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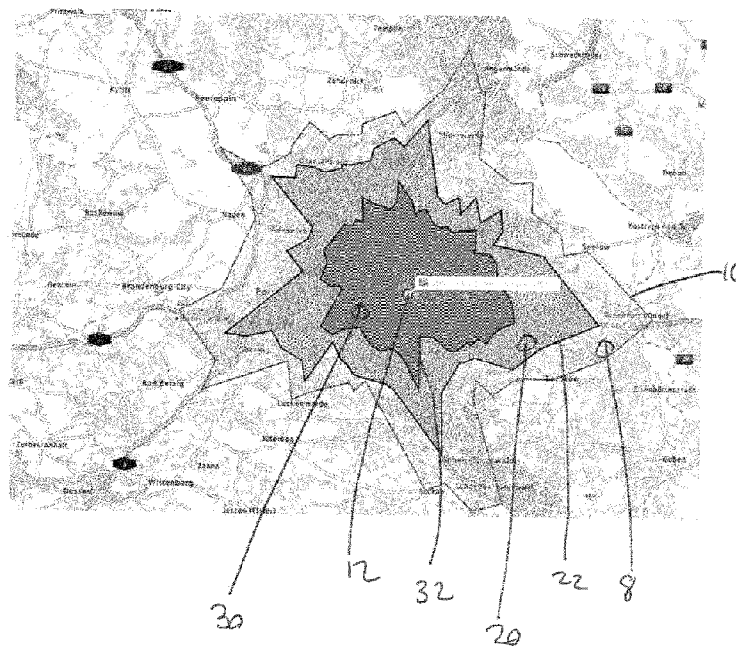


Figure 2

(57) Abstract: A method of determining a reachable area for one or more vehicles traversing a navigable network in a region covered by an electronic map includes; obtaining data indicative of a current location of the vehicle; identifying at least one set of one or more constraints limiting the distance which may be travelled by the vehicle from a current location, and, for the or each set of one or more constraints, using the identified set of one or more constraints, the obtained current location data and the electronic map data to determine data indicative of a polygon representing a reachable area as represented by the electronic map, wherein the perimeter of the polygon is indicative of a limit of an area which may be reached by the vehicle from the current location taking into account the set of one or more constraints, and generating data indicative of the polygon.



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METHODS AND SYSTEMS USING ELECTRONIC MAP DATA

Field of the Invention

5 This invention relates to methods and systems for determining a reachable area for one or more vehicles in relation to an electronic map representing a navigable network. The invention is particularly, although not exclusively, applicable to determining such an area in the context of managing a fleet of vehicles.

Background to the Invention

10 Various fleet management systems (FMS) are known, which may enable a fleet manager to perform various tasks. For example, fleet management systems may be used to assign driving duties to different drivers, and to plan routes and estimated arrival times. Other tasks which may be supported by a FMS include monitoring and attempting to improve vehicle performance, fuel efficiency or driver safety, supporting risk management, and generally seeking to improve fleet efficiency. Typical fleet management systems involve a combination of software, such as a "Software-as-a-Service" (SaaS) application, and vehicle-based technology.

15 In general, fleet management systems may at least assist a fleet manager in managing routes and destinations of vehicles, and to better manage the use of the vehicles. Some systems may support management of the vehicle drivers and their destinations. For example, itineraries may be planned for individual drivers, incorporating all the destinations required by the driver to fulfil a set of tasks in a given period. This may be useful in the context of fleets in which the vehicles perform tasks such as picking up or delivering goods at a number of destinations, or perform a service operation at multiple destinations.

20 One key consideration which must be taken into account by a fleet manager is the remaining driving time for each driver. This is the remaining permitted time that a driver may spend performing driving duties in a predetermined period e.g. day, week or two weekly period, as defined by the applicable working time regulations. The remaining permitted time may be governed by a number of different regulations, including working time and driver's hours regulations. Local, national and, in some cases, international regulations may be applicable. For example, drivers of large commercial vehicles are restricted by legislation in the EU regarding how drivers may conduct driving duties in different periods e.g. day, week, two weekly etc. These restrictions are detailed in European Commission mandates (e.g. 25 2006/561/EC, and 2003/88/EC) and there is a requirement for dedicated equipment (Tachograph) to be fitted to all qualifying vehicles to accurately record the status of the driver; driving, resting, available, performing other work. Similar regulations exist in other countries (US, AU). Compliance with such regulations is paramount, and penalties for contravening regulations high.

30 When a fleet manager needs to assign a new driving duty, remaining driving time for available drivers must be considered along with other factors, such as proximity of drivers to the origin and/or destination, which may be more generally required to be considered when planning a route. Remaining driving time will limit the area which may be reached by a vehicle from a current location, and hence has an impact on the allocation of driving duties. Remaining driving time therefore adds another level of

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complexity to vehicle duty assignment and route planning tasks. Planning responses to unplanned events may be particularly complex, especially where more than one vehicle is to be considered.

5 Consideration of remaining driving time is usually conducted by a human operator, making decisions based upon information obtained from multiple different planning tools. The operator may construct a plan e.g. itinerary for each for vehicle taking into account remaining driving time for the driver and then provide this to the FMS. However, such methods are labour intensive, and require the operator to collate information from multiple sources. It may be difficult to respond to unplanned events which may occur, and which might prompt a change in the vehicle route plans. Such changes might include additional work, driver sickness, customer cancellations or vehicle breakdowns, which might necessitate 10 a reallocation of assignments, or accidents, roadworks, congestion or road closures which might have an impact on journey times, and likewise may necessitate a reallocation of duties in order to ensure that all required assignments are performed. The operator will be required to update vehicle route plans in order to take account of such unplanned events, and redistribute assignments among the vehicles and drivers.

15 The Applicant has realised that there is scope to improve existing fleet management systems (FMS), particularly in relation to take into account applicable constraint(s), such as, although not limited to, remaining driving time, which may limit an area which may be reached by a vehicle. For example, existing FMS fail to take adequate account of remaining driving time, which may result in sub-optimal planning e.g. assignment of driving assignments, or provision of accurate estimations of arrival time (e.g. delivery time), and, in some cases, could lead to contravention of permitted driving time regulations. 20 While remaining driving time is one important example of a constraint which needs to be considered when performing fleet management operations, other constraints may limit the reachable area for a vehicle e.g. remaining fuel, response time targets etc.

25 **Summary of the invention**

In accordance with a first aspect of the invention there is provided a method of determining a reachable area for one or more vehicles traversing a navigable network in a region covered by an electronic map, the electronic map comprising a plurality of segments representing navigable elements of the navigable network, the segments being connected by a plurality of nodes, the method comprising, for 30 the or each vehicle:

obtaining data indicative of a current location of the vehicle;

identifying at least one set of one or more constraints limiting the distance which may be travelled by the vehicle from a current location,

and, for the or each set of one or more constraints, using the identified set of one or more 35 constraints, the obtained current location data and the electronic map data to determine data indicative of a polygon representing a reachable area as represented by the electronic map, wherein the perimeter of the polygon is indicative of a limit of an area which may be reached by the vehicle from the current location taking into account the set of one or more constraints, and generating data indicative of the polygon.

The present invention determines, for each one of one or more set of one or more constraints, a polygon representing a reachable area for a vehicle within the region covered by the electronic map. The perimeter of the polygon (or reachable area) is indicative of the limit of an area which may be reached by a vehicle from a current location thereof taking into account the set of one or more constraints limiting the distance which may be travelled by the vehicle. The reachable area is an area with respect to the electronic map.

The reachable area is in the form of a polygon, and not merely a circle with a particular radius based on the current location of the vehicle. It has been recognised that, in order to more realistically reflect the actual situation, the reachable area should have a varying diameter, as the distance which may be travelled by a vehicle in any direction while satisfying the constraint(s) will be limited by the road network. For example, a vehicle may be able to travel further in one direction, where road segments are associated with higher speed limits than in another direction, where the road network is made up of segments corresponding to more minor navigable elements of the road network. The polygon whose perimeter defines the boundary of the reachable area is determined using the electronic map data e.g. using path calculations based thereon, as will be discussed in more detail below.

Any one of the features described herein in relation to a set of one or more constraints, or the use of the set of one or more constraints to determine data indicative of a polygon representing a reachable area based on the set of one or more constraints, is, unless the context demands otherwise, applicable to any one of the one or more sets of one or more constraints, and the resulting polygon(s) determined. Likewise, the methods described herein may be applied to one or more vehicles. Any of the features described herein in relation to performing the method in respect of a vehicle may be used in performing the method in relation to any further vehicle.

The steps of the method may be performed in any desired order. Thus, the step of obtaining data indicative of a current location of a vehicle may be performed before, after or at the same time as identifying the at least one set of one or more constraints.

A reachable area as used herein is an area as represented by the electronic map including all locations that the vehicle may reach from its current location without contravening any one of the applicable set of one or more constraints. The perimeter of the reachable area (and hence the polygon) is indicative of a limit of the reachable area. The perimeter defines a boundary of the reachable area. The reachable area is a continuous area.

The set of one or more constraints may include a single constraint, or a plurality of constraints which must be simultaneously satisfied. The one or more constraints may be of any type. Each constraint may be indicative of a limit e.g. upper limit of a parameter.

Preferably the set of one or more constraints includes one or more time related constraint.

A time related constraint may be a maximum response time for a vehicle. For example, the distance which may be travelled by an emergency or assistance vehicle may be limited by a maximum response time. Of course, a response time may be applicable in other contexts e.g. corresponding to a target for a maximum time to arrival e.g. for collection or delivery of an item etc.

In preferred embodiments a time related constraint is a remaining driving time for the vehicle driver. The remaining driving time may be a remaining continuous driving time e.g. until the next break.

Alternatively or additionally the remaining driving time may be a remaining driving time within a given time period e.g. 2 hours or 24 hours. It will be appreciated that the remaining driving time for a vehicle driver may differ, depending upon the period considered. For example, the driver may only be able to drive for 1 hour in the next 2 hour period, based on the time driven since the last break. However, when the next 24 hours is considered, the driver may be able to drive for a certain number of hours within that period, taking into account the time already driven. Thus, the remaining driving time within a given time period may not necessarily be a continuous remaining driving time.

The "remaining driving time" as used herein refers to a remaining permissible time that a driver may conduct driving duties, and will be a function of applicable regulations and any other rules affecting driving times e.g. based on an employment contract, a driver's particular circumstances e.g. health etc.

Alternatively or additionally, the set of one or more constraints may include a vehicle energy related constraint e.g. an energy budget of the vehicle. A vehicle energy related constraint may be a remaining amount of energy of the vehicle e.g. a remaining amount of fuel or charge level.

Alternatively or additionally, the set of one or more constraints may include a constraint relating to financial cost. Thus, the distance which a vehicle may travel may be limited by a limit e.g. upper limit as to financial cost incurred.

The above exemplified constraints are merely provided by way of illustration, and it will be appreciated that numerous possible constraints may be used. For example, constraints may be customised depending upon a particular user e.g. fleet manager's requirements e.g. based on the type of operation provided by the vehicles etc.

Accordingly, in embodiments the one or more constraints include one or more of; an energy related constraint, a time related constraint and a constraint relating to financial cost.

The set of one or more constraints may be identified in any suitable manner. Identifying a constraint may comprise receiving data indicative of a constraint, or identifying a predefined constraint. For example, a constraint may be input by a user e.g. fleet manager. However, in embodiments, the method comprises obtaining data indicative of one or more vehicle parameters relating to the vehicle, and using the obtained data to identify at least some of the set of one or more constraints for the or each vehicle. The one or more vehicle parameters may relate to the vehicle itself e.g. a fuel level of the vehicle, or may relate to the driver of the vehicle e.g. a time driven since the last break. The one or more vehicle parameters may include data indicative of a current driving time of the vehicle, a current condition of the vehicle e.g. remaining energy e.g. fuel or charge amount, and/or a current condition of a driver of the vehicle. Preferably in embodiments in which the set of one or more constraints includes a remaining driving time or remaining energy amount for a vehicle, the remaining driving time or energy amount is identified using the obtained vehicle parameter data e.g. using data indicative of a current driving time or current condition of the vehicle.

The data indicative of the one or more vehicle parameters relating to a vehicle may be obtained from any suitable source or sources. The data may be obtained from one or more device associated with the vehicle, such as a telematics device and/or tachograph. 'Telematics' devices, are devices which do not provide navigation functionality, but log data for storage and/or other purposes, for example for provision to a server. Such devices are often provided for the purpose of monitoring fleets of commercial

vehicles such as lorries, buses, taxis, and the like, and/or for providing feedback to a driver. The TomTom® LINK devices are examples of such telematic control devices. The remaining driving time may be determined using data obtained from a tachograph associated with a vehicle. For example, a tachograph may provide data indicative of a time driven e.g. since last break for a driver. The obtained data may be obtained directly or indirectly from the device(s) as discussed below. The data may be obtained from the device(s) over a wireless communications link.

The steps of the method of the present invention in any of its aspects or embodiments may be carried out by a server. For example, the steps may be performed as part of a fleet management system operated by a server. The fleet management system may be a software-as-a-service (SaaS) system implemented by the server. Where the method is performed by a server, data indicative of the one or more vehicle parameters for a vehicle may be obtained directly from the vehicle, e.g. through transmission of data from a device associated with the vehicle to the server, or the data may be transmitted from the device associated with the vehicle to another device, such as a device associated with a fleet manager, and provided to the server as required. The device associated with the fleet manager may be a computing device, such as a portable computing device, running a software application that communicates with a fleet management system e.g. SaaS run by a server. In other embodiments, it is envisaged that the method may be implemented by a server e.g. of an electronic map provider, and then provided to another server or other device implementing a fleet management system. For example, the reachable area data may be provided to a server implementing a fleet management system together with the relevant electronic map data. It will be appreciated that it is not necessary for the steps to be performed by a server, and at least some of the steps may be performed e.g. by a device associated with a user e.g. fleet operator. The method may be performed by a server alone, another device alone, or any combination thereof.

The current location of the vehicle may be obtained in any suitable manner e.g. from a device associated with the vehicle. For example, the location may be provided by positional data obtained from any suitable positioning system associated with the vehicle, e.g. a GPS system. The positional data may be data received from the vehicle e.g. by a wireless communications link, and may be provided as a feed, e.g. a live feed. The data may be time stamped positional data. The data is preferably real time positional data. Such data may e.g. be GPS data or any other positional data.

The method comprises, for the or each set of one or more constraints, using the identified set of one or more constraints, the obtained current location data and the electronic map data for the or each vehicle to obtain data indicative of the polygon representing the reachable area for the vehicle. This may be performed in any suitable manner.

The step of obtaining the data indicative of a polygon preferably takes into account live conditions on the navigable network. This may be achieved using real-time information indicative of conditions on the navigable network. For example, such information may be provided using a live feed. The live conditions may include live traffic conditions, and/or road conditions (e.g. road status, such as closures or roadworks, accidents, weather conditions etc.) The method may therefore take into account live data relating to the traversal of segments of the navigable network.

Alternatively or additionally, the step of obtaining the data indicative of a polygon may take into account historical data relating to the traversal of segments of the navigable network e.g. historical traversal times for segments.

5 Alternatively or additionally, the step of obtaining the data indicative of a polygon may take into account the driving behaviour of the vehicle driver e.g. a driving efficiency. For example, a driver may have a particularly economical driving profile, which may mean that a vehicle may be able to travel further given the same energy related constraint than another driver.

10 Taking into account any of these factors may be achieved using appropriate sources of the data. For example, a live feed of data may be provided, indicative of conditions on the network e.g. traffic conditions, or relating to driver behaviour. Driver behaviour may be provided by a feed from an FMS. Alternatively or additionally, live or historical data e.g. traversal time data may be associated with segments of the electronic map.

15 The following discussion in relation to the way in which a polygon may be determined based upon a set of one or more constraints may apply to any or each polygon that may be obtained in respect of a set of one or more constraints where multiple sets of one or more constraints are used.

20 The method may comprise determining the data indicative of the polygon based on a cost of traversing segments in the navigable network represented by the electronic map, wherein the method comprises determining a set of one or more applicable cost values in respect of each one of the segments of the electronic map to be considered, wherein each applicable cost value is in respect of a respective one of the set of one or more constraints, and wherein each constraint defines a limit e.g. an upper limit (i.e. permissible (e.g. upper) limit) for the cost of a path through the navigable network represented by the electronic map in respect of the constraint. A path as used herein may comprise one or more segments of the electronic map. The cost value is indicative of a cost of traversing the segment i.e. travelling between nodes defining each end of the segment.

25 The determination of a set of one or more applicable cost values may take into account historical data relating to the traversal of segments of the network, real-time information indicative of conditions on the navigable network and/or historical driving behaviour of the vehicle driver. Thus, the effect of any one or ones of these factors may be taken account of by means of the cost values associated with segments.

30 It will be appreciated that a constraint will typically define an upper limit of the cost of traversing a path through the navigable network in respect of the constraint, although this need not necessarily be the case.

A cost value in respect of a constraint may be any value which may vary to indicate a value of a variable parameter whose limit e.g. upper limit is defined (whether directly or indirectly) by the constraint. For example, a cost value for a segment in respect of an energy e.g. fuel or charge related constraint may be an amount of energy e.g. fuel or charge required to traverse the segment, while a cost value in respect of a remaining driving time constraint may be a time to traverse the navigable segment. A cost value in respect of a financial cost constraint may be a financial cost to traverse the navigable segment.

40 The cost values associated with the segments may be obtained in any suitable manner. The step of determining the cost values may involve deriving the cost values, or obtaining already existing data e.g. stored data indicative thereof, or combinations thereof. Cost values may be obtained from different

sources. For example, a cost value for a segment may be obtained from the electronic map data e.g. already being associated with e.g. stored in conjunction with the segment, or may be obtained from another source e.g. from a server. This may be appropriate where existing data may be used to provide the cost value. For example, segments of an electronic map will typically be associated with data
5 indicative of traversal time for use in route generation. In some systems, which support obtaining routes taking into account other factors than time e.g. energy efficiency, segments may be associated with data indicative of an energy required to traverse the segment. Such data may be used in route generation in determining a least cost route. In some embodiments, such data may provide a suitable cost value for traversing the segment in respect of one of the constraints e.g. a cost value in respect of a time related or
10 energy related constraint as appropriate. However, in some embodiments, the method may extend to deriving at least some of the set of one or more applicable cost values associated with segments of the navigable network. Deriving a cost value may involve using a cost function. Thus, in embodiments the step of determining the set of one or more applicable cost values may comprise using a cost function to derive the or each applicable cost value. Deriving a cost value may be performed based on other data,
15 such as other data associated with the segment in the electronic map e.g. traversal time data or energy to traverse data. A cost function may provide a way of taking into account further factors, such as driver efficiency e.g. by including a term which will modify a generic cost value which would otherwise be determined to customise it to a particular driver.

Accordingly, the cost value associated with a segment of the navigable network indicative of a
20 cost of traversing the segment in respect of a given constraint in respect of any one of the one or more set of one or more constraints may be determined using a cost function.

It is envisaged that, in some situations, the same cost value may be used in respect of multiple constraints for a given segment, where the cost is indicative of a value of a parameter, and each constraint may be defined by an appropriate limit e.g. upper limit for this same parameter. Likewise, for
25 multiple sets of one or more constraints, the same cost value may be used in respect of constraints in different ones of the sets e.g. where these provide different limits e.g. upper limits in respect of the same parameter.

When determining the polygon, an applicable cost value is used for each segment considered. The applicable cost value may be a cost value applicable to the current time. It will be appreciated that a
30 cost value for a segment in respect of a constraint may be time dependent. For example, a cost indicative of a time to traverse a segment may depend upon the time of day, since traffic conditions will typically vary throughout the day. A constraint itself is typically not time dependent.

A cost value for a segment, in respect of any constraint, may be based at least in part on historical data. For example, the cost value may be based upon historical data relating to an applicable
35 time period. A cost value in respect of remaining driving time may be, or be based on a traversal time for the segment based upon historical traversal times for the applicable time period.

Alternatively or additionally, a cost value for a segment, in respect of any constraint, may be based at least in part on live data. For example, the cost value may be based upon live data. For example, the cost of traversing a segment may take into account live traffic conditions, roadworks etc. A

cost value in respect of remaining driving time may be, or be based on a traversal time for the segment based upon live traversal times.

Alternatively or additionally, a cost value for a segment, in respect of any constraint, may be based at least in part on the driving behaviour of the vehicle driver e.g. a driving efficiency.

5 Of course, combinations of historical and live data may be used. For example, live data may be used to modify applicable historical data where the current conditions differ significantly from those expected.

10 Live data as used herein in accordance with any of the aspects or embodiments of the invention refers to data which is relatively current and provides an indication of the relatively conditions in the network. The live data may typically relate to the conditions within the last 30 minutes, 15 minutes, 10 minutes or 5 minutes. "Historical" data, in contrast, refers to data that is not live, that is data that is not directly reflective of conditions in the network at the present time or in the recent past (perhaps within roughly the last five, ten, fifteen or thirty minutes).

15 It is not necessary that cost values are determined in respect of each segment of the electronic map, provided that such data is determined at least in respect of those segments being considered. For example, only a subset of the segments may be considered in determining the polygon e.g. corresponding to a particular map layer and/or area of the electronic map.

20 In some embodiments the perimeter of the polygon is defined by a closed polyline, and the method comprises determining data indicative of a closed polyline representing a perimeter of the polygon.

The term "polyline" is used herein in its conventional sense. The polyline is defined by a series of points connected by line segments. The data indicative of the polyline may be indicative in any manner of the polyline, whether directly or indirectly. For example, the polyline data may comprise a list of the locations, (e.g. in the form of latitude and longitude coordinates) defining the polyline and/or data
25 indicative of the line segments connecting the points.

Each point defining the polyline corresponds to a location as represented by the electronic map. The location may be a location along a segment of the electronic map or may be a node thereof.

30 In some embodiments each point on the polyline is indicative of a furthest node representing a junction of the navigable network which may be reached when traversing the navigable network represented by the electronic map without contravening the (applicable) set of one or more constraints.

35 In embodiments the method comprises determining a set of one or more applicable cost values in respect of each one of the segments of the electronic map to be considered, wherein each applicable cost value is in respect of a respective one of the set of one or more constraints, and wherein each constraint defines a limit (e.g. upper permissible limit) for the cost of a path through the navigable network represented by the electronic map in respect of the constraint, and the method comprises using the cost values associated with segments to identify a set of furthest nodes representing junctions of the navigable network which may be reached from the current location by traversing a path comprising one or more segments of the electronic map without exceeding the (upper) limit defined by the applicable constraint for any one of the costs related to ones of the set of one or more constraints.

Determination of the furthest nodes may be achieved using any suitable algorithm. In some embodiments an algorithm is used which utilises a recursive function to determine all paths to all nodes of the electronic map representing junctions and determines a constraint cost value to travel to each node (junction) from the current vehicle location. As discussed below, the algorithm may build a tree, where
5 the nodes of the tree represent nodes (junctions) of the electronic map. Each node may contain a collection of constraint cost values.

In other embodiments, each point defining the polyline may be a location along a path generated from the current location to a destination, wherein the location along the path is a location beyond which further travel is not possible without contravening one of the set of one or more constraints. The
10 destination is the furthest point which may be reached before one i.e. any one of the set of one or more constraints is contravened. The location along the path may be identified using a suitable cost calculation based on assigning cost values to navigable segments of the navigable network in respect of the or each constraint in a similar manner to the above described embodiment.

In embodiments the method comprises determining a set of one or more applicable cost values in
15 respect of each one of the segments of the electronic map to be considered, wherein each applicable cost value is in respect of a respective one of the set of one or more constraints, and wherein each of the segments of the electronic map is associated with a set of one or more cost values in respect of respective ones of the set of one or more constraints, and each constraint defines a limit (e.g. upper limit) in respect of the constraint for the cost of a path through the navigable network represented by the
20 electronic map comprising one or more of the segments, and wherein each location corresponds to a furthest location which may be reached from the current location along a path to the destination without exceeding the upper limit defined by the applicable constraint for any one of the costs related to ones of the set of one or more constraints.

The set of destinations used in determining the points defining the polyline may be obtained in
25 any suitable manner. In some embodiments the method may comprise identifying a maximum range (i.e. linear distance) which may be travelled by the vehicle without contravening any one of the set of one or more constraints, generating a circular area centred on the current location of the vehicle and having the maximum range (i.e. linear distance) as radius, determining a set of points corresponding to locations at which the perimeter of the circular area intersects segments of the road network as represented by the
30 electronic map, and using the set of points to provide destinations used in determining the points defining the polyline. The maximum range may be determined in any suitable manner. The maximum range may be a maximum range taking into account only a subset of the navigable segments of the electronic map e.g. corresponding to one level of a multi-level map i.e. a higher level thereof, as described below. The maximum range is an approximate range based on assuming the same range in every direction starting
35 from the current location, and without taking into account the road network.

The step of determining the set of points corresponding to locations at which the perimeter of the circular area intersects segments of the road network as represented by the electronic map, may
comprise determining the set of points corresponding to locations at which the perimeter of the circular area intersects segments representing elements of a sub network of the network of navigable elements
40 corresponding to a higher level road network. The higher level road network may comprise those

elements corresponding to higher capacity, long distance roads. The segments representing elements of the sub network corresponding to the higher level road network may correspond to segments of a first, higher level of the electronic map.

5 In these embodiments the method may further comprise determining a further set of points corresponding to locations at which the perimeter of a circular area intersects segments representing elements of a further sub network of the network of navigable elements corresponding to a lower level road network. The method may comprise using the further set of points to provide (further) destinations for use in determining the points defining the polyline. The lower level road network may comprise those elements corresponding lower capacity, local roads. The segments representing elements of the sub
10 network corresponding to the lower level road network may correspond to segments of a second, lower level of the electronic map.

In embodiments the circular area used in determining the further set of points has a radius which is smaller than the radius of the circular area used in determining the (first) set of points. For example, the radius may be a percentage of the radius of the (first) circular area corresponding to the maximum
15 range (i.e. linear distance) of the vehicle. This reflects that the range of a vehicle when travelling through a sub network of the navigable network corresponding to the second level of the road network may be smaller than the corresponding range when travelling through the first level of the road network, which may define a maximum range of the vehicle.

The higher map level may be used for longer distance navigation, with the lower level i.e. more
20 detailed map level being used to route a vehicle to and from a segment of the higher map level at the start and end of navigation respectively. A navigation system using two map levels is described in EP 0835426B1.

Each constraint may be indicative of an upper limit of a parameter (and may define an upper limit of a cost in respect of the constraint).

25 The upper limit may be a maximum value of the parameter. The reachable area will then be a maximum reachable area.

In embodiments, for the or each vehicle, the method may be performed in respect of a plurality of sets of one or more constraints, with data indicative of a polygon representing a reachable area being determined in respect of each set of constraints. The plurality of sets of one or more constraints may
30 comprise a first set of one or more constraints, each constraint being indicative of a maximum value of a respective parameter. The corresponding polygon determined based on this first set of one or more constraints may be referred to as the "first" polygon. The at least one set of one or more constraints may comprise one or more further set of one or more constraints limiting the distance which may be travelled by the vehicle based on the first set of one or more constraints, wherein each further set of one or more
35 constraints is more limiting than the previous set of one or more constraints. A value of a respective parameter defined by one or more, or each constraint of the or each further set of one or more constraints may correspond to a predefined percentage of a value of the corresponding parameter defined in the first set of one or more constraints.

40 Where multiple further sets of constraints are considered, the value of any one or more or each, respective parameter in each successive set of constraints may correspond to a progressively lower

predefined percentage of the value of the corresponding parameter defined in the first set of one or more constraints. For example, each constraint of a first further set of one or more constraint may correspond to 75% of the maximum value of the parameter in respect of the constraint set by the value of the constraint in the first set of one or more constraints. Each constraint of a second further set of one or more constraints may correspond to 50% of the maximum value of the parameter in respect of the constraint set by the value of the constraint in the first set or one or more constraints and so on. The value of the parameter in respect of each constraint in a given set of multiple constraints may be set to the same level relative to the value of the parameter in the first set of constraints e.g. each may be set to 50% or 75% of the first value etc.

In accordance with the invention, each set of one or more constraints is used together with the obtained current location data and the electronic map data to determine, for the or each vehicle, data indicative of a respective polygon representing a reachable area as represented by the electronic map, wherein the perimeter of the reachable area is indicative of a limit of the area which may be reached by the vehicle from the current location taking into account the respective set of one or more constraints.

Data indicative of the polygon is generated. In embodiments, where each set of constraints is progressively more limiting, each further polygon will lie within the or each preceding polygon, as the progressively more limiting values of the constraints will result in progressively smaller reachable areas.

In a further embodiment, the method may enable the effect of lifting and imposing different constraints to be explored. The method may comprise performing the method using a first set of constraints including a first constraint to obtain a first polygon representing a first reachable area, and then repeating the method using a second set of constraints comprising a second constraint and not the first constraint to obtain a second polygon representing a second reachable area, and optionally repeating the method using one or more further set of constraints, wherein each further set of constraints includes a further constraint and does not include any of the constraints specified in relation to the previous sets of constraints i.e. the first and second constraints, to obtain one or more further polygon representing a boundary of a respective reachable area. Thus, a third set of constraints will include a third constraint, and not the first and second constraints, to obtain a third polygon representing a boundary of a third reachable area, and so on. Preferably each set of constraints contains only one constraint i.e. the first contains only the first constraint, the second contains only the second constraint and so on. The first and second, and any further constraints in different sets of constraints relate to different parameters. The first and second, and where applicable, any further constraints may be progressively less limiting constraints. For example, the first constraint may be an energy related constraint e.g. remaining fuel limit. The second constraint may be a remaining drive time constraint, relating to remaining drive time over a first, shorter period. The third constraint, if used, may be a remaining drive time constraint over a second, longer period. This may provide an illustration of the effect of lifting the first constraint i.e. by refuelling, then lifting the second constraint i.e. by providing a driver rest. The determination of a reachable area may factor in additional time required to lift a constraint as appropriate e.g. to account for stoppage time.

The method extends to the step of using the generated data indicative of the or each polygon to cause a representation of the polygon to be displayed (or to display such a representation) on a representation of the electronic map. For example, data may be sent by a server to a device associated

with a fleet manager to cause the representation to be displayed. At least a representation of the perimeter of the polygon i.e. representing the boundary of the reachable area will be displayed, and preferably an indication of the reachable area defined within the perimeter. Any representation of the polygon, i.e. the perimeter and/or the interior area defined therein may be used which enables the polygon i.e. reachable area to be distinguished from the surrounding areas of the electronic map. For example, the reachable area may be coloured to enable it to be distinguished from surrounding areas of the electronic map.

Where multiple polygons in respect of a given vehicle are determined e.g. in relation to different sets of constraints, a representation of the or each polygon may be displayed (or caused to be displayed) simultaneously i.e. a representation of the or each further polygon may be displayed (or caused to be displayed) along with a representation of the first polygon. Each polygon will be displayed on a representation of the electronic map. Where multiple polygons are determined in respect of different sets of constraints, each polygon may be represented in a manner to permit the polygon to be distinguished from each other

At least a representation of the perimeter of the or each polygon representing the boundary of the corresponding reachable area will be provided.

In embodiments in which a first polygon is determined in relation to a first set of one or more constraints, and one or more further polygon is determined in relation to one or more further set of one or more constraints, wherein each set of constraints is progressively more limiting, each further polygon may define a sub-area within the area defined by the or each preceding polygon.

In embodiments a representation of each area defined between the perimeter of one polygon and the perimeter of any next polygon disposed inwardly thereof is provided. A representation of the entire area defined within the innermost polygon may be provided.

Each such representation of an area (whether between adjacent polygons or within an innermost polygon) may be provided in a manner so as to be distinguishable from each other such area e.g. by using different colours. Each area may be representative of an area reachable with constraint values within a range of values having a limit or limits defined by the constraints associated with the or each polygon defining a boundary of the area.

The method in accordance with any of the embodiments may be performed in respect of one or more vehicles. The one or more vehicles in respect of which the method is performed are preferably one or more vehicles of a fleet. The method may, in embodiments, only be performed in respect of those vehicles (e.g. in the applicable area) which are determined to be available e.g. which have an available status. This may be determined using data obtained from an FMS. The one or more vehicles may be one or more vehicles determined to be available in respect of an assignment to be allocated.

A set of one or more polygons each in respect of a respective one of a set of one or more constraints may be determined in respect of each vehicle in accordance with any of the embodiments previously described.

The method may comprise performing the steps of obtaining a polygon representing a reachable area for corresponding sets of one or more constraints for each vehicle (whether a single set of constraints, or multiple such sets of constraints). The corresponding sets of constraints may be

constraints which are in respect of corresponding parameters e.g. remaining drive time, remaining energy, response time etc. In some embodiments the constraints are not vehicle/driver specific e.g. a response time. The corresponding sets of constraints may include a single constraint being response time. One or more such corresponding set of constraints may be used e.g. setting different limits in relation to parameters e.g. predefined percentages of a maximum value.

The method may comprise displaying an indication of the or each reachable area on a representation of the electronic map. Where multiple reachable areas are determined in respect of each vehicle, reachable areas associated corresponding sets of constraints for different vehicles may be represented in the same manner e.g. using the same colour. This will allow all regions of the electronic map which can be reached by any vehicle based on a particular set of constraints e.g. within a remaining driving time limit to be identified.

Where the reachable areas defined within the boundaries of respective polygon obtained for different vehicles in respect of corresponding sets of one or more constraints overlap, the method may comprise determining data indicative of a polygon representing a single, combined reachable area corresponding to the combination of the reachable areas defined by the respective polygons for the different vehicles in respect of the given set of one or more constraints, and generating data indicative of the polygon.

The method may comprise using the generated data to cause an indication of the polygon representing the combined reachable area to be displayed on a representation of the electronic map (or to display such an indication). The indication may be a representation of at least the perimeter of the polygon representing the boundary of the combined reachable area. The combined reachable area will indicate an area which may be reached within the applicable limit(s) set by the constraint(s) associated therewith by any one of the vehicles to which the polygons indicative of individual reachable areas upon which it was based related. The representation of the combined polygon may be (caused to be) displayed instead of the representation of the polygons indicative of the original individual reachable areas upon which it was based.

Where a vehicle becomes unavailable, the associated indication(s) of a polygon may cease to be displayed.

In embodiments, the present invention may enable information to be presented to a fleet operator in a manner which will enable the operator to readily identify which areas of an electronic map may be reached by which vehicles of the fleet within a given timeframe, or other constraint, and hence to more easily assign duties. The invention enables the reachable areas to readily be adjusted in response to live events on the network, facilitating the decision making process. In other embodiments, the determined polygon data may be used to enable assignment of driving duties to vehicles to be achieved automatically. The method may extend to such a step.

The method of determining a reachable area in accordance with the invention in any of its aspects or embodiments may be triggered in any desired manner. For example, in some embodiments the method is triggered by an input by a user e.g. a fleet manager. In other embodiments the method may be triggered automatically e.g. by a particular fleet management operation e.g. a particular operation

involved in route planning. In some embodiments the method is triggered when a new potential destination to be assigned to a vehicle e.g. a vehicle of a fleet of a plurality of vehicles is received.

5 The method may comprise receiving an indication of a destination associated with a new driving assignment to be assigned to a vehicle of a fleet of vehicles, and performing the method in response to receiving the indication of the destination. The method may be performed in respect of a set of one or more vehicles, and preferably a plurality of vehicles, determined to be available for the assignment. Thus, a reachable area may be determined in respect of each one of the set of one or more constraints considered for each vehicle.

10 The method may further comprise determining a vehicle to be allocated the assignment based on the data indicative of the or each polygon indicative of a reachable area determined in the method, and providing data indicative of the destination associated with the assignment to the vehicle. The determined vehicle may be a vehicle from a set of a plurality of available vehicles. In these embodiments, the determined vehicle may be a vehicle determined by an operator by consideration of the polygon data i.e. based on displayed reachable area polygons for the vehicles, or may be determined automatically using the determined polygon data. The step of providing the data indicative of the destination to the vehicle may be performed automatically and may involve transmitting the data e.g. wirelessly to the vehicle.

The present invention extends to a system for carrying out a method in accordance with any of the aspects or embodiments of the invention herein described.

20 In accordance with a second aspect of the invention there is provided a system for determining a reachable area for one or more vehicles traversing a navigable network in a region covered by an electronic map, the electronic map comprising a plurality of segments representing navigable elements of the navigable network, the segments being connected by a plurality of nodes, the method comprising, for the or each vehicle:

25 means for obtaining data indicative of a current location of the vehicle;
means for identifying at least one set of one or more constraints limiting the distance which may be travelled by the vehicle from a current location,
and, for the or each set of one or more constraints, means for using the identified set of one or more constraints, the obtained current location data and the electronic map data to determine data
30 indicative of a polygon representing a reachable area as represented by the electronic map, wherein the perimeter of the polygon is indicative of a limit of an area which may be reached by the vehicle from the current location taking into account the set of one or more constraints, and means for generating data indicative of the polygon.

Preferably the system comprises, or is, a server.

35 As will be appreciated by those skilled in the art, this further aspect of the present invention can and preferably does include any one or more or all of the preferred and optional features of the invention described herein in respect of any of the other aspects of the invention, as appropriate. If not explicitly stated, the system of the present invention herein may comprise means for carrying out any step described in relation to the method of the invention in any of its aspects or embodiments, and vice versa.

The present invention is a computer implemented invention, and any of the steps described in relation to any of the aspects or embodiments of the invention may be carried out under the control of a set of one or more processors. The means for carrying out any of the steps described in relation to the system may be a set of one or more processors.

5 Any of the methods in accordance with the present invention may be implemented at least partially using software e.g. computer programs. The present invention thus also extends to a computer program comprising computer readable instructions executable to perform, or to cause a system e.g. server to perform, a method according to any of the aspects or embodiments of the invention.

10 The invention correspondingly extends to a computer software carrier comprising such software which, when used to operate a system or apparatus comprising data processing means causes, in conjunction with said data processing means, said apparatus or system to carry out the steps of the methods of the present invention. Such a computer software carrier could be a non-transitory physical storage medium such as a ROM chip, CD ROM or disk, or could be a signal such as an electronic signal over wires, an optical signal or a radio signal such as to a satellite or the like. The present invention
15 provides a machine readable medium containing instructions which when read by a machine cause the machine to operate according to the method of any of the aspects or embodiments of the invention.

It should be noted that the phrase "associated therewith" in relation to one or more segments should not be interpreted to require any particular restriction on data storage locations. The phrase only requires that the features are identifiably related to a segment. Therefore association may for example be
20 achieved by means of a reference to a side file, potentially located in a remote server.

The term "segment" as used herein takes its usual meaning in the art. A segment may be a navigable link that connects two nodes, or any portion thereof. While embodiments of the present invention are described with reference to road segments, it should be realised that the invention may also be applicable to other navigable segments, such as segments of a path, river, canal, cycle path, tow path,
25 railway line, or the like. For ease of reference these are commonly referred to as a road segment, but any reference to a "road segment" may be replaced by a reference to a "navigable segment" or any specific type or types of such segments.

Where not explicitly stated, it will be appreciated that the invention in any of its aspects may include any or all of the features described in respect of other aspects or embodiments of the invention to the extent they are not mutually exclusive. In particular, while various embodiments of operations have
30 been described which may be performed in the method and by the apparatus, it will be appreciated that any one or more or all of these operations may be performed in the method and by the apparatus, in any combination, as desired, and as appropriate.

Advantages of these embodiments are set out hereafter, and further details and features of each of these embodiments are defined in the accompanying dependent claims and elsewhere in the following
35 detailed description.

Brief Description of the Drawings

Embodiments of the invention will now be described, by way of example only, with reference to
40 the accompanying Figures, in which;

Figure 1 is a flow chart illustrating one embodiment of a method for determining reachable areas in accordance with the invention;

Figure 2 illustrates a set of reachable areas determined in respect of a vehicle;

Figure 3 illustrates sets of overlapping reachable areas determined in respect of five vehicles;

5 Figure 4 illustrates the change in the reachable areas of Figure 3 when one of the vehicles is no longer available;

Figure 5 illustrates a further example of reachable areas determined in respect of five vehicles; and Figure 6 illustrates the effect on the reachable areas determined in Figure 5 when one vehicle is no longer available.

10 Detailed description of the Figures

Embodiments of the present invention are described with reference to road segments. It should be realised that the invention may also be applicable to other navigable segments, such as segments of a path, river, canal, cycle path, tow path, railway line, or the like. For ease of reference these are commonly referred to as a road segment.

15 The present invention provides a method which may be used in the context of a fleet management system.

When managing a vehicle fleet, one particularly important factor to take into account when assigning driving duties e.g. determining driving itineraries is the remaining driving time for the vehicle drivers. The remaining driving time is the remaining permissible time that a driver may conduct driving duties in a given period (e.g. day/week/two weekly period), taking into account relevant working time regulations. The remaining driving time is the amount of time available (e.g. within a given period) before a driver must cease driving activities and commence a break or rest. The working hours of drivers are tightly regulated by regulations relating to working time, and driver hours, and including international, national and local regulations. For example, drivers of large commercial vehicles are restricted by legislation in the EU regarding how the drivers may conduct driving duties in a given period. These restrictions are detailed in European Commission mandates (e.g. 2006/561/EC, and 2003/88/EC) and there is a requirement for dedicated equipment (Tachograph) to be fitted to all qualifying vehicles to accurately record the status of the driver e.g. driving, resting, available, performing other work. Similar regulations exist in other countries (US, Australia).

25 30 Compliance with regulations is of great importance to a fleet manager, and potential fines for violating rules or regulations are high. The Applicant has realised that existing FMS (fleet management systems) fail to enable an operator to adequately take remaining driving time into consideration. This is a particular problem when planning a response e.g. reassigning driving duties in response to unplanned events. Such events may require a fleet operator to make estimates of which vehicles are best suited for a new assignment considering the remaining driving time available to each driver, and other factors, including a distance of the vehicle to the destination associated with the new assignment etc. Planning responses to unplanned events becomes even more complex in case of considering more than one vehicle at a time. The need to take remaining driver time into consideration adds another layer of complexity when responding to dynamic changes when performing fleet operational planning.

Existing FMS may result in an operator failing to adequately consider remaining driving time, which may result in sub-optimal planning, inability to provide accurate information to third parties e.g. regarding arrival times of drivers, or even failure to comply with driving time regulations.

5 A Fleet Management System (FMS) is an industry term used to refer to a broad range of solutions for vehicle-related applications that help companies manage their fleets of vehicles, such as cars, vans, trucks and buses. A fleet management system (FMS) may be provided by a combination of vehicle-based technology (e.g. telematics devices, positioning systems) and. Software-as-a-Service (SaaS). An FMS may be intended to help a fleet operator to improve overall fleet efficiency and vehicle performance, e.g. save fuel, improve driver safety, aid risk management, enhance job-dispatching etc.

10 An FMS may help a fleet operator to manage the use of vehicles e.g. the assignment of routes and destinations, and may also help with the management of vehicle drivers, and destinations. This may be of assistance where vehicles in the fleet pick up or deliver goods at a multiple destinations, perform a service operation at several destinations, etc. The FMS operator has a need to manage the cost of operating a fleet.

15 Typically, the management of fleet operations e.g. the assignment of duties, is performed by a human operator with assistance from various planning tools, including an FMS. These tools may be used to generate a vehicle travel plan, which may then be provided to the FMS. However, inaccuracies in vehicle plans commonly occur due to dynamic changes caused by unforeseen circumstances, e.g. additional work, accidents, road closures, car breakdowns, sickness, customer cancellations, etc. The fleet operator must update vehicle plans to try to compensate for these unplanned events e.g. by redistributing assignments to the current set of operating vehicles and drivers. Given the complexity of such tasks, although remaining driving time may be available to the operator via some system, it is difficult to take this into account together with other factors, and operators may simply ignore remaining driving time when managing operations, particularly when making changes in response to unplanned events.

20 Embodiments of the present invention provide an improved method for determining a reachable area for a vehicle in view of one or more constraints, which may include remaining driving time, although are not limited thereto. The invention may also provide the ability to provide information regarding the reachable area to an operator in a manner which enables the operator to more readily take the information into account when managing a fleet. While the invention will be described with particular reference to fleet management, it will be appreciated that it is not limited to use with a fleet of vehicles, and can be applied to one or more vehicles in any context where it is desired to obtain a reachable area. For example, this might include a situation where it is desired to obtain a reachable area in view of a remaining amount of fuel or charge of a vehicle. Thus, the invention is not limited to considering reachable areas defined by a time-related constraint, although embodiments will be described in relation to such an example.

35 The invention may be implemented by means of a server running FMS software. The server is in communication with a remote device of a fleet operator e.g. tablet, desktop, mobile etc. running a FMS application.

The server obtains data over a wireless communication network from each vehicle in a fleet of vehicles from devices associated with the vehicle e.g. telematics devices. Alternatively, it is envisaged that the devices associated with the vehicles may send data to the device of the fleet operator running the FMS application, which may then communicate with the server to provide the data thereto as required.

5 The fleet operator uses the FMS to update vehicle plans e.g. the assignment of driving duties, vehicle itineraries etc. The FMS system sends the updated vehicle plan(s) to the relevant vehicle devices. The fleet operator may make updates via their own device, which may then cause the updates to be sent out to the devices (typically via the server).

10 An embodiment of the method of the invention will be described by reference to the flow chart of Figure 1. This method may be implemented by a server, although this need not necessarily be the case. For example, the method may be implemented by a device associated with a fleet operator, or some steps may be performed by a server, and some by the operator's device, or any other suitable arrangement may be used as discussed further below.

15 The following method may be performed in relation to one or more, or each vehicle in the fleet, as required. The vehicles in respect of which the method is performed are, in embodiments, vehicles which are available for performing a new assignment. The method may be triggered in response to the FMS system receiving an indication of a new assignment to be allocated to a vehicle. The assignment is associated with a destination.

20 In step 1, a current position of the vehicle and one or more vehicle parameters are obtained. The vehicle parameters may include a remaining driving time of the driver or a remaining energy amount e.g. fuel or charge amount for the vehicle.

In step 3, a set of one or more constraints limiting the distance which may be travelled by the vehicle from the current location is identified. These constraints may, in this example, be the remaining energy amount and/or remaining driving time.

25 In other embodiments, the constraints may be identified from another source e.g. if they are not vehicle specific. For example, a maximum response time for the vehicle may be obtained e.g. from the FMS. Thus, in these embodiments, only a current location for a vehicle need be obtained.

30 The set of one or more constraints may correspond to the obtained vehicle parameters, or may be derived using the obtained parameters. For example, a constraint may, rather than being a maximum limit for remaining driving time, corresponding to the available remaining driving time obtained from the vehicle, be a percentage of that maximum limit e.g. 75% etc. Such embodiments are described below. More than one set of constraints may be obtained e.g. a first based on a maximum value of each constraint, and one or more further sets being predefined percentages thereof.

35 In step 5 a polygon is obtained having a perimeter indicative of the limit i.e. boundary of an area which may be reached by the vehicle from the current location, taking into account the set of one or more constraints. The polygon is obtained using the set of one or more constraints, the current location of the vehicle, and electronic map data. The electronic map data comprises segments connected by nodes, and the segments are indicative of the road elements of the road network.

40 In step 7, a representation of the polygon is provided to the fleet operator superposed on the electronic map.

The operator is thus provided with a clear indication of the reachable area for the or each vehicle. The reachable area is defined by a polygon around a current location of a vehicle that includes all locations that the vehicle can reach without violating any one of the applicable set of constraints (e.g. one or more of; remaining driving time, energy budget, financial cost). The perimeter of the polygon is
5 determined in a manner which takes into account the road network. Thus, it is recognised that the distance a vehicle may travel in different directions from the current location subject to the applicable constraint(s) may differ, depending upon the properties of the elements of the navigable network, current conditions etc..

Where the method is triggered by receiving an indication of an assignment to be allocated to an
10 available vehicle, the method may extend to determining a vehicle to which the assignment is to be allocated using the reachable areas, e.g. receiving an indication thereof from an operator, and transmitting data indicative of the destination associated with the assignment to the determined vehicle.

Some methods by which the polygon may be obtained will now be described.

One example of an algorithm for calculating a polygon indicative of reachable area determines,
15 for each segment of the electronic map being considered (which segment extends between two nodes (junctions) represented by the electronic map), a constraint cost value in respect of each constraint in the set of one or more constraints. The algorithm may use a set of constraints (ConstraintSet), where each constraint *c* in the ConstraintSet has an associated cost function (*c*.CostFunction()) for use in calculating a cost value in respect of the constraint for traversing a segment. The constraint cost value in respect of
20 a segment will be indicative of a value of a parameter related to the applicable constraint. For example, the cost value may be a time to travel between two nodes using the segment i.e. a segment traversal time. This would be applicable for a time related constraint, such as remaining driving time or response time. A cost value in respect of a vehicle energy related might be an amount of energy (e.g. fuel) to traverse the segment. A cost value in respect of a financial cost constraint may be indicative of a
25 financial cost to traverse the segment. The cost function may enable other factors to be considered in obtaining the cost value for a segment. For example, a driver's historic behaviour may be considered e.g. based on data available to the FMS. This may, for example, show that the driver drives with greater than average fuel efficiency. The cost function may then take account of this, and provide an appropriate adjustment of the cost value that would otherwise be determined e.g. based on average fuel required to
30 traverse the segment.

The cost values associated with traversing segments may be used to identify paths across the road network which may be traversed without contravening any of the constraints. For example, each constraint may set an upper limit e.g. a maximum limit for the cost of a traversed path. The perimeter of the polygon may then be determined by considering the distance which may be travelled along paths
35 through the network from the current location without the total cost for any constraint in the set of one or more constraints (based on the cost values of traversing the segments in the path) exceeding the limit set by the constraint.

In some embodiments a polyline representing a perimeter of the polygon defining the reachable area is determined, where each point defining the polyline corresponds to a furthest node which may be
40 reached from the current location without contravening any one of the set of one or more constraints.

This may be performed in various manners.

In one example, the algorithm may build a tree where the nodes represent the nodes in the map. Each node contains a collection of constraint values.

The simplistic algorithm uses a recursive function to determine all paths to all nodes representing junctions in the road network represented by the electronic map and record the constraint cost values to travel to the node (junction) location from the current vehicle location. A schematic example of such a recursive function is shown below.

```

FollowSegment(NStart, S, Tree)
10     J = GetJunction(Nstart, S)
        N = GetJunctionNodeInTree(Tree, J)
        if N empty
            for c in ConstraintSet
                N.c = Nstart.c + c.CostFunction(Nstart, N, S)
15                 if N.c exceeds c.maxvalue
                    return
                AddNode(N, Tree)
                for segment in N.connections
                    FollowSegment(N, segment, Tree)
20     else
        for c in ConstraintSet
            c.TreeUpdate(N, Nstart, S, Tree)
        return
    end FollowSegment
25

```

The function starts from a junction described as the node Nstart. It then looks up a destination junction node J by following the segment S to obtain a next junction node. It then obtains a node in the tree for that junction. If the node does not exist, the new node is configured with all constraint cost values to reach the junction J from the current location of the vehicle using the constraints from node Nstart and the constraint cost to travel segment S. After storing parameters in the node, a recursion step determines the constraint costs by following all road segments connected to the junction.

If the search for junction J shows that there exists a node for the junction in the tree, the FollowSegment function updates the constraint parameters in the subtree when the constraints values are lower than the current values. This parameter update also triggers a further recursive step for the leaf nodes of the subtree which is not shown in the above code fragment. The recursive function terminates when nodes cannot be added due to exceeding any one of the constraint parameters.

It will be appreciated that this exemplary implementation is a variant of Dijkstra's algorithm. The example is a basic algorithm that follows each possible route in a network (a graph). At each intersection, the algorithm keeps track of the 'cost' to reach that location. As there may have been another path that also leads to that location, the lowest cost version will take preference. Thus, when the alternative route is

a more cost efficient, searching based on the current route is not continued. If the current route is more cost efficient, it is considered to be a better route, and so the route is extended from that intersection by following all the segments connected to the junction. The recursive function used in the example is approximate.

5 After the tree construction briefly described above, the leaf nodes of the tree contain the junction node locations that are reachable without contravening any one of the set of constraints, and from which no further segments can be traversed without contravening one of the set of one or more constraints. So, the leaf nodes comprise the set of nodes that form the outer perimeter of the reachable area.

10 A representation of this reachable area is a closed polyline, which will define a perimeter of the polygon representing the reachable area. This is a sequence of locations sorted by angle in a polar coordinate representation of the locations. This means that for a current vehicle location (x_0, y_0) , each point on the perimeter (x_i, y_i) is expressed as (r, φ) with $r \cos \varphi = x_i - x_0$ and $r \sin \varphi = y_i - y_0$. Sorting the perimeter locations by φ results in a closed polyline description of the reachable area.

15 An example of a polygon defined by a polyline in this manner is shown in Figure 2. The polygon 8 is displayed on an electronic map. The perimeter 10 of the polygon is defined by the polyline. The polygon defines a reachable area including all locations which may be reached from the current location 12 of a vehicle without contravening any of the applicable set of one or more constraints. This view includes a number of further polygons which are located within the largest polygon 8, and will be described below.

20 There are other methods for determining a polygon indicative of a reachable area. A variant algorithm uses the set of one or more constraints to calculate a maximum linear distance which may be travelled by the vehicle from a current location. This is equal to the maximum range of the vehicle. As vehicles are restricted by the available road network, the reachable area will be smaller than the maximum range area defined by a circle with the current vehicle location as its centre and a radius equal to the maximum range.

25 The next step of the algorithm is to intersect the maximum range area with a higher level road network (comprising high capacity, long distance roads). The intersects are points on a main road that are unlikely to be reachable by the vehicle without violating any of the applicable set of one or more constraints (e.g. driver work time, energy budget, cost) as described above. The algorithm then treats the intersects as a set of destinations. For each destination it determines a route from the current vehicle location to the destination, with an endpoint where any of the constraints for the vehicle is met i.e. such that travel beyond the end point will contravene one of the set of one or more constraints. The set of endpoints then provide points on the perimeter of the reachable area.

30 The algorithm can be adapted to include intersect points of a lower level road network and a smaller range circle around the current vehicle location (e.g. a range that is a percentage of the maximum range). This may yield additional endpoints on the lower level network for use in providing additional points on the perimeter of the reachable area.

 The determined points on the perimeter of the reachable area may be connected to provide the polygon indicative of the reachable area.

A higher map level may contain a road network for longer distance navigation. In navigation systems a common approach consists of a start phase, a main network phase and an end phase. During the start phase the vehicle is guided using a detailed map level to a road that is part of the higher level road network. The main road network phase provides a route that gets the vehicle near its destination. The end-phase uses a detailed map level to route the vehicle from a road that is part of the higher level road network to the destination. A navigation system using two map levels is described in patent EP0835426B1.

Of course, it is not necessary to consider different map levels in this manner.

The algorithms above are examples of the way in which the present invention may be implemented. In any of its embodiments, the method determines a polygon indicative of reachable area, providing a realistic maximum driving area given the applicable set of one or more constraints, and taking into account the actual road network. A time related constraint e.g. remaining driving time, may be in respect of a given time or date range (e.g. 24h or 2h). A remaining driving time constraint may take into account a driver's history (driving time, working time, availability) and compliance related time constraints. Such factors may be used in determining the constraint e.g. based on information from the FMS and/or vehicle.

The methods of the invention may take into account live conditions on the road network. This may be achieved, in embodiments, by adjusting traversal times for segments, or other costs associated with segments, to reflect current conditions. The conditions may include traffic and/or road conditions as exemplified below. Furthermore, the cost values for given constraints may be time dependent e.g. based on typical traffic conditions at different times of day. Thus, the applicable cost values for any constraint may be used to obtain an accurate reachable area applicable to the current time. Historic data indicative of applicable costs e.g. traversal times or fuel consumption to traverse for segments at different times may be obtained and used.

The list below shows examples of the constraints and constraint related factors that may be used in determining the polygon representing reachable area:

- Energy budget. Each vehicle (e.g. as identified via a vehicle identifier) has a current remaining amount of energy for powering the vehicle. This may be used to set a vehicle energy related constraint. The FMS may also maintain historic data on the energy needed for a vehicle to travel on road segments under various traffic and road conditions. This may be used e.g. in determining a cost for traversing a segment relating to energy budget.

- Driving time. Each driver has a remaining driving time that may be used for assignments. The remaining driving time can be determined e.g. from an interface to a tachograph. For example, the FMS software may comprise an interface to obtain real-time data from a tachograph.

- Driver efficiency. Some drivers have a more economical driving profile and can travel a longer distance for a given vehicle and energy budget. Historical data may be obtained by the FMS software in any suitable manner, and used to improve the accuracy of the reachable area predictions. This may be done e.g. by adjusting cost values determined for segments, or in any other suitable manner.

- Traffic conditions. The FMS software may comprise an interface to one or more navigation systems that collect real time traffic information to estimate congestion. Congestion and road parameters determine the time necessary to travel a road segment.

- Road conditions. The FMS software may comprise an interface to a component that provides real time road network information e.g. road closures, partial road closures, accidents, weather impact on roads. The road condition information impacts available routes and travel times.

- Traffic regulations. A country may have specific regulations restricting driving without special permit e.g. on Sunday or during holidays for specific vehicle types.

It will be appreciated that the methods described herein may be implemented in various manners, using one or more servers and/or devices associated with an operator.

In the exemplary embodiments described, the method of determining reachable area(s) may be implemented using a FMS. A fleet operator may then use a web browser in their device (e.g. PC or mobile device) to interact with a server running the FMS software. However, other arrangements may be used. For example, the reachable area(s) may be determined using an application run by a device of the operator e.g. PC or mobile device. In either case, some of the above information (e.g. map data, traffic data, road closure information) may need to be obtained from other sources. For example, a map service provider may provide map and traffic data. A map service provider may also provide routing functionality, or may, instead of a server running an FMS, even implement the methods described herein of determining reachable area(s).

Wherever the reachable area(s) are determined, they may be displayed on a device of the operator, e.g. a PC or mobile device. The device may then receive the information regarding the area(s) and positions of vehicles from one or more servers. For example, a server may make its data available to an application running on the device, or instead may enable a user to interact therewith using a web browser.

Figure 2 illustrates a method in which multiple polygons are obtained for a vehicle, corresponding to different sets of one or more parameters.

In Figure 2, two additional polygons are shown inside the polygon 8. The outermost polygon 8 is obtained using a set of one or more constraints, where a parameter associated with each constraint is at its maximum e.g. corresponds to total remaining driving time or fuel. Thus, the upper limit defined by the constraint is at its maximum. A second polygon 20, having a perimeter 22 is then determined with the constraint parameter(s) set to 75% of this maximum value e.g. 75% of the total remaining driving time or fuel. A third polygon 30 having a perimeter 32 is determined with the constraint parameter(s) set to 50% of this maximum value.

The areas defined between the boundaries of each polygon may each be shaded a different colour as shown in Figure 2. In this example, the area (inner darkest grey area) defined within the innermost polygon 30 represents the reachable area with up to 50% of the maximum level of the parameter associated with the constraint e.g. 50% of available remaining driving time, the area (middle area shaded mid-grey) between the perimeter 32 of this polygon and the perimeter 22 of the next outer polygon 20 represents the reachable area with from 50-75% of the available constraint parameter (e.g. driving time). The outermost area (shaded lightest grey) defined between the perimeter 22 of the polygon

20 and the perimeter 10 of the outermost polygon 8 corresponds to the area reachable using 75-100% of the available constraint parameter.

Figure 3 illustrates a situation in which there are five vehicles within the area covered by the map, vehicles 42, 43, 44, 45 and 46. Each vehicle is available for a new assignment. For each vehicle, a set of polygons indicative of reachable areas based on first, second and third corresponding sets of constraints is obtained. These areas may be based upon different values for remaining driving time as illustrated in Figure 2 above e.g. 50%, 75%, and 100% of available remaining driving time, or may be in respect of different values of response time. For example, the outermost polygon may be based upon a maximum permitted response time, showing the maximum possible reachable area, with middle and inner polygons based upon certain predefined percentages of this maximum reachable area. The inner, middle and outer reachable areas for each vehicle are shaded darkest grey, mid-grey and lightest grey, as in the Figure 2 example.

As shown in Figure 3, some of the corresponding polygons for the respective sets of constraints overlap for the different vehicles, i.e. the inner, middle or outer polygons associated with different ones of the vehicles may overlap. In this situation, a single combined polygon is obtained with a perimeter encompassing the combined area defined by the corresponding overlapping polygons. In the example of Figure 3, the innermost polygons for vehicles 44-46 overlap in this way, and a combined polygon having a perimeter 52 and defining an inner reachable area 50 is defined. It will be seen that combined "inner", "middle" and "outer" areas are obtained, with the outer area for the set of vehicles, with the combined inner, middle and outer areas having the usual darkest, mid and light grey shading.

As a further example, Figure 4 shows the same map area with five vehicles, of one vehicle, vehicle 44 is now not available for another assignment. No polygons are associated with this vehicle, changing the overall pattern of areas provided.

Figures 5 and 6 are similar to Figures 3 and 4, but this time based on a longer maximum available driving time (with this setting the constraint used to provide the outermost polygon, with the middle and inner polygons for each vehicle being set at 75% and 50% thereof). Figure 5 illustrates the case where all five vehicles are available, and Figure 6 the case where only 4 are available.

In both cases, the figure shows the vehicles with a combined reachable area for all available vehicles in a map view. As the driving time constraint is larger (20 minutes in the figures), the each corresponding reachable area is larger too. In the figure, the shaded area indicate a fraction of the constraint (0-50%, 50-75% and 75-100%).

Based on the reachable areas illustrated as in Figure 3 and 4 or 5 and 6, a fleet operator can make a more informed decision and assign an updated plan to a vehicle. In an example, the operator may assign an emergency vehicle to a reported incident requiring assistance.

The present invention may also allow the effect of lifting and imposing constraints to be explored.

When a driver has a relatively long driving time remaining, the most limiting constraint of a set of constraints considered including driving time and fuel budget may be fuel budget. A refuelling stop is the obvious way to address that limit.

In embodiments multiple polygons defining multiple reachable areas may be obtained, where a first limiting constraint defines a polygon providing an innermost reachable area, and a second outer

polygon is defined using a second, less limiting constraint, based on the first constraint having been removed. The second outer polygon may be arranged so as to factor in a stationary period required to resolve the first constraint.

5 The resulting set of polygons may again be as shown in Figure 2. This time the innermost polygon 30 represents the boundary of the area that can be reached without refuelling. The middle area is defined between the perimeter 22 of the middle polygon 20 and the perimeter 22 of the innermost polygon, and represents the area that can be reached with refuelling and without a driver rest period. The outermost area defined between the perimeter 10 of the polygon 8 and the perimeter 22 of polygon 20 is the area that the vehicle can reach with refuelling and a driver rest until the maximum driving time.

10 In embodiments at least, the invention may display a map for displaying a map, showing for one or more vehicles the current location of the vehicle on the map, and, for each of the one or more vehicles indicating on the displayed map, a reachable area (a map area) comprising all map locations that the vehicle can reach, where the reachable area is defined by a polygon, and is determined using any combination of; a driving time, a current condition of the vehicle, current condition of a driver of the vehicle, a current and estimated traffic conditions, and current and estimated road conditions. The vehicles may be one or more vehicles of a fleet which are available for performing a driving duty. Thus, the vehicles may be a subset of vehicles in the area.

15 The invention may, in embodiments at least, increase overall accuracy of the information used by a fleet operator and reduce manual planning effort. For example, telematics data relevant for the operational time may be used in the process of obtaining the reachable areas.

20 Determination and display of reachable area(s) may be triggered in response to a command from a fleet manager, or, for example, by the selection of a new potential destination for one or more vehicles.

25 The invention may, in embodiments, enable a vehicle fleet planner to make better decisions for handling unplanned events. Usage of accurate reachable area information leads more informed ad-hoc planning decisions and impacts the cost of operating a vehicle fleet in a positive way.

The method may extend to using the reachable area(s) determined for the or each vehicle to assign a driving duty to a vehicle, and to provide data indicative of the duty e.g. a destination associated therewith, to the vehicle.

30 All of the features disclosed in this specification (including any accompanying claims, abstract and drawings), and/or all of the steps of any method or process so disclosed, may be combined in any combination, except combinations where at least some of such features and/or steps are mutually exclusive.

35 Each feature disclosed in this specification (including any accompanying claims, abstract and drawings), may be replaced by alternative features serving the same, equivalent or similar purpose, unless expressly stated otherwise. Thus, unless expressly stated otherwise, each feature disclosed is one example only of a generic series of equivalent or similar features.

40 The invention is not restricted to the details of any foregoing embodiments. The invention extends to any novel one, or any novel combination, of the features disclosed in this specification (including any accompanying claims, abstract and drawings), or to any novel one, or any novel combination, of the steps of any method or process so disclosed. The claims should not be construed to

cover merely the foregoing embodiments, but also any embodiments which fall within the scope of the claims.

CLAIMS:

1. A method of determining a reachable area for one or more vehicles traversing a navigable network in a region covered by an electronic map, the electronic map comprising a plurality of segments representing navigable elements of the navigable network, the segments being connected by a plurality of nodes, the method comprising, for the or each vehicle:

obtaining data indicative of a current location of the vehicle;

identifying at least one set of one or more constraints limiting the distance which may be travelled by the vehicle from a current location,

and, for the or each set of one or more constraints, using the identified set of one or more constraints, the obtained current location data and the electronic map data to determine data indicative of a polygon representing a reachable area as represented by the electronic map, wherein the perimeter of the polygon is indicative of a limit of an area which may be reached by the vehicle from the current location taking into account the set of one or more constraints, and generating data indicative of the polygon.

2. The method of claim 1 further comprising obtaining data indicative of one or more vehicle parameters relating to each one of the one or more vehicles, and using the obtained data to identify, for the or each vehicle, at least some of the set of one or more constraints limiting the distance which may be travelled by the vehicle from the current location.

3. The method of any preceding claim wherein the one or more constraints include one or more of; a vehicle energy related constraint, a time related constraint and a constraint relating to financial cost.

4. The method of claim 3 wherein the time related constraint is a remaining driving time for the vehicle.

5. The method of any preceding claim wherein the step of determining the data indicative of a polygon takes into account live conditions on the navigable network.

6. The method of any preceding claim wherein the step of determining the data indicative of the polygon takes into account historical data relating to the traversal of segments of the network, real-time information indicative of conditions on the navigable network and/or historical driving behaviour of the vehicle driver.

7. The method of any preceding claim wherein the method comprises determining the data indicative of the polygon based on a cost of traversing segments in the navigable network represented by the electronic map, wherein the method comprises determining a set of one or more applicable cost values in respect of each one of the segments of the electronic map to be considered, wherein each

applicable cost value is in respect of a respective one of the set of one or more constraints, and wherein each constraint defines an upper limit for the cost of a path through the navigable network represented by the electronic map in respect of the constraint.

5 8. The method of any preceding claim wherein the perimeter of the polygon is defined by a closed polyline, and the method comprises determining data indicative of a closed polyline representing a perimeter of the polygon.

10 9. The method of claim 8 wherein each point on the polyline is indicative of a furthest node which may be reached when traversing the navigable network represented by the electronic map without contravening the set of one or more constraints.

15 10. The method of claim 9 as dependent upon claim 7 wherein the method comprises using the cost values associated with segments to identify a set of furthest nodes representing junctions of the navigable network which may be reached from the current location by traversing a path comprising one or more segments of the electronic map without exceeding the upper limit defined by the applicable constraint for any one of the costs related to ones of the set of one or more constraints.

20 11. The method of any one of claims 1 to 8 wherein each point defining the polyline is a location along a path generated from the current location to a destination, wherein the location along the path is a location beyond which further travel is not possible without contravening one of the set of one or more constraints.

25 12. The method of claim 11 as dependent upon claim 7 wherein the location corresponds to a furthest location which may be reached from the current location along the path to the destination without exceeding the upper limit defined by the applicable constraint for any one of the costs related to ones of the set of one or more constraints.

30 13. The method of claim 12 comprising identifying a maximum range which may be travelled by the vehicle without contravening any one of the set of one or more constraints, generating a circular area centred on the current location of the vehicle and having the maximum range as radius, determining a set of points corresponding to locations at which the perimeter of the circular area intersects segments of the road network as represented by the electronic map, and using the set of points determined as the set of destinations used in determining the points defining the polyline.

35 14. The method of any preceding claim wherein the set of one or more constraints provides a first set of one or more constraints, each constraint being indicative of a maximum value of a respective parameter.

15. The method of claim 14 wherein the at least one set of one or more constraints comprises a plurality of sets of one or more constraints, the plurality of sets comprising a first set of one or more constraints, each constraint being indicative of a maximum value of a respective parameter, and one or more further set of one or more constraints limiting the distance which may be travelled by the vehicle based on the first set of one or more constraints, wherein each further set of one or more constraints is more limiting than the previous set of one or more constraints.

16. The method of claim 15 wherein a value of a respective parameter defined by one or more, or each constraint of the or each further set of one or more constraints corresponds to a predefined percentage of a value of the corresponding parameter defined in the first set of one or more constraints.

17. The method of any preceding claim comprising using the generated data to cause an indication of the or each polygon to be displayed superposed on a representation of the electronic map.

18. The method of any preceding claim, wherein the method is performed in respect of each one of a plurality of vehicles in a fleet of vehicles.

19. The method of claim 18 wherein the method comprises obtaining a polygon representing a reachable area for one or more corresponding sets of one or more constraints for each one of the plurality of vehicles, and, when the reachable areas defined by respective polygons obtained for different vehicles in respect of corresponding sets of one or more constraints overlap, determining data indicative of a polygon representing a single, combined reachable area corresponding to the combination of the reachable areas defined by the respective polygons for the different vehicles in respect of the given set of one or more constraints, and generating data indicative of the polygon.

20. The method of claim 19 further comprising causing an indication of the polygon representing the single, combined reachable area to be displayed on a representation of the electronic map.

21. The method of any preceding claim further comprising receiving an indication of a destination associated with a new driving assignment to be assigned to a vehicle of a fleet of vehicles, and performing the method in respect of a set of one or more vehicles available for the assignment.

22. The method of claim 21 wherein performance of the method is triggered by receipt of the indication of the destination.

23. The method of claim 21 or claim 22 further comprising determining a vehicle to be allocated the assignment based on the data indicative of the or each polygon indicative of a reachable area determined, and providing data indicative of the destination associated with the assignment to the vehicle.

24. A system for determining a reachable area for one or more vehicles traversing a navigable network in a region covered by an electronic map, the electronic map comprising a plurality of segments representing navigable elements of the navigable network, the segments being connected by a plurality of nodes, the method comprising, for the or each vehicle:

means for obtaining data indicative of a current location of the vehicle;

means for identifying at least one set of one or more constraints limiting the distance which may be travelled by the vehicle from a current location,

and, for the or each set of one or more constraints, means for using the identified set of one or more constraints, the obtained current location data and the electronic map data to determine data indicative of a polygon representing a reachable area as represented by the electronic map, wherein the perimeter of the polygon is indicative of a limit of an area which may be reached by the vehicle from the current location taking into account the set of one or more constraints, and means for generating data indicative of the polygon.

25. A computer program product comprising instructions which, when read by a machine, cause the machine to operate according to the method of any one of claims 1 to 23.

26. A computer readable medium having the computer program product of claim 25 stored therein.

Determine current position and vehicle parameters- step 1



Determine set of one or more constraints- step 2



Obtain polygon having perimeter defining reachable area based on set of one or more constraints- step 5



Display representation of polygon- step 7

Figure 1

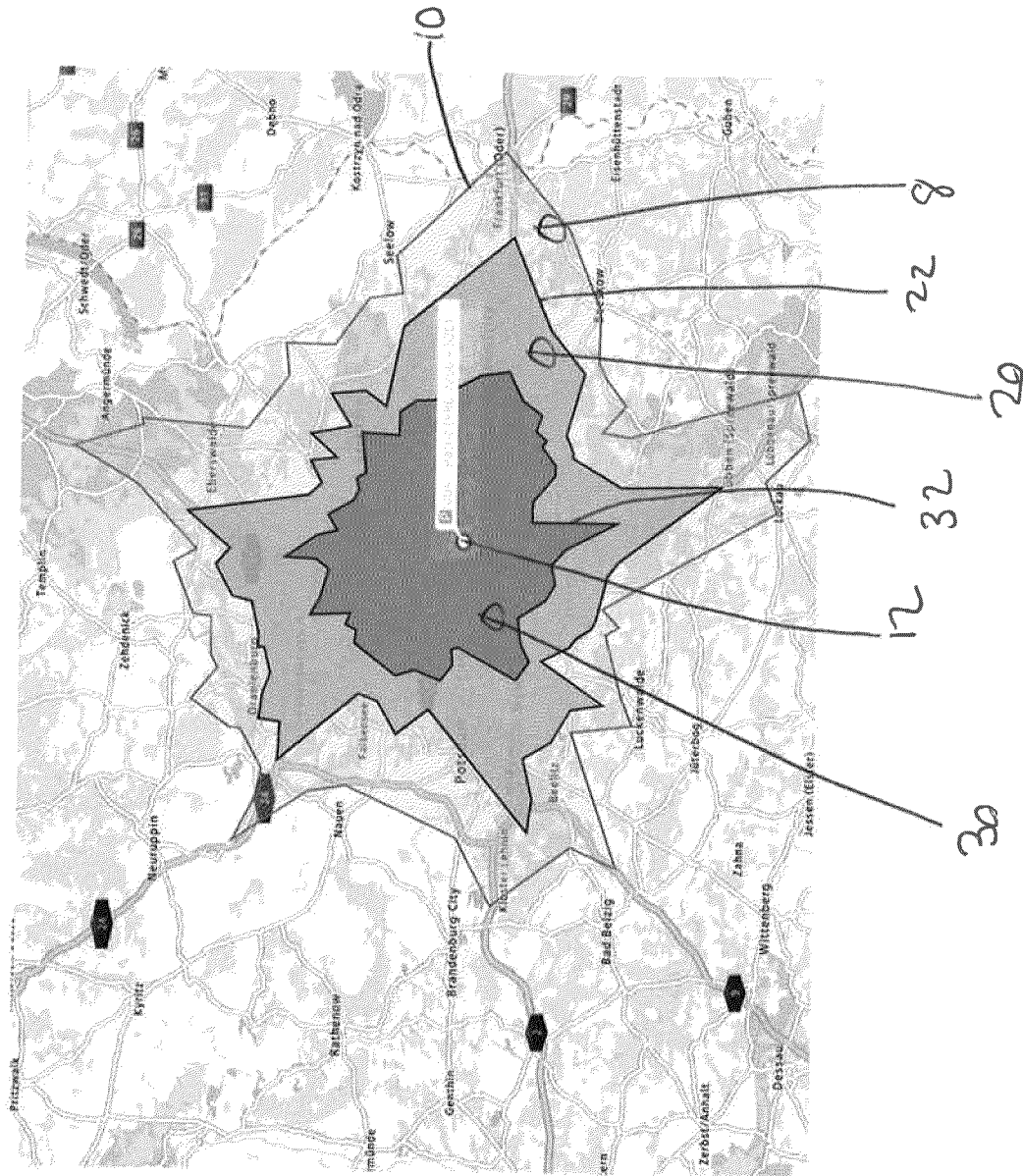


Figure 2

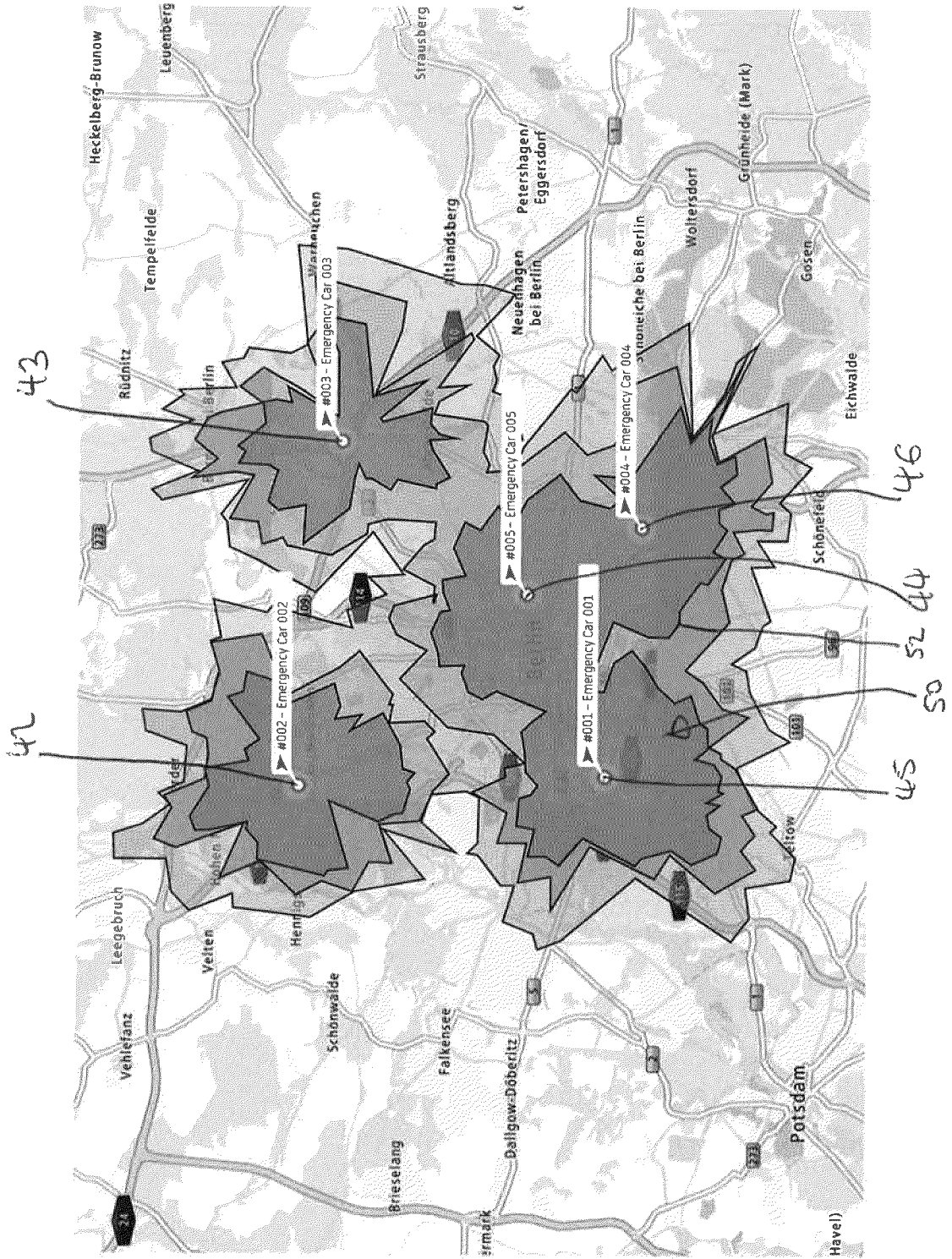


Figure 3



Figure 4



Figure 5



Figure 6

INTERNATIONAL SEARCH REPORT

International application No
PCT/EP2020/053199

A. CLASSIFICATION OF SUBJECT MATTER
INV. G01C21/34
ADD.

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

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
G01C

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)
EPO-Internal, WPI Data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	EP 2 867 618 A1 (TOMTOM DEV GERMANY GMBH [DE]) 6 May 2015 (2015-05-06) paragraph [0060] - paragraph [0103]; figures 5-9	1-18, 24-26
X	WO 2017/191241 A1 (TOMTOM NAVIGATION BV [NL]) 9 November 2017 (2017-11-09) page 16, line 9 - page 30, line 20; figures 1-3	1-17, 24-26
X	DE 10 2009 040966 A1 (AUDI AG [DE]; AUDI ELECTRONICS VENTURE GMBH [DE]) 24 March 2011 (2011-03-24) the whole document	1-17, 24-26
X	DE 10 2008 037262 A1 (DAIMLER AG [DE]) 7 May 2009 (2009-05-07) the whole document	1-17, 24-26

Further documents are listed in the continuation of Box C.

See patent family annex.

* Special categories of cited documents :

- "A" document defining the general state of the art which is not considered to be of particular relevance
- "E" earlier application or patent but published on or after the international filing date
- "L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)
- "O" document referring to an oral disclosure, use, exhibition or other means
- "P" document published prior to the international filing date but later than the priority date claimed

- "T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
- "X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
- "Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art
- "&" document member of the same patent family

Date of the actual completion of the international search
7 April 2020

Date of mailing of the international search report
25/06/2020

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INTERNATIONAL SEARCH REPORT

International application No.
PCT/EP2020/053199

Box No. II Observations where certain claims were found unsearchable (Continuation of item 2 of first sheet)

This international search report has not been established in respect of certain claims under Article 17(2)(a) for the following reasons:

1. Claims Nos.:
because they relate to subject matter not required to be searched by this Authority, namely:

2. Claims Nos.:
because they relate to parts of the international application that do not comply with the prescribed requirements to such an extent that no meaningful international search can be carried out, specifically:

3. Claims Nos.:
because they are dependent claims and are not drafted in accordance with the second and third sentences of Rule 6.4(a).

Box No. III Observations where unity of invention is lacking (Continuation of item 3 of first sheet)

This International Searching Authority found multiple inventions in this international application, as follows:

see additional sheet

1. As all required additional search fees were timely paid by the applicant, this international search report covers all searchable claims.

2. As all searchable claims could be searched without effort justifying an additional fees, this Authority did not invite payment of additional fees.

3. As only some of the required additional search fees were timely paid by the applicant, this international search report covers only those claims for which fees were paid, specifically claims Nos.:

4. No required additional search fees were timely paid by the applicant. Consequently, this international search report is restricted to the invention first mentioned in the claims; it is covered by claims Nos.:

1-18, 24-26

Remark on Protest

- The additional search fees were accompanied by the applicant's protest and, where applicable, the payment of a protest fee.
- The additional search fees were accompanied by the applicant's protest but the applicable protest fee was not paid within the time limit specified in the invitation.
- No protest accompanied the payment of additional search fees.

FURTHER INFORMATION CONTINUED FROM PCT/ISA/ 210

This International Searching Authority found multiple (groups of) inventions in this international application, as follows:

1. claims: 1-18, 24-26

nodes representing junctions

2. claims: 19-23

single, combined reachable area

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No

PCT/EP2020/053199

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