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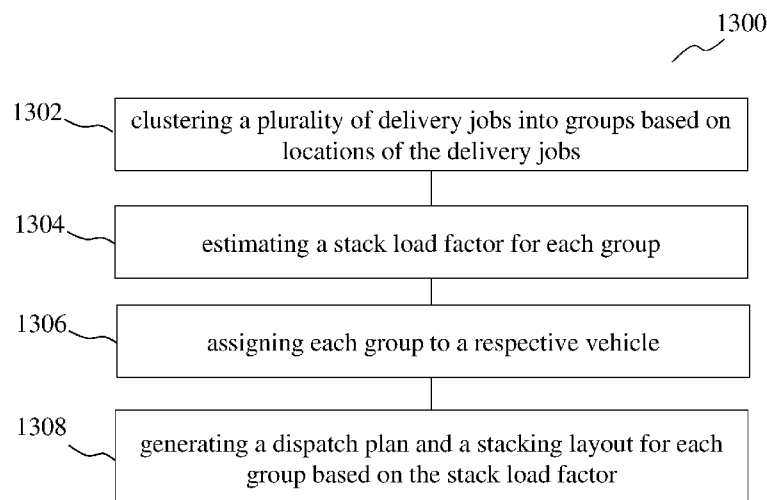


FIG. 13

(57) Abstract: According to various embodiments, there is provided a method of generating product delivery plans. The method includes: clustering a plurality of delivery jobs into groups based on locations of the delivery jobs; estimating a stack load factor for each group, wherein the stack load factor defines a useable proportion of a vehicle capacity; assigning each group to a respective vehicle; and generating a dispatch plan and a stacking layout for each group based on the stack load factor, wherein each dispatch plan includes a sequence and time of carrying out the delivery jobs in the group; and wherein each stacking layout defines an arrangement of products of the delivery jobs with respect to the assigned vehicle.

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METHODS AND APPARATUSES FOR GENERATING PRODUCT DELIVERY PLANS

TECHNICAL FIELD

[0001] Various embodiments relate to methods and apparatuses for generating product delivery plans.

BACKGROUND

[0002] A diverse and low-volume production model is increasingly common in response to specific, customized customer needs. Transport logistics play an important role to support this model. To maintain operational efficiency such as high loading rate and cost-effective transportation cost, various products of different types, i.e. heterogeneous products, may be loaded together in a delivery vehicle for a combined delivery. Arranging the heterogeneous products in the delivery vehicle to meet stacking constraints such as stability, load limit, stackable height, and also to optimize the quantity of products loaded, may be challenging since the products may have different dimensions, weight and loading considerations. In addition, the need to arrange the products such that they are easily retrievable according to the order of delivery adds further complexity to the process of optimizing the stacking arrangement. In existing transport logistics processes, delivery route planning and stacking arrangement are handled separately. The group of products to be loaded onto a vehicle may be determined based on the delivery routes, may be determined to optimize loading rate, delivery time or vehicle resource assignment. The stacking arrangement of the group of products may be determined only after the delivery routes are planned and prior to loading the vehicle.

SUMMARY

[0003] According to various embodiments, there may be provided a method for generating product delivery plans. The method may include: clustering a plurality of delivery jobs into groups based on locations of the delivery jobs; estimating a stack load factor for each group, wherein the stack load factor defines a useable proportion of a vehicle capacity; assigning each group to a respective vehicle; and generating a dispatch plan and a stacking layout for each

group based on the stack load factor, wherein each dispatch plan includes a sequence and time of carrying out the delivery jobs in the group; and wherein each stacking layout defines an arrangement of products of the delivery jobs with respect to the assigned vehicle.

[0004] According to various embodiments, there may be provided an apparatus for generating product delivery plans. The apparatus may include: a cluster module configured to cluster a plurality of delivery jobs into groups based on locations of the delivery jobs; a stack load factor estimator configured to estimate a stack load factor for each group, wherein the stack load factor defines a useable proportion of a vehicle capacity; a delivery planner configured to assign each group to a respective vehicle, and further configured to generate a dispatch plan and a stacking layout for each group based on the stack load factor; wherein each dispatch plan comprises a sequence and time of carrying out the delivery jobs in the group; and wherein each stacking layout defines an arrangement of products of the delivery jobs with respect to the assigned vehicle.

BRIEF DESCRIPTION OF THE DRAWINGS

[0005] In the drawings, like reference characters generally refer to the same parts throughout the different views. The drawings are not necessarily to scale, emphasis instead generally being placed upon illustrating the principles of the invention. In the following description, various embodiments are described with reference to the following drawings, in which:

[0006] FIG. 1 shows a schematic diagram of a logistical system according to various embodiments

[0007] FIG. 2 shows a conceptual diagram of an apparatus for generating product delivery plans according to various embodiments.

[0008] FIG. 3A-3D show examples of data formats for various data that the apparatus of FIG. 2 stores, generates, receive or transmit.

[0009] FIG. 4 shows a line interaction diagram showing an example of interactions for generating a product delivery plan according to various embodiments.

[0010] FIG. 5 shows a line interaction diagram showing an example of interactions for during delivery of a product, according to various embodiments

[0011] FIG. 6A to 6B show a flow diagram of the process for generating product delivery plans according to various embodiments.

[0012] FIG. 7 shows a diagram of an example of the clustering of jobs according to various embodiments.

[0013] FIG. 8 shows an example data table for determining a stack load factor.

[0014] FIG. 9 is a flowchart for a method of generating a product delivery plan using volume or weight information according to various embodiments.

[0015] FIGS. 10A-10F show examples of data formats according to various embodiments.

[0016] FIG. 11A shows a map and a delivery timeline of an example of a dispatch plan of a vehicle.

[0017] FIG. 11B shows a table of a delivery and stacking guide that corresponds to the dispatch plan shown in FIG. 11A.

[0018] FIG. 12A shows an example of a container layout view.

[0019] FIG. 12B shows an example of a stacking guide corresponding to the example of FIG. 12A.

[0020] FIG. 13 shows a flow diagram of a method for generating product delivery plans according to various embodiments.

[0021] FIG. 14 shows a conceptual diagram of an apparatus for generating product delivery plans according to various embodiments.

DESCRIPTION

[0022] Embodiments described below in context of the apparatuses are analogously valid for the respective methods, and vice versa. Furthermore, it will be understood that the embodiments described below may be combined, for example, a part of one embodiment may be combined with a part of another embodiment.

[0023] It will be understood that any property described herein for a specific apparatus may also hold for any apparatus described herein. It will be understood that any property described herein for a specific method may also hold for any method described herein. Furthermore, it will be understood that for any apparatus or method described herein, not necessarily all the components or steps described must be enclosed in the device or method, but only some (but not all) components or steps may be enclosed.

[0024] In this context, the apparatus as described in this description may include a memory which is for example used in the processing carried out in the apparatus. A memory used in the embodiments may be a volatile memory, for example a DRAM (Dynamic Random Access Memory) or a non-volatile memory, for example a PROM (Programmable Read Only Memory), an EPROM (Erasable PROM), EEPROM (Electrically Erasable PROM), or a flash memory, e.g., a floating gate memory, a charge trapping memory, an MRAM

(Magnetoresistive Random Access Memory) or a PCRAM (Phase Change Random Access Memory).

[0025] The term “coupled” (or “connected”) herein may be understood as electrically coupled or as mechanically coupled, for example attached or fixed, or just in contact without any fixation, and it will be understood that both direct coupling or indirect coupling (in other words: coupling without direct contact) may be provided.

[0026] In order that the invention may be readily understood and put into practical effect, various embodiments will now be described by way of examples and not limitations, and with reference to the figures.

[0027] In the context of various embodiments, the phrase “dispatch plan” may be but is not limited to being interchangeably referred to as “delivery plan”.

[0028] In the context of various embodiments, the phrase “stack load rate” may be but is not limited to being interchangeably referred to as “stack load factor”.

[0029] According to various embodiments, a method for generating product delivery plans may consider the constraints of delivery jobs, as well as the ability of the products to be stacked, in planning the delivery schedule and the stacking layout of products in the delivery vehicles. This sets the method apart from prior arts where the creation of a delivery plan and stacking layout are separately conducted. In prior arts, the delivery plan is usually first generated, followed by the stacking layout. This may result in some infeasible stacking layouts due to stacking constraints of the products to be delivered. This may then require repeated re-planning of the delivery schedule until a feasible stacking layout is devised. In other cases, the stacking arrangement may be feasible but the loading of products may take much longer than planned due to the difficulty of stacking when stacking rearrangements are made. This may lead to delays in the delivery jobs. The delays may be magnified when the delivery vehicle has to travel to multiple locations and conduct several pick-up and/or drop-off operations. In such a scenario, the products in the vehicle may need to be re-arranged after the pick-up/drop-off operations and the rearrangement time may exceed the time duration allocated in the delivery schedule. The method described herein may resolve the abovementioned issues and may create delivery plans with feasible stacking layouts.

[0030] The method may result in more optimized stacking arrangements and delivery plans. A conventional delivery route planning process may assume fixed loading and unloading times. However, these assumptions may differ widely from the actual loading and unloading time, depending on the stacking arrangement. For example, if the first product to be delivered is stacked underneath many other products, the time spent in unloading the other products in order

to reach the first product, and then loading the other products back in after retrieving the first product, may cause a large deviation from the planned delivery schedule. Further, while the products may be grouped to optimize the delivery time during delivery planning, the optimized delivery time may not be realizable because of specific stacking constraints, which are only considered during the stacking arrangement. For example, it may not be possible to fit the group of products into the same vehicle because they cannot be stacked due to fragility. One goal of grouping the products may be to realize a high loading rate for the delivery vehicle. However, the nature of the products may dictate stacking constraints that results in unusable space. The method according to various embodiments may recognize these stacking constraints in planning the delivery route, so that the stacking arrangement is feasible. By considering product grouping in both delivery planning and stacking arrangement enables the creation of stacking layout that requires times for loading and unloading which are within the required time durations at destinations. The method may include verifying a stacking arrangement with respect to the stacking constraints. The method may include optimizing usage of the vehicle capacity, while still respecting the stacking constraints so as to avoid damage to the products during transportation.

[0031] In a stacking problem, the main goal may be to minimize gaps or space in order to maximize loading. There are various rule of thumbs or rule sets applied with respect to creating a stacking arrangement, for example, placing a heavy product at lower layers, spreading products to achieve a low center of gravity, and avoiding a pyramid shape. For similar shapes, the arrangement may be made to achieve column stack and for the purpose of stability, an interlocking stack is preferred. The method according to various embodiments may utilize existing palletizing methods in solving the stacking problem. The method may include finding a delivery plan and a corresponding stacking layout of the products to be delivered in the delivery plan that satisfies the stacking constraints and also optimizes the delivery plan.

[0032] According to various embodiments, the method for generating product delivery plans may consider both scheduling and stacking parameters in the creation of the delivery plan. For example, the loading and unloading time of products may be typical planning parameters in delivery planning. The values of the planned parameters may have large differences compared to the actual loading and unloading times. One cause is that the loading and unloading times may be affected by the arrangement of products inside a delivery vehicle. The method may generate an accurate delivery plan since the values of the loading and unloading times computed may take into consideration the stacking layout. Moreover, the method may allow optimizing the loading rate, transport cost, or delivery time while considering stacking

constraints of products. It may enable assigning a vehicle type and finding a practical loading rate for the vehicle considering the stacking constraints of a product. A stack load rate may be calculated for each vehicle type based on product mix, vehicle type, job size, dimensional characteristics, and allocated container capacity. The stack load rate may be based on historical data to virtually change the vehicle capacity during the generation of delivery plans. It may manipulate the vehicle loading capacity into a lower value to “make room” for the spaces due to stacking constraints. The benefit of using stack load rate is to find a practical load rate of a vehicle type without the need of frequently conducting a simulation for a stacking rearrangement, which can be a timely consuming process when every possible combinations of delivery jobs as well as vehicles are simulated. Further, delivery jobs may be grouped based on locations, job size, and product similarity (e.g. less variance in dimensions). The grouping of jobs based on nearby locations or along or near a route, in combination with product similarity may increase the loading rate of vehicles and may provide the possibility to generate a less complicated stacking layout while at the same time considering the stacking constraints.

[0033] Commercially available solutions for scheduling (referred to as legacy solutions) may optimize delivery planning schedule without the guarantee of a feasible stacking layout. In order for these solutions to take into account stacking constraints, the method may calculate a candidate of practical loading of each vehicle based on a stack load rate, to virtually manipulate the vehicle capacity during the generation of delivery plans using legacy solution. By manipulating the vehicle capacity, fewer number of groups in product grouping are selected for delivery in a vehicle, which allows space for products with stacking constraints. Then, these dispatch plans are verified through a simulation by generating a stacking layout. The result may be a set of dispatch plans with different stacking layout and that are evaluated based on its arrangement complexity, and other performance indicators such as actual loading rate, total delivery time, and delivery cost.

[0034] FIG. 1 shows a schematic diagram 100 of a logistical system according to various embodiments. The logistical system may include a stacking and delivery planning device 170. The stacking and delivery planning device 170, also referred herein as “the Device 170”, may be able to accept delivery jobs, monitor the delivery jobs, and determine delivery plans and stacking arrangements. The delivery plans may include delivery schedule and delivery routes. The Device 170 may include a processing unit 176 configured to perform calculations and optimizations to generate delivery plans and stacking layouts. The processing unit 176 may include various modules, including at least one of a delivery job handling module 171, a delivery monitoring module 172, a planner interface module 173, and a stacking and delivery

planning module 174. In various embodiments, the Device 170 may include multiple processing units or processors, and each processor may include a respective module. The Device 170 may include a memory 175 configured to store various data, including at least one of planning parameters 121, delivery job data 182, delivery rule set 183, stacking rule set 184, product data 185, vehicle data 186, location data 187, routing data 188, delivery history data 189 and other data 190. In various embodiments, the Device 170 may include multiple memories or databases, and each memory or database may store a respective type of data. In various embodiments, the various data may be stored in memories or databases that are external to the Device 170, and the Device 170 may retrieve the data from the external memories or databases.

[0035] The Planning Parameters 121 may include information on vehicle speed by vehicle type, routing, time duration of loading and unloading at each destination. The delivery job data 182 may include information such as an identifier for the delivery job, the product for delivery, the delivery time, the origin location, the destination location, the operation as either pick-up or drop-off, and the product quantity. The delivery rule set 183 may include information on constraints for planning the delivery. These constraints may be expressed in logical expressions, equations and/or formulae. For instance, the delivery rule set 183 may include that for a specific routing, a vehicle of specific type has to be used, for a specific product ordered by a customer, vehicle type of another specific type has to be used. The delivery rule set 183 may also include a formula for optimization function. The stacking rule set 184 may include rules for stacking the products. The stacking rule set 184 may include stacking constraints such as those arising from product characteristics and vehicle characteristics. For example, the stacking rule set 184 may include information on special cases such as stacking constraints that are unique and specific to a particular product. For example, the stacking rule set 184 may include a maximum number of stacking layers arising from the height limitation of the vehicle container or the stability of the vehicle. The stacking rule set 184 may also include arbitrary rules that may not be part of stacking constraints. The stacking rule set 184 may also include rules that may apply only to a specific delivery job, for example, a logic to indicate that two or more items have to be shipped together because they are assembly parts of a single larger item. The stacking rule set 184 may also include rules based on empirical results or observations, or past experiences. The product data 185 may include information on the products to be delivered, including at least one of an identifier for the product, dimensions of the product, weight of the product, description of the product, as well as stacking constraints of the product. The stacking constraints of the product may include at least one of load limit, orientation

constraint, stackability and stack layer limit. Load limit may indicate the maximum weight that can be stacked above the product. Orientation constraint may indicate the orientation that the product has to be arranged at. Stackability may indicate whether the product can be stacked above another product. Stack layer limit may indicate the layer that the product can be stacked at, for example, whether can be stacked at a second, third, fourth, or fifth layer. The vehicle data 186 may include information on delivery vehicles. The vehicle data 186 may include at least one of an identifier for the vehicle, the payload capacity of the vehicle, and dimensions of the vehicle container. The vehicle data 186 may also include information on the vehicle's availability according to time, such as its associated operating start time and end time. Location data 187 may include information on locations along the delivery route. The location data 187 may include an identifier for the location, the position of the location (for example, expressed in latitude and longitude), address of the location, the opening time and closing of the location. The location data 187 may also include the operation time associated with the loading or unloading during the delivery. Routing data 188 may include information on the path from one location to another location which may include road segments. Routing data 188 may include multiple paths of the same origin location and the same destination location. Routing data 188 may also include information of each path such the distance, the driving time, the starting time and the estimated end time. Delivery History data 189 may include information on previous delivery transactions. Delivery History data 189 may include information on the delivery jobs, the vehicle data utilized in the delivery 261, the corresponding product data and type of the jobs 262, the container types of the vehicles 263, the stacking layouts 264, the loading and unloading times 265, the scheduling parameters 266, and the stacking parameters 267, among others. Other data 190 may include external information that affects the delivery such as traffic, incident data, specific customer request in regard to delivery of a product, among others.

[0036] The logistical system may include a network 160. The Device 170 may include interfaces to communicate with the network 160. The network 160 may be a wired or a wireless network, and may allow the Device 170 to communicate with various applications, including at least one of a shipper application 110, a planner application 120, a loader application 130, a driver application 140, and a receiver application 150. The shipper application 110 may be configured to send delivery job data 111 and to receive confirmation 112 and updates 113 of the delivery jobs. The planner application 120 may be configured to set planning parameters 121 or performance indicators. The planner application 120 may receive key output parameters 122. The planner application 120 may also generate reports of a current or previous delivery jobs, the delivery job status, among other things. The loader application 130 may be used by a

loader at a warehouse. The loader application 130 may receive stacking plans 132. The stacking plans 132 may include information on which products are to be delivered based on the delivery plan and may also include information to guide the loader on how the products should be loaded onto the vehicle based on a generated stacking layout. The loader application 130 may transmit a confirmation 131 to the network, upon receipt of the stacking plan 132. The driver application 140 may be used by a driver assigned to a delivery plan. The driver application 140 may receive dispatch plan updates 142 and stacking plan updates 143. The dispatch plan updates 142 may include delivery plan schedules, delivery details and any changes made to the deliver jobs. The stacking plan updates 143 may include information to guide the driver as to stacking re-arrangements that may be required at various destinations. The driver application 140 may also transmit delivery updates 141, which may include status updates of the delivery jobs. The receiver application 150 may receive delivery updates 151, i.e. information on the status of the delivery jobs. The receiver application 150 may be provided to customers or recipients of the products, so that they may know when to expect the deliveries. The abovementioned applications may be installed in mobile devices such as tablets, cell phones, smartphones, or laptops, or other computing devices such as personal computers, workstations, or servers. These applications may be stand-alone applications or may be functions that are integrated into other systems via application program interfaces (API). The other systems may be for example, Delivery Management System, Warehouse Management System, Delivery Order Management System, Fleet management System or any other logistics, transport delivery-related systems.

[0037] FIG. 2 shows a conceptual diagram 200 of an apparatus for generating product delivery plans according to various embodiments. The apparatus may be the Device 170. The delivery job handling module 171 may include various sub-modules, including a delivery job receiving sub-module 211, a reply and confirmation sub-module 212, a dispatch plan updating sub-module 213 and a stacking plan updating sub-module 214. The delivery job receiving sub-module 211 may handle delivery job requests received from the shipper application 110. The reply and confirmation sub-module 212 may provide a confirmation in response to the received job requests. The dispatch plan updating sub-module 213 may send dispatch plan updates 142 to the driver application 140. The stacking plan updating sub-module 214 may send stacking plan updates 143 to the driver or stacking plans 132 to the loader application 130.

[0038] The monitoring module 172 may include a delivery status monitoring sub-module 221 and a stacking monitoring sub-module 222. The delivery status monitoring sub-module 221 may monitor the delivery status 145 of on-going deliveries based on at least one of the location of the delivery vehicles and delivery updates 141 sent by the driver application 140. The

delivery status 145 may indicate whether the delivery job is delayed, on-time or stalled. The stacking monitoring sub-module 222 may monitor the status of the stacking rearrangement. The stacking monitoring sub-module 222 may monitor the status based on confirmation messages sent by the driver application 140. After pick-up or drop-off, the driver of the delivery vehicle may send a confirmation that a stacking rearrangement has been made before proceeding to another destination. The confirmation may be a simple click from a confirmation button, a text or call, or sending a picture to the Device 170 as a proof of completion for stack rearrangement.

[0039] The planner interface module 173 may include a planning parameter receiving sub-module 231 and an output plan display sub-module 232. The planning parameter receiving sub-module 231 may provide an interface to the planner application 120 for receiving user inputs on at least one of the planning parameters 121, delivery rule sets 183 and stacking rule sets 184. The Output Plan Display sub-module 232 may provide output and display in the form of texts, charts, tables, graphs, maps to display the computing results of the Device 170.

[0040] The stacking and delivery planning module 174 may include various sub-modules, including at least one of a stacking constraint determination sub-module 251, a stacking arrangement planner sub-module 252, a scheduling parameter determination sub-module 253, a product loading/unloading estimation sub-module 254, delivery routing solver sub-module 255, and a delivery plan optimization sub-module 256. The stacking constraint determination sub-module 251 may determine whether a delivery job includes a product with stacking constraints. The stacking constraint determination sub-module 251 may determine the products of a delivery job and may retrieve the product data 185 and the stacking rule set 184 that are associated with the products. The stacking constraint determination sub-module 251 may determine the stacking constraints of the products based on the retrieved associated product data 185 and stacking rule set 184. The stacking arrangement planner sub-module 252 may create a stacking arrangement for the products, based on the container size of the assigned vehicle such as maximum capacity, dimensions, and space clearance, as well as the order of delivering the products, among others. The stacking arrangement planner sub-module 252 may construct a three-dimensional (3D) virtual environment of the container of the delivery vehicle. The virtual environment may be composed of cell spaces that may be defined as occupied or unoccupied. The stacking arrangement planner sub-module 252 may also create a virtual 3D model representative of each product for the delivery job based on computer aided drawing (CAD) data or simplified box bounding models. The virtual environment may be initialized as being empty, i.e. all the cell spaces may be initialized as being unoccupied. The stacking

arrangement planner sub-module 252 may place the 3D models of the products in the empty virtual environment based on the stacking constraints and the stacking rule set. The stacking arrangement planner sub-module 252 may change the definition of cell spaces where the 3D model of the product is placed, from “unoccupied” to “occupied”. The stacking arrangement planner sub-module 252 may repeatedly arrange and re-arrange the 3D models of the products, until all (or a maximum quantity of) the 3D models are placed in the virtual environment while satisfying the stacking constraints and the stacking rule set. If some of the constraints cannot be satisfied, or if some of the 3D models cannot be fitted into the virtual environment, the stacking arrangement planner sub-module 252 may provide feedback that the selection of products for the delivery vehicle may need to be modified, for example, to remove some products from the delivery vehicle. The scheduling parameter determination sub-module 253 may determine practical values for the scheduling parameters such as vehicle speed, loading and unloading parameters based on the delivery history data 189. The delivery history data 189 may include information relating to past delivery jobs. The information may include at least one of vehicle types 261, product types 262, container types 263, stacking layouts 264, loading/unloading times 265, scheduling parameters 266, and stacking parameters 267. The information on vehicle types 261, scheduling parameters 266 and stacking parameters 267 may be especially relevant to the determination of practical values for the scheduling parameters. The product loading/unloading estimation sub-module 254 may estimate the time for loading and unloading the products based on the stacking arrangement in a container. For example, unloading a desired product may involve various steps including moving another product that is placed on top of it to another position, moving the desired product to the container door, and re-loading the other product. Each of these steps may be associated with a respective unit time value to estimate the loading and unloading time. The product loading/unloading estimation sub-module 254 may use loading and unloading times 265 of past delivery jobs, to adjust the unit time values. The delivery routing solver sub-module 255 may determine a route between two locations based on a performance index. The performance index may include minimal time, minimal distance, etc. The delivery routing solver sub-module 255 may determine routes of at least two jobs with defined destinations. Further, the delivery routing solver sub-module 255 may accept two sets of input data, the first set including two jobs with defined destinations, and the second set including at least one job with defined locations, and determine the jobs from the second set that are located along the route of the first set of jobs. Furthermore, the delivery routing solver sub-module 255 may accept a delivery job with a defined location and

a set of jobs, and determine the jobs from the second set that are at nearby location of the first set defined by proximity measurements (e.g., reachable in 15 minutes).

[0041] The delivery plan optimization sub-module 256 may create an optimized delivery plan based on at least one of the delivery job data 111, planning parameters 121, delivery status 145, delivery rule set 183, and stacking rule set 184, other delivery job data 182, product data 185, vehicle data 186 and location data 187. The delivery plan optimization sub-module 256 may optimize the delivery plan by clustering delivery jobs based on delivery requirements such as destination attribute and product similarity. The delivery plan optimization sub-module 256 may also determine the vehicle type with a load capacity that matches the job size (including total weight and size) of a cluster of delivery jobs. If the job sizes exceed the container limits, the delivery plan optimization sub-module 256 may regroup the cluster. In addition, the delivery plan optimization sub-module 256 may arrange the order of locations in delivering products. The delivery plan optimization sub-module 256 may take into account the stacking parameters by conducting a stacking arrangement verification. In order to reduce the computation efforts for verifying the stacking arrangement, the delivery plan optimization sub-module 256 may determine a stack load factor based on the product mix of jobs of a cluster. An implementation of scheduling optimization is described with respect to FIG. 6.

[0042] FIG. 3A-3D show examples of data formats for various data that the Device 170 stores, generates, receive or transmit. These data may be essential data used by the Device 170 to conduct delivery planning with stacking layout. It should be understood that the information contained in the respective type of data may not be limited to the fields shown in these figures, and may not include all of the fields shown in these figures.

[0043] FIG. 3A shows a table 300A representing the data format of delivery job data 182 according to various embodiments. Each row of the table 300A may correspond to a respective delivery job. The “job number” column 302 may store a number for each delivery job. The numbers in this column may be in running order. The number may indicate a sequence of receiving the delivery job. The “job ID” column 304 may store a unique identifier for each delivery job. The “origin” column 306 may store a starting position for the vehicle in carrying out the delivery job. The “destination” column 308 may store an end position for the vehicle in carrying out the delivery job. The operation” column 310 may indicate the type of action that is performed at the destination, for example, pick-up or drop-off of a product. The “product item” column 312 may store an identifier or a descriptor of the product that is picked up or dropped off in the delivery job. The “product quantity” column 314 may indicate the quantity of the product that is carried in the delivery job. The “delivery date” column 316 may indicate

the date of the delivery. The operation time window” column 318 may indicate the time window where the operation was carried out, or was required to take place in.

[0044] FIG. 3B shows a table 300B representing the data format of product data 185 according to various embodiments. Each row of the table 300B may correspond to a respective product. The “product number” column 320 may store a number for each product. The numbers in this column may be in running order. The “product ID” column 322 may store a unique identifier for each product. The “height” column 324, “length” column 326 and “width” column 328 may store dimensions of the product along three axes of measurements. The “weight” column 330 may store information on the weight of the product. The “load limit” column 330 may indicate a maximum weight that the product can support. The “description” column 334 may store a description of the product, for example, the type of object. The “orientation constraint” column 336 may indicate whether the product needs to remain in a fixed orientation during transportation. The “stackable” column 338 may indicate whether the product can be stacked onto other products. The “stack layer limit” 340 may indicate the highest layer number that the product can be stacked on. The product data 185 may further include 3D CAD data that the stacking arrangement planner sub-module 252 may use to create 3D models of the products. The product data 185 may also include shape information on the products. The information in the “load limit” column 332, the “orientation” column 336, the “stackable” column 338 and the “stack layer limit” column 340 may be part of the stacking constraints of the products, or the basis for determining the stacking constraints of the products. These stacking constraints may be determined based on manufacturing data, product specifications, or empirical data. The information in the “stackable” column 338 may be determined based on the product packaging, specifically, the type of material holding the product. The stacking constraint may also include a maximum count of products of the same type that can be loaded in each vehicle type.

[0045] FIG. 3C shows a table 300C representing the data format of vehicle data 186 according to various embodiments. Each row of the table 300C may correspond to a respective vehicle. The “vehicle ID” column 342 may store a unique identifier for each vehicle, for example, car plate number. Vehicles 1, 2 and 3 may be each be associated with a specific vehicle type, such as a 4-wheel van, a 6-wheel truck etc. The “maximum payload capacity” column 344 may indicate the maximum cargo weight that the vehicle may be capable of transporting. The “interior height” column 346, the “interior length” column 348 and the “interior width” column 350 may store the dimensions of the storage space of the vehicle, in three measurement axes. The “earliest start time” column 352 may indicate the earliest time that the vehicle may be available for taking on jobs. The “latest end time” column 354 may indicate the latest time that

the vehicle may be on the road. The table 300C may further include a column that indicates the vehicle type. The vehicle type may be used as a parameter in determining the stack load factor. [0046] FIG. 3D shows a table 300D representing the data format of location data 187 according to various embodiments. Each row of the table 300D may correspond to a respective location. The “location code” column 360 may store a unique code for each location, for example a postal code. The “address” column 362 may store an address of each location. The “latitude” column 364 and the “longitude” column 366 may store geographical positions of the locations. The “opening time” column 368 and the “closing time” column 370 may define the time availability of the locations. The “operation time duration” column 372 may store an allowable, or past operation time for job deliveries.

[0047] FIG. 4 shows a line interaction diagram 400 showing an example of interactions for creating a delivery plan with stacking layout according to various embodiments. The line interaction diagram 400 shows an example where multiple delivery jobs begin at the same distribution point where the delivery vehicles are loaded with products. It is also possible that some of the products may be picked up enroute during other delivery jobs. The Device 170 may provide functionality to receive, and send information from the shipper application 110, the planner application 120, the loader application 130, the driver application 140 and the receiver application 150 to facilitate timely delivery of products. In 401, the planner application 120 may transmit planning parameters 121 to the Device 170. In 402, the shipper application 110 may send a delivery request to the Device 170. The delivery request may include the delivery job data 111. In 403, the Device 170 may accept the delivery request, and in 404, the Device 170 may send confirmation 112 to the shipper application 110, to indicate its acceptance of the delivery request. In 405, the Device 170 may decide whether to generate the dispatch plan with stacking layout. By default, the Device 170 may proceed to generate the dispatch plan with a stacking layout. Alternatively, the Device 170 may be configured to generate the dispatch plan only after a predetermined time, or according to a predetermined frequency. Alternatively, the Device 170 may be configured to generate a plurality of dispatch plans with their respective stacking layouts, only after a predetermined number of delivery job requests have been received. If the Device 170 decides not to generate the dispatch plan with a stacking layout, the Device 170 may return to 403. If the Device 170 decides to generate the dispatch plan with a stacking layout, in 406, the Device 170 may generate the dispatch plan together with a stacking layout. In 407, the Device 170 may send the dispatch plan update 142 to the driver application 140 and may send the stacking plan 132 to the loader application 130. In 408, the driver application 140 may prepare the delivery vehicle, for example, direct the

delivery vehicle to the loading point. When the delivery vehicle has reached the loading point, the driver application 140 may send a delivery update 141 to the loader application 130. In 409, the loader application 130 may arrange to pick up products. Upon receiving the delivery update 141, in 410, the loader application 130 may arrange for staff or machinery to load the products onto the delivery vehicle based on the stacking plan 132. After loading the products onto the delivery vehicle, the loader application 130 may transmit a confirmation 131 to the Device 170. In 411, the Device 170 may send a delivery update 151 to the receiver application 150 upon receiving the confirmation 131.

[0048] FIG. 5 shows a line interaction diagram 500 showing an example of interactions for during delivery of a product, according to various embodiments. In 501, the driver application 140 may send delivery update 141 to the Device 170. The delivery update 141 may include a status of the delivery status and the present location of the delivery vehicle. In 502, the Device 170 may receive the delivery update 141. In 503, the Device 170 may determine whether the delivery vehicle is reaching the destination. If in 503, the Device 170 determines that the vehicle is not yet reaching the destination, the Device 170 may return to 502. If the Device 170 determines that the delivery vehicle is already reaching the destination, in 504, the Device 170 may proceed to load instructions for unloading the product based on the stacking layout. In 504, the Device 170 may also send to the driver application 140, information about the product to be dropped off or to be picked up, and the stacking plan update 143. The stacking plan update 143 may include information on the stacking layout and information on how to execute the loading and unloading of the product and other affected products, and information on how to rearrange the stacking layout if a rearrangement is necessary. In 505, after unloading the product, the driver application 140 may send a confirmation of the unloading (i.e. successful delivery) of the product, to the Device 170. In 506, the driver application 140 may deliver the product to a recipient. The driver application 140 may transmit at least one of the confirmation of the unloading and the delivery to the Device 170 via a delivery update 141. The device 170 may transmit delivery update 151 to the receiver application 150 after receiving the confirmation of delivery from the driver application 140. In 507, the Device 170 may check the stacking layout of the remaining products in the delivery vehicle. The Device 170 may compute a new stacking layout based on the remaining products. The new stacking layout may be computed such that minimal rearrangement is required, so as to save time on the loading process. The Device 170 may also compute the new stacking layout before the delivery is completed. However, in some cases which may involve changes in the destination location, or change in the pick-up item specification, a computation of the new stacking layout may be

required in real time. The computation may be made while an actual handover/receiving of a product from/to driver to/from a receiver/shipper is being made. In 508, the Device 170 may generate a dispatch plan with the new stacking plan layout. In 509, the Device 170 may confirm the change in the stacking layout after receiving the delivery update 141, and may send a stacking plan update 143 to the driver application 140. In 510, the driver application 140 may rearrange the remaining products in the vehicle based on the stacking plan update 143. Rearrangement may be required for the stability of the stacking of the products. Rearrangement may also be made to reduce the unloading time at a subsequent destination where the allowable unloading time is short. In such a case, the rearrangement may be carried out at a location where the allowable loading and unloading time duration is longer than at the subsequent destination. The Device 170 may be configured to determine when a stacking rearrangement is required based on the current container content, product for delivery in the next location, and based on the loading and unloading time duration of the delivery locations. In 511, the driver application 140 may send a confirmation to the Device 170 and may proceed to follow the dispatch plan. In 512, the Device 170 may check if all delivery jobs have been completed. If all the delivery jobs have been completed, the Device 170 may proceed to end the interactions. If there are remaining delivery jobs, the Device 170 may proceed to 502 to continue the interactions.

[0049] FIG. 6A to 6B show a flow diagram of the process for generating dispatch plans according to various embodiments. The dispatch plans may be generated at least partially based on the stacking constraints of the products. The process shown in FIGS. 6A-6B may include simulation-based optimization where a solution may be improved based on a parametric search. The search methodology may include heuristics and metaheuristics methods such as nearest neighbor method, tabu search, simulated annealing, among other algorithms.

[0050] FIG. 6A shows a first flow diagram 600A. The process of generating the dispatch plans may follow 405 of FIG. 4, or 507 of FIG. 5. This process may be performed by the Delivery Plan Optimization sub-module 256. In 601, the Device 170 may retrieve relevant data including at least one of the input data types shown in the memory 175 of FIG. 1. In 602, the Device 170 may analyse the delivery jobs based on their location attributes. In the analysis, the Device 170 may identify delivery jobs with destinations near one another, or delivery jobs that are at least substantially along common routes. The common routes may be calculated by the Delivery Routing Solver sub-module 255. The Device 170 may also consider the delivery requirements, including at least one of the delivery time duration, the pick-up time, the pick-up time duration, at each location. The Device 170 may be configured to avoid clustering delivery jobs that have

the same delivery time requirement but differing destinations. In 603, the Device 170 may determine characteristics of the delivery job. The characteristics may include at least one of physical properties of the product, job size, dimensional data and delivery time requirement. The physical properties may include, for example, the product type, the product shape, the product packaging shape, or the material of the packaging. The job size may include, for example, total volume and total weight of the products. The dimensional data may include, for example, the length, width and height of the products. The delivery time requirement may stipulate a time window for the product to be delivered.

[0051] FIG. 6B shows a second flow diagram 600B that follows from 603 of FIG. 600A. In 604, the Device 170 may cluster unassigned delivery jobs based on their job characteristics and location attributes obtained in 602 and 603. Delivery jobs with similar job characteristics and location attributes may be clustered together. In 605, the Device 170 may select a cluster. The selection may be made based on priority, for example a cluster including jobs with the earliest delivery times, a cluster including jobs with the largest sizes, or a cluster including jobs with large dimensional variances. The initial selection of cluster may not affect the final result as long as the number of iterations or the calculation time for finding the job clusters is sufficient to derive a global optimal solution. In 606, the Device 170 may check whether the space requirements of the selected cluster exceeds a maximum vehicle capacity. The maximum vehicle capacity may be the capacity of a preferred vehicle type. The preferred vehicle type may be selected based on operation constraints. For example, a delivery destination may ban trucks from entering within a specified time period. Thus, a truck may be less preferred for the delivery job as it will have a limited time window to complete the delivery as compared to other types of vehicles. The preferred vehicle type may alternatively, or additionally, be selected based on cost-effectiveness and availability. Alternatively, the maximum vehicle capacity may be the capacity of a largest capacity vehicle amongst the available delivery vehicles, such as a trailer truck. If the space requirement of the cluster exceeds the maximum vehicle capacity, the Device 170 may remove at least one delivery job from the cluster in 607. The Device 170 may select the job for removal, based on the job size, so as to reduce the cluster size to be less than the maximum vehicle capacity. The Device 170 may also select the job for removal, based on its variance from the job characteristics of the rest of the cluster, so as to increase the uniformity of the products within the cluster. With increased similarity between the products, the stack layout may be less complicated and the loading and unloading time may be shorter. The removed delivery job may be added to another cluster, based on proximity of

pickup or drop-off locations. The removed delivery job may be temporarily added to a list and may be assigned to a cluster only after further iterations of 604.

[0052] If the space requirement of the cluster is less than the maximum vehicle capacity, in 608, the Device 170 may determine whether the space requirement is less than a minimum practical volume. The minimum practical volume may be determined based on economic considerations, such as whether the amount of delivery jobs may cover the delivery cost. The revenue or profit may be measurable from the space requirement, as some deliveries may be charged by volume of the delivered product. In some cases, there may be no other jobs available for addition to the cluster so the minimum volume may not be achieved. If the space requirement is less than the minimum practical volume, in 609, the Device 170 may add delivery job(s) to the cluster. The delivery planning may be deferred until the minimum practical volume is met. The selection of a job to be added may be based on nearby locations, a job with location along a route, a job with same job characteristics, or a combination thereof. The job may be selected from the list of jobs removed in 607 or from another cluster, or a job with a delivery time requirement that is compatible with existing jobs in the cluster. The added job may be checked for compatibility with existing jobs in the cluster, based on whether its delivery time window has no conflicts with the delivery time requirements of other jobs in the cluster, and whether the total travel time after including the added job may still meet the desired delivery time limit. If the space requirement meets the minimum practical volume for delivery, in 610, the Device 170 may determine a stack load factor for a stacking arrangement of the products in the cluster. The stack load factor may be calculated based on the product mix of a cluster. The stack load factor calculation will be described in further details with respect to FIG. 8.

[0053] In 611, the Device 170 may generate a stacking layout based on job characteristics of the cluster. The job characteristics may include the stacking constraints, and the loading and unloading time duration constraints of the destinations. The stacking arrangement planner submodule 252 may simulate the stacking layout and may check for stacking constraints. The processes in 611 may be conducted several times by following the loop from 611, 612, 613, and 614. Alternatively, to save on computational resources and to reduce the computing time, the number of iterations may be reduced by using information in the data table 800 to estimate whether the stack load factor value that may result in a feasible stacking arrangement. For example, if the stack load factor is lower than that in the table 800, it is likely to be feasible. By reducing the stack load factor to less than one, the container capacity makes a “room” or allocate buffer space that may be necessary in dealing with stacking constraints. The

determination of the ideal amount of room or space may be complicated, may be empirical values or determined by simulation, and may require several considerations of the product mix, product types, container size, total job size, dimensions, among other factors. The method of determining the stacking layout may include solutions similar to the arrangement of cargo onto pallets, in that it may involve packing heterogeneous objects into a fixed volume. A person skilled in the art would be aware of the solutions that are available for optimizing the stacking layout given the stacking constraints. In 612, the product loading/unloading estimation sub-module 254 may check if the generated stacking layout meets the constraint for loading and unloading time duration at the destinations. The stacking arrangement planner sub-module 252 may check if the stacking layout is valid with respect to the stacking constraints. If the stacking layout does not satisfy any one of the stacking constraints or the loading/unloading time duration constraints, the Device 170 may determine, in 613, whether the stack load factor is within a practical limit. If the stack load factor is within the practical limit, in 614, the Device 170 may adjust the stack load factor. The adjustment may reduce the stack load factor. The practical limit may be set based on a product type.

[0054] There may be a range of stack load factors that may be practical, for example, 70% as the minimum and 100% as the maximum. The goal may be to find the maximum practical stack load factor. The range of stack load factor values may vary depending on product mix and other factors. The practical range of stack load factor may be determined by iterating the process of checking the validity of the stacking layout, with an initial stack load factor of 100%, then decrementing the stack load factor by a small step such as 1%, until 70% through each round of iteration. For each iteration, the highest stack load factor where the stacking layout is valid may be selected. This process of high resolution search, however, may be computationally expensive or may require long calculation time. Another possible solution may be to decrement the stack load factor by a larger step such as 10% (low resolution search). When a stacking load factor that gives a valid stacking layout is reached, the iteration may be repeated for small changes in values of the stack load factor. For example, if at the second iteration, 90% stack load factor is valid, a high resolution search may be performed to test stack load factors between 90% and 100%.

[0055] If the stack load factor falls outside of the practical limit, the stack layout may not be feasible for the jobs in the cluster. Therefore, in 616, the Device 170 may eliminate job(s) and may add the eliminated jobs to the list of unassigned jobs. As a result, the product mix of the cluster changes. The Device 170 then returns to 610 to set a new stack load factor. The Device 170 may select the job for elimination, based on the job size, the job similarity and evaluating

the uniformity of the resulting cluster after the elimination. The Device 170 may obtain data from the data table, like shown in FIG. 8, to find a similar pattern to increase the probability of generating a valid stack layout. If in 612, the stacking layout is valid with respect to the constraints, in 615, the Device 170 may assign a delivery timing to each job in the cluster. The timing may be determined based on at least one of the delivery time requirement, the stacking rearrangement requirement, the time availability of the vehicle, the expected loading/unloading time of the jobs, and the delivery time needed from one location to another. Since a cluster may have multiple job deliveries of differing locations, the process of generating stack layout from 611, 612, 613, 616 and 614 may be repeated for each location. This may be necessary to ensure that the stacking layout satisfies the stacking constraints when a job is dropped-off or picked-up from a location.

[0056] In 617, the Device 170 may calculate the total delivery time based on the assigned timing in 615. The total delivery time may be calculated by finding the difference between the end time of the last operation and the start time of the first operation in the delivery plan. The Device 170 may determine if the total delivery time falls within a desired limit. The limit may be determined based on the maximum working time of a driver or a team of drivers or other factors. If the total delivery time is exceeded, the order of jobs in the cluster may be changed in 618. By changing the order of jobs in a cluster, the total delivery time may be shortened and thus satisfy the desired limit for total delivery time. With respect to the stacking requirement, it may not change at the first location where the loading of majority of jobs may not change. However, it may change the requirement of the succeeding locations as the order is changed and the Device 170 reverts to 610, to set a new stack load factor based on the new order of jobs. The process of changing the job order within a cluster may be considered as the travelling salesman problem wherein the travel time between locations are needed to find the shortest delivery time among the locations of a cluster. It may be solved using exact or heuristic algorithms. The process of changing the order of the jobs should take into consideration the travelling time between the jobs, as well as the loading and unloading time at each destination. The loading and unloading time may depend on the stack layout and as such, the total delivery time may only be determined in 617. In 619, the Device 170 may check if delivery plans have been generated for all delivery jobs. If yes, the Device 170 may conclude the process of generating dispatch plans with stacking layouts. The Device 170 may then proceed to 407 or 509. If there is any unassigned job remaining, the Device 170 may go back to 604.

[0057] According to various embodiments, the method described with respect to FIGS. 6A-6B may further include a process between 608 and 610, to estimate a total delivery time before

generating a stacking plan. This may allow the order of delivery jobs to be determined at an earlier stage, although the order may still need to be changed after factoring in the loading and unloading times which are determined only after the stacking layout is generated.

[0058] According to various embodiments, the Device 170 may be configured to re-optimize the delivery plan and the stacking layout when there are changes in the delivery jobs or job requirements. The Device 170 may update the delivery plan and the stacking layout in real-time, according to the changes. For example, a delivery vehicle may already be en route to the delivery destinations when an existing job order is canceled or a new job order is received. The Delivery Job Handling module 71 may handle the cancellation and addition of new delivery jobs. The Stacking and Delivery Planning module 174 may change the sequence of the delivery and/or the stacking layout based on the changes in the delivery jobs. The existing stacking layout may no longer be optimal with respect to the changes in the delivery jobs and with respect to the succeeding deliveries. At the same time, the delivery sequence may not be optimal as a result of the delivery changes. In this case, the delivery sequence may be determined based on a feasible stacking layout determined by Stacking Arrangement Planner sub-module 252. The Delivery Plan Optimization sub-module 256 may optimize the dispatch plan.

[0059] FIG. 7 shows a diagram 700 of an example of the clustering of jobs in 604 according to various embodiments. The diagram 700 shows a distribution centre 710 and various delivery jobs represented by circles. The line 711 represents distance from the distribution centre 710. The jobs may have varying levels of product similarities as represented by the legend 715. The jobs may have varying levels of job volume, as represented by the legend 716. The diagram 700 shows clustering based on location attributes. In other words, nearby jobs may be grouped into a cluster, like Cluster 1 712, Cluster 2 713 and Cluster 3 714. The clusters may be re-grouped, like in 607, 609 and 618. Based on stacking constraints, scheduling constraints, vehicle capacity limit, among other factors (e.g., constraints that are checked in 606, 607, 612, 617), some jobs from different clusters may be combined. Finally, the goal is that all jobs will be assigned into one cluster. The cluster becomes a group of jobs that has corresponding delivery schedule assigned to a vehicle and with stacking layout/s.

[0060] FIG. 8 shows an example data table 800 for determining the stack load target. The stack load target may be a target value for the stack load factor. Each row of the data table 800 may be a group of jobs that are handled by an allocated vehicle. A stack load target may be calculated for each vehicle type or a single stack load target may be calculated for all vehicle types. The data table 800 may include a “delivery number” column 802 indicating a sequence,

or identifier of the delivery job. The data table 800 may also include a “product mix” column 804, a “vehicle allocation” column 806, a “container capacity allocated” column 808 and a “stack load factor” column 810. The “product mix” column 804 may include a proportion of each product in the cluster (for example, expressed in percentage) and the total product volume of the cluster. The “product mix” column 804 may further include a measurement referred herein as dimensional variance. The dimensional variance may be the variance of the individual dimensions of products of jobs in a cluster. The dimensions may include length, width and size. The dimensional variance is large when the products in a cluster differ greatly in size and/or shape. The “vehicle allocation” column 806 may indicate the vehicle that is allocated to deliver the cluster of products. The container capacity” column 808 may indicate the capacity of the allocated vehicle. From these data, a statistical analysis may be made to generate a model for determining a stack load factor. The value of stack load factor may range from 0 to 1.0. A stack load factor of 1.0 may mean that the entire container capacity may be utilized for stacking products. This is an ideal case when all of the products may be stacked without constraints and that the physical properties of the products allow stacking to maximize the use of container space. On the other end, a stack load factor of close to zero may mean that the entire container space may not be utilized, for example when the product is a fragile thin plate that covers the entire container area and cannot be stacked with other products. The data table 800 may further include vehicle type information. The stack load factor may be determined based on the vehicle type.

[0061] FIG. 9 is a flowchart 900 for a method of generating a delivery plan using volume or weight information according to various embodiments. The method may generate the delivery plan, taking into consideration stacking constraints of the products. The Device 170 evaluate the dispatch plan by taking into consideration the stacking requirements by manipulating the stack load factor. In 910, the Device 170 may receive job data, location data, vehicle data, scheduling parameter and stacking parameters as inputs. In 920, a dispatch plan may be created based on volume or weight information instead of detailed product data. A key parameter may be the stack load factor to virtually change the vehicle capacity. A single value of the stack load factor may be applied to all vehicle types or that each vehicle type may be assigned a respective load factor. The effect of stack load factor may be seen in 1032 (see FIG. 10D) such that a new vehicle capacity may be calculated by multiplying the vehicle capacity with the stack load factor. These calculated vehicle capacity in 1032 may be used in the delivery plan creation. With the stack load factor, the maximum vehicle capacity for the purpose of generating delivery plans may be varied from full capacity (1.0) to less than capacity (e.g. 0.9).

By doing so, the remainder capacity (e.g. 0.1) may not be utilized for assigning delivery jobs but may be reserved as an unused space of products with stacking constraints. Another effect of changing the vehicle capacity is that, the job grouping becomes different for each delivery plan and that the total job requirement (e.g., volume or weight) may be different. The output 921 of 920 may be multiple delivery plans with associated stack load factor. In 930, each dispatch plan may be generated with an associated stacking arrangement. The Device 170 may verify if the stacking layout is feasible stacking given the delivery plan and stacking constraints. The Device 170 may generate a stacking arrangement for every location by taking into consideration the remaining delivery jobs in the container after every delivery and the stacking constraints. The Device 170 may generate the stacking arrangement after every delivery based on the actual capacity or dimension of the vehicle container. The output 931 delivery plans with corresponding stacking layouts. Some plans may not have stacking layout, in this case stacking verification is said to have failed. It may be the cause of inability to satisfy the stacking constraint or that the stack load factor may not be appropriate. For plans with valid stacking layout, these may be evaluated based on specific key performance indices such as actual loading rate, total delivery time, delivery cost, among others. A delivery plan may be selected based on an index or a combination of indices. For example, in FIG. 10F, in the data table 1051, KPI evaluation may include the actual loading rate, total delivery time and cost. The actual loading rate may be calculated by dividing the total job volume with the total container capacity of allocated vehicles. The total delivery time may be calculated based on the route of vehicles. It may be calculated by getting the difference of between the latest time to complete the delivery and the earliest start time of all assigned vehicles. The cost may be calculated based on the cost of using a vehicle as provided in 1021. The result of 1051 may be utilized to decide an optimal delivery plan with stacking rearrangement in 941.

[0062] According to various embodiments, the method shown in FIG. 9 may be adapted to be similar to the method shown in FIGS. 6A-6B, by considering only clustering based on destination attribute, delivery requirement and job characteristics only associated to job size without considering stacking parameters. It may proceed without checking the stacking constraint but only considering timing requirements, the change of job order within a cluster and changing the cluster by adding and eliminating jobs may be conducted by only considering the job size and location. Alternatively, the delivery planning may utilize readily available solutions using only volume or weight information of products.

[0063] FIGS. 10A-10F show examples of data formats according to various embodiments. It should be understood that the information contained in the data may not be limited to, and need not include all of, the fields shown in these examples.

[0064] FIG. 10A shows a table 1011 containing job data. The “job number” column may state a number for each job. The numbers in the various rows may be in sequential order. The “job identifier” column 1004 may state a unique identifier for each job. The “from address” column 1006 may list an origin address for the job, while the “to address” column 1008 may list a destination address for the job. The “product item” column 1010 may indicate a product description or a product identifier. The “product quantity” column 1012 may indicate a quantity of the product that is delivered in the job. The “total volume” column 1014 states the sum of product volumes in the job.

[0065] FIG. 10B shows a table 1021 containing vehicle type data. The “vehicle ID” column 1020 may store a unique identifier for each vehicle type. The “maximum capacity” column 1022 may indicate the maximum cargo weight that the vehicle may be capable of transporting. The “speed” column 1024 may indicate the maximum speed of the vehicle. The “cost” column 1026 may indicate the cost of hiring the vehicle.

[0066] FIG. 10C shows a table 1031 containing stack load factor settings. The column “setting number” 1030 may indicate a reference number for each stack load factor setting. The “stack load factor setting” column 1034 may indicate the stack load factor settings for each vehicle.

[0067] FIG. 10D shows a table 1032 containing vehicle capacity used for delivery planning. The numbers in “vehicle capacity used for delivery planning” column 1042 may be a multiplication product of the vehicle’s maximum capacity and the stack load factor setting corresponding to the setting number of column 1030. The numbers in column 1042 may indicate the vehicle capacity used for delivery planning for each vehicle.

[0068] FIG. 10E shows a table 1041 containing dispatch plans for various vehicle types. The table 1401 shows an example of dispatch plans generated based on the various stack load factor settings. Columns 1052, 1054 and 1056 may each contain dispatch plans for a respective vehicle type, corresponding to various settings according to the column 1030. The dispatch plans may indicate a sequence of locations, for example, “L1 -> L3 -> L4 -> L1” may mean that the vehicle travels from L1 to L3, then from L3 to L4, and then from L4 back to L1. For example, for Set 1, one Vehicle 1 Type and one Vehicle2 Type may be used for delivery of Jobs from 1 to 3. For conciseness, the dispatch plans in 1041 do not show the products but the products may be recognized based on the routes of the vehicles. For example in Set 1, Vehicle

1 has route L1->L3->L4->L1 thus based on the table 1011, Vehicle 1 may deliver jobs Job #2 and Job #3.

[0069] FIG. 10F shows a table 1051 containing information on stacking verification. The “vehicle assignment” column 1060 may show the number of vehicles per vehicle type that is to be used for the delivery jobs, according to the dispatch plans in the table 1040. The “stacking verification” column 1062 may show the verification results, either success or failure. The “actual loading rate” column 1064 may indicate the actual loading rate of the vehicle, which may be expressed as a percentage of the actual product volume in relation to the maximum vehicle capacity. The “total delivery time” column 1066 may show an estimated total time taken to complete the dispatch plans. The “cost” column 1068 may show an estimated total cost of each set of dispatch plans, for example, including the operating costs of the vehicle and the wages of the vehicle drivers. The settings where the stacking verification has failed may be eliminated from consideration.

[0070] FIG. 11A shows a map 1100 and a delivery timeline 1130 of an example of a dispatch plan of a vehicle. The map 1100 shows a route of the vehicle and the operations of the vehicle at each location along the route. The delivery timeline 1130 shows a step-by-step account of the vehicle’s operations which corresponds to the map 1100. At 1102, the vehicle may be at location 1 to pick up products. At 1104, the vehicle may travel from location 1 to location 2. At 1106, the vehicle may drop off product(s) at location 2. At 1108, the vehicle may travel from location 2 to location 3. At 1110, the vehicle may drop off product(s) at location 3. At 1112, the vehicle may pick up product(s) at location 3. At 1114, the vehicle may travel from location 3 to location 4. At 1116, the vehicle may drop off product(s) at location 4. At 1118, the vehicle may travel from location 4 to location 5. At 1120, the vehicle may pick up product(s). At 1122, the vehicle may travel from location 5 to location 1. At 1124, the vehicle may product off product(s) at location 1.

[0071] FIG. 11B shows a table 1103 of a delivery and stacking guide that corresponds to the dispatch plan shown in FIG. 11A. “Location” column 1140 indicates the location of the vehicle. “Transaction” column 1142 shows the type of transaction that takes place for example, loading (in other words: pick-up) or unloading (in other words: drop-off). More than one type of transaction may take place at each location. “Delivery guide” column 1144 may describe the transactions, including the product and the quantity of the product that is being transacted. “Stacking guide” column 1146 may provide information on stacking actions required at every location. “Layout guide” column 1148 may include the stacking layout associated with the required stacking actions. “Duration” column 1150 may indicate the time that the vehicle may

stay at each location. The time may include the time taken to pick up and/or drop off, and to rearrange the stacking.

[0072] FIG. 12A shows an example of a container layout view 1200A. The container view layout view 1200A may be part of the graphical user interface of the loader application 130. The container layout view 1200A may provide a destination selection field 1201. Upon selection of the destination, a layout guide field 1202 may be automatically updated to show the relevant layouts. For example, when the destination is indicated as Location 2, the layout guide field 1202 may be updated to show the change between layout 1 and layout 2. The stacking layout may be recomputed at each destination. The container layout view 1200A shows that at Location 2, Layout 1 1203 may need to be transformed to Layout 2 1204 as a result of dropping off 2 units of product 1 (P1). A stacking guide for carrying out the rearrangement may be provided.

[0073] FIG. 12B shows an example of a stacking guide corresponding to the example of FIG. 12A. The stacking guide may include step-by-step instructions, on how to transform Layout 1 1203 to Layout 2 1204. For example, a first step may include unloading product 5 (P5) that are on top of P1, so that 2 units of P1 may be dropped off. A second step may include unloading product 3 (P3) so as to clear space for product 2 (P2). A third step may include rearranging P2 by stacking P2 in three layers as shown in Layout 2 1204. A fourth step may include stacking P5 on top of P2. A fifth step may include loading P3.

[0074] FIG. 13 shows a flow diagram 1300 of a method for generating product delivery plans according to various embodiments. 1302 may include clustering a plurality of delivery jobs into groups based on locations of the delivery jobs. 1302 may include, or may be part of 604 of FIG. 6B. 1304 may include estimating a stack load factor for each group. The stack load factor may define a useable portion of a vehicle capacity. 1304 may include, or may be part of 610 of FIG. 6B. 1306 may include assigning each group to a respective vehicle. 1306 may include, or may be part of 606 of FIG. 6B. 1308 may include generating a dispatch plan and a stacking layout for each group based on the stack load factor. Each dispatch plan may include a sequence and time of carrying out the delivery jobs in the group. Each stacking layout may define an arrangement of products of the delivery jobs with respect to the assigned vehicle. Estimating the stack load factor for each group may include: computing correlations of stack load factors with respect to product mixes based on historical delivery jobs, and estimating the stack load factor for each group based on the computed correlations. 1308 may include 611 and 615 of FIG. 6B.

[0075] According to various embodiments, the dispatch plan may be optimized based on the stacking layout. Alternatively, the stacking layout may be optimized based on the dispatch plan. The dispatch plan and the stacking layout may also be simultaneously optimized.

[0076] According to various embodiments, the method shown in FIG. 13 may further include modifying the dispatch plan and the stacking layout for each group based on stacking constraints of the products of the delivery jobs. The stacking constraints may define at least one of whether the products are stackable, maximum loading limit on the products, and orientation constraint of the products. The stack load factor may be an approximation of the stacking constraints.

[0077] According to various embodiments, the method shown in FIG. 13 may further include determining a total volume of the products of the delivery jobs in each group, and assigning each group to the respective vehicle based on the total volume, the vehicle capacity and the stack load factor.

[0078] According to various embodiments, the method shown in FIG. 13 may further include comparing a total volume of the products of the delivery jobs in each group to the vehicle capacity of the respective assigned vehicle, and removing delivery jobs from the group if the total volume exceeds the vehicle capacity of the assigned vehicle.

[0079] According to various embodiments, the method shown in FIG. 13 may further include: generating a plurality of stack load factors for each group; generating a corresponding plurality of dispatch plans and stacking layouts for each group based on the plurality of stack load factors; computing a performance index for each dispatch plan and stacking layout of each group; and selecting an optimal dispatch plan and stacking layout for each group from the plurality of dispatch plans and stacking layouts, based on the performance index. The performance index may include at least one of a proportion of the vehicle capacity that is utilised, total delivery time and cost.

[0080] According to various embodiments, the method shown in FIG. 13 may further include: constructing a virtual three-dimensional environment to represent cargo space in the assigned vehicle; constructing virtual three-dimensional models of products of the delivery jobs; and virtually arranging the models in the environment according to the stacking layout, to verify that the stacking layout is feasible. The method may further include verifying that the virtual arrangement fulfils stacking constraints of the products of the delivery jobs, wherein the stacking constraints define at least one of whether the products are stackable, maximum loading limit on the products, and orientation constraint of the products.

[0081] According to various embodiments, the method shown in FIG. 13 may further include: generating new stacking layouts for delivery jobs that remain after completion of a subset of the plurality of delivery jobs; estimating time required to rearrange the remaining delivery jobs according to the new stacking layouts; and verifying feasibility of the dispatch plans further based on the estimated time.

[0082] According to various embodiments, the method shown in FIG. 13 may further include generating at least one of a new dispatch plan and a new stacking layout upon receiving notification of a change in at least one delivery job of the plurality of delivery jobs.

[0083] FIG. 14 shows a conceptual diagram of an apparatus 1400 for generating product delivery plans according to various embodiments. The apparatus 1400 may include a cluster module 1402, a stack load factor estimator 1404 and a delivery planner 1406. The cluster module 1402 may be configured to cluster a plurality of delivery jobs into groups based on locations of the delivery jobs. The stack load factor estimator 1404 may be configured to estimate a stack load factor for each group. The stack load factor may define a useable proportion of a vehicle capacity. The delivery planner 1406 may be configured to assign each group to a respective vehicle, and may be further configured to generate a dispatch plan and a stacking layout for each group based on the stack load factor. Each dispatch plan may include a sequence and time of carrying out the delivery jobs in the group, while each stacking layout may define an arrangement of products of the delivery jobs with respect to the assigned vehicle. The cluster module 1402, the stack load factor estimator 1404, and the delivery planner 1406 may be coupled with each other, like indicated by lines 1440, for example electrically coupled, for example using a line or a cable, and/ or mechanically coupled. The apparatus 1400 may include, or may be part of, the Device 170.

[0084] According to various embodiments, the apparatus 1400 may allow planning, sharing, and modifying of delivery plan with stacking layout among stakeholders such as logistics planner, loader at the warehouse, delivery driver or personnel. Further, the apparatus 1400 may allow dynamic rearrangement of stacking layout at a pick-up or drop-off location. The apparatus 1400 may provide a stacking layout and guide, for the delivery driver or other personnel to rearrange the products within a specified time duration at a location.

[0085] While embodiments of the invention have been particularly shown and described with reference to specific embodiments, it should be understood by those skilled in the art that various changes in form and detail may be made therein without departing from the spirit and scope of the invention as defined by the appended claims. The scope of the invention is thus indicated by the appended claims and all changes which come within the meaning and range

of equivalency of the claims are therefore intended to be embraced. It will be appreciated that common numerals, used in the relevant drawings, refer to components that serve a similar or the same purpose.

[0086] It will be appreciated to a person skilled in the art that the terminology used herein is for the purpose of describing various embodiments only and is not intended to be limiting of the present invention. As used herein, the singular forms "a", "an" and "the" are intended to include the plural forms as well, unless the context clearly indicates otherwise. It will be further understood that the terms "comprises" and/or "comprising," when used in this specification, specify the presence of stated features, integers, steps, operations, elements, and/or components, but do not preclude the presence or addition of one or more other features, integers, steps, operations, elements, components, and/or groups thereof.

[0087] It is understood that the specific order or hierarchy of blocks in the processes / flowcharts disclosed is an illustration of exemplary approaches. Based upon design preferences, it is understood that the specific order or hierarchy of blocks in the processes / flowcharts may be rearranged. Further, some blocks may be combined or omitted. The accompanying method claims present elements of the various blocks in a sample order, and are not meant to be limited to the specific order or hierarchy presented.

[0088] The previous description is provided to enable any person skilled in the art to practice the various aspects described herein. Various modifications to these aspects will be readily apparent to those skilled in the art, and the generic principles defined herein may be applied to other aspects. Thus, the claims are not intended to be limited to the aspects shown herein, but is to be accorded the full scope consistent with the language claims, wherein reference to an element in the singular is not intended to mean "one and only one" unless specifically so stated, but rather "one or more." The word "exemplary" is used herein to mean "serving as an example, instance, or illustration." Any aspect described herein as "exemplary" is not necessarily to be construed as preferred or advantageous over other aspects. Unless specifically stated otherwise, the term "some" refers to one or more. Combinations such as "at least one of A, B, or C," "one or more of A, B, or C," "at least one of A, B, and C," "one or more of A, B, and C," and "A, B, C, or any combination thereof" include any combination of A, B, and/or C, and may include multiples of A, multiples of B, or multiples of C. Specifically, combinations such as "at least one of A, B, or C," "one or more of A, B, or C," "at least one of A, B, and C," "one or more of A, B, and C," and "A, B, C, or any combination thereof" may be A only, B only, C only, A and B, A and C, B and C, or A and B and C, where any such combinations may contain one or more member or members of A, B, or C. All structural and functional equivalents to the

elements of the various aspects described throughout this disclosure that are known or later come to be known to those of ordinary skill in the art are expressly incorporated herein by reference and are intended to be encompassed by the claims. Moreover, nothing disclosed herein is intended to be dedicated to the public regardless of whether such disclosure is explicitly recited in the claims. The words “module,” “mechanism,” “element,” “device,” and the like may not be a substitute for the word “means.” As such, no claim element is to be construed as a means plus function unless the element is expressly recited using the phrase “means for.”

CLAIMS

1. A method for generating product delivery plans, the method comprising:
clustering a plurality of delivery jobs into groups based on locations of the delivery jobs;
estimating a stack load factor for each group, wherein the stack load factor defines a useable proportion of a vehicle capacity;
assigning each group to a respective vehicle; and
generating a dispatch plan and a stacking layout for each group based on the stack load factor,
wherein each dispatch plan comprises a sequence and time of carrying out the delivery jobs in the group; and
wherein each stacking layout defines an arrangement of products of the delivery jobs with respect to the assigned vehicle.
2. The method of claim 1, wherein the dispatch plan is optimised based on the stacking layout.
3. The method of claim 1, wherein the stacking layout is optimised based on the dispatch plan.
4. The method of any one of claims 1 to 3, further comprising:
modifying the dispatch plan and the stacking layout for each group based on stacking constraints of the products of the delivery jobs, wherein the stacking constraints define at least one of whether the products are stackable, maximum loading limit on the products, and orientation constraint of the products.
5. The method of any one of claims 1 to 4, further comprising:
determining a total volume of the products of the delivery jobs in each group; and
assigning each group to the respective vehicle based on the total volume, the vehicle capacity and the stack load factor.
6. The method of any one of claims 1 to 5, further comprising:

comparing a total volume of the products of the delivery jobs in each group to the vehicle capacity of the respective assigned vehicle; and

removing delivery jobs from the group if the total volume exceeds the vehicle capacity of the assigned vehicle.

7. The method of any one of claims 1 to 6, wherein estimating the stack load factor for each group comprises:

computing correlations of stack load factors with respect to product mixes based on historical delivery jobs; and

estimating the stack load factor for each group based on at least one of the computed correlations and a vehicle type.

8. The method of any one of claims 1 to 7, wherein estimating the stack load factor for each group comprises estimating the stack load factor based on a vehicle type of the assigned vehicle.

9. The method of any one of claims 1 to 8, further comprising:

generating a plurality of stack load factors for each group;

generating a corresponding plurality of dispatch plans and stacking layouts for each group based on the plurality of stack load factors;

computing a performance index for each dispatch plan and stacking layout of each group; and

selecting an optimal dispatch plan and stacking layout for each group from the plurality of dispatch plans and stacking layouts, based on the performance index.

10. The method of claim 9, wherein the performance index comprises at least one of a proportion of the vehicle capacity that is utilised, total delivery time and cost.

11. The method of any one of claims 1 to 10, further comprising:

constructing a virtual three-dimensional environment to represent cargo space in the assigned vehicle;

constructing virtual three-dimensional models of products of the delivery jobs; and

virtually arranging the models in the environment according to the stacking layout, to verify that the stacking layout is feasible.

12. The method of claim 11, further comprising:
verifying that the virtual arrangement fulfils stacking constraints of the products of the delivery jobs, wherein the stacking constraints define at least one of whether the products are stackable, maximum loading limit on the products, and orientation constraint of the products.
13. The method of any one of claims 1 to 12, further comprising:
generating new stacking layouts for delivery jobs that remain after completion of a subset of the plurality of delivery jobs;
estimating time required to rearrange the remaining delivery jobs according to the new stacking layouts; and
verifying feasibility of the dispatch plans further based on the estimated time.
14. The method of any one of claims 1 to 13, further comprising:
generating at least one of a new dispatch plan and a new stacking layout upon receiving notification of a change in at least one delivery job of the plurality of delivery jobs.
15. An apparatus for generating product delivery plans, the apparatus comprising:
a cluster module configured to cluster a plurality of delivery jobs into groups based on locations of the delivery jobs;
a stack load factor estimator configured to estimate a stack load factor for each group, wherein the stack load factor defines a useable proportion of a vehicle capacity;
a delivery planner configured to assign each group to a respective vehicle, and further configured to generate a dispatch plan and a stacking layout for each group based on the stack load factor;
wherein each dispatch plan comprises a sequence and time of carrying out the delivery jobs in the group; and
wherein each stacking layout defines an arrangement of products of the delivery jobs with respect to the assigned vehicle.
16. The apparatus of claim 15, wherein the delivery planner is further configured to modify the dispatch plan and the stacking layout for each group based on stacking constraints of the products of the delivery jobs, wherein the stacking constraints define at least one of

whether the products are stackable, maximum loading limit on the products, and orientation constraint of the products.

17. The apparatus of any one of claims 11 to 16, wherein the delivery planner is further configured to determine a total volume of the products of the delivery jobs in each group, and assigning each group to the respective vehicle based on the total volume, the vehicle capacity and the stack load factor.

18. The apparatus of any one of claims 11 to 17, wherein the delivery planner is further configured to compare a total volume of the products of the delivery jobs in each group to the vehicle capacity of the respective assigned vehicle, and configured to remove delivery jobs from the group if the total volume exceeds the vehicle capacity of the assigned vehicle.

19. The apparatus of any one of claims 11 to 18, wherein the stack load estimator is configured to compute correlations of stack load factors with respect to product mixes based on historical delivery jobs, and configured to estimate the stack load factor for each group based on the computed correlations.

20. The apparatus of any one of claims 11 to 19, wherein the stack load estimator is configured to generate a plurality of stack load factors for each group; wherein the delivery planner is configured to generate a corresponding plurality of dispatch plans and stacking layouts for each group based on the plurality of stack load factors; wherein the delivery planner is configured to compute a performance index for each dispatch plan and stacking layout of the each group, and to select an optimal dispatch plan and stacking layout for each group from the plurality of dispatch plans and stacking layouts based on the performance index.

21. The apparatus of any one of claims 11 to 20, wherein the performance index comprises at least one of a proportion of the vehicle capacity that is utilised, total delivery time and cost.

22. The apparatus of any one of claims 11 to 21, further comprising:
a stacking arrangement planner configured to construct a virtual three-dimensional environment to represent cargo space in the assigned vehicle, construct virtual three-

dimensional models of products of the delivery jobs, and to virtually arrange the models in the environment according to the stacking layout to verify that the stacking layout is feasible.

23. The apparatus of claim 22, wherein the stacking arrangement planner is further configured to verify that the virtual arrangement fulfils stacking constraints of the products of the delivery jobs, wherein the stacking constraints define at least one of whether the products are stackable, maximum loading limit on the products, and orientation constraint of the products.

24. The apparatus of any one of claims 11 to 23, wherein the delivery planner is further configured to generate new stacking layouts for delivery jobs that remain after completion of a subset of the plurality of delivery jobs, and estimate time required to rearrange the remaining delivery jobs according to the new stacking layouts, and verify feasibility of the dispatch plans further based on the estimated time.

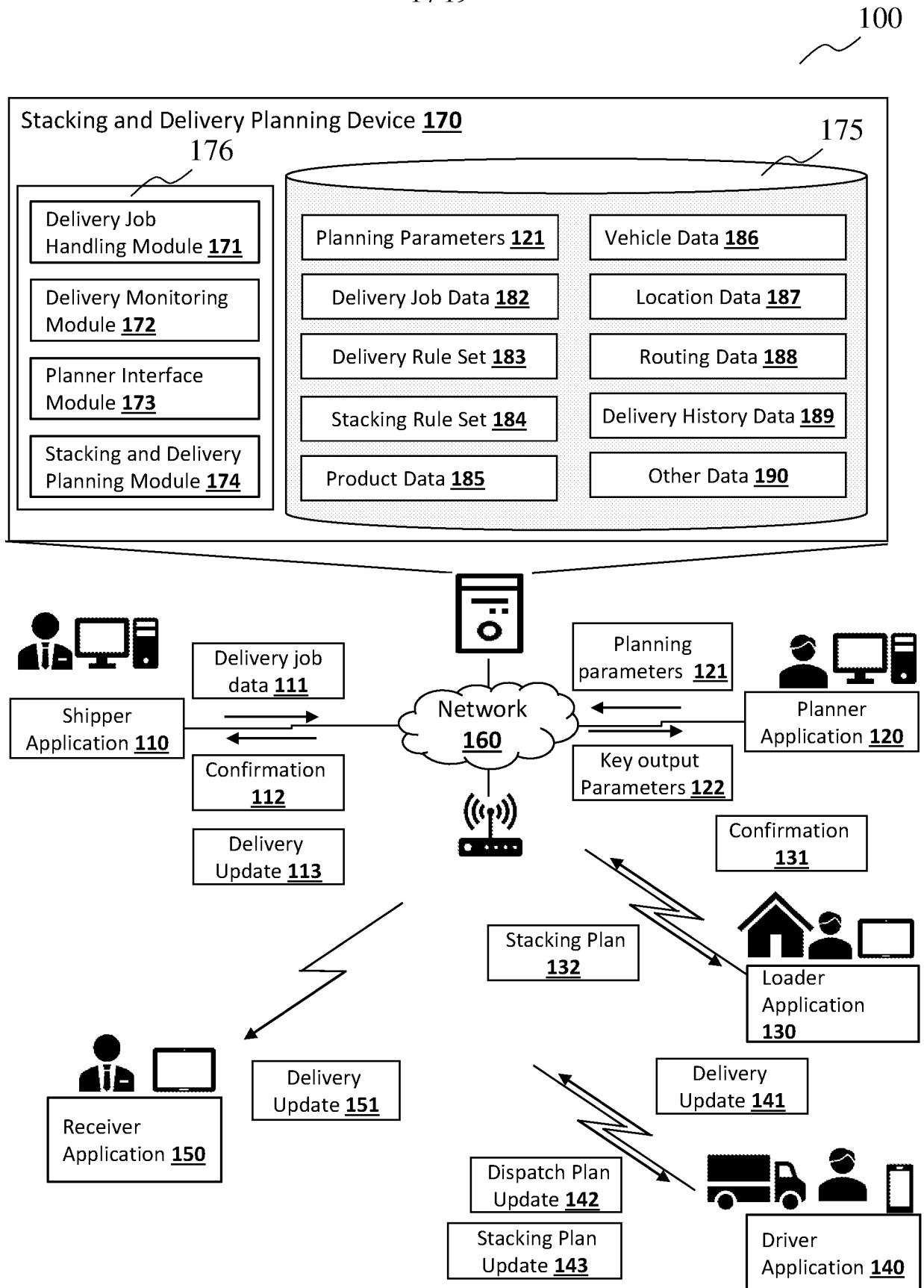


FIG. 1

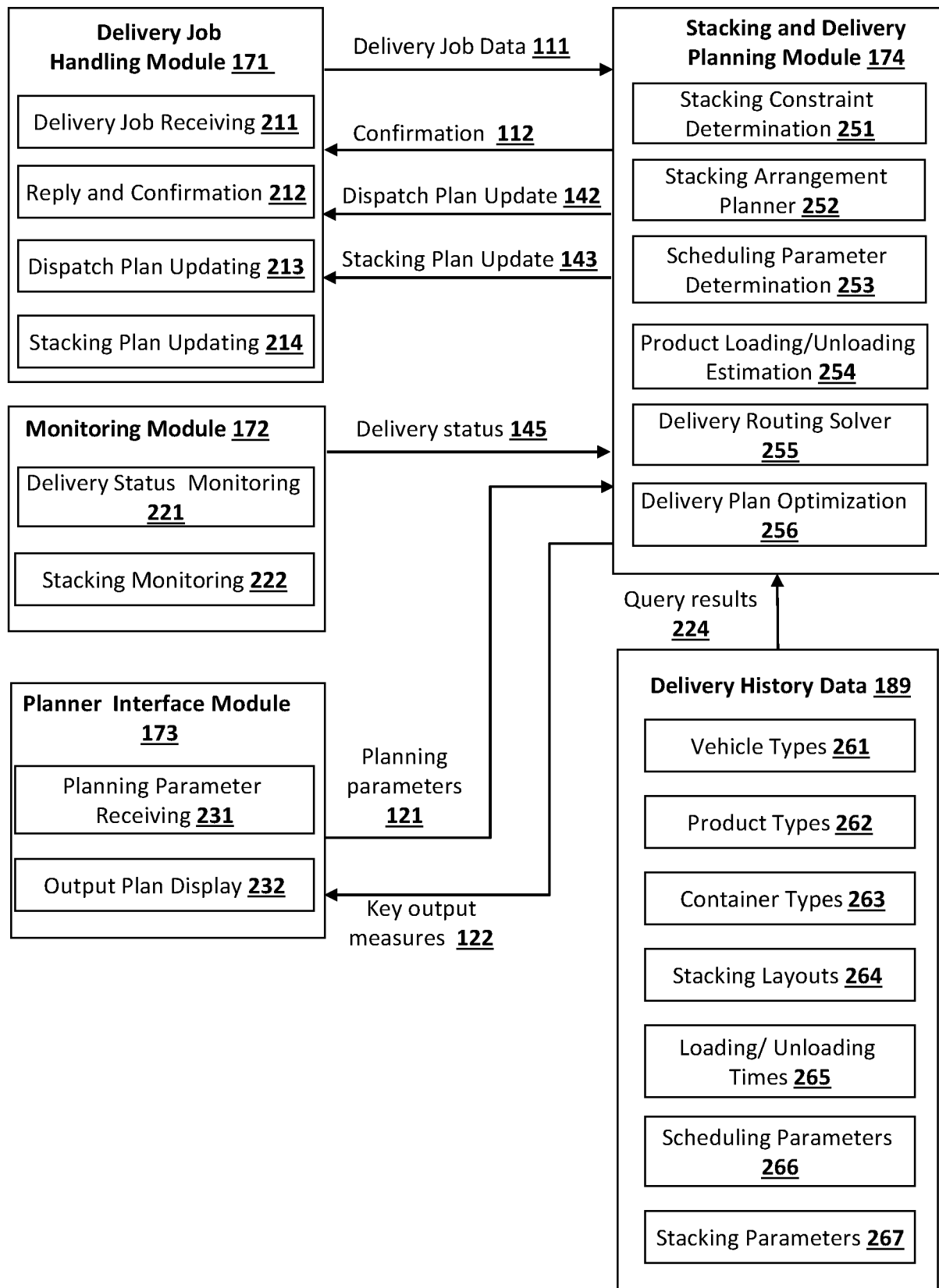


FIG. 2

302	304	306	308	310	312	314	316	318	300A
Job #	Job ID	Origin	Destination	Operation @ Destination	Product Item	Product Quantity	Delivery Date	Operation Time Window	
1	P10001	Loc0003	Loc0001	Pick-up	Prod5	3	2019-06-28	9:20-10:30	
2	P10002	Loc0005	Loc0001	Pick-up	Prod4	7	2019-06-28	13:00-13:30	
3	P10003	Loc0006	Loc0001	Pick-up	Prod2	10	2019-06-28	15:10-15:30	
4	P10004	Loc0007	Loc0001	Pick-up	Prod3	5	2019-06-28	12:00-12:30	
5	D20001	Loc0001	Loc0002	Drop-off	Prod1	10	2019-06-28	08:00-08:10	
6	D20002	Loc0001	Loc0003	Drop-off	Prod2	5	2019-06-28	08:30-9:00	
7	D20003	Loc0001	Loc0004	Drop-off	Prod3	2	2019-06-28	11:10-11:40	

FIG. 3A

320	322	324	326	328	330	332	334	336	338	340	300B
Product #	Product ID	Height (mm)	Length (mm)	Width (mm)	Weight (kg)	Load Limit	Description	Orientation constraint	Stackable	Stack Layer Limit	
1	Prod1	1150	800	800	0	1150	Washer	None	No	-	
2	Prod2	1500	900	200	20	1500	Steel Panel	None	Yes	5	
3	Prod3	1550	800	800	100	1550	Fridge	Vertical	No	-	
4	Prod4	90	2500	80	50	-	Stand rod	Vertical	Yes	5	
5	Prod5	410	335	265	5	-	Cooker	No	Yes	5	

FIG. 3B

300C

342 Vehicle ID	344 Maximum Payload Capacity (kg)	346 Interior Height (m)	348 Interior Length (m)	350 Interior Width (m)	352 Earliest Start Time	354 Latest End Time
Vehicle1	840	1.55	1.87	1.55	07:00	17:00
Vehicle2	1500	1.8	3	1.5	07:00	17:00
Vehicle3	2500	2	4	1.8	07:00	17:00

FIG. 3C

300D

360 Location Code	362 Address	364 Latitude	366 Longitude	368 Opening Time	370 Closing Time	372 Operation Time Duration (min)
Loc0001	504 Line St.	Lat1	Long1	09:00	23:00	30
Loc0002	409 Arc Avenue	Lat2	Long2	09:00	23:00	10
Loc0003	510 San Francisco	Lat3	Long3	09:00	12:00	10
Loc0004	1202 San isidro	Lat4	Long4	09:00	23:00	20
Loc0005	101 Crescent Blvd	Lat5	Long5	09:00	12:00	60
Loc0006	510 Santo Tomas	Lat6	Long6	09:00	12:00	10
Loc0007	1202 Saint Giles	Lat7	Long7	09:00	23:00	20

FIG. 3D

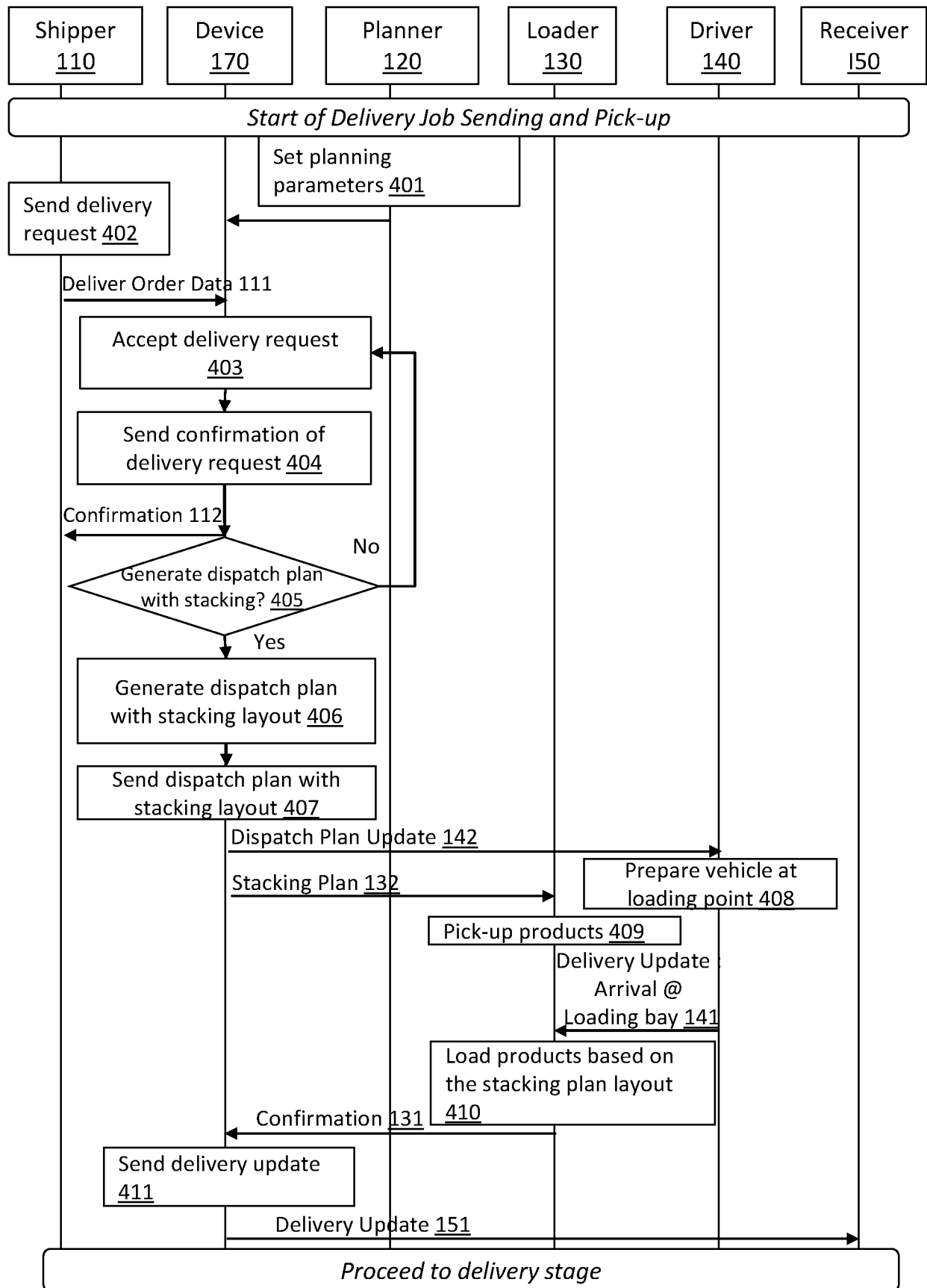


FIG. 4

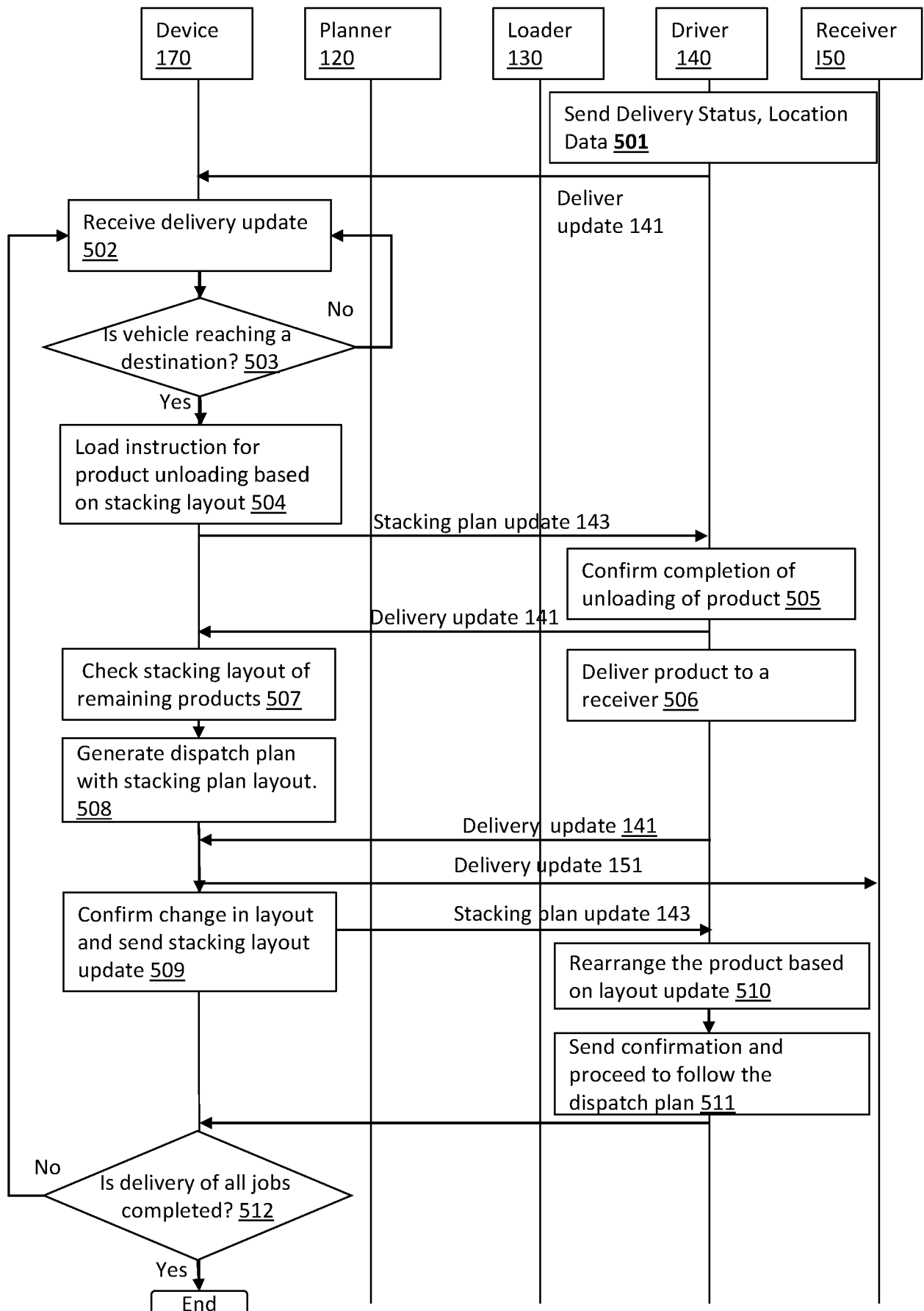


FIG. 5

7 / 19

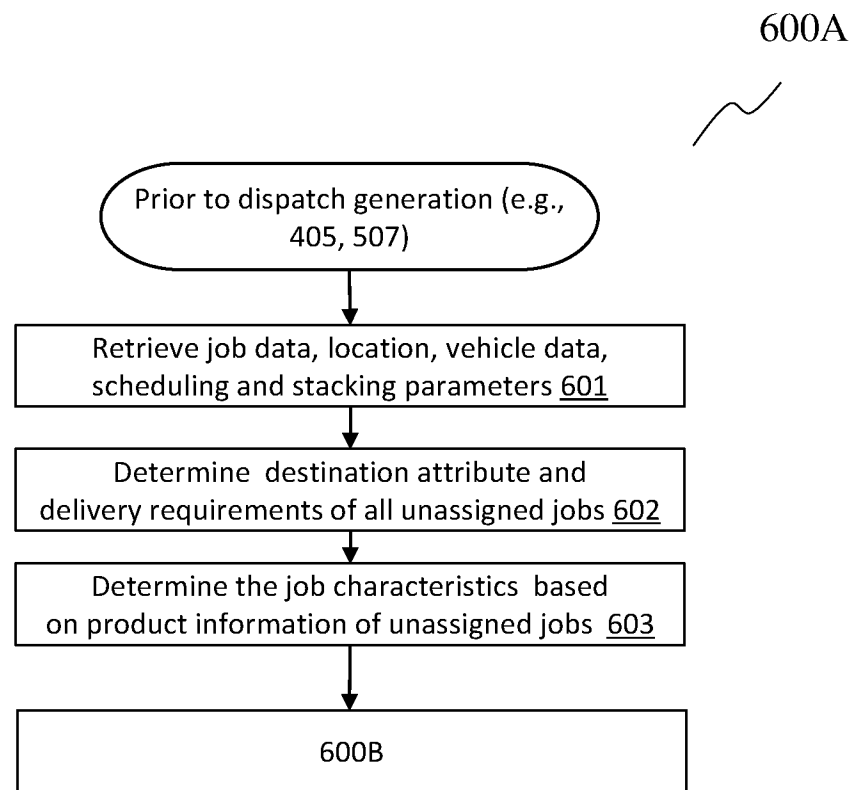


FIG. 6A

8 / 19

600B

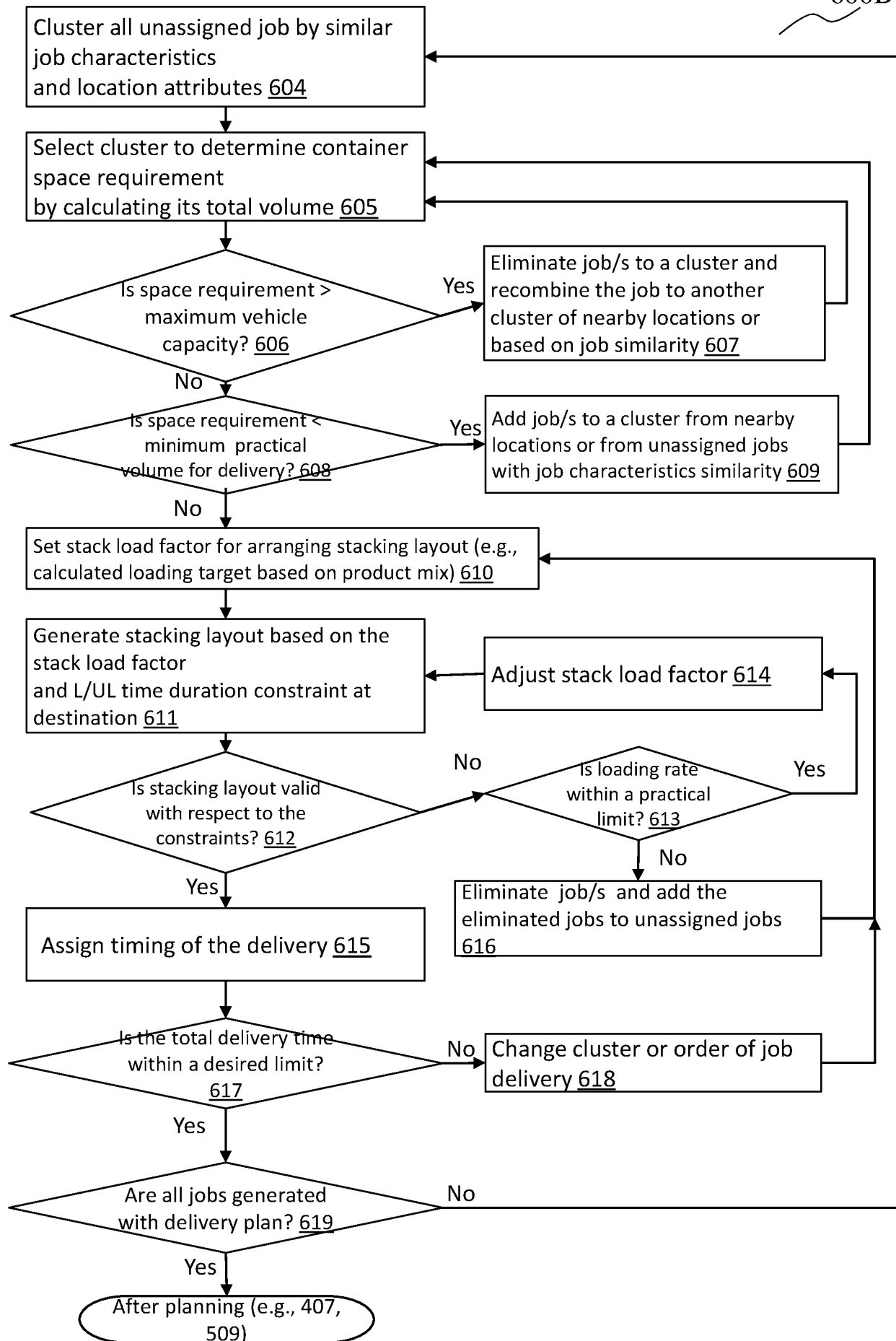


FIG. 6B

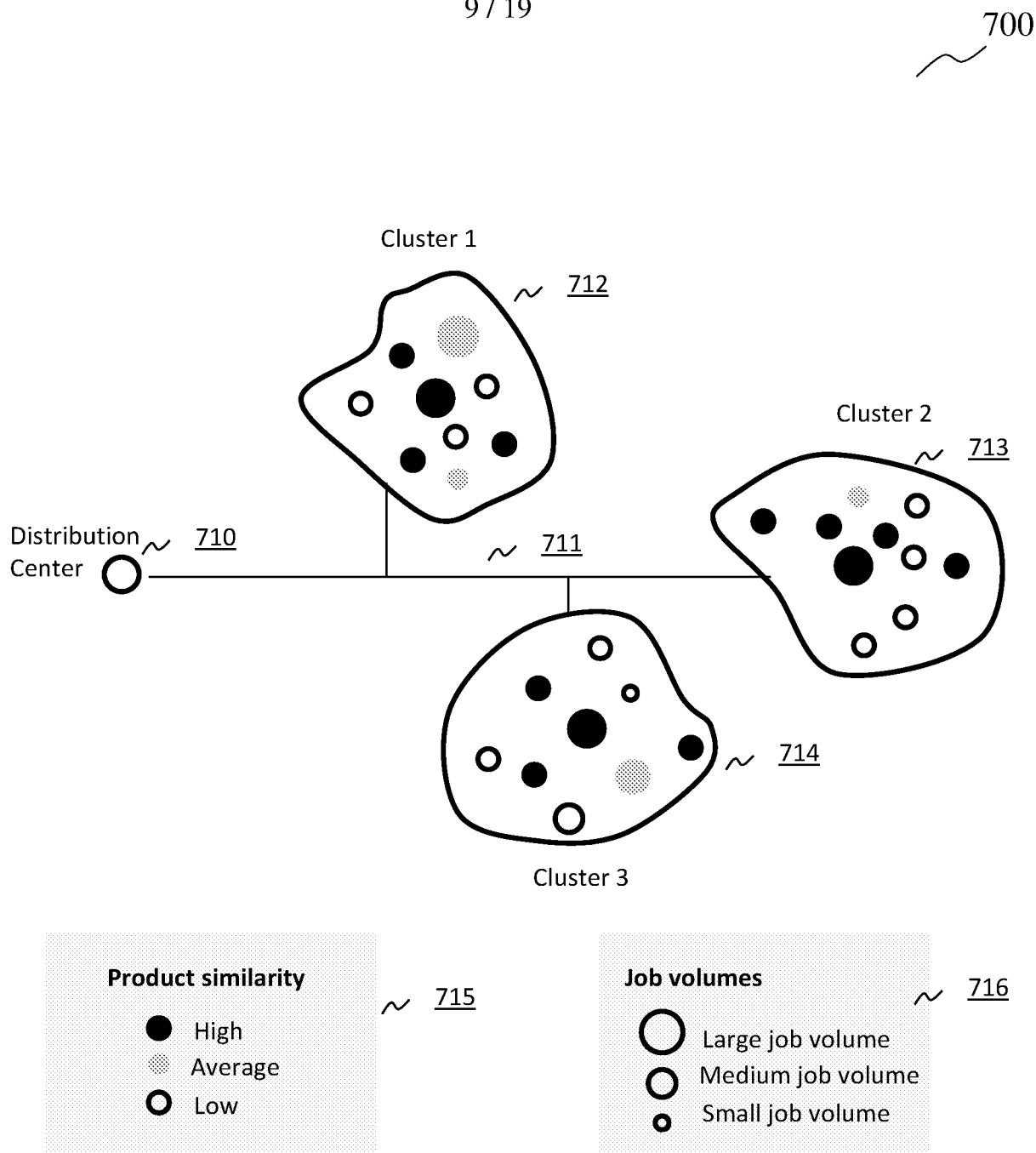


FIG. 7

800

Delivery #	Product Mix					Vehicle allocation	Container Capacity Allocated	Stack load factor
	Product 1	Product 2	Product 3	Product 4	Dimensional Variance	Total Volume		
1	14.29	35.71	14.29	35.71	646.57	3.36	4.5	0.8
2	20.00	40.00	20.00	20.00	653.19	14.95	18.9	0.85
3	83.33	16.67	0.00	0.00	865.94	9.92	12.6	0.9
4	0.00	0.00	20.00	80.00	516.58	0.36	4.5	0.73
5	25.00	25.00	25.00	25.00	675.07	3.86	4.5	0.75

FIG. 8

11 / 19

900

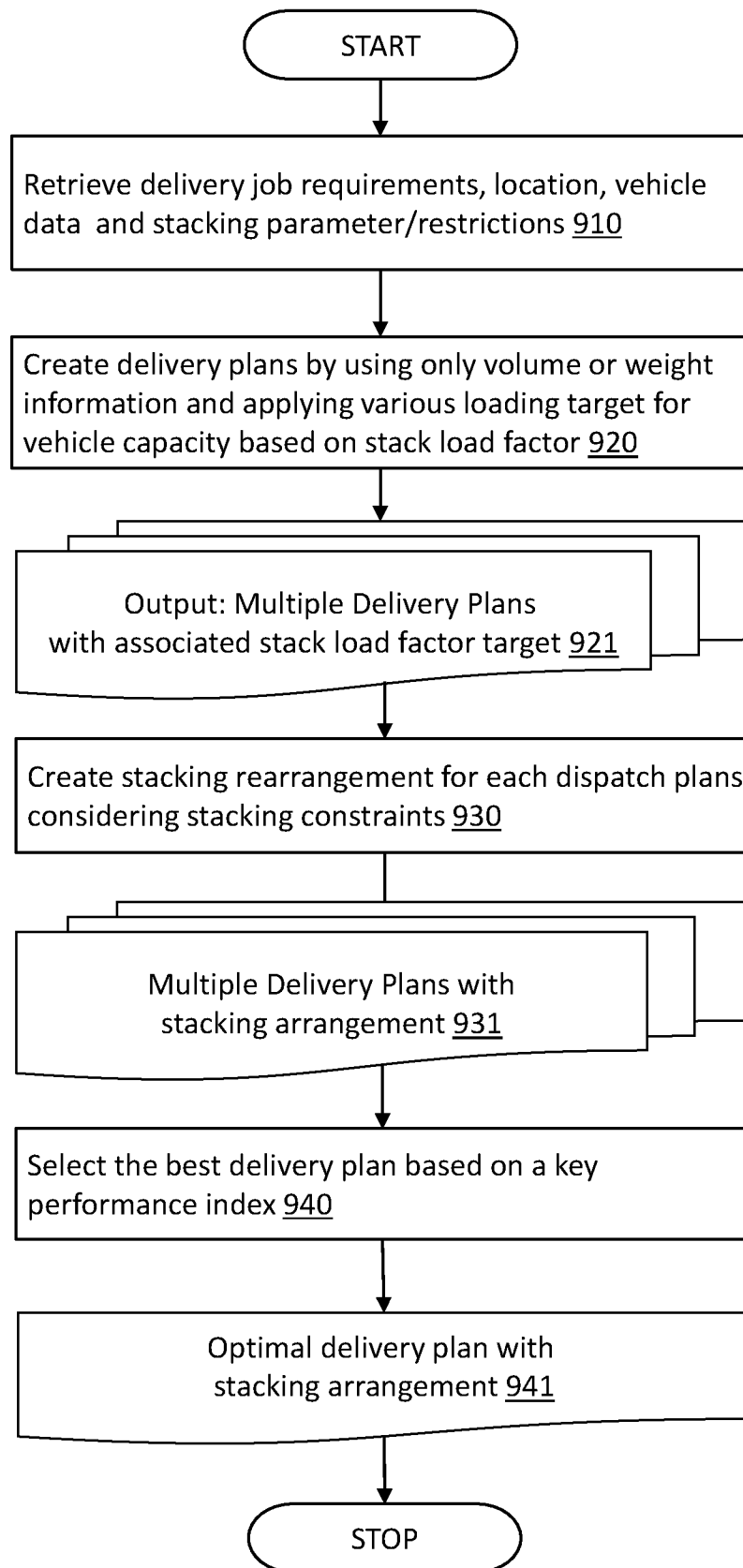


FIG. 9

1011

1002		1004	1006	1008	1010	1012	1014
		Job ID	From Address	To Address	Product Item	Product Quantity	Total Volume
1		D20001	L1	L2	Prod1	10	7.36
2		D20002	L1	L3	Prod2	5	1.35
3		D20003	L1	L4	Prod3	2	1.984

FIG. 10A

1021

1020		1022	1024	1026
		Maximum Capacity	Speed	Cost
Vehicle1		4.5 CBM	65 KPH	\$100
Vehicle2		8.1 CBM	60 KPH	\$180
Vehicle3		14.4 CBM	55 KPH	\$250

FIG. 10B

1031

Setting #	Stack load factor setting		
	Vehicle1	Vehicle 2	Vehicle 3
Set 1	1.0	1.0	1.0
Set 2	1.0	0.9	0.8
Set 3	1.0	0.8	0.8
Set 4	0.9	0.8	0.8
Set 5	0.9	0.9	0.7

FIG. 10C

1032

Setting #	Vehicle capacity used for delivery planning (CBM)		
	Vehicle1	Vehicle 2	Vehicle 3
Set 1	4.5	8.1	14.4
Set 2	4.5	7.29	11.52
Set 3	4.5	6.48	11.52
Set 4	4.05	6.48	11.52
Set 5	4.05	7.29	10.08

FIG. 10D

1041

1056

1054

1052

1030

Settings	Vehicle1 Type	Vehicle2 Type	Vehicle3 Type
Set 1	1: L1->L3->L4->L1	2: L1->L2->L1	-
Set 2	-	-	1: L1->L2->L3->L4->L1
Set 3	-	1: L1->L2->L3->L4->L1 2: L1->L2->L1	-
Set 4	1: L1->L2->L1 2: L1->L2->L1 3: L1->L3->L4->L1	-	-
Set 5	1: L1->L3->L4->L1	-	2: L1->L2->L1

FIG. 10E

1051

1068

1066

1064

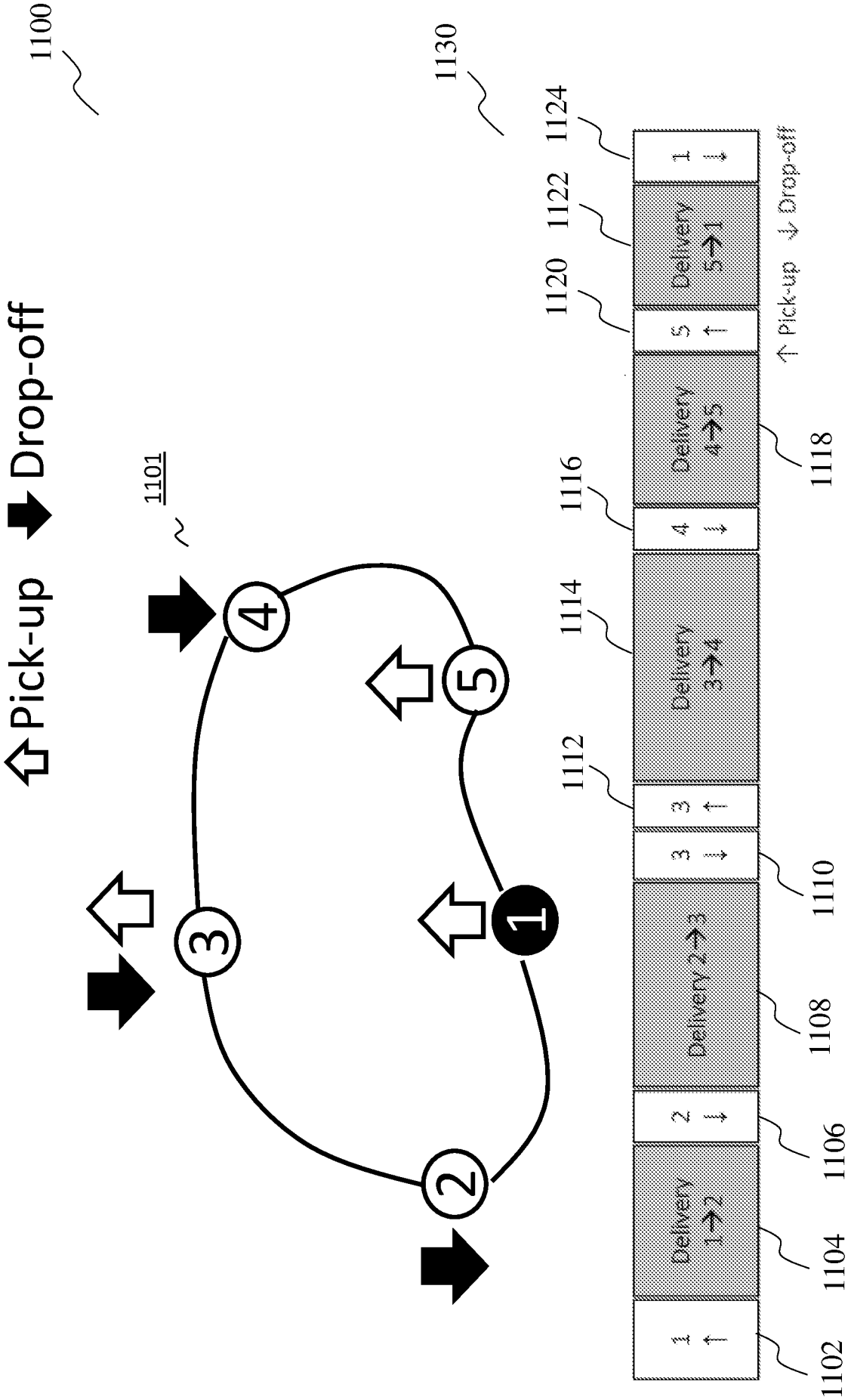
1062

1060

1030

Stack load factor Setting	Vehicle assignment			Stacking verification	Actual loading rate	Total delivery time	Cost
	Vehicle1	Vehicle 2	Vehicle 3				
Set 1	1	1	0	Failed	85%	1.69 hr	\$280
Set 2	0	0	1	Failed	74%	1.09 hr	\$250
Set 3	0	2	0	Success	66%	1.00 hr	\$360
Set 4	3	0	0	Success	80%	1.69 hr	\$300
Set 5	1	0	1	Success	57%	1.07 hr	\$350

FIG. 10F



1103

1140		1142		1144		1146		1148		1150	
Location #	Transaction	Delivery guide		Stacking guide	Layout guide	Duration (min)					
1	Loading @ DC	1. Load P3 2. Load P2 3. Load P1 4. Load P5	Arrange based on Layout 1	<u>Layout 1</u>	20						
2	Drop-off	1. Drop-off P1	Rearrange based on Layout 2	<u>Layout 2</u>	10						
3	Drop-off/Pick-up	1. Drop-off 3 units of P2, P3 2. Pick-up P4	Rearrange based on Layout 3	<u>Layout 3</u>	10						
4	Drop-off	1. Drop-off 3 units of P2, P5	Rearrange based on Layout 4	<u>Layout 4</u>	10						
5	Pick-up	1. Pickup P4	-	-	10						
1	Unload @ DC	1. Drop-off P4	-	-	30						

FIG. 11B

Container Layout View

Select destination: Location 2 ~ 1201

Layout guide: Layout 1 → Layout 2 ~ 1202

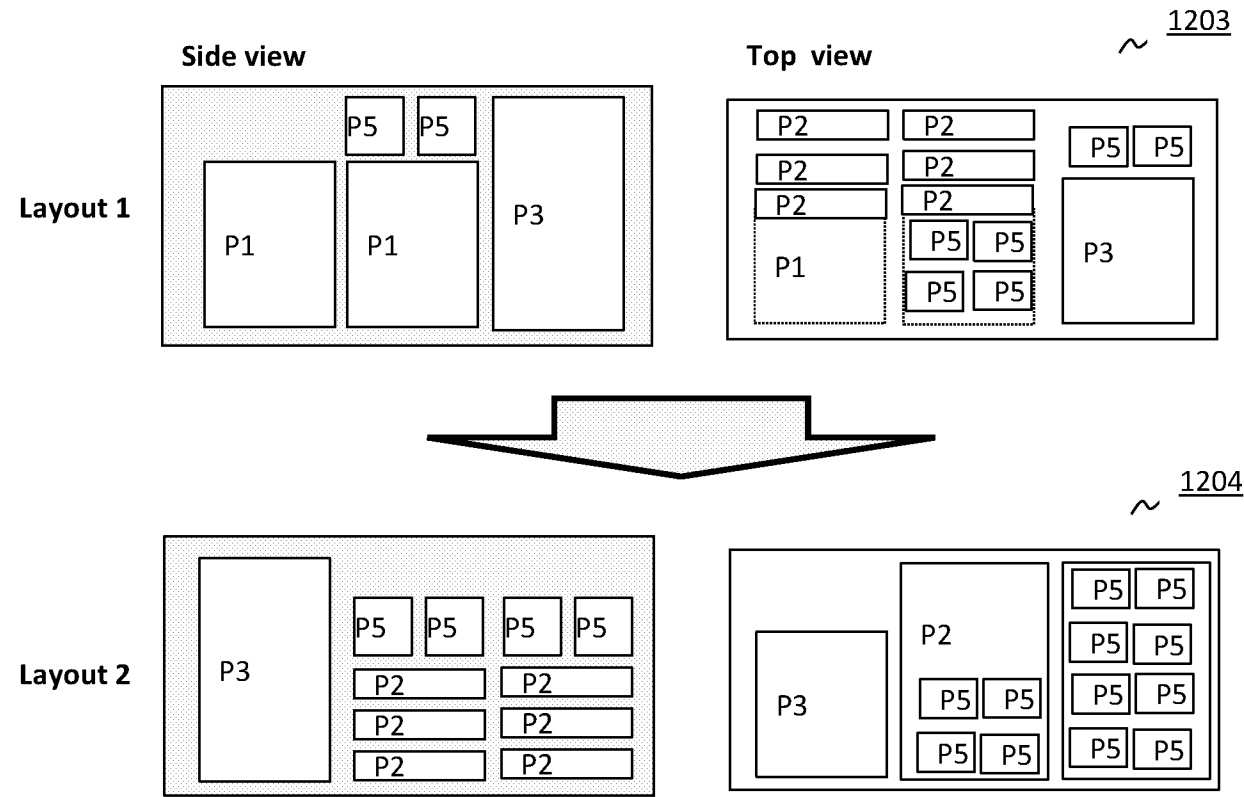
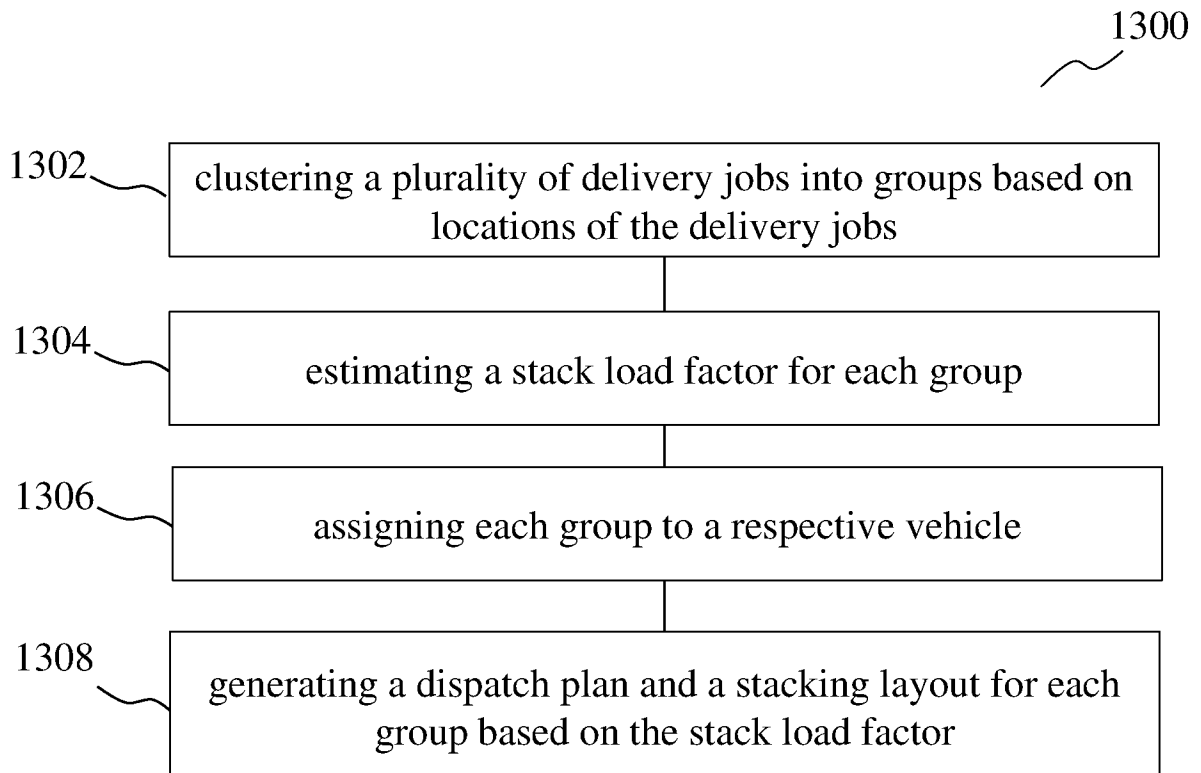
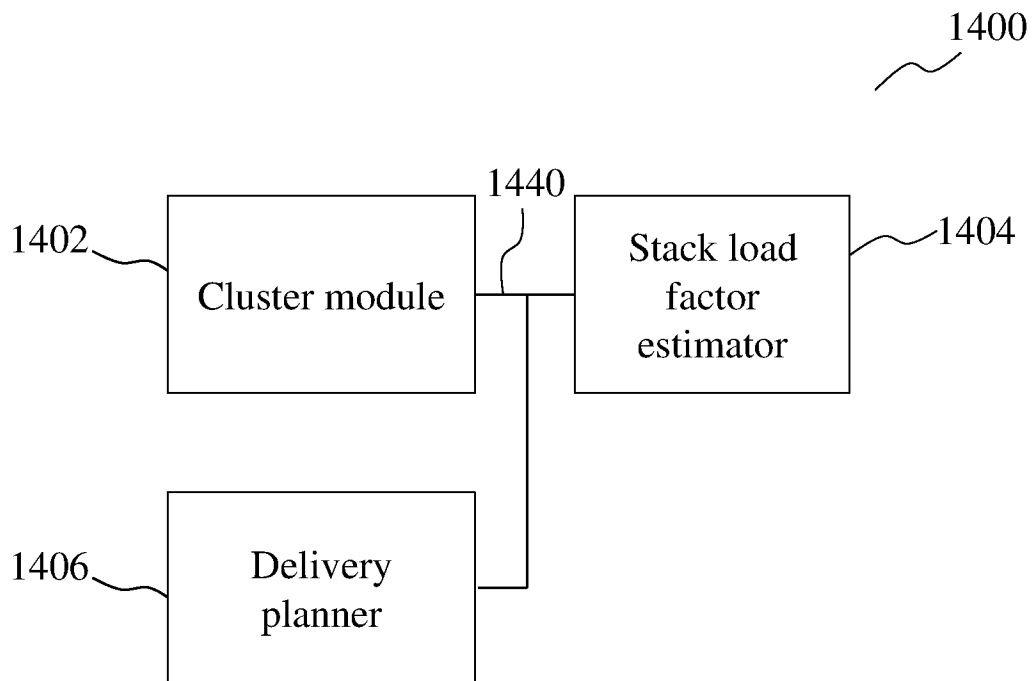


FIG. 12A

Stacking Order	Step
1	Drop-off 2 units of P1 and unload temporarily P5 units on top of P1 as needed
2	Unload temporarily P3 to clear space for P2
3	Rearrange P2 by stacking in 3 layers as shown in Layout 2
4	Stack P5 on top of P2
5	Load P3

FIG. 12B**FIG. 13**

**FIG. 14**

INTERNATIONAL SEARCH REPORT

International application No.

PCT/SG2019/050434

A. CLASSIFICATION OF SUBJECT MATTER

G06Q 10/08 (2012.01) G06Q 50/28 (2012.01)

According to International Patent Classification (IPC)

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

G06Q

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

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

Databases: Fampat, Internet

Search terms: stack, heap, pile, store, placement, arrange, cluster, group, team, region, sort, batch, set, deliver, dispatch, distribute, conveyance, transport, drop off, unload, shipping, plan, route, sequence, proposal, schedule, time, capacity, space, volume, usage, 堆, 叠, 码, 排列, 装车, 摆放, 放置, 装箱, 组, 区, 分批, 批次, 分拣, 送货, 快递, 运送, 速递, 派送, 递送, 配送, 计划, 路线, 顺序, 时间, 安排, 容量, 容积, 空间 and related terms

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	CN 109345017 A (NANJING UNIVERSITY OF AERONAUTICS & ASTRONAUTICS (NUAA)) 15 February 2019 Paras. [0014]-[0015], [0055]-[0056], [0079]-[0101] of the original non-English language document (a machine translation is enclosed only for your reference)	1-6, 8-18, 20-24
X	CN 106022506 A (ZHEJIANG UNIVERSITY) 12 October 2016 Paras. [0007]-[0017], [0054]-[0077] of the original non-English language document (a machine translation is enclosed only for your reference)	1-6, 8-18, 20-24
A	WO 2017/036756 A1 (LUFTHANSA CARGO AG) 9 March 2017 Whole document particularly Fig. 2 of the machine translation	
A	US 2008/0065262 A1 (GOTTLIEB J. ET AL.) 13 March 2008 Whole document	

☐ Further documents are listed in the continuation of Box C.

☒ See patent family annex.

*Special categories of cited documents:

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Date of the actual completion of the international search

10/10/2019

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18/10/2019

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INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No.

PCT/SG2019/050434

Note: This Annex lists known patent family members relating to the patent documents cited in this International Search Report. This Authority is in no way liable for these particulars which are merely given for the purpose of information.

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
CN 109345017 A	15/02/2019	NONE	
CN 106022506 A	12/10/2016	NONE	
WO 2017/036756 A1	09/03/2017	DE 102015216595 A1	02/03/2017
US 2008/0065262 A1	13/03/2008	NONE	