axles of the trailer 320 and the fifth wheel;

L is the distance between the spread axes;

$Lfifth$ is the distance between the positions of the center of mass of the cargo on the trailer 320 and the foam of the fifth wheel;

$DMfifth$ is by how much the weight of the fifth wheel increased after loading; and

$Lspread$ is the distance between the positions of the center of mass of the cargo on the trailer 320 to the point of application of the cargo load, which ensures the available mass distribution between the spread axles.

[0085] By providing the weight of all axles of the vehicle 310 and the trailer 320, the processor 102 may calculate the maximum weight the additional load may have and in which range of positions it should be placed on the trailer 320.

ADDITIONAL ADVANTAGES AND BENEFITS

[0086] In this way, advantages including determining whether vehicles and trailers meet legal weight limits on the road benefits carriers because may save fuel, and reduce the number of trips required to deliver partial loads because vehicles and trailers may be loaded to full legal capacity may be provided. Vehicle drivers will have fewer fines because they may determine that there is a sufficient weight reserve on each axle.

[0087] Another implementation of the method allows drivers to get more fuel to the fuel tanks and still be legal on the road. At present, vehicle drivers must use certified scales to find out the weight of the vehicle axles. The method is of most importance when the gross weight of the vehicle 310 and trailer are close to the maximum legal

limit. It is well known that the weight of one gallon of fuel in the fuel tanks is about 7 pounds. But most of the drivers do not know how this weight in tanks is distributed between the vehicle axles. So, to avoid having the axles being overweight, vehicle drivers routinely assume that total weight of added fuel may increase the weight of the drive axle 340. Such an assumption is not accurate because the fuel tanks are located between the vehicle's drive and steering axle(s) 330, and thus part of the weight of the fuel is distributed to the steering axle 330. Vehicle drivers thus pump less fuel in the fuel tanks than is legally permissible (i.e., when the drive axle 340 still has enough of a weight reserve). This leads to drivers making more fuel stops than are necessary, which wastes time.

[0088] Measuring the distances that determine the length of the fuel tanks and their location on the vehicle 310 may help predict how the weight of added fuel will be distributed between the axles. The possible results may be calculated by the processor 102.

[0089] Another implementation of the method utilizes GPS and online fuel pricing to advise the driver of the truck where to purchase fuel and the amount of fuel to purchase in order to minimize the expense for purchasing fuel. The implementation involves consideration of the price of the fuel, the amount of fuel required for the trip (or next fuel stop) and the amount of fuel that can be added to the tank without exceeding load limits, which leads to use of less fuel and cost savings to the driver.

[0090] Another advantage of methods according to the invention is that weight value estimations can be made when the load is placed into the trailer by the driver on location. If the weight value exceeds a predetermined weight used for determining the fee or price for transportation, the driver can request additional compensation in real time for the additional weight of the load placed on the trailer or refuse to transport it.

[0091] Another advantage provided by methods of the invention is that load value estimates can be obtained quickly (on site and in real time) as partial loads are placed onto or removed from the trailer. This allows the driver to determine whether additional partial loads can be picked up during transit, which minimizes the number of partial loads that must be hauled and saves fuel.

[0092] Another advantage provided by methods of the invention is that over time, changes in fuel usage and other characteristics can be monitored to determine whether maintenance and/or service should be performed on the vehicle.

[0093] Yet another advantage is that over time, the vehicle information saved in memory allows for calculations to be made after the trailer is loaded (no empty weight must be acquired to make load calculations). Furthermore, calibrations can be updated based on measurements taken at certified scales without the need for acquiring empty weight measurements.

SOFTWARE APPLICATION

[0094] The processor 102 may function on a smartphone to run a software application, which may receive respective inputs discussed herein, provide drivers with directions on how to perform periodic control inspection of the vehicle 310 and trailer, record the performance of this routine by using a camera or other communication methods, and provide one or more outputs such as suggested actions, notifications, guides, etc. The processor 102 may help freight carriers to reduce repair costs on the road and increase safety scores due to periodic review and control of the condition of the vehicles and trailers.

SUGGESTED ACTION – LOAD MANAGEMENT

[0095] The processor 102 may advise drivers regarding the pressure values to be obtained in the air-ride suspensions when there is a maximum weight on the axle, and/or recommended a maximum value of pressure that will ensure a safe axle weight reserve. These results may be provided for both the drive axle 340 and the trailer axle 350. For example, the processor 102 may generate a suggested action pertaining to the load based on determining the legal limit determination to not be in accordance with the legal limit.

[0096] In this regard, the processor 102 may determine the weight of the freight, cargo, or load in the trailer 320 and the weight capacity for additional partial loads that may be added without the axles becoming overweight, determine the possible weight capacity of the loaded vehicle and trailer without moving the fifth wheel and adding the

fuel to picking up additional partial loads, determine the weight of the front part of the trailer 320 that is leaning on the fifth wheel and the weight capacity of the fifth wheel to determine whether the drive axle 340 of the particular vehicle will be legal on the road with a particular trailer and freight loaded in it, determine the gross weight of the loaded vehicle and trailer to follow the legal weight limits on the road, determining the projected weight of the loaded vehicle and trailer and their axles after possible fueling to full tank capacity, determine the weight of the freight, cargo, or load inside the trailer 320 for possible reloading of it or adding more freight, cargo, or load to the trailer 320 based on the above discussed inputs (e.g., pressure, vehicle information, load information, etc.). The processor 102 may also estimate of the weight of a loaded trailer and the vehicle 310 without the trailer 320 for determining whether a particular vehicle may be connected to a particular trailer after sliding the axles without exceeding the legal weight limits on the road, estimate the legal weight capacity that may be attached to the fifth wheel, estimate the projected weight of the vehicle axles and gross weight of the vehicle 310 and loaded trailer after possible fueling to the maximum capacity of the fuel tanks, estimate the weight of the freight inside the trailer 320 for future reloading partial loads or for adding freight to the trailer 320, etc. This enables the vehicle 310 to be legal on the road during the trip, including immediately and/or after refueling.

SUGGESTED ACTION – FIFTH WHEEL CONFIGURATION

[0097] As another example, the processor 102 may generate a suggested action pertaining to a fifth wheel vehicle configuration based on the pressure, the vehicle information, and the load information (e.g., by moving the trailer axle 350 to meet legal weight limits and improve the fuel efficiency by distributing the weight between the drive axle 340 and trailer axle 350 more evenly, by determining whether the axles of the particular vehicle and any particular loaded trailer may be moved (e.g., via sliding) properly to meet legal weight limits on the road and, if so, by how much, by sliding the fifth wheel to the optimal position for near-permanent usage).

CHANGE SIMULATOR AND LOAD DISTRIBUTION VALUE ESTIMATE

[0098] Further, the processor 102 may assist the driver of the vehicle 310 with how a potential change would affect the legality of the vehicle 310 in terms of axel weight and/or load distribution. For example, the processor 102 may receive a potential change associated with the vehicle information or a potential change associated with the load information, calculate a load distribution value estimate based on the pressure, the potential change associated with the vehicle information and/or the potential change associated with the load information, and/or corresponding coefficient of weight distributions, and determine a legal limit determination of whether the load distribution is in accordance with a legal limit and notify a user of the legal limit determination based on one or more of the equations and/or formulas described herein.

[0099] Further, the processor 102 may summarize the influence of each potential change utilized in the calculation to the axle weight of the vehicle 310 and display additional information, such as suggestions (e.g., in the form of video tutorials, etc.), about these factors to the driver via the output device.

[0100] FIG. 2 is an exemplary flow diagram of a method 200 for generating axle weight and load distribution value estimates, according to one aspect. The method 200 for generating axle weight and load distribution value estimates may be implemented at least in part on a computer via a processor, a memory, a storage drive, etc., and may include receiving 202 a pressure associated with an air-ride suspension of a drive axle of a vehicle or a trailer axle of the vehicle, receiving 204 vehicle information associated with a characteristic of the vehicle, receiving 206 load information associated with a load of the vehicle, and calculating 208 a weight value estimate including at least one of a gross weight of the vehicle, a single-axle weight for the vehicle, or a tandem-axle weight for the vehicle based on a calibration, the pressure, the vehicle information, and the load information. The method may include determining 210 a legal limit determination of whether the weight value estimate is in accordance with a legal limit and notifying 212 a user of the legal limit determination and generating 214 a suggested action based on determining the legal limit determination to not be in accordance with the legal limit or based on the pressure, the vehicle information, and the load information. The suggested action may pertain to moving the load from a first position to a second

position within the semi-trailer or reconfiguring the vehicle or tractor's fifth wheel positioning.

[0101] FIG. 3 is an exemplary schematic side view of a vehicle and a semi-trailer on which the system and method for generating axle weight and load distribution value estimates may be implemented, while FIG. 4 is an exemplary schematic bottom plan view of the vehicle and the semi-trailer of FIG. 3, according to one aspect.

[0102] For example, an exemplary vehicle 310 having a semi-trailer 320 coupled thereto is shown in FIGS. 3 and 4. The vehicle 310 includes a steering axle 330 and a drive axle 340. In the illustrated embodiment, two rear axles collectively comprise the drive axle 340, although any number of rear axles may be implemented. The vehicle 310 and semi-trailer 320 are used in the illustrations because this is a common vehicle type used to haul freight. A driver 312, a fuel tank 532, a DEF tank 612 and a load 522 are shown in Fig. 3. The fuel tank 534 on the passenger side of the vehicle 310 is shown in Fig. 4.

[0103] The semi-trailer 320 includes a trailer axle 350. In the illustrated embodiment, the trailer axle 350 comprises a tandem or pair of axles. It will be appreciated that other arrangements and numbers of axles or groups of axles could be implemented (e.g., greater or fewer number of axles). In the illustrated embodiment, the trailer axle 350 is adjustable forward or back relative to the rear 360 of semi-trailer 320 to redistribute weight on the axles.

[0104] The steering axle 330 and the drive axle 340 of the vehicle 310 are fixed relative to each other. As seen in FIGS. 3 and 4, the vehicle 310 includes a fifth wheel 370, which is adapted to be slidably adjustable on the frame 380 of the vehicle 310 forward or back relative to the rear 390 of the vehicle 310. By moving the trailer axle 350 and/or the fifth wheel 370, weight may be redistributed between the trailer axle 350, the drive axle 340 and the steering axle 330.

[0105] With reference to FIG. 4, the semi-trailer 320 includes an air-ride suspension that includes air bags 400. The air bags 400 are supplied with air through a line 410, which extends from an air reservoir or tank 420 mounted to the vehicle 310. The air-ride suspension typically includes an air leveler. The air bags 400 are interconnected together and isolated from the line 410 using a valve 422.

[0106] Additionally, the vehicle 310 also includes an air-ride suspension. Sometimes, the air-ride suspension only includes air bags 430 for the drive axle 340, which are supplied with air through a line 440 that extends from the air reservoir or tank 420. But in other embodiments, the air-ride suspension further comprises air bags 450 for the steering axle 330, which are supplied with air through a line 460 that extends from the air reservoir or tank 420. The air bags 430 are interconnected together and isolated from the line 440 using a valve 424. The air bags 450 are generally not connected together, but rather each (left and right) is isolated from the line 460 using a valves 426, 428.

[0107] According to one embodiment, at least one air fitting 470 is installed in an isolated portion of the air-ride suspension system of the trailer 320 that includes an air bag 400. According to one aspect, at least a second air fitting 480 is installed in the isolated portion of the air-ride suspension system for the vehicle 310 that includes the air bags 430. Optionally, an additional air fitting 490 may be installed in the isolated portion of the air-ride suspension system for the vehicle 310 that includes an air bag 450. In the illustrated embodiment shown in FIG. 4, only one air fitting 490 is installed. It will be appreciated that an air fitting could be installed in both the left and the right isolated portions of the vehicle 310 containing air bags 450.

[0108] The air fittings 470, 480, 490 may be Schrader valves, for example. But other types of air fittings may be utilized, if desired. The air fittings 470, 480, 490 may be installed on the operator's side of the vehicle 310 in a location that is easily accessible to the operator while the operator is standing on the ground next to the vehicle 310 and semi-trailer 320. The air fittings 470, 480, 490 permit the operator to accurately and quickly measure the air pressure in each of the isolated portions of the air-ride suspensions, which contain air bags 400, 430, and optionally 450, respectively, using a hand-held air gauge.

[0109] According to another aspect, sensors 152 may be installed at locations near 470, 480, 490 to measure the air pressure in each of the isolated portions of the air-ride suspensions, thereby measuring or sensing the pressure associated with the air-ride suspension of the corresponding axles 330, 340, 350 of the vehicle 310 or the semi-trailer 320. To measure the pressure in the air suspension, it may be desired to place

an additional airline and place the Schrader valve in a convenient location for measurement. Further, it may be desirable to determine the deviation of each pressure gauge, and calibrate all the air suspensions to monitor the load of each vehicle and trailer with air suspension using the system 100 for generating axle weight and load distribution value estimates.

[0110] FIG. 5 and the following discussion provide a description of a suitable computing environment to implement aspects of one or more of the provisions set forth herein. The operating environment of FIG. 5 is merely one example of a suitable operating environment and is not intended to suggest any limitation as to the scope of use or functionality of the operating environment. Example computing devices include, but are not limited to, on-board truck computers, personal computers, server computers, hand-held or laptop devices, mobile devices, such as mobile phones, ELD's, Personal Digital Assistants (PDAs), media players, and the like, multiprocessor systems, consumer electronics, mini computers, mainframe computers, distributed computing environments that include any of the above systems or devices, etc.

[0111] Generally, aspects are described in the general context of "computer readable instructions" being executed by one or more computing devices. Computer readable instructions may be distributed via computer readable media as will be discussed below. Computer readable instructions may be implemented as program modules, such as functions, objects, Application Programming Interfaces (APIs), data structures, and the like, which perform one or more tasks or implement one or more abstract data types. Typically, the functionality of the computer readable instructions are combined or distributed as desired in various environments.

[0112] FIG. 5 illustrates a system 700 including a computing device 712 configured to implement one aspect provided herein. In one configuration, the computing device 712 includes at least one processing unit 716 and memory 718. Depending on the exact configuration and type of computing device, memory 718 may be volatile, such as RAM, non-volatile, such as ROM, flash memory, etc., or a combination of the two. This configuration is illustrated in FIG. 5 by dashed line 714.

[0113] In other aspects, the computing device 712 includes additional features or functionality. For example, the computing device 712 may include additional storage

such as removable storage or non-removable storage, including, but not limited to, magnetic storage, optical storage, etc. Such additional storage is illustrated in FIG. 5 by storage 720. In one aspect, computer readable instructions to implement one aspect provided herein are in storage 720. Storage 720 may store other computer readable instructions to implement an operating system, an application program, etc. Computer readable instructions may be loaded in memory 718 for execution by the at least one processing unit 716, for example.

[0114] The term "computer readable media" as used herein includes computer storage media. Computer storage media includes volatile and nonvolatile, removable, and non-removable media implemented in any method or technology for storage of information such as computer readable instructions or other data. Memory 718 and storage 720 are examples of computer storage media. Computer storage media includes, but is not limited to, RAM, ROM, EEPROM, flash memory or other memory technology, CD-ROM, Digital Versatile Disks (DVDs) or other optical storage, magnetic cassettes, magnetic tape, magnetic disk storage or other magnetic storage devices, or any other medium which may store the desired information and which may be accessed by the computing device 712. Any such computer storage media is part of the computing device 712.

[0115] The term "computer readable media" includes communication media. Communication media typically embodies computer readable instructions or other data in a "modulated data signal" such as a carrier wave or other transport mechanism and includes any information delivery media. The term "modulated data signal" includes a signal that has one or more of its characteristics set or changed in such a manner as to encode information in the signal.

[0116] The computing device 712 includes input device(s) 724 such as keyboard, mouse, pen, voice input device, touch input device, infrared cameras, video input devices, or any other input device. Output device(s) 722 such as one or more displays, speakers, printers, or any other output device may be included with the computing device 712. Input device(s) 724 and output device(s) 722 may be connected to the computing device 712 via a wired connection, wireless connection, or any combination thereof. In one aspect, an input device or an output device from another computing

device may be used as input device(s) 724 or output device(s) 722 for the computing device 712. The computing device 712 may include communication connection(s) 726 to facilitate communications with one or more other devices 730, such as through network 728, for example.

[0117] Still another aspect involves a computer-readable medium including processor-executable instructions configured to implement one aspect of the techniques presented herein. An aspect of a computer-readable medium or a computer-readable device devised in these ways is illustrated in FIG. 6, wherein an implementation 800 includes a computer-readable medium 802, such as a CD-R, DVD-R, flash drive, a platter of a hard disk drive, etc., on which is encoded computer-readable data 804. This encoded computer-readable data 804, such as binary data including a plurality of zero's and one's as shown in 804, in turn includes a set of processor-executable computer instructions 806 configured to operate according to one or more of the principles set forth herein. In this implementation 800, the processor-executable computer instructions 806 may perform a method 808, such as the method 200 for generating axle weight and load distribution value estimates of FIG. 2. In another aspect, the processor-executable computer instructions 806 may be configured to implement a system, such as the system 100 for generating axle weight and load distribution value estimates of FIG. 1. Many such computer-readable media may be devised by those of ordinary skill in the art that are configured to operate in accordance with the techniques presented herein.

EXEMPLARY USER EXPERIENCE

[0118] Using the information described above, a user (typically a driver of a vehicle) can access a software program using any type of device (e.g., smartphone, tablet, ELD etc.). The software application may access information stored in a database that is specific to the vehicle and trailer (e.g., dimensions and locations of fuel and DEF tanks, fifth wheels, trailer axles etc.). Alternatively, the user can be prompted to enter the information. To aid in the acquisition of accurate information, the software application can provide graphic illustrations of what measurements should be taken and provide data entry points for the information being measured. Once the vehicle and trailer data

is obtained, the software application can access the pressure data relating to the pressures within the isolated portions of the air ride systems for the vehicle and trailer. This information can be accessed by the software app via wireless communication from sensors on the vehicle and trailer. In addition, or alternatively, this pressure information can be entered manually by the user after measurements are taken at specified locations using hand-held devices. Once this information is entered into the software app, when a load is placed into the trailer, the user can use the software app to see how the weight values on the axles changes (ideally, sensors obtain pressure readings in the air ride suspension when the pressures settle out, and the software calculates the approximate weight values). As the user moves the fifth wheel and/or the trailer axle(s), additional pressure readings are taken and changes to the approximate weight values on the axles are displayed to the user via the software app. The user can continue to use the app to obtain additional information such as how much fuel to add, where to purchase the fuel, whether there is an opportunity to pick up an additional partial load yet remain under the legal weight requirements etc. The information is transmitted to the user's device in near real time (the vehicle and trailer need to be on a generally horizontal/flat surface, and the air ride suspension pressures need a bit of time to settle out).

[0119] As used in this application, the terms "component", "module," "system", "interface", and the like are generally intended to refer to a computer-related entity, either hardware, a combination of hardware and software, software, or software in execution. For example, a component may be, but is not limited to being, a process running on a processor, a processing unit, an object, an executable, a thread of execution, a program, or a computer. By way of illustration, both an application running on a controller and the controller may be a component. One or more components residing within a process or thread of execution and a component may be localized on one computer or distributed between two or more computers.

[0120] Further, the claimed subject matter is implemented as a method, apparatus, or article of manufacture using standard programming or engineering techniques to produce software, firmware, hardware, or any combination thereof to control a computer to implement the disclosed subject matter. The term "article of manufacture" as used

herein is intended to encompass a computer program accessible from any computer-readable device, carrier, or media. Of course, many modifications may be made to this configuration without departing from the scope or spirit of the claimed subject matter.

[0121] Although the subject matter has been described in language specific to structural features or methodological acts, it is to be understood that the subject matter of the appended claims is not necessarily limited to the specific features or acts described above. Rather, the specific features and acts described above are disclosed as example aspects.

[0122] Various operations of aspects are provided herein. The order in which one or more or all of the operations are described should not be construed as to imply that these operations are necessarily order dependent. Alternative ordering will be appreciated based on this description. Further, not all operations may necessarily be present in each aspect provided herein.

[0123] As used in this application, "or" is intended to mean an inclusive "or" rather than an exclusive "or". Further, an inclusive “or” may include any combination thereof (e.g., A, B, or any combination thereof). In addition, "a" and "an" as used in this application are generally construed to mean "one or more" unless specified otherwise or clear from context to be directed to a singular form. Additionally, at least one of A and B and/or the like generally means A or B or both A and B. Further, to the extent that "includes", "having", "has", "with", or variants thereof are used in either the detailed description or the claims, such terms are intended to be inclusive in a manner similar to the term "comprising”.

[0124] Further, unless specified otherwise, “first”, “second”, or the like are not intended to imply a temporal aspect, a spatial aspect, an ordering, etc. Rather, such terms are merely used as identifiers, names, etc. for features, elements, items, etc. For example, a first channel and a second channel generally correspond to channel A and channel B or two different or two identical channels or the same channel. Additionally, “comprising”, “comprises”, “including”, “includes”, or the like generally means comprising or including, but not limited to.

[0125] Additional advantages and modifications will readily occur to those skilled in the art. Therefore, the invention in its broader aspects is not limited to the specific

details and illustrative examples shown and described herein. Accordingly, various modifications may be made without departing from the spirit or scope of the general inventive concept as defined by the appended claims and their equivalents.

What is claimed is:

1. A system for generating axle weight and load distribution value estimates for a vehicle having a steering axle and at least one drive axle that is coupled to a trailer having at least one trailer axle, the system comprising:

a memory storing one or more instructions; and

a processor configured to execute the one or more of the instructions stored in the memory to perform steps of:

receiving a pressure reading associated with an air-ride suspension of the at least one drive axle and/or an air-ride suspension of the at least one trailer axle;

receiving dimensional characteristics information for the vehicle and the trailer;

calculating load information associated with a load supported on the trailer; and

calculating one or more weight value estimates including at least one of an estimated gross weight of the vehicle, the trailer and the load, an estimated axle weight for the at least one drive axle of the vehicle, and an estimated axle weight for the at least one trailer axle of the trailer, said weight value estimates being calculated based, at least in part, on the pressure readings received from the air-ride suspension of the at least one drive axle and/or the air-ride suspension of the at least one trailer axle, the dimensional characteristics information for the vehicle and the trailer and the calculated load information.

2. The system of claim 1, wherein the processor is configured to execute one or more instructions stored in memory to determine whether the axle weight and load distribution value estimates comply with a legal limit for a geographic area in which the vehicle is to be operated and notifies a user of the legal limit determination.

3. The system of claim 2, wherein the processor is configured to execute one or more instructions stored in memory to generate a suggested action pertaining to movement of the at least one trailer axle based on the legal limit determination to not be in accordance with the legal limit.

4. The system of claim 2, wherein the processor is configured to execute one or more instructions stored in memory to generate a suggested action pertaining to movement of a fifth wheel of the vehicle based on the legal limit determination to not be in accordance with the legal limit.

5. The system of claim 1, wherein the processor is configured to:

receive a potential change associated with the dimensional characteristics information of the vehicle and/or the trailer and/or a potential change associated with the load information;

calculate a load distribution value estimate based on the pressure, the potential change associated with the vehicle information and/or the potential change associated with the load information; and

determine a legal limit determination of whether the load distribution is in accordance with a legal limit and notifies a user of the legal limit determination.

6. The system of claim 1, wherein the system further comprises:

a sensor for measuring the pressure associated with the air-ride suspension of the vehicle and/or the trailer; and

a communication interface configured to receive a sensed pressure value from the sensor and to pass the sensed pressure value to the processor.

7. The system of claim 1, wherein the dimensional characteristics information for the vehicle and the trailer includes at least one of a length dimension associated with the vehicle, a length of a component of the vehicle, a length dimension associated with

the trailer coupled to the vehicle, and a position associated with the component of the vehicle.

8. The system of claim 7, wherein the component of the vehicle is a fuel tank or a fifth wheel.

9. The system of claim 1, wherein the load information includes at least one of a position of the load on the trailer, a weight of the load, a dimension associated with the load, and a distance from a portion of the vehicle to a center of mass of the load.

10. The system of claim 1, wherein the dimensional characteristics information for the vehicle and the trailer includes at least one of a weight of fuel in a fuel tank, a weight of DEF in a DEF tank and a weight of a passenger in the vehicle.

11. A method for generating axle weight and load distribution value estimates for a vehicle having a steering axle and at least one drive axle that is coupled to a trailer having at least one trailer axle, the method comprising:

taking measurements including at least one selected from the group consisting of a length of a base the vehicle, locations of fuel tanks, DEF tanks, and other components of the vehicle, location of driver, location of a fifth wheel of the vehicle, distance between locations where the fifth wheel is relocatable, location of trailer axle, distance between locations of spread trailer axles, distance between locations where trailer axle is relocatable, and length of available space on trailer for potential additional partial loads;

receiving, in an electronic device having a memory and a processor, a pressure value associated with an air-ride suspension of the at least one drive axle of the vehicle and/or the at least one trailer axle of the vehicle;

receiving, in the electronic device, vehicle information associated with a dimensional characteristics information for the vehicle and the trailer;

receiving, in the electronic device, load information associated with a load placed on the trailer; and

calculating, using the electronic device, one or more weight value estimates including at least one of an estimated gross weight of the vehicle, the trailer and the load, an estimated axle weight for the at least one drive axle of the vehicle, and an estimated axle weight for the at least one trailer axle of the trailer, said weight value estimates being calculated based, at least in part, on the pressure readings received from the air-ride suspension of the at least one drive axle and/or the air-ride suspension of the at least one trailer axle, the dimensional characteristics information for the vehicle and the trailer and the calculated load information.

12. The method of claim 11, further comprising determining, using the electronic device, whether the axle weight and load distribution value estimates comply with a legal limit for a geographic area in which the vehicle is to be operated and notifying, using the electronic device, a user of the legal limit determination.

13. The method of claim 12, further comprising generating, using the electronic device, a suggested action pertaining to movement of the at least one trailer axle based on the legal limit determination to not be in accordance with the legal limit and displaying the suggested action to the user.

14. The method of claim 12, further comprising generating, using the electronic device, a suggested action pertaining to movement of a fifth wheel of the vehicle based on the legal limit determination to not be in accordance with the legal limit and displaying the suggested action to the user.

15. The method of claim 11, further comprising:

receiving, in the electronic device, a potential change associated with the dimensional characteristics information of the vehicle and/or the trailer and/or a potential change associated with the load information;

automatically calculating, using the electronic device, a load distribution value estimate based on the pressure, the potential change associated with the vehicle information and/or the potential change associated with the load information; and

determining, using the electronic device, a legal limit determination of whether the load distribution is in accordance with a legal limit and notifying a user of the legal limit determination.

16. The method of claim 11, wherein the one or more weight value estimates are calculated after a load has placed on the trailer but before the vehicle and trailer bearing the load has been weighed on a certified scale.

17. The method of claim 16, wherein the one or more weight value estimates is the weight of the load.

18. The method of claim 11, wherein the one or more weight value estimates are calculated after a load has placed on the trailer and after the vehicle and trailer bearing the load has been weighed on a certified scale.

19. The method of claim 16, wherein the electronic device calculates and displays to the user the distribution of the weight of cargo for potential associated transportation of less than truckload (LTL) partial loads.

20. A non-transitory computer-readable medium storing instructions that, when executed by a processor, cause the processor to perform steps of:

receiving a pressure reading associated with an air-ride suspension of the at least one drive axle and/or an air-ride suspension of the at least one trailer axle;

receiving dimensional characteristics information for the vehicle and the trailer;

calculating load information associated with a load supported on the trailer; and

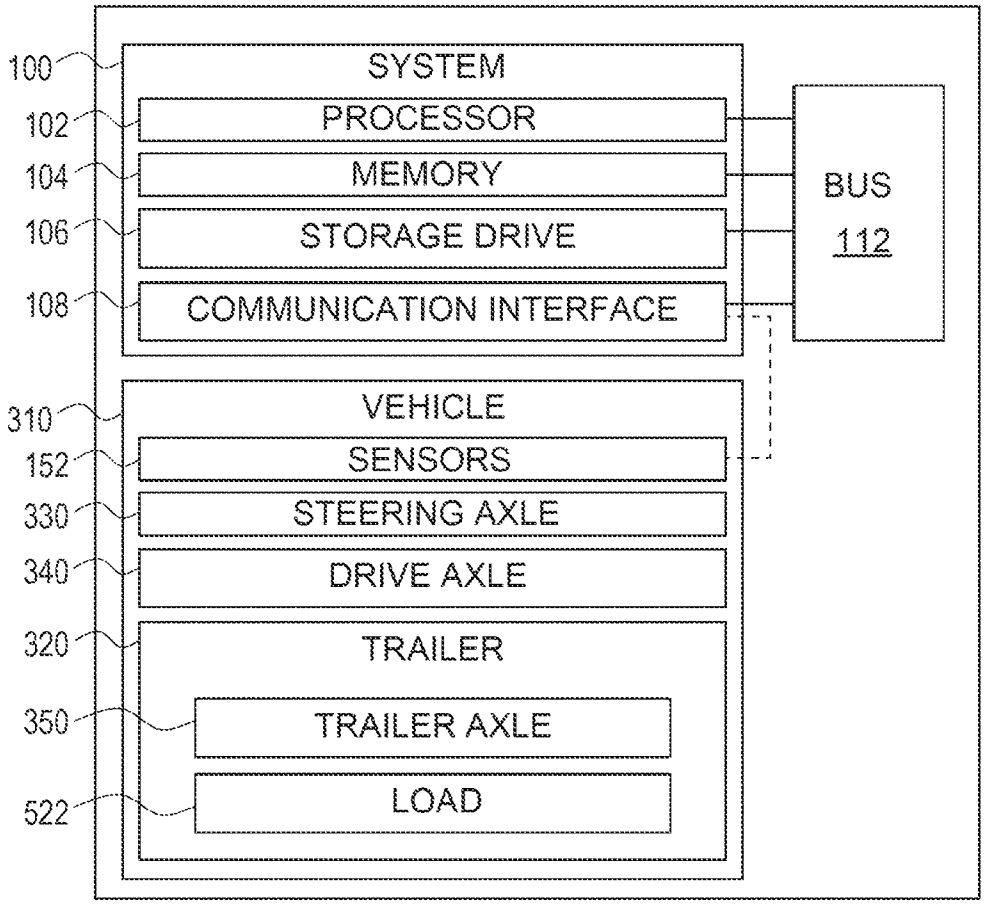
calculating one or more weight value estimates including at least one of an estimated gross weight of the vehicle, the trailer and the load, an estimated axle weight for the at least one drive axle of the vehicle, and an estimated axle weight for the at least one trailer axle of the trailer, said weight value estimates being calculated based, at least in part, on the pressure readings received from the air-ride suspension of the at least one drive axle and/or the air-ride suspension of the at least one trailer axle, the dimensional characteristics information for the vehicle and the trailer and the calculated load information.

21. The non-transitory computer-readable medium of claim 20, wherein the dimensional characteristics information for the vehicle and the trailer includes at least one of a length dimension associated with the vehicle, a length of a component of the vehicle, a length dimension associated with the trailer coupled to the vehicle, and a position associated with the component of the vehicle.

22. The non-transitory computer-readable medium of claim 21, wherein the component of the vehicle is a fuel tank or a fifth wheel.

23. The non-transitory computer-readable medium of claim 20, wherein the load information includes at least one of a position of the load, a weight of the load, a dimension associated with the load, or a distance from a portion of the vehicle to a center of mass of the load.

24. The non-transitory computer-readable medium of claim 20, wherein the load includes at least one of a fuel tank, fuel in the fuel tank, an additive to the fuel in the fuel tank, a passenger, a fifth wheel, or cargo.


100
SYSTEM
102
PROCESSOR
104
MEMORY
106
STORAGE DRIVE
108
COMMUNICATION INTERFACE
BUS
112
310
VEHICLE
152
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330
STEERING AXLE
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DRIVE AXLE
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TRAILER
350
TRAILER AXLE
522
LOAD

FIG. 1

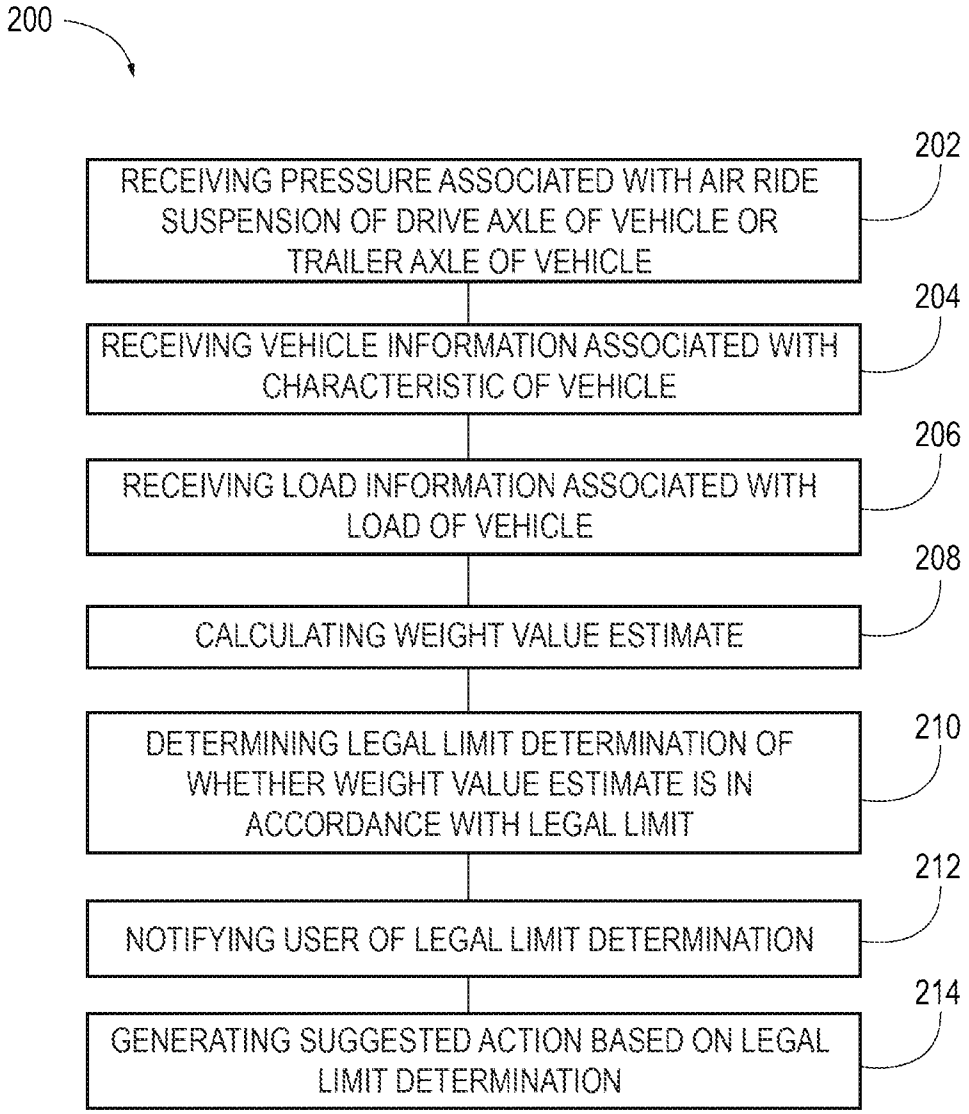

200
RECEIVING PRESSURE ASSOCIATED WITH AIR RIDE SUSPENSION OF DRIVE AXLE OF VEHICLE OR TRAILER AXLE OF VEHICLE
202
RECEIVING VEHICLE INFORMATION ASSOCIATED WITH CHARACTERISTIC OF VEHICLE
204
RECEIVING LOAD INFORMATION ASSOCIATED WITH LOAD OF VEHICLE
206
CALCULATING WEIGHT VALUE ESTIMATE
208
DETERMINING LEGAL LIMIT DETERMINATION OF WHETHER WEIGHT VALUE ESTIMATE IS IN ACCORDANCE WITH LEGAL LIMIT
210
NOTIFYING USER OF LEGAL LIMIT DETERMINATION
212
GENERATING SUGGESTED ACTION BASED ON LEGAL LIMIT DETERMINATION
214

FIG. 2

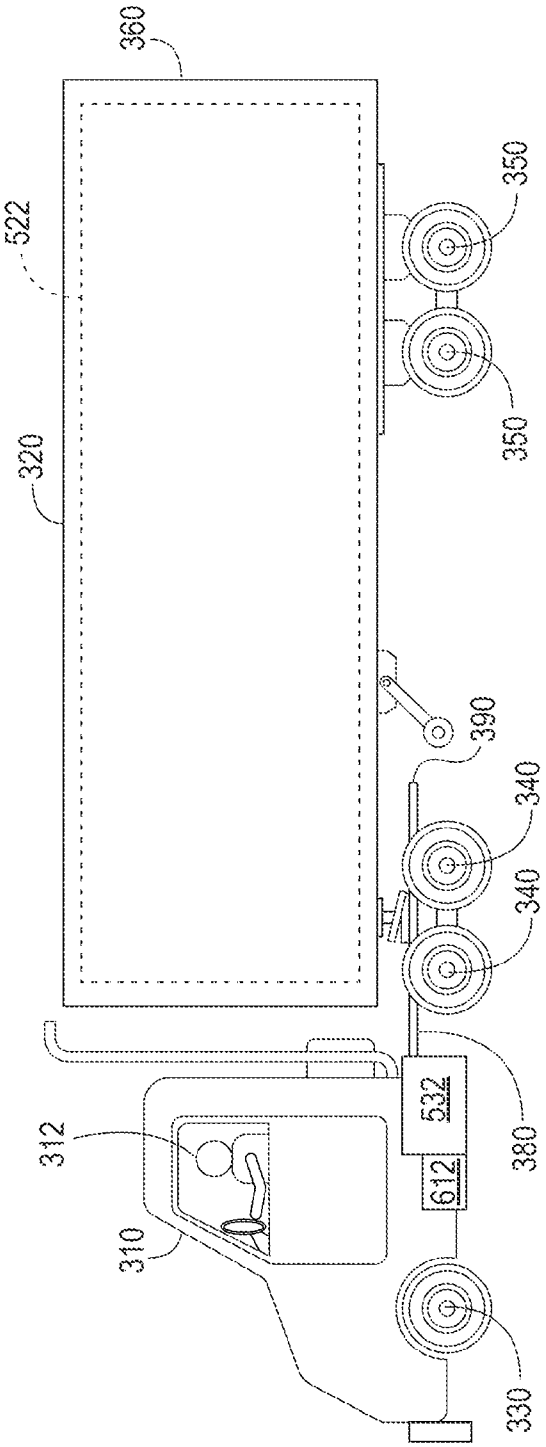
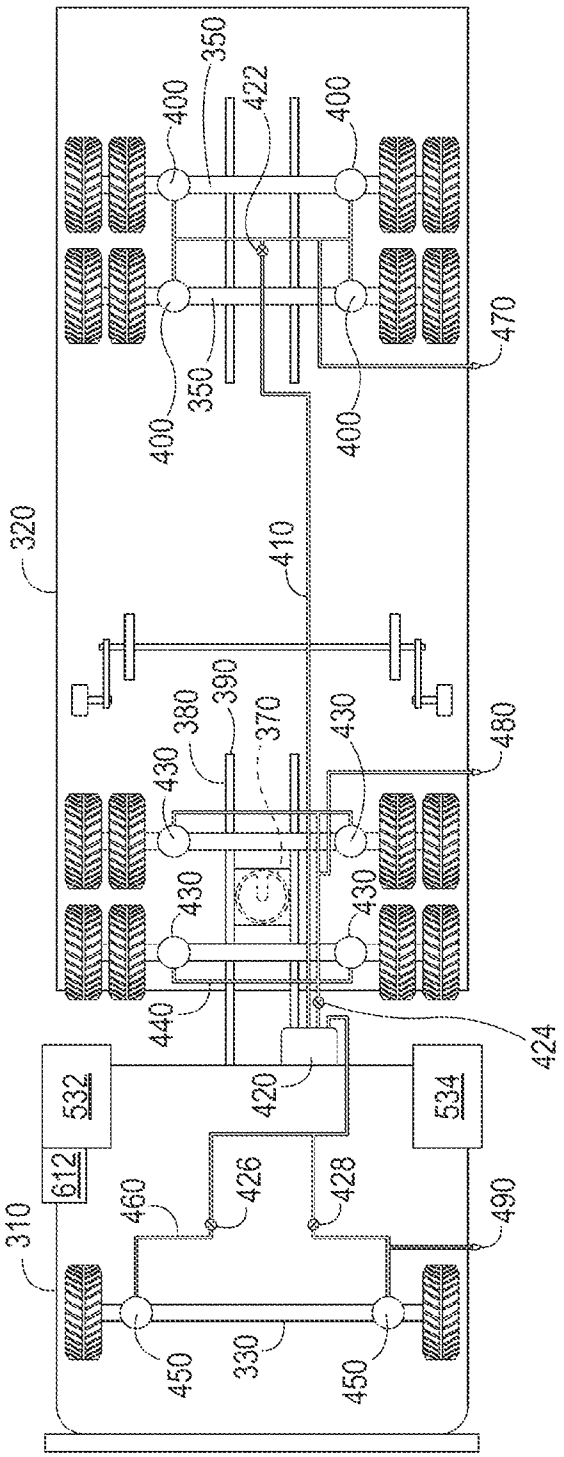


FIG. 3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400
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380
370
430
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426
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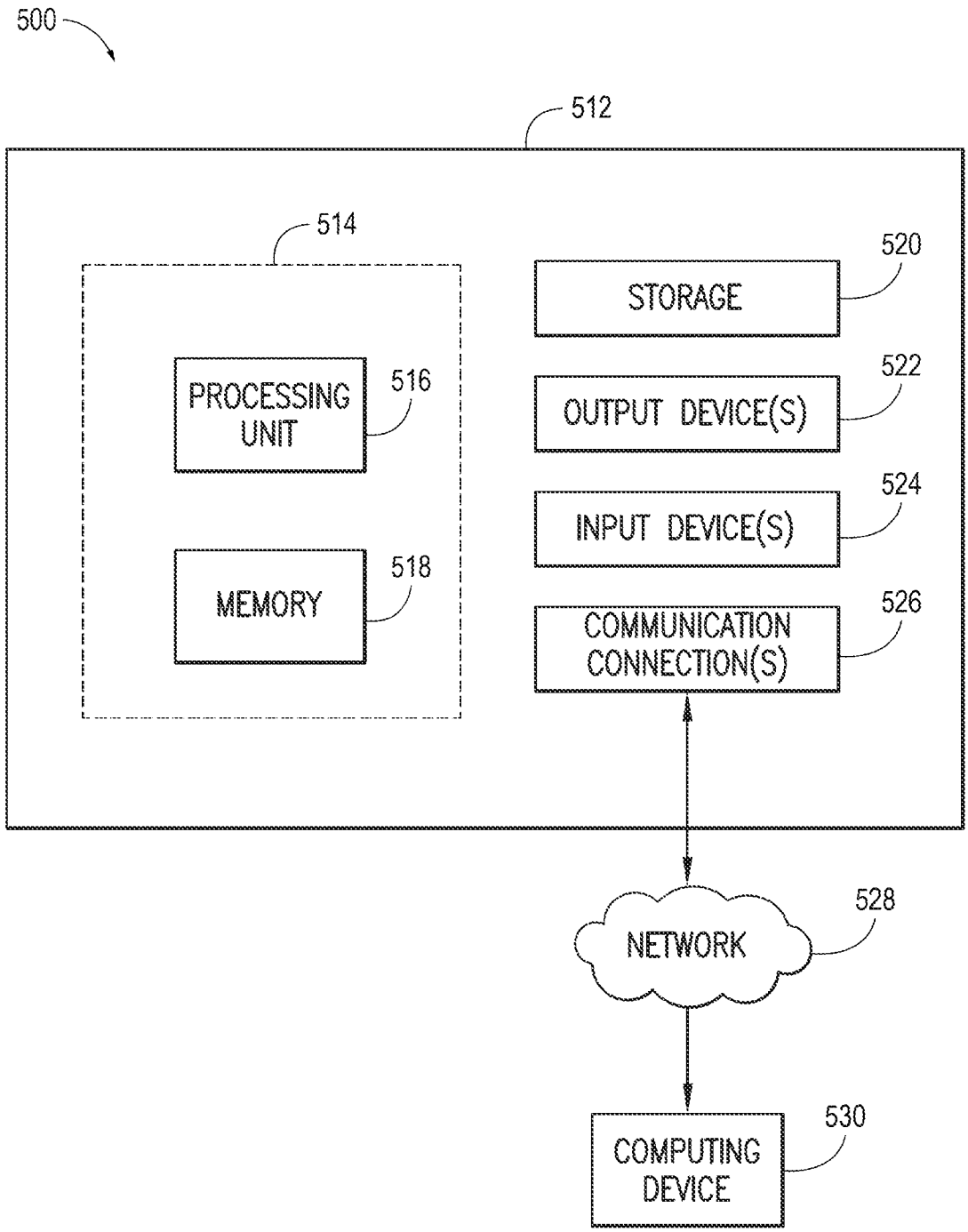
450

FIG. 4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512
514
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MEMORY
518
STORAGE
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OUTPUT DEVICE(S)
522
INPUT DEVICE(S)
524
COMMUNICATION CONNECTION(S)
526
NETWORK
528
COMPUTING DEVICE
530

FIG. 5

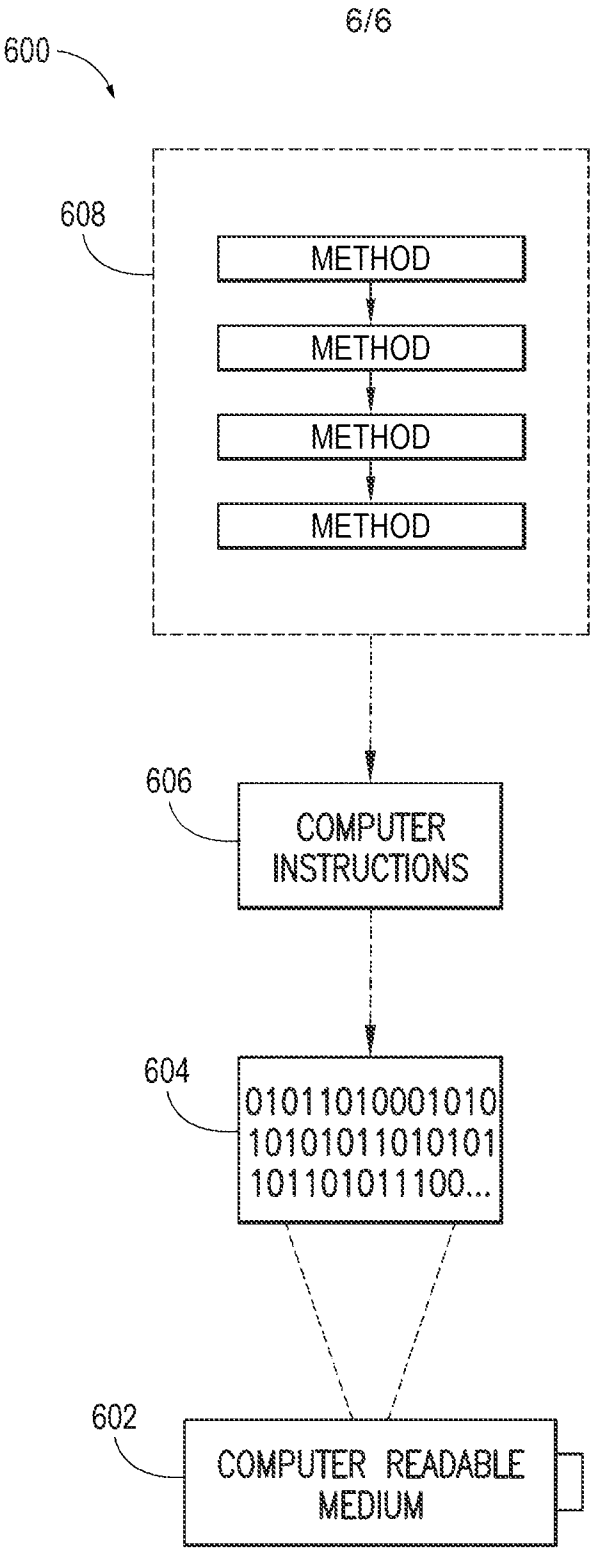
600
608
METHOD
METHOD
METHOD
METHOD
606
COMPUTER INSTRUCTIONS
604
01011010001010
10101011010101
101101011100...
602
COMPUTER READABLE MEDIUM

FIG. 6

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US2024/042304

A. CLASSIFICATION OF SUBJECT MATTER

IPC: ***B62D 53/06*** (2024.01); ***G01G 19/08*** (2024.01); *B62D 53/08* (2024.01); *B60G 17/018* (2024.01); *B60G 17/019* (2024.01)

CPC: ***B62D 53/068; G01G 19/08;*** *B62D 53/08; B60G 17/018; B60G 17/019*

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

See Search History Document

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

See Search History Document

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

See Search History Document

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
	US 2003/0155164 A1 (MANTINI et al.) 21 August 2003 (21.08.2003)	
X	entire document	1-9, 11-15, 20-24
Y	entire document	10, 16-19
	US 5,610,372 A (PHILLIPS et al.) 11 March 1997 (11.03.1997)	
Y	entire document	10
	US 4,854,407 A (WAGNER) 08 August 1989 (08.08.1989)	
Y	entire document	16-19
	US 2011/0029448 A1 (BENDA et al.) 03 February 2011 (03.02.2011)	
Y	entire document	19

☐ Further documents are listed in the continuation of Box C. ☐ See patent family annex.

* Special categories of cited documents:

"A" document defining the general state of the art which is not considered to be of particular relevance

"D" document cited by the applicant in the international application

"E" earlier application or patent but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
29 October 2024 (29.10.2024)	**05 November 2024 (05.11.2024)**

Name and mailing address of the ISA/US	Authorized officer
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Facsimile No. **571-273-8300**	Telephone No. **571-272-4300**