LIFE GreenYourRoute: A European innovative logistic platform for last mile delivery of goods in urban environment

Deliverable A1.4: *Review of developments after the proposal submission*

Partner responsible for this report: UTH

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Abbreviations

C-ITS	Cooperative Intelligent Transport Systems
CVRP	Capacitated VRP
CO	Carbon Monoxide
DBMS	Database Management System
DCVRP	Distance-Constrained CVRP
EA	Evolutionary Algorithm
EAP	Environment Action Program
END	Environmental Noise Directive
EU	European Union
EM	Emission Model
GA	Genetic Algorithm
GHG	Greenhouse Gas
GYR	GreenYourRoute
ICTs	Information and Communications Technologies
IP	Integer Program
ITS	Intelligent Transport Systems
KEA	Knowledge-based Evolutionary Algorithm
LEZs	Low Emissions Zones
LGA	Localized GA
LOF	Localized Optimization Framework
MCP	Medium Combustion Plant
NAM	Nearest Addition Method
NH_3	Ammonia
NEC	National Emissions Ceiling
NMHC	Non-Methane Hydrocarbons
NMVOC	Non-Methane Volatile Organic Compounds
NOx	Nitrogen Oxides

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ORM	Object Relational Mapping
$PM_{2,5}$	Fine Particulate Matter
PSO	Particle Swarm Optimization
RSM	Response Surface Methodology
SA	Simulating Annealing
SME	Small-Medium Enterprise
SO_2	Sulphur Dioxide
SQL	Structured Query Language
SUMPs	Sustainable Urban Mobility Plans
TSP	Travelling Salesman Problem
ULP	Urban Logistics Plans
VRP	Vehicle Routing Problem
VRPB	VRP with Backhauls
VRPBTW	VRP with Backhauls and Time Windows
VRPPD	VRP with Pickup and Delivery
VRPPDTW	VRP with Pickup and Deliveries and Time Windows
VRPSPD	VRP with Simultaneous Pickup and Delivery
VRPTW	VRP with Time Windows
WWW	World Wide Web

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Abstract

Deliverable A1.4 is a review of methods, tools and practices which LIFE GYR consortium deals with such as database design, architecture and structure, the vehicle routing problem and EU policies, standards, directives and practices on air quality, noise and urban mobility. With this report the team updates knowledge and experience, highlights the recent progress in various scientific fields and matches them with the specific problem addressed in this project.

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1 Introduction

Deliverable A1.4 "Review of developments after the proposal submission" is organized as follows:

In Section 2, new database designs, architectures and structures used in web applications for the general Vehicle Routing Problem (VRP) are been reviewed. In Section 3, new algorithms for solving the Green-VRP and its variants (e.g. with time windows) are presented. The VRP is the model based on which GreenYourRoute (GYR) platform generates the optimal green routes of a logistics company. The VRP is modeled and solved using mathematical programming techniques which encompass exact, heuristics and hybrid algorithms. The scope of the above two reviews is to further uptake and improve the database, modeling and optimization algorithms of Green-VRP developed in the frame of previously implemented by University of Thessaly European projects and comprise a set of recommendations and guidelines for GYR implementation actions. The resources used could be the latest version of EMEP/EEA air pollutant emission inventory guidebook, scientific publications, technical reports & deliverables of research projects, manuals of existing routing online services, etc. The aforementioned objectives are equally important for a complete overview of the current situation in the research and the market, the success of after-life communication plan, the replicability and transferability plan, the business plan and the networking activities implemented in the implementation actions of the project.

An additional objective of Deliverable A1.4 is to assess new EU policies, standards, directives, practices and initiatives on air quality, noise and urban logistics, presented in Section 4. Extensive background information on different new EU policies, standards and directives is conducted and their related environmental, socio-economic impacts are studied. A set of best practices and initiatives which foster green logistics in urban areas and are proved to have contributed towards the efficient use of energy in road transport are also included.

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2 Database design, architecture and structure

2.1 General information

This section introduces the exciting topic of combining World Wide Web (WWW) technology with that of databases. It is about bridging a gap between new technologies and 'old' in order to achieve what has never been achievable before. The emergence of the WWW is arguably one of the most important technological advances in this century, and since its birth a decade ago, it has changed many people's lives and had a profound impact on society. The Web has been expanding at an incredible speed.

It is fair to say that the WWW is playing and will continue to play an important role (perhaps the most important role) in shaping the future world of technology, business and industry. The database technology has been around for a long time now, and for many business and government offices, databases systems have already become an essential and integral part of the organization. Now the new technology has given the 'old' a shot in the arm, and the combination of the two creates many exciting opportunities for developing advanced database applications, which will in turn produce additional benefits for the traditional database applications. A multinational company, for example, can create a Web-based database application to enable the effective sharing of information among offices around the world. As far as database applications are concerned, a key aspect of the WWW technology is that it offers a brand new platform to collect, deliver and disseminate information. Via the Web, a database application can be made available, interactively, to users and organizations anywhere in the world.

Modern web applications face the challenge of processing a growing amount of data while serving increasingly impatient users. On one hand, popular web applications typically increase their user bases by 5– 7% per week in the first few years, with quickly growing data that is produced or consumed by these users and is managed by applications. On the other hand, studies have shown that nearly half of the users expect a site to load in less than 2 seconds and will abandon a site if it is not loaded within 3 seconds, while every extra 0.5 second of latency reduces the overall traffic by20%.

To manage large amounts of data, modern web applications often follow a two-stack architecture, with a front-end application stack fulfilling application semantics and a back-end Database Management System (DBMS) storing persistent data and processing data retrieval requests. To help developers construct such database-backed web applications, Object Relational Mapping (ORM) frameworks have become increasingly popular, with implementations in all common general-purpose languages: the Ruby on Rails framework (Rails) for Ruby, Django for Python, and Hibernate for Java. These ORM frameworks allow developers to program such database-backed web applications in a DBMS oblivious way, as the frameworks expose APIs for developers to operate persistent data stored in the DBMS as if they are regular heap objects, with regular looking method calls transparently translated to SQL queries by frameworks when executed.

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Unfortunately, ORM frameworks inevitably bring concerns to the performance and scalability of web applications, whose multi stack nature demands cross-stack performance understanding and optimization. On one hand, it is difficult for application compilers or developers to optimize the interaction between the application and the underlying DBMS, as they are unaware of how their code would translate to queries by the ORM. On the other hand, ORM framework and the underlying DBMS are unaware of the high level application semantics and hence cannot generate efficient plans to execute queries. Making things even worse, data-related performance and scalability problems are particularly difficult to expose during in-house testing, as they might only occur with large amounts of data that only arises after the application is deployed.

Below, we will also study the most commonly used approaches for creating Web databases, and discuss related issues such as dynamic updating of Web pages in line with the changes in databases, performance, and security concerns.

2.2 Web application design

Web-based database applications are a new type of client-server application. Some of the traditional client-server database techniques may still be adapted. In short, a Web database application normally interacts with an existing database, using the Web as a means of connection and having a Web browser or client program on the front end. Typically such applications use HTML forms for collecting user input (from the client); CGI (Common Gateway Interface, to be discussed later) to check and transfer the data from the server; and a script or program which is or calls a database client to submit or retrieve data from the database. The diagram (Figure 1) below gives a graphical illustration of such a scenario.

A database application is any application that accesses stored data and allows you to view and perhaps modify or manipulate that data. In most cases, the data is stored in a database. However, data can also be stored in files as text, or in some other format.

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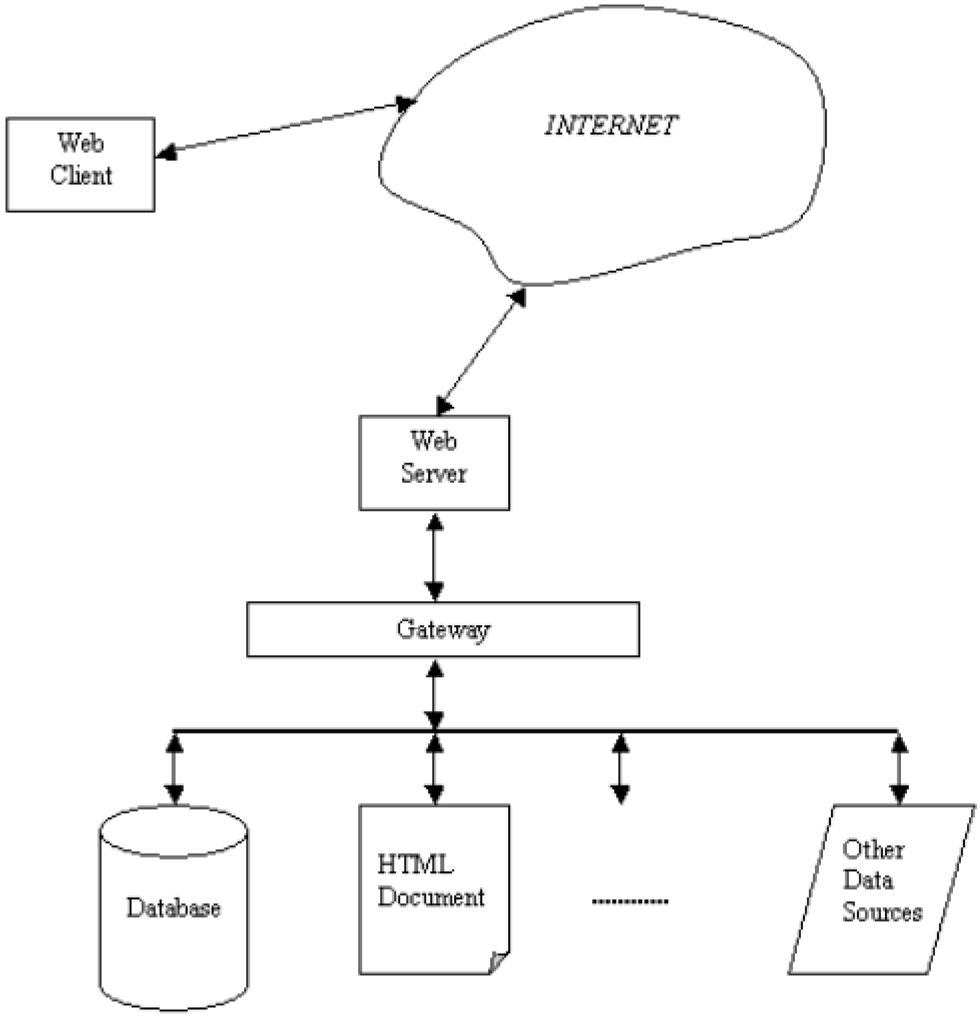

Figure 1. Web application design

2.3 Database design

Databases, and especially relational databases have since the beginning of Web application history been the most popular form of storing persistent data. Other alternatives have also been used such as flat-file storage (where the content is stored as plain text or binary data) or XML- or object databases. Much of the reason for the success of relational databases however, is that it provides durability, which in the context of data persistency means that once the data is stored, it is guaranteed to exist even if machines holding the data crashes. Also, a reason for the relational database's popularity is that it stores information in a structured format, which often fits the structured data formats that are manipulated by the Web applications. However, other types of databases that differs from the traditional SQL format has recently entered the marked. These are commonly referred to as NoSQL databases.

Database management systems often guarantee a set of properties for reliability. Each property that is guaranteed in the database design is defined below:

- Atomicity guarantees that either all the commands in a transaction completes, or non-do.
- Consistency guarantees that all the data will always be in a consistent state according to pre-defined rules. A transaction brings the system to a new consistent state.
- Isolation guarantees that parallel transaction executions are always processed as if they happen serially, i.e. no interference of any two parallel transactions.
- Durability guarantees that committed transactions are safe, and lasts even during system errors or crashes.

In Web application, the four essential database operations are the following: *Create, Read, Update* and *Delete*. These are the main operations performed by the Web application, on the data that needs to be persisted. When an operation is executed, it is the application's responsibility to convert the data into a format that fits the database's technology, and vice-versa. This process is called marshalling, or serializing. One example is when the application is to save a new object in the database. In this case, a Create operation will be performed where the application will transform the object from whatever programming language syntax the object is currently described in, into a structure that fits the given database's syntax. The application will send this transformed (marshalled) object to the database, which is now able to parse the object and save it to its storage structure.

Depending on the design of the databases, we may have the different designs shown below:

- Relational databases: Relational database management systems is a storage system based on a formalism known as the relational model. The formalism is based on structure and relationships, where the data entities are stored into tables that contain a set of attributes that describe the table. The tables can be related to each other to form groupings. RDBMS's stores a collection of tables, where each data entity is represented as a row in a specific table, and each column in a row represents an attribute for that entity. The most popular form of manipulating data in a RDBMS is SQL (Structured Query Language). This is a query language used to insert and manipulate data in a relational database. There are popular dialects of the language, generated by database vendors such as Oracle's SQL, Microsoft's MS SQL, MySQL and the open source PostgreSQL.
- NoSQL: NoSQL is a broad class of various database management systems who all have in common that they don't share the relational structure from normal SQL databases. The reason for its existence starts with the rise of Web 2.0 applications, when developers saw the need for simplifying replication of data, higher availability, and a new way to manipulate data that can avoid the need to perform tedious mappings between SQL strings and objects in any given programming language. The main potential for NoSQL databases is to perform operations on massive amounts of data that is not structured or connected in complex relationships. Very often this applies to Web 2.0 applications, because much of the information in such applications can be gathered in coherent entities, thus avoiding the need for complex relationships and

tedious operations to join them together. A typical example is users that has arrays of blog posts, and blog posts has arrays of comments, in which case all these fields are nested inside the user abstraction.

- Document-oriented databases: Is a datastore that is based on documents that contain unstructured content. Documents are often separated into unstructured collections (can be viewed upon as SQL-tables), where unstructured here means that content in the same collection can have different structure. However there is some variation in the way the different database implementations choose to define the formats of the documents, but it can be assumed that each document encapsulates some logically associated data in a predefined format. An interesting property with these databases is that performance is often not the main goal, but rather programming satisfaction. As many of these are implemented in JavaScript and offers querying semantics and data structures based on JavaScript objects, it is really easy and flexible to perform database operations on them. Examples include CouchDB and MongoDB.
- Column-oriented databases: Is a database system where data is organized as columns, as opposed to row-oriented databases such as SQL based databases. In this scenario, every value that would usually be in a row gets its own instance in a column together with its belonging identifier. As such, it is very efficient to perform range queries over a big amount of column data. Examples are Cassandra and Google Big Table (although these are not pure column-oriented, but rather a hybrid).

2.4 Web database architectures

Web database applications may be created using various approaches. However, there are a number of components that will form essential building blocks for such applications. In other words, a Web database application should comprise the following four layers (i.e. components):

- Browser layer
- Application logic layer
- Database connection layer
- Database layer

2.4.1 Browser layer

The browser is the client of a Web database application, and it has two major functions. First, it handles the layout and display of HTML documents. Second, it executes the client-side extension functionality such as Java, JavaScript, and ActiveX (a method to extend a browser's capabilities).

The three most popular browsers at the present are Mozilla Firefox (Firefox for short), Google Chrome and Microsoft Internet Explorer (IE). All three browsers are graphical browsers. During the early days of the Web, a text-based browser, called Lynx, was popular. As loading graphics over the Internet can be a slow and time-consuming process, database performance may be affected. If an application requires a speedy client and does not need to display graphics, then the use of Lynx may be considered. All browsers implement the HTML standard. The discussion of HTML is beyond this chapter, but you need to know that it is a language used to format data/documents to be displayed on the Web.

Browsers are also responsible for providing forms for the collection of user input, packaging the input, and sending it to the appropriate server for processing. For example, input can include registration for site access, guest books and requests for information. HTML, Java, JavaScript or ActiveX (for IE) may be used to implement forms.

2.4.2 Application logic layer

The application logic layer is the part of a Web database application with which a developer will spend the most time. It is responsible for:

- Collecting data for a query (e.g. a SQL statement).
- Preparing and sending the query to the database via the database connection layer.
- Retrieving the results from the connection layer.
- Formatting the data for display.

Most of the application's business rules and functionality will reside in this layer. Whereas the browser client displays data as well as forms for user input, the application logic component compiles the data to be displayed and processes user input as required. In other words, the application logic generates HTML that the browser renders. Also it receives, processes and stores user input that the browser sends.

Depending on the implementation methods used for the database application, the application logic layer may have different security responsibilities. If the application uses HTML for the front end, the browser and server can handle data encryption (i.e. a security measure to ensure that data will not be able to be intercepted by unauthorized parties). If the application is a Java applet and uses Java for the front end, then it itself must be responsible for adopting transmission encryption.

2.4.3 Database connection layer

This is the component which actually links a database to the Web server. Because manual Web database programming can be a daunting task, many current Web database building tools offer database connectivity solutions, and they are used to simplify the connection process.

The database connection layer provides a link between the application logic layer and the DBMS. Connection solutions come in many forms, such as DBMS net protocols, API (Application Programming Interface [see note below]) or class libraries, and programs that are themselves database clients. Some of these solutions resulted in tools being specifically designed for developing Web database applications. In Oracle, for example, there are native

API libraries for connection and a number of tools, such as Web Publishing Assistant, for developing Oracle applications on the Web.

The connection layer within a Web database application must accomplish a number of goals. It has to provide access to the underlying database, and also needs to be easy to use, efficient, flexible, robust, reliable and secure. Different tools and methods fulfil these goals to different extents.

2.4.4 Database layer

This is the place where the underlying database resides within the Web database application. As we have already learned, the database is responsible for storing, retrieving and updating data based on user requirements, and the DBMS can provide efficiency and security measures.

In many cases, when developing a Web database application, the underlying database has already been in existence. A major task, therefore, is to link the database to the Web (the connection layer) and to develop the application logic layer.

2.4.5 2-tier client-server architecture

Traditional client-server applications typically have a 2-tier architecture as illustrated in the figure below. The client (tier 1) is primarily responsible for the presentation of data to the user, and the server (tier 2) is responsible for supplying data services to the client. The client will handle user interfaces and main application logic, and the server will mainly provide access services to the underlying database.

If such a 2-tier architecture is used to implement a Web database application, tier 1 will contain the browser layer, the application logic layer and the connection layer. Tier 2 accommodates the DBMS. This will inevitably result in a fat client.

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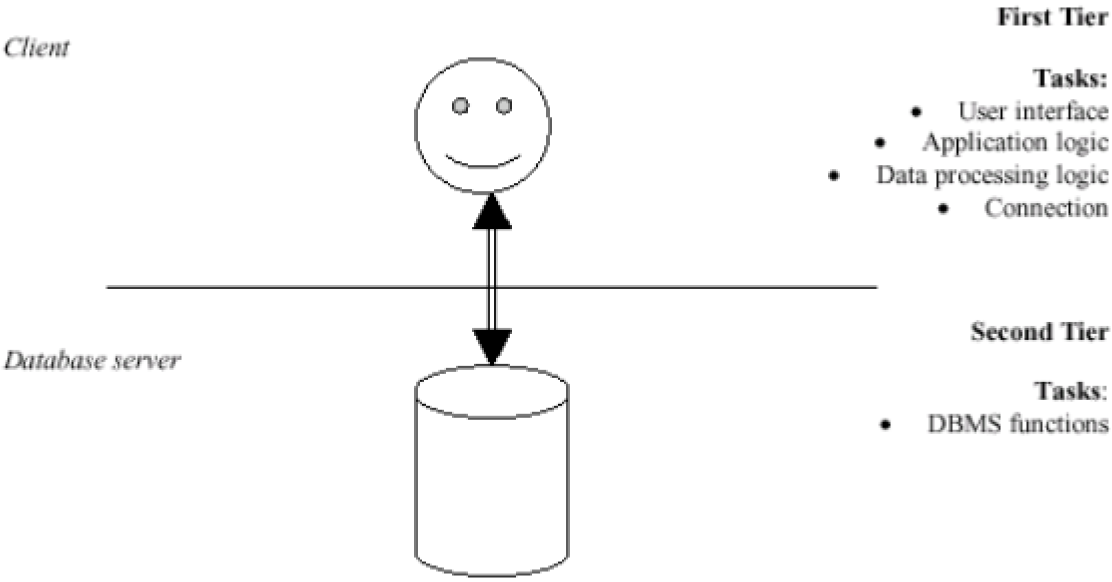

Figure 2. 2-tier architecture

2.4.6 3-tier client-server architecture

In order to satisfy requirements of increasingly complex distributed database applications, a 3-tier architecture was proposed to replace the 2-tier one. There are three tiers in this new architecture, each of which can potentially run on a different platform.

The first tier is the client, which contains user interfaces. The middle tier accommodates the application server, which provides application logic and data processing functions. The third tier contains the actual DBMS, which may run on a separate server called a database server.

The 3-tier architecture is more suitable for implementing a Web database application. The browser layer can reside in tier 1, together with a small part of the application logic layer. The middle tier implements the majority of the application logic as well as the connection layer. Tier 3 is for the DBMS.

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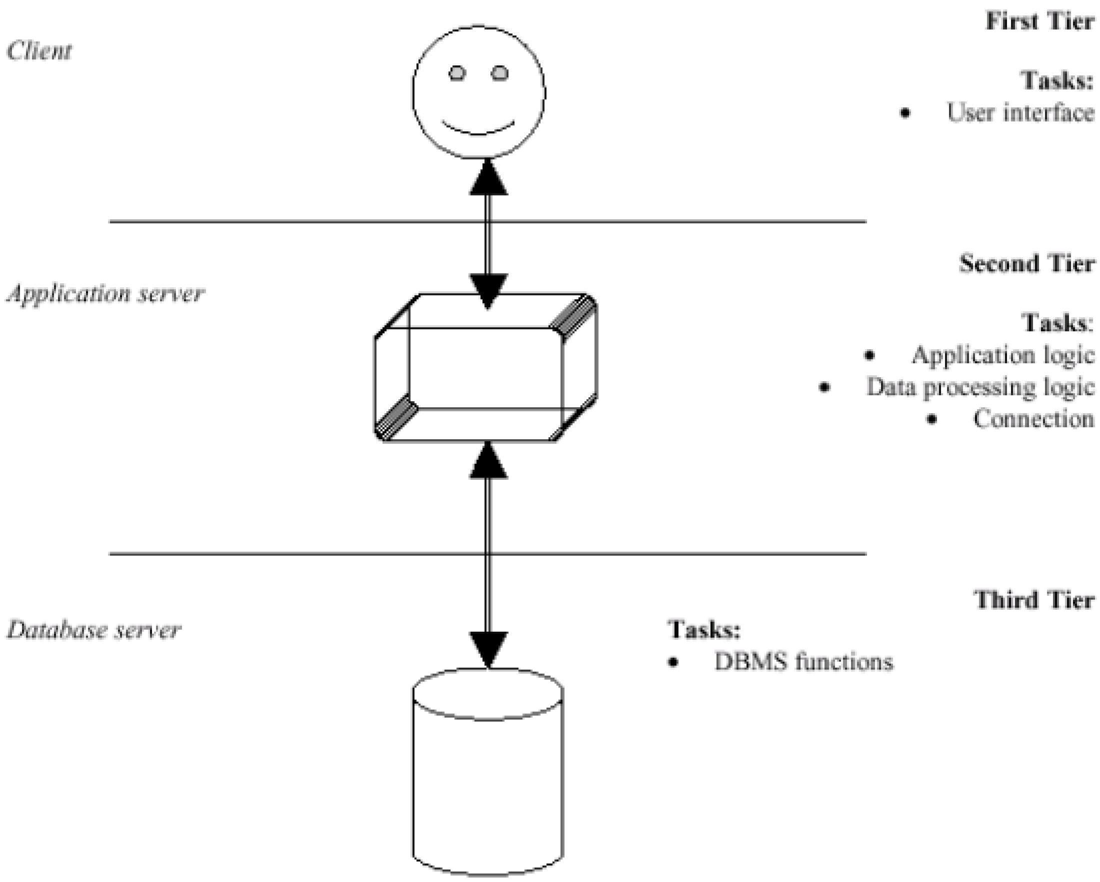

Figure 3. 3-tier architecture

3 The vehicle routing problem: State of the art classification

In this section, we review the algorithms proposed in the last years for the solution of the Vehicle Routing Problem (VRP), and more specifically the Green-VRP. Subsection 3.1, introduces the definition of VRP and its variants. In subsection 3.2, the basic VRP is defined with the corresponding notation. Finally, section 3.3 includes a classification of the VRPs and Green-VRPs.

3.1 Introducing VRP and Green-VRP

The VRPs, also frequently referred to by some as the truck dispatching problems are commonly encountered by organizations with complex operations where it is always of primary interest to find reliable means of obtaining optimal routes to different locations especially as fuel and truck drivers' wages (or salaries, packages) are due to increase with time. A VRP involves finding a set of optimal route for a fleet of capacitated vehicles which are available at a location to service the demands of a set of customers. In its simplest form, a customer is required to be visited once and the capacity of a vehicle must not be exceeded. A very typical example of organizations where VRP is of utmost importance is the newspaper industry.

The distribution of goods concerns the service, in a given time period, of a set of customers by a set of *vehicles,* which are located in one or more *depots,* are operated by a set of crews *(drivers),* and perform their movements by using an appropriate *road network.* In particular, the solution of a VRP calls for the determination of a set of *routes,* each performed by a single vehicle that starts and ends at its own depot, such that all the requirements of the customers are fulfilled, all the *operational constraints* are satisfied, and the global *transportation cost* is minimized.

At this point, the typical characteristics of customers are shown below:

- Location of the customer;
- Amount of goods *(demand),* possibly of different types, which must be delivered or collected at the customer;
- Periods of the day *(time windows)* during which the customer can be served;
- Time required to deliver or collect the goods at the customer location *(unloading* or *loading times,* respectively); and
- Subset of the available vehicles that can be used to serve the customer.

Concerning the vehicles, their typical characteristics include the following:

- *Home depot* of the vehicle;
- *Capacity* of the vehicle, expressed as the maximum weight, or volume, or number of pallets, the vehicle can load;
- Possible subdivision of the vehicle into *compartments,* each characterized by its capacity and by the types of goods that can be carried;
- Devices available for the loading and unloading operations; and

- *Costs* associated with utilization of the vehicle (per distance unit, per time unit, per route, etc.).

Last but not least, several, and often contrasting, objectives can be considered for the VRPs. Typical objectives are the following:

- Minimization of the *global transportation cost,* dependent on the global distance traveled (or on the global travel time) and on the fixed costs associated with the used vehicles (and with the corresponding drivers);
- Minimization of the number of vehicles (or drivers) required to serve all the customers;
- Balancing of the routes, for travel time and vehicle load;
- Minimization of the penalties associated with partial service of the customers;

or any weighted combination of these objectives.

The different objectives introduce the different VRPs that are summarized below.

The basic version of VRP is the *Capacitated VRP* (CVRP). In the CVRP, all the customers correspond to deliveries and the demands are deterministic, known in advance, and may not be split. The vehicles are identical and based at a single central depot, and only the capacity restrictions for the vehicles are imposed. The objective is to minimize the total cost (i.e., a weighted function of the number of routes and their length or travel time) to serve all the customers. The case in which both the vehicle capacity and the maximum distance constraints are present is called *Distance-Constrained CVRP* (DCVRP).

The *VRP with Time Windows* (VRPTW) is the extension of the CVRP in which capacity constraints are imposed and each customer is associated with a time interval, called a time window. More specifically, the service of each customer must start within the associated time window, and the vehicle must stop at the customer location for a specific time that must be within the time limits of the time window.

The *VRP with Backhauls* (VRPB) is the extension of the CVRP in which the customer set is partitioned into two subsets. The first subset, L, contains n Linehaul customers, each requiring a given quantity of product to be delivered. The second subset, B, contains m Backhaul customers, where a given quantity of inbound product must be picked up. In the VRPB, a precedence constraint between linehaul and backhaul customers exists: whenever a route serves both types of customer, all the linehaul customers must be served before any backhaul customer may be served. In addition, the case of VRPB in which time windows are present has been studied in the literature and is called the *VRP with Backhauls and Time Windows* (VRPBTW).

In the basic version of the *VRP with Pickup and Delivery* (VRPPD), each customer is associated with two quantities, representing the demand of homogeneous commodities to be delivered and picked up at customer. Sometimes, only one demand quantity is used for each customer. Often the origin or the destination of the demands are common (for example they are associated with the depot, as in CVRP and VRPB), and hence there is no need to explicitly indicate them. This problem is known as the *VRP with Simultaneous Pickup and Delivery*

(VRPSPD). The case of VRPPD in which time windows are present has been studied in the literature and is called the *VRP with Pickup and Deliveries and Time Windows* (VRPPDTW).

Nowadays there is a tendency in green vehicle routing research to consider methodology and procedures, which will help logistics companies to develop cleaner solutions. The main purposes are not to pollute the environment so much, to emit less harmful substances and to create less noise without causing other types of pollution. All the above environmental friendly issues are strongly related with transportation costs. Environmental effects are generally not considered in the classical VRP. *Green-VRPs* are concerned with reducing energy consumption. Routes are designed to optimize both environmental and financial objectives. Changes in distance travelled may provide environmental benefits when fuel consumption (and consequently pollutants) are reduced. The amount of CO_2 emitted by a vehicle is proportional to fuel consumption. Fuel consumption is influenced by several factors such as distance travelled, average driving speed and acceleration, load, engine type and size, road gradient and weather effects such as temperature. Fuel consumption can be estimated using real time on-board measurements. An alternative approach is to use an analytical Emission Model (EM).

3.2 Basic model of VRP

In this section, the basic model of the VRP is presented. The model can be extended based on different objectives, constraints and requirements.

Consider, for instance, a fleet of capacitated vehicle $k \in K$ at a depot designated as node $i = 1$ and a set of customers to be visited, each having a request$j$ $(j = 2, \dots, n)$. The tours of the vehicles at the depot on the set of arc, say$A = \{(i, j): j = 1, \dots, n | i \neq j\}$, such that the total distance covered in minimized while satisfying the requests at each node. Hence, the general objective in a VRP is formulated as follows:

$$\min \sum_{k \in K} \sum_{(i,j) \in A} c_{ij} x_{ijk}$$

$$s.t. \sum_{i=1}^{n} x_{i1k} = \sum_{j=1}^{n} x1jk = 1, \forall k \in K \ (1)$$

$$\sum_{i,j=1}^{n} x_{ijk} = 1, \forall k \in K \ (2)$$

$$\sum_{k \in K} x_{ijk} = y_{ij}, \forall i, j \ (3)$$

$$\sum_{i=2}^{n} \sum_{j=1}^{n} d_j x_{ijk} \leq C, \forall k \in K \ \ (4)$$

$$\sum_{(i,j)\in N\chi N} y_{ij} \leq |N| - 1, \forall N\complement\{2,3,..,n\}(5)$$

where $c_{ij}$is the cost of visiting location j from i. This cost could be the distance covered, the time spent on each arc, the amount of fuel consumed, etc. $x_{ijk}$is a binary variable that takes the value of 1 if vehicle k travels the arc (i,j) and 0, otherwise. Constraint (1) assures that every vehicle leaving a depot most return to the depot at the close of operation. Another constraint (equation 2) is that demand at each node must be served exactly once. Hence, a vehicle must enter and exit at a node. A common assumption is that the service at each node is performed by one and only one vehicle. This is captured by another binary variable, say yij which is 1 given any vehicle uses arc (i,j) and0, otherwise (equation 3). Apart from the general attribute of the fleet, the capacity of each vehicle must not be violated, i.e., a vehicle may not carry more than it is designed to carry. Hence, if the capacity of a vehicle is C and d_j is the demand at node$j = 1, \dots, n$, then the capacity constraint is given in equation 4. Subtours are tours that do not start and end at the depot. In the presence of subtours, solutions with cycles using nodes $2, 3, \dots, n$ are encountered. Since in the desired result, all moves must start and end at the depot, it is important to seek a way of eliminating such cycles that amount to subtours. A subtour elimination constraint is defined by equation 5.

3.3 Classification of VRPs and Green-VRPs

3.3.1 Classification of CVRPs

In a typical CVRP [1], a vehicle is allowed to visit and serve each customer on a set of routes exactly once. The vehicle starts and ends its visit at the central depot such that the total travel cost (distance or time) is minimized and the vehicle total capacity is not exceeded. This forms the basic problem of vehicle routing since VRP without the capacity constraint and with a single vehicle can also be seen as a traveling salesman problem (TSP). A model with independent route length was formulated using linear integer programming approach by Tavakkoli-Moghaddan et al. [2]. The objective of their work was to minimize the cost associated with heterogeneous fleet and maximize the capacity utilization. They proposed a near-neighborhood-based hybrid Simulated Annealing (SA) to solve the problem. In the drive to provide an efficient, effective and practicable means of managing garbage collection system. Tavakkoli-Moghaddan et al. [3] addressed the problem for optimal fleet cost and total travel distance by considering the case of split services at each demand node and heterogeneous fleet with the aid of mixed integer linear model formulation. They solved the problem by using SA technique. Bortfeldt [4] extended the work to CVRP and proposes a hybrid algorithm of Tabu search and tree search for optimal vehicle routing and packing plan.

Several other techniques have been proposed for CVRP. Ai and Kachitvichyanukul [5] proposed a Particle Swarm Optimization (PSO) algorithm which is a stochastic and adaptive nature-inspired optimization technique [6], [7] and a swarm-based method capable of producing low cost, fast, and robust solutions to many hard optimization problems ([8]; [9]), for finding the solution to a CVRP. Wang and Lu [10] presented a three-phase hybrid Genetic

Algorithm (GA) to address the CVRP. In the first stage, rather than adopting either of Nearest Addition Method (NAM) or the sweep algorithm, NAM was incorporated into the sweep algorithm in order to generate a well-structured initial chromosome population. The crossover and mutation probabilities were optimized at the second stage using a Response Surface Methodology (RSM), while the final stage enhances the exploration diversity of the GA by incorporating an improved SA into the Juan et al. [11], using state-of-the-art random number generators, combined a classical heuristic of CVRP with the Monte- Carlo simulation technique to develop a hybrid algorithm called SR-GCWS (Simulated Routing via the Generalized Clarke and Wright Savings heuristic). Liu et al. [12] utilize the combined tool of mathematical programming and graph theory to model a multi-depot CVRP with full truckloads. To solve the problem for minimum empty vehicle movement, they proposed a two-phase greedy algorithm which generates cycles in the first and constructs a closed chain in the second.

A solution-starter-based, two-independent- phased algorithm was developed to tackle the problem by Ke and Feng [13]. The algorithm utilizes different perturbation and local search operators for improving the solution. Lysgaard and Wohlk [14] propose a branch-and-cut-and-price technique backed up with computational results. This is probably the first exact algorithm that addresses the Cumulative Capacitated Vehicle Routing Problem (CCVRP). VRP finds an important application in the delivery of relief materials immediately after a major disaster especially in cases of urgency is a critical factor. Rivera et al. [15] presented a new variant of CCVRP with a single vehicle performing multiple trips. The authors proposed an exact algorithm for finding minimizing the arrival time and the method was compared with two mathematical formulations of the original problem based on reformulation as a resource constraint shortest path problem. The solution was accelerated by some dominance rules and conditions on the lower bounds.

3.3.2 Classification of VRPTWs

In a VRPTW, the classical VRP put into consideration the expected time a particular customer is to be served. The objective is to find, for a fleet of vehicle at a central depot, sets of routes that start and end at the depot at a minimum cost for serving the requests of known customers within a specified time interval. Occasionally, a vehicle may arrive outside the bounds of the time windows, in which case, it either wait or incurs a penalty for the lateness.

Hashimoto et al. [16] generalized the standard VRPTW by limiting travel times and costs to be time dependent functions. The resulting problem was addressed using a proposed iterated local search algorithm whose neighborhood consists of little modifications to the 2-opt, cross exchange and Or-opt neighborhoods. Ghannadpour et al. [17] used the assumption of random arrival of real time requests with non-deterministic information for dispatcher on location and request size prior to arrival to formulate a model for the multi-objective dynamic VRP with fuzzy time windows. The authors proposed a GA consisting of three modules: management module to check the state of the system; strategy module to organize information generated by management module; and the optimization module. The model was test run using the case of hospitals blood bags distribution from one or more central distribution location. An iterative procedure running between two phases called the Localized Optimization Framework (LOF) was introduced by Ursani et al. [18] to develop a Localized GA (LGA) taking the VRPTW as a domain space. Jiang et al. [19] modelled a new variant of VRP which is limited to heterogeneous fleet and time windows. A tabu search based on two assignment decision variables were proposed by Nguyen et al. [20] by first assigning vehicles to supply locations followed by the assignment of customers' demands to vehicle.

Chiang and Hsu [21] proposed a Knowledge-based Evolutionary Algorithm (KBEA) to find a set of pareto optimal solution to the multi-objective VRPTW with the objective of simultaneously minimizing the number of vehicle and the total travel distance using the general Evolutionary Algorithm (EA) approach. Apart from the usual EA parameters of population size and generation count, the authors incorporated two more parameters in their work: the exchangeable candidate route in the crossover operator and the number of customer locations to be re-inserted in the mutation operator. Vidal et al. [22] used a hybrid genetic search metaheuristic with three components of assignment, sequencing and route evaluation.

3.3.3 Classification of PVRPs

The PVRP generalizes the classical VRP and it involves the construction of vehicle routes over a period of time. This class of problem arises in many real world events including waste collection, courier services, machine replenishment, distribution of materials, and many more. In a typical PVRP, during each time spanning over the entire period of route construction, a fleet of capacitated vehicles tour routes that begin and end at a single depot. The goal of a PVRP is to find a set of routes for each utilized vehicle that minimizes the total travel cost (e.g. distance) such that basic requirements of customer's demands and vehicle capacities are satisfied.

A PVRP was proposed by Angelelli and Speranza [23], called the PVRP with intermediate facilities (PVRPIF). This variant does not make use of multi-depots, instead it introduces the idea of ''roll-off'' points where vehicles can make their stop-overs along their routes thereby giving room to capacity replenishment. They used tabu search to solve the resulting problem. Francis et al. [24] gave a further extension of the PVRP characterized with service frequency and vehicle capacity requirement called the PVRP with service choice (PVRP- SC). The authors combined Lagrangian relaxation and branch-and-cut methods to solve the problem. Their result shows that savings depends largely on the geographical location of customers. The PVRP have been used is solving quite a number of real-world problems. Hemmelmayr et al. [25], placing significant importance on consistency in deliveries, investigate the application of PVRP to the periodic delivery of blood products to hospitals by the Red Cross Society of Austria. Their problem was modelled as an Integer Program (IP) as well as a PVRP, with solution provided using an IP solver and a variable neighborhood search method respectively.

3.3.4 Classification of Green-VRPs

Globalization and its new approach of industrial out-sourcing, imposed an imperative role on freight transportation sector. Logistics is one of the primary activities, and transportation is the main part of the logistics. This is the most visible aspect of supply chain that occupies one-third of the logistics costs. In today's competitive environment, logistics has been placed in the center of attention by company managers. Responsiveness as one of the determinants of service quality, stands as a main driver for differentiation, and this will be evaluated by giving prompt services. On the other hand, global warming and emission of Greenhouse Gases (GHGs) are presented as the challenges of the century. In actuality, the most important side effect of vehicle transportation is emission of GHGs, particularly carbon-di-oxide. GHGs are gases that trap heat in the atmosphere and transportation is responsible for 28 % of total emission in the United States.

As a result, decision-makers should deal with three problems including traditional objective of the VRP, strengthening the customers' satisfaction influenced by service levels, and environmental concerns. Relevant to this issue, balancing between environmental and business concerns have been dealt with in a few researches. Additionally, there exist a number of studies which consider customers' satisfaction level and economic objectives. Toro et al. [26] have declared that presentation of tradeoffs between environmental and economic concerns, in presence of customers' satisfaction, have not been dealt yet. They have proposed this subject in their review paper as the future direction in the green VRP. Another review paper in the field of green VRP has been proposed by Lin et al. [27]. They have proposed exploring the trade-off between economic and environmental costs with soft time window constraints.

As in Toro et al. [26], and to the best of authors' knowledge, incorporating all three matters in one problem has been neglected. It could significantly help decision makers select a solution that accounts not just for the economic orientation, but also for customer's satisfaction with respect to the environmentally friendly aspects. Our purpose is to introduce a new vehicle routing problem variant, called Satisfactory-Green Vehicle Routing Problem (S-GVRP) where in addition to traditional objectives, both pollution and customer's satisfaction have been taken into account.

In real-life transportation, time windows may be violated due to several reasons as given in Tang et al. [28]. They propose the idea of vehicle routing with fuzzy time windows. In their model, deviation of service time from the customer-specific time window against a decreasing customer's satisfaction level is accepted. To solve this bi-objective problem they consider a two-stage algorithm in which defuzzification of the values of each satisfaction level (corresponding to time windows) must be calculated separately. It is notable that originally the concept of fuzzy die-time in vehicle routing and scheduling context is defined by Cheng et al. [29]. They believe the customers' preferences for services can be classified into two kinds: the tolerable and desirable interval of service time. They propose fuzzy approach for handling both concepts simultaneously. Triangular fuzzy number for stating the grade of customer satisfaction is applied in their model.

Dekker et al. [30] investigate the contribution of operations research to having a better environment. They discuss that efficiency of trade-offs between cost and environmental factors can be analyzed by operations research. The amount of pollution emitted by a vehicle depends on several factors. Over the years, a wide range of emission and fuel consumption models have been presented. A comprehensive analysis of several vehicle emission models for road freight transportation is presented by Demir et al. [31]. In their research the 'comprehensive modal emission model' is exploited. Incorporating the fuel consumption and CO2 emissions into existing planning methods for vehicle routing was introduced by Bektas¸ and Laporte [32]. They offer some new integer programming formulations for the VRP, named pollution routing problem that minimizes both operational cost, and carbon tax. Extending their model with independent objective function for emission level will be very useful, because emission tax is trivial in comparison with other costs. Moreover, considering heterogeneous fleet of vehicle instead of homogenous may lead to more reductions in energy consumption.

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4 EU policies, standards, directives, practices and initiatives

The current session's objective is to assess new European Union policies, standards, directives, practices and initiatives (see Section 4.1) and more specifically on air quality (see Section 4.2), noise (see Section 4.3) and urban logistics (see Section 4.4). Extensive background information on different new EU policies, standards and directives is conducted and their related environmental, socio-economic impacts are studied. The result of this section is also a set of best practices and initiatives (see Section 4.5) which foster green logistics in urban areas and are proved to have contributed towards the efficient use of energy in road transport.

4.1 General policies, standards and directives

4.1.1 7th Environment Action Program (EAP)

The 7th Environment Action Program or General Union Environment Action Programme to 2020 "Living well, within the limits of our planet" [33], entered into force in 2014 by replacing the 6th European Action Program, sets out the environmental priority objectives to be met until 2020 and a vision on where the EU should be in 2050. Three priority objectives are addressed within the program:

- The protection of the natural capital of the EU;

- EU should evolve into a resource-efficient, green, and competitive low-carbon economy;

- EU's residents should be safe from environment-related threats and hazards to health and safety.

Regarding the second priority objective, the vision set for 2050 is threefold and addresses the following:

- Reduction of greenhouse gas emissions by 80-95% compared to 1990 levels;

- reduction of the overall environmental impact of all major sectors of the Union economy, e.g. food, housing and mobility sectors through new technologies and lifestyle changes;

- adoption of green public procurement rules.

Regarding the third priority, the vision set is the improvement of outdoor air quality and the decrease of noise pollution. The vision of the first priority objective is beyond the scope of the current review.

Regarding the implementation of the program, one of its objectives is the improved access to environment related information and the achievement of more effective data collection and application. According to the program, markets on their own will not reach the desired results, and in order to improve their environmental performance, SMEs, in particular, will need assistance in applying new technologies.

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4.1.2 The European Green Deal

The European Green Deal [34] is Europe's roadmap to achieving the viability of the EU economy. This will occur by turning climate and environmental challenges into opportunities in all policy areas and by achieving a fair and inclusive transition.

The European Green Deal provides an action plan for the following:

- Enhancing the efficient use of resources by moving to a clean, cyclical economy;
- biodiversity restoration and pollution reduction.

The plan describes the required investments and the available financial instruments. It also explains how a fair and inclusive transition can be ensured.

The EU intends to be climate neutral in 2050. Therefore, a European climate law was proposed that will turn this political commitment into a legal obligation. Achieving this goal will require action in all sectors of the economy, such as:

- Investments in environmentally friendly technologies;
- support for innovation in the industrial sector;
- developing cleaner, more inexpensive and healthier forms of private and public transport;
- removing carbon emissions from the energy sector;
- ensuring the energy efficiency of buildings;
- collaborating with international partners to improve global environmental standards

The EU will also provide financial support and technical assistance to those affected the most by the transition to a green economy.

One of the goals set through the European Green Deal is accelerating the shift to sustainable and smart mobility. To achieve climate neutrality, a 90% reduction in transport emissions is needed by 2050. Transport should become drastically less polluting, especially in cities. A combination of measures should address emissions and urban congestion. The Commission will propose more stringent air pollutant emissions standards for combustion-engine vehicles. The Commission will also propose to revise by June 2021 the legislation on CO_2 emission performance standards for cars and vans, to ensure a clear pathway from 2025 onwards towards zero-emission mobility. In parallel, it will consider applying European emissions trading to road transport, as a complement to existing and future CO_2 emission performance standards for vehicles.

4.1.3 Driving time regulation

EU Regulation 2020/1054 [35] introduces new rules for road transport, which will put an end to the distortion of competition in the sector, ensuring better working conditions for drivers.

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The package includes three key elements: better enforcement of cabotage rules, secondment of drivers and driver rest hours.

The new rules for posted workers, based on the principle of "equal pay for equal work", will apply to cabotage deliveries, in line with the adopted amendments. In practice, this means that the same pay rules apply to truck drivers who deliver goods to another Member State after cross-border delivery, as it does to host country drivers.

The members of the Transport Committee also introduced changes to ensure better rest conditions for drivers. For example, companies should organize their itineraries so that, every three weeks, drivers can return home or to another location of their choice for a weekly rest.

4.1.4 Regulation on electronic freight transport information

EU Regulation 2020/1056 [36] on electronic freight transport information sets out the new rules to make it easier for freight companies to submit information to the authorities in digital form. Enhanced digitization of freight transport and logistics will lead to significant savings for businesses and improve the efficiency and viability of the industry.

The new rules will create a single legal framework for the use of electronic freight information for all modes of transport.

All responsible public authorities will be required to accept information submitted electronically on certified platforms when companies choose to use this format to submit information as proof of compliance with regulatory requirements. However, companies will retain the ability to submit the information in hard copy if they prefer. Currently, most freight companies and other transport operators use printed documents.

4.1.5 Sustainable and Smart Mobility Strategy

The European Commission developed the "Strategy for Sustainable and Smart Mobility" [37] at the end of 2020, accompanied by an action plan of 82 initiatives that will guide its work for the next four years.

This strategy lays the groundwork for how the green and digital transformation of the EU transport system can be achieved and become more resilient to future crises. As outlined in the Europe Green Deal, the implementation of the strategy will result in a 90% reduction in emissions by 2050, which will be achieved through a smart, competitive, secure, accessible and affordable transport system.

All modes of transport need to be made more sustainable, with widely available green alternatives and with the right incentives to promote the transition to the new transport system. To make the EU objectives a reality, the strategy identifies a total of 82 initiatives in key areas of action, each with specific measures.

In order for transport to be sustainable, in practice this means:

- Enhance the absorption of zero-emission vehicles, boats and airplanes, renewable and low-carbon emissions and related infrastructure - for example by installing 3 million public charging points by 2030.

- Environmental control of commercial transport.

- CO_2 pricing and better incentives for users - for example by pursuing a comprehensive set of measures to ensure fair and efficient pricing on all transport.

Innovation and digitization will shape the way passengers and goods travel in the future, if the right conditions are in place. The strategy envisages enhancing innovation and the use of data and artificial intelligence (AI) for smarter mobility.

Transport was one of the areas hardest hit by the covid-19 pandemic, and many companies in the sector are facing enormous operational and financial difficulties. The Commission is therefore committed to:

- Strengthening the single market - for example by stepping up efforts and investment to complete the trans-European transport network by 2030 and supporting the sector for better growth through increased investment, public and private, in modernizing all transportation modes.

- Strengthen transport security in all areas of transport - including the approach of the death toll close to zero by 2050.

4.2 Policies, standards and directives on air quality

4.2.1 The Clean Air Policy package

The clean air package aims to substantially reduce air pollution across the EU. The proposed strategy sets out objectives for reducing the health and environmental impacts of air pollution by 2030, and contains legislative proposals to implement stricter standards for emissions and air pollution.

The Clean Air Policy package was adopted by the European Commission in 2013 after an extensive review of the EU policy on air and consists of a communication on the "clean air program for Europe", and additionally three legislative proposals on emissions and air pollution. It includes the Clean Air Program for Europe [38], a Commission strategy outlining measures to ensure that existing targets are met and setting out new air quality objectives for the period up to 2030, the National Emissions Ceiling (NEC) Directive (revised Directive on the reduction of national emissions of certain atmospheric pollutants), the Medium Combustion Plant (MCP) Directive (Directive on limitation of emissions of certain pollutants into the air from medium combustion plants) and a proposal to approve amended international rules on long-range trans boundary air pollution (the Gothenburg Protocol) at EU level. The MCP Directive is beyond the scope of the current review.

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4.2.1.1 A Clean Air Program for Europe

A Clean Air Program for Europe [38] includes measures to ensure that existing targets are met in the short term, and new air quality objectives for the period up to 2030. The package also includes support measures to assist reduction of air pollution, focusing on refining air quality in urban areas, supporting research and innovation, and encouraging international cooperation.

In the suggested measures for air quality compliance, measures to support sustainable urban mobility are suggested instead of further restricting EU vehicles' emissions standards to achieve air policy targets.

4.2.1.2 The NEC Directive

The National Emission Ceilings Directive [39] includes rigorous national emission reduction obligations in EU for the six main pollutants, namely sulphur dioxide (SO_2), nitrogen oxides (NOx), non-methane volatile organic compounds (NMVOC), ammonia (NH3), fine particulate matter ($PM_{2,5}$) and carbon monoxide (CO).

The NEC Directive highlights the significance of Member States to frequently report air pollutant emission inventories for evaluating their improvements with reducing air pollution in the EU and for establishing if the Member States are complying with their obligations. Road transport emissions shall be counted and stated based on the fuels sold or fuels used or kilometres driven in each Member State.

4.2.2 A European Strategy for Low-Emission Mobility

The European Strategy for Low-Emission Mobility [40] outlines the required context and activities for EU Member States to move to lower-emission mobility schemes and renovate their transport system successfully. The strategy suggests that the initial point to succeed this is by improving the effectiveness of the transport system, by exploiting digital technologies, smart pricing and additionally promoting the transition to lower emission transport modes. Other elements of the strategy include accelerating the development of low-emission alternative energy for transport, such as advanced biofuels, electricity, hydrogen and renewable synthetic fuels and removing barriers to the electrification of transport and moving towards zero-emission vehicles, which are beyond the scope of the current review.

Digital technologies, especially Cooperative Intelligent Transport Systems (C-ITS), have a huge potential to improve road safety as well as the effectiveness and attractiveness of transport. The Commission is preparing a Plan to stimulate the use of such technologies, in particular communication links between vehicles and between vehicles and infrastructure. The Commission is also working on improving road charges, to make it reasonable and more effective and better replicate the polluter-pays and user-pays values. This includes common criteria for a distance-based charging system in the EU. The Commission will also take further measures to encourage connections between different modes of transport, helping in the creation of unified logistics chains.

4.2.3 Thematic strategy on air pollution

The thematic strategy on air pollution [41] establishes short-term objectives for air pollution in the EU and suggests suitable measures for attaining them. According to the strategy, the current legislation should be updated, should concentrate on the most serious pollutants and environmental aspects should considered into other policies and programs.

The strategy evaluates the current situation (as of 2005, in which the strategy was published) and sets the objectives to be accomplished by 2020 and recommends actions and means to achieve them. Regarding transport in the general concept, the strategy suggests revolving into reduced congestion and the internalization of externalities into transport costs. Regarding land transport, Member States should develop and implement sustainable urban transport plans, integrating transport demand management to ensure a contribution of transport activities to the achievement of air quality, noise and climate change objectives.

4.2.4 Directive on ambient air quality and cleaner air for Europe

The objective of Directive 2008/50/EC of the European Parliament and of the Council of 21 May 2008 on ambient air quality and cleaner air for Europe [42] is to assess ambient air quality, i.e. quality of outdoor air, excluding workplaces and non-public places. The directive presents the strategy by which EU Member States can monitor, present and inform the European Commission and its citizens about harmful air quality. Under this strategy, the European Union set to its members upper and lower thresholds for harmful substances. These substances include sulphur dioxide, nitrogen dioxide and oxides of nitrogen, particulate matter (PM_{10} and $PM_{2,5}$), lead, benzene and carbon monoxide.

The Directive highlights the necessity for the European Community to also take measures to limit the exhaust emissions of engines installed in light and heavy duty vehicles. According to the Directive, action plans should be drawn up by each Member State to control and suspend activities when the defined values of the substances are exceeded. These action plans may include measures in relation to motor vehicle traffic as well.

Commission Directive (EU) 2015/1480 of 28 August 2015 amended several annexes to Directive 2008/50/EC establishing the rules concerning reference methods, data validation and location of sampling points for the assessment of ambient air quality [43].

4.2.5 Regulation on emission performance standards for new light commercial vehicles

EU Regulation No 2019/631 [44], setting emission performance standards for new light commercial vehicles as part of the Union's integrated approach to reduce CO_2 emissions from light-duty vehicles, establishes CO_2 emissions performance requirements for new light commercial vehicles. This regulation is setting cost-effective CO_2 emission reduction targets

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for new light-duty vehicles up to 2030 combined with a dedicated incentive mechanism to increase the share of zero/low-emission vehicles.

4.2.6 Directive on the promotion of clean and energy-efficient road transport vehicles

Directive 2009/33/EC on the promotion of clean and energy-efficient road transport vehicles [45] requires contracting authorities, contracting units and specific operators to consider lifetime energy and environmental impacts, including energy consumption and emissions of CO_2 and of certain pollutants, when purchasing road transport vehicles with the objectives of promoting and inspiring the market for clean and energy-efficient vehicles and improving the contribution of the transport sector to the environment, climate and energy policies of the EU.

When purchasing road transport vehicles, operational lifetime energy and environmental impacts that should be taken into account are the following:

- Energy consumption;

- Emissions of CO_2; and

- Emissions of NOx, NMHC and particulate matter.

Other environmental aspects should also be taken into account.

These requirements shall be satisfied according to the following alternatives:

- by setting technical specifications for energy and environmental performance in the documentation for the purchase of road transport vehicles on each of the impacts considered, as well as any additional environmental impacts; or

- by including energy and environmental impacts in the purchasing decision.

4.2.7 Directive on emissions from air conditioning systems in motor vehicles

Directive 2006/40/EC of the European Parliament and of the Council of 17 May 2006 relating to emissions from air conditioning systems in motor vehicles [46] establishes the requirements of vehicles regarding emissions from air-conditioning systems fitted on vehicles, as well as their safe functionality. The Directive applies to motor vehicles of categories M1 and N1 (vehicles used for the carriage of passengers and comprising no more than eight seats in addition to the driver's seat and vehicles used for the carriage of goods and having a maximum weight not exceeding 3.75 metric tons respectively, according to Directive 70/156/EEC of 6 February 1970 [47]).

According to Directive 2006/40/EC, if a vehicle is fitted with an air-conditioning system designed to contain fluorinated greenhouse gases, the specific gas must have a global warming potential (GWP) ≤ 150 (related to CO_2 and a time horizon of 100 years). This restriction is in force since January 2011 for retrofitting operations and since January 2017 for refilling operations. If a mixture of gases is used (n number of gases), the GWP should be calculated as follows:

$$GWP = \sum\Big(\big(SubstanceX_1\ \%x\ GWP(X_1)\big) + \big(SubstanceX_2\ \%x\ GWP(X_2)\big) + \cdots + \big(SubstanceX_n\ \%x\ GWP(X_n)\big)\Big)$$

where % is the contribution by weight with a weight tolerance of $\pm$ 1 %.

4.2.8 Regulation on CO_2 emission performance standards for new heavy-duty vehicles

EU Regulation 2019/1242 [48] lays down the requirements for the monitoring and reporting of CO_2 emissions and fuel consumption by new heavy goods vehicles registered in the Union.

The regulation will ensure that between 2025 and 2029 new trucks emit an average of 15% less CO2 compared to 2019 emission levels. By 2030 onwards they should emit 30% less CO_2 on average. These targets are binding, and non-compliant truck manufacturers will be fined in the form of an emission exceedance price.

By 2025, manufacturers should ensure that at least 2% of their share of new vehicle sales is made up of zero and low-emission vehicles, to meet the steadily rising emissions from road transport, of which about a quarter is attributed to heavy vehicles.

The Council and the European Parliament also agreed on concrete measures to ensure the availability of sound and reliable data. The data will be obtained from in-vehicle devices that will monitor the actual fuel and energy consumption of heavy commercial vehicles.

4.3 Policies, standards and directives on noise

4.3.1 Environmental noise directive

Directive 2002/49/EC relating to the assessment and management of environmental noise (the Environmental Noise Directive – END) [49] is the principal EU mechanism to classify noise pollution levels and to activate the necessary action both at Member State and at EU level. It includes three action areas:

- The definition of exposure to environmental noise;

- Safeguarding that EU citizens are aware of data on environmental noise and its impact;

- Prevention and reduction of environmental noise where required and maintaining environmental noise quality where it is good.

The Directive applies to noise, to which humans are exposed, particularly in urban areas, in public squares or other quiet areas in an agglomeration, in quiet areas in open country, near schools, hospitals and other noise-sensitive buildings and areas. It does not apply to noise that

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is caused by the exposed person himself, noise from home activities, noise created by neighbors, noise at work places or noise inside means of transport or due to military actions in military areas.

4.3.2 Regulation on the sound level of motor vehicles

Regulation (EU) No 540/2014 on the sound level of motor vehicles and of replacement silencing systems [50] establishes the administrative and technical requirements for the EU type-approval of all new vehicles, i.e. motor vehicles with at least four wheels designed and constructed for the carriage of passengers or goods with regard to their sound level, and of replacement silencing systems and components thereof type-approved as separate technical units designed and constructed for vehicles for the carriage of passengers and comprising no more than eight seats in addition to the driver's seat and for the carriage of goods and having a maximum mass not exceeding 3,5 tones with a view to facilitating their registration, sale and entry into service within the Union.

4.3.3 Regulation on the labeling of tyres with respect to fuel efficiency

Regulation (EC) No 1222/2009 on the labeling of tyres with respect to fuel efficiency or Tyre Labeling Regulation [51] states the labeling of tyres, in order to offer customers more information on fuel efficiency, security and noise, allowing them to acquire accurate, relevant and comparable information on those features when obtaining tyres. This will help improving the efficiency of tyre labeling so as to ensure cleaner, safer and quieter vehicles and to maximize the label's impact to the decarbonization of the transport sector.

Tyre labeling forms part of EU legislation on the energy effectiveness of products. This includes ecodesign regulations, which set minimum requirements that energy-related products must fulfill before they can be employed on the Union market, and energy labeling regulations, which offer consumers with evidence on the energy consumption and other essential characteristics of products, helping them to take informed, cost-effective and environment-friendly purchasing decisions that are both good for the environment and save money.

4.4 Policies, standards and directives on urban logistics

4.4.1 White Paper on Transport

The European Commission adopted a roadmap of 40 concrete initiatives for the next decade to build a competitive transport system that will increase mobility, remove major barriers in key areas and fuel growth and employment [52]. At the same time, the proposals will significantly restrict Europe's reliance on imported oil and decrease carbon emissions in transport by 60% by the year 2050.

By 2050, key objectives will include:

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- No more conventionally-fuelled cars in urban areas.
- 40% use of sustainable low carbon fuels in air travel and at least 40% decrease in emissions from shipping.
- A 50% shift of medium distance intercity passenger and freight transfers from road to rail and waterborne transport.
- All the above will contribute to a 60% decrease in transport emissions by the middle of the century.

In 2016, the Commission Services published an Implementation report [53] on the 2011 White Paper.

4.4.2 Regulation on statistical returns in respect of the carriage of goods by road

Regulation (EU) No 70/2012 of the European Parliament and of the Council of 18 January 2012 on statistical returns in respect of the carriage of goods by road [54] establishes the guidelines for the production of comparable EU-wide statistics on freight transport by road. EU countries must each gather and communicate to the Commission (Eurostat) data relating to goods transported by means of road transport vehicles listed in their region.

4.4.3 DG Move Study on Urban Freight Transport

In 2012 DG Move published a study on Urban Freight Transport [55] aiming to review existing and planned practices and measures related to the urban section of the freight transport chain across the Member States of the EU with a view to define if, to what extent and in which form, action at the European level can be envisaged to encourage successful solutions and develop the performance of freight transport. The study's objectives are in line with the objectives established in the White Paper on Transport.

The study contains an analysis of the stakeholders involved in urban freight transport, including receivers, shippers, producers and transport operators and additionally local authorities, residents and visitors. The urban freight transport market is also analyzed, and each freight transport sector, i.e. retail, construction, courier, waste, etc. Existing measures and policies are reviewed and classified. The classification includes:

- Regulatory measures: time windows establishment in urban areas, vehicle weight and size restrictions to prevent road infrastructure damage and establishment of Low Emissions Zones (LEZs), in which freight transport vehicles are not allowed if they don't meet certain emissions standards.

- Market-based measures: application of fiscal measures (taxes and tolls) in prices of products which have negative effects. These include congestion charging zones, i.e. charges for driving a vehicle in specific areas and mobility credit schemes chosen by the final receiver.

- Land-use planning measures: development of parking spaces for loading and unloading of freight and development of logistics zones in the surrounding areas.

- Infrastructure measures: development of rail connected logistics parks for successive distribution in urban areas and on-street loading bays.

- Technology measures: substitution of conventional vehicles with electric and hybrid technology vehicles. These technologies are not mature yet and therefore Information and Communications Technologies (ICTs) and Intelligent Transport Systems (ITS) should be taken into account instead and adopted.

- Management measures: Urban Logistics Plans (ULP) as part of Sustainable Urban Mobility Plans (SUMPs) should be developed.

The study concludes with EU policy recommendations. The recommendations concern policy measures in six categories: efficiency of deliveries in urban areas, take-up of low emission vehicles in last-mile delivery areas, the development of ITS for last-mile delivery, the encouragement of night deliveries, the use of sustainable modes of transport through intermodal transfer facilities and the dissemination of good practices among EU Member States.

4.4.4 Action Plan on Urban Mobility

The European Commission implemented the Action Plan on urban mobility on 30 September 2009 [56].

The Action Plan suggested twenty measures to foster and support local, regional and national authorities in accomplishing their objectives for sustainable urban mobility. With the Action Plan, the European Commission introduced for the first time a complete support package in the field of urban mobility.

The actions were implemented during the three years after the Action Plan's approval. The European Commission after reviewing the execution of the Action Plan proceeded in developing the 2013 Urban Mobility Package.

Action 19 of the plan was dedicated to urban freight transport. The Commission's intention is to offer assistance on the optimization of urban logistics effectiveness, including the improvement of the links between long-distance, inter-urban and urban freight transport, aiming to ensure efficient 'last mile' delivery. It focuses on how to better integrate freight transport in local policies and plans and how to better manage and monitor transport flows.

4.4.5 Urban Mobility Package

With the Urban Mobility Package, the Commission aids its supporting measures in the area of urban transport by:

- Exchanging experiences, presenting best practices, and encouraging collaboration;

- Providing targeted financial support,

- Aiming research and innovation on providing solutions for urban mobility challenges,

- Involving the Member States and enhance international cooperation.

The principal component of the Urban Mobility Package is the Communication "Together towards competitive and resource efficient urban mobility" [57]. It is supplemented by an annex, named "A Concept for Urban Mobility Plans" [58], which establishes the idea of Sustainable Urban Mobility Plans, and additionally four Staff Working Documents on urban logistics [59], urban access regulations [60], mobilization of Intelligent Transport System solutions in urban areas [61] and urban road safety [62].

4.4.6 Green Paper on Urban Mobility

The European Commission adopted the Green Paper "Towards a new culture for urban mobility" on 25 September 2007 [63]. With the Green Paper, the Commission established a new European agenda for urban mobility, while considering the responsibilities of local, regional and national authorities in this area. The Commission intention is to enable the search for solutions by, for example, exchanging best practices.

According to the green paper on urban mobility, one of the challenges urban areas have to face in the framework of sustainable development is that of freight transport. Delivery of goods in urban areas involves effective crossing points between long-distance transport and short distance delivery to the final destination. Smaller, efficient and clean vehicles could be used for urban deliveries. Negative effects of long haul freight transport driving in urban areas should be minimized through planning and technical procedures.

According to the green paper, the effectiveness of urban freight distribution can also be fostered by the assistance of ITS, more specifically through better scheduling of operations, higher loading factors and more efficient usage of vehicles. It entails integrated systems that include intelligent route planning, driver assistance systems, intelligent vehicles and interaction with infrastructures.

4.5 Best practices and initiatives

4.5.1 The CIVITAS initiative

CIVITAS is a network of cities for cities dedicated to cleaner, better transport in Europe and beyond [64]. Since it was launched by the European Commission in 2002, the CIVITAS Initiative has tested and applied over 800 measures and urban transport solutions as part of demonstration projects in more than 80 Living Lab cities Europe-wide.

CIVITAS offers practitioners opportunities to see innovative transport solutions being developed and set out directly, and acquire experience from peers and experts working in the field. CIVITAS develops political commitment, new marketable solutions, and offers funding and knowledge exchange with a view to creating development and better linked, more sustainable transport modes.

The project works on 10 thematic areas, related to sustainable transport mobility covering among others urban freight logistics. The latter aims at demonstrating overall strategies to create cleaner and better freight transport in urban areas and raising awareness and increase knowledge of urban freight issues and challenges by providing a general overview of urban freight issues and definitions, as well as, indications of future trends.

CIVITAS cities take an integrated planning approach that addresses all modes and forms of transport in cities. Their objective is to demonstrate that it is possible to guarantee a high level of mobility for all inhabitants, offer a high quality of urban space and protect the environment through sustainable mobility. It is this integrative approach based on innovation, collaboration, research and results-orientation that sets CIVITAS apart.

The research projects run under CIVITAS 2020 focus on establishing new knowledge or exploring the feasibility of a new or improved technology, product, process, service or solution related to transport

Concerning Greece, under the CIVITAS initiative, a number of mobility solutions are currently been developed for the city of Rethymno, Crete. These include the development of a freight logistics plan which aims to optimize goods delivery routes and reduce environmental and social impacts in the city. Logistics stakeholders are actively involved in the conception of the plan.

4.5.2 The INSPIRE initiative

The INSPIRE (Infrastructure for Spatial Information in Europe) initiative [65] was initiated by the European Commission and established together with the EU Member States. Its objective is to create a European Union spatial data infrastructure assisting EU environmental policies and policies or activities which may have environmental effects. This European Spatial Data Infrastructure allows the exchange of environmental spatial data among public sector organizations, enables public access to spatial information across Europe and assist policy-making across boundaries.

INSPIRE is based on the infrastructures for spatial information established and operated by the Member States of the European Union. The INSPIRE Directive addresses 34 spatial data themes needed for environmental applications.

4.5.3 The European Green Capital initiative

The European Green Capital Award [66] has been conceived to disseminate and reward efforts to resolve environmental challenges our society is dealing with in urban areas. The European Green Capital Award is the result of an initiative taken by 15 European cities (Tallinn, Helsinki, Riga, Vilnius, Berlin, Warsaw, Madrid, Ljubljana, Prague, Vienna, Kiel, Kotka, Dartford, Tartu & Glasgow) and the Association of Estonian cities on May 15th 2006 in Tallinn, Estonia.

Their green vision was translated into a joint Memorandum of Understanding launching an award to distinguish cities that are leading the way with environmentally friendly urban living. The initiative was initiated by the European Commission in 2008. The award supports cities in inspiring each other and exchange examples of good practices on the spot.

Starting in 2010, one European city is assigned each year as the European Green Capital of the year. The award is given to a city that:

- Provides consistent data of attaining high environmental standards;
- Is dedicated to continuing and ambitious goals for further environmental improvement and sustainable development;
- Can act as a role model to inspire other cities and promote best practices to all other European cities.

The award aims to provide an incentive for cities to inspire each other and share best practices, while at the same time engaging in friendly competition. In other words, the cities become role models for each other.

4.5.4 Europe on the move

"Europe on the Move" [67] is a wide-ranging set of initiatives launched by the European Commission to activate modernization of European mobility and transport. The first series of eight legislative initiatives specifically target road transport, which is of high importance for the economic competitiveness of cities and regions as well as for strengthening social, economic and territorial cohesion in the EU.

The Commission is completing its agenda for a low-emission mobility system by putting forward the first ever CO_2 emissions standards for heavy-duty vehicles. In 2025, average CO_2 emissions from new trucks will have to be 15% lower than in 2019. For 2030, an indicative reduction target of at least 30% compared to 2019 is proposed. These targets are consistent with the EU's commitments under the Paris Agreement and will allow transport companies – mostly SMEs – to make significant savings thanks to lower fuel consumption (€25,000 over five years). To allow for further CO_2 reductions, the Commission is making it easier to design more aerodynamic trucks and is improving labeling for tyres.

EU Road Safety Policy Framework 2021-2030

The EU set an ambitious long-term goal of almost zero deaths by 2050 ("Vision Zero"). In the "Europe on the move" package, the European Commission proposed a new approach to EU road safety policy, as well as a medium-term strategic action plan in order to achieve its goals. The concept of not accepting deaths in the air should also apply on the road and become the basis for all safety decisions.

The revision of the regulation on general vehicle safety, which was agreed in early 2019, makes mandatory a set of new advanced safety features: intelligent speed control system, emergency lane-keeping assist system and instant visibility requirements for buses and lorries. This regulation will also contribute to accident analysis, as all new vehicles will be required to be equipped with event data logging systems.

Vehicle procurement is also an interesting opportunity to exert a positive influence on road safety. The EU is currently exploring ways in which it can financially support initiatives to upgrade fleet security under the "platform for safer transport", a one-stop-shop service in the field of road safety under the auspices of the European Investment Advisory Center.

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