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Abstract. In today's challenging sector of logistics and transportation, companies, seek to adapt software which leads to efficient solutions at an acceptable cost. Conventional routing software is developed to solve vehicle routing problem and help managers and planners in decision making. Simultaneously, specific constraints and different VRP (Vehicle Routing Problem) variants are considered each time, such as the Capacitated, the Multi Depot and the Pickup and Delivery VRP. However, the last few years the need for more reliable deliveries and better customer services arose. In addition, reducing travel distance, travel cost and environmental impact are important factors encountered in urban freight transportation. Therefore, routing software need**s** to take into account multiple constraints. Such constraints are traffic congestion, speed limits, transportation regulations and restricted zones. These constraints affect mainly Time dependent VRP, VRP with Time Windows, Dynamic VRP and Green VRP. Data collection and processing are essential in routing software for solving these variants and offering the best solution. The methods for solving these problems, along with technological achievements, including cloud computing, can lead to efficient, easily adaptable routing software. Such software solutions can eventually render companies with complex transportation and logistics problems, competitive. The scope of this paper is to describe the concept and methodological approach for the development of such a routing and scheduling system, operating in a cloud environment. The definition of its requirements and the development of the system is the main purpose of an ongoing research project, being in its first stages of system's analysis and design.

Keywords: Vehicle Routing Problem, Scheduling, Urban Freight Transportation, City Logistics, Routing Software, Software as a Service, SaaS, Cloud Software

1 Introduction

Logistic professionals have faced the Vehicle Routing Problem (VRP) in practice, ever since multi-drop freight carrying vehicles were introduced. VRP is still encountered in our days, mainly in the domain of transportation and logistics and it is one of the most widely studied topics in the field of Operational Research [1]. Still, theoretical research in the field of vehicle routing started in 1959, when Dantzig and Ramser [2] posed the "truck dispatching problem", utilizing hand calculations and a linear programming formulation in order to find a near optimal solution with four routes to a problem of twelve drop points. Extended research has been achieved in the field of VRP and plethora of articles have been published, as described by Braekers et al. [1]. In spite of all this research into vehicle routing, there is no single algorithm that optimally solves every problem. Algorithms and methods have been developed for optimally solving certain classes of vehicle routing and scheduling problems, tackling only a single issue in order to minimize the number of variables under consideration, in order to simplify real-life business cases.

Routing of vehicles and scheduling of deliveries from distribution centers to several drop points, is affected from multiple variables and constraints such as vehicle capacity, number of depots, traffic conditions, regulations and other restrictions. Traffic congestion in urban areas along with various time restrictions make the optimization of routing and scheduling operation particularly difficult. Furthermore, restrictions for minimizing CO2 emissions, which depend on truck speed, have been recently taken into consideration [3]. All these variables and constraints are identified and connected with multiple VRP variants such as the Capacitated VRP, the Multi Depot VRP and the Dynamic VRP. These variants, along with the VRP with Time Windows, the Time Dependent VRP and the Green VRP, are some of the most studied topics from researchers [4], [5], concerning logistics companies as well.

The need for software which can combine all the above VRP variants and attribute an optimal solution, giving priority to specific variants has appeared. Conventional information systems are usually designed case by case, having many issues in fields of system elasticity, while the purchase of hardware and software is of outmost need [6]. However, the main disadvantage these systems present is in the absence of real time data and big data analytics, which can contribute in solving specific time dependent VRP variants and offering more reliable solutions.

On the other side, routing Software as a Service (SaaS), which is a software distribution model in which a third-party provider hosts applications and makes them available to customers over the Internet, have become very popular nowadays as they provide i) Big Data Analytics [7], ii) Flexible Payments iii) Scalable Usage, iv) Automatic Updates and v) Accessibility and Persistence [8]. Such software can offer both reliable deliveries and minimization of costs, mainly, due to the usage of advanced algorithms in powerful servers and due to the advantages of big data analytics. The aim of the described ongoing research is the development of a routing and scheduling SaaS, covering the contemporary requirements of logistics companies, offering simultaneously a holistic approach in the cases of static and dynamic vehicle routing and scheduling. This holistic approach makes the system innovative, as there is no such a system described in the literature.

In the remainder of this paper, the contribution of big data and internet of things (IoT) in VRP is presented in Section 2. Section 3, introduces the system development approach and the conceptual model of the routing and scheduling SaaS as part of the ongoing research project. In section 4 conclusions and further research are discussed, featuring the next steps of the research in order to develop an advanced cloud-based vehicle routing and scheduling system for urban freight transportation.

2 Big Data and Internet of Things in VRP Software

The concepts of Big Data and Internet of Things (IoT) are not just buzzwords. They are new approaches to unify everything in our world and analyze various data under a common infrastructure [9]. Massive quantities of data, relevant to businesses and to services, both in private and public sector can easily be collected, due to technological advances which are simultaneously the reason of the explosion big data appear [10]. Objects such as electronics, sensors, software and network connectivity are related to IoT and to the big data phenomenon as too.

The main differences big data present compared with traditional data are in i) volume ii) velocity and iii) variety [11]. In cases, such as the vehicle routing and scheduling of deliveries, in which, traffic conditions change dynamically, and the re-routing of vehicles sometimes seem necessary to avoid delays and improve deliveries, the speed of data creation is significant, for decision makers. Furthermore, big amount of data can lead to better statistical analysis and better forecast and prediction models of traffic, calculating travel time between delivery points. Travel time is essential for static vehicle routing as well as for the dynamic routing, when exceptional cases appear. In the case of static routing, historical data are used for defining the initial routes of vehicles, using forecasting methods. Furthermore, real-time data are used when the distribution of products has started, in order to avoid traffic congestion and simultaneously, delays of deliveries.

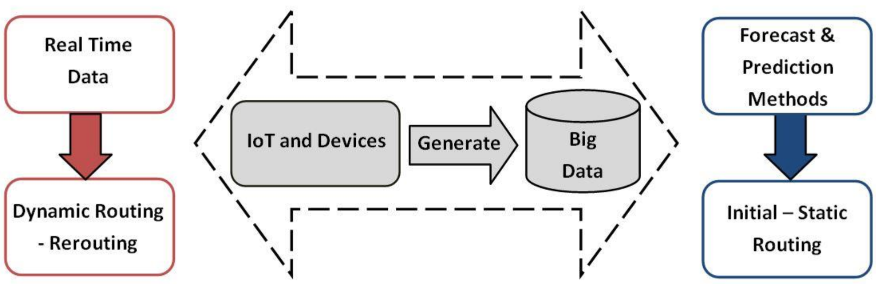

Figure 1 Data, Methods & Decision Making for Vehicle Routing and Scheduling

In order to receive the desired outcome and be able to develop a vehicle routing SaaS system, solving specific variants of the VRP and leading to reliable deliveries without despising constraints, big amount of data is required. Simultaneously, data analysis, which refers to the techniques used to analyze and acquire intelligence from big data [12], is crucial, as without it, data cannot be reclaimed to the maximum extent. Global Positioning System (GPS) signal and sensors can provide enormous amount of data, related to the location, the speed of vehicles and their direction as well [10]. Real-time data of vehicles locations in addition with real-time traffic data can adjust delivery estimates in order to detect inconsistencies of schedules and required modifications. Figure 1 describes the way through which traffic data are collected using various data inputs like public or private traffic management services, or even existing equipment in vehicles for route tracking. Forecasting and prediction methods are used for the static routing of vehicles in order to offer data for expected traffic and delivery. Finally, Figure 1 encompasses the important role that real time data play in the rerouting of vehicles. Through this procedure better decision making for vehicle routing and scheduling is accomplished and efficient deliveries are succeeded. The significance of using big data in the described routing and scheduling software is presented in the next section.

3 Developing a Routing and Scheduling System

3.1 System Development Approach

This paper reports ongoing work and initial results from a project in Greece which aims to enhance the capabilities of routing and scheduling operations of Transportation and Logistics companies. The system presented in this paper is intended to support the decisions of the static routing and scheduling problem, as well as the dynamic aspects of the problem and is being developed in the context of the research project "SMARTRANS". The project participants include i) a major technological University responsible for the theoretically informed analysis and design of the new system, the development of the algorithms for the static and dynamic routing problem, and the creation of methods for traffic data collection and analysis, ii) an IT company implementing the system and applying technological solutions of the theoretical design, and iii) a Greek logistics company as an industrial partner for testing and validating the system.

The research project's phases are presented in Figure 2, including four main phases. The first phase is the preparation phase of a comprehensive literature review concluding to the "state of the art" of three main research areas: VRP variants for the static and dynamic problem, the algorithms for solving them, forecasting methods for travel time estimation in order to schedule the deliveries and innovative big data techniques for traffic data collection in a dynamic way (see also the "Research" perspective in Figure 3). The forecasting and prediction methods which are developed use historical traffic and delivery data, making assumptions about the future. However, through computer simulation the performance of these methods can be studied while the set of initial parameters change, leading to significant and more accurate results.

Information technologies for routing software and cloud-based application are analyzed as well.

The design and analysis of Business Process Models of logistics companies are also included in preparation phase, leading to requirements analysis, which are the system's services, constraints, and goals that are established through consultation with the system users. Often, one requirement generates or constrains other requirements. In order to ensure that services/features are delivered properly, system requirements need to specify both services and features of the system and the necessary functionality [13]. Use case scenarios are also developed based on business processes, in order to test and validate the implementation in later phases, leading to the identification of functionality with potentially improvement.

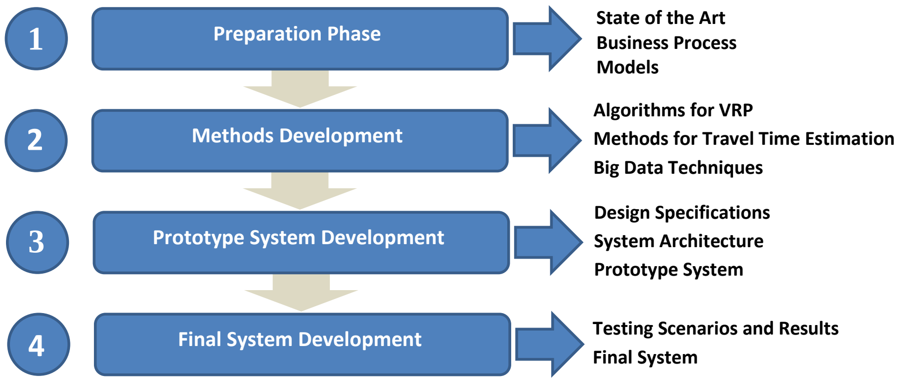

Figure 2 Research Project's Phases and Outcomes

Preparation phase has been completed and algorithms for the static and dynamic VRP are being developed in order to support the decisions for the scheduling of deliveries in real-life companies. Forecasting methods for travel time estimation in urban environment, as well as big data techniques for real-time traffic data collection and processing will be devolved in the second phase (methods development). The third and fourth phases will be carried out after the first year of the project and will finally conclude to the advanced and innovative system, described in the next section and in Figure 3.

3.2 System Design Concept

The designed system for vehicle routing and scheduling of the deliveries integrates both static and dynamic version of the VRP, as depicted in Figure 3 in the "Outputs" perspective of the conceptual model. The software, using the outcome of the VRP algorithms, is able to solve static VRP, in which, information does not change during deliveries, choosing the best scenario among all the alternative ones. The static routing provides alternative scenarios of deliveries based on different objectives of the VRP. System user can decide for the most preferable scenario or let the system choose the optimum, based on a combination of constraints and parameters for the variants of the VRP. These parameters and constraints are related to capacity (weight, volume and height), time windows, driving hours and road regulations and restrictions. The objective function is complex, as the optimization is not related only to the minimization of travel distance and the number of vehicles. It is also vital to minimize travel costs and carbon dioxide emissions, while maximizing customer service and accuracy of deliveries.

All these parameters are inputs ("Inputs" perspective) in solving the problem. In addition, inputs also include the customer orders, the available vehicles (which in turn have specific weight and volume capacities) and the depots. Real time traffic data are gathered from various applications such as Google Maps, HERE WeGo Maps and from traffic police reports. These data are stored to the system, processed, and finally contribute in the development of a forecasting and prediction model of travel times. This functionality can assist the calculation of travelling time of each route in a more accurate way, leading to feasible routes and deliveries, especially in traffic congestion cases.

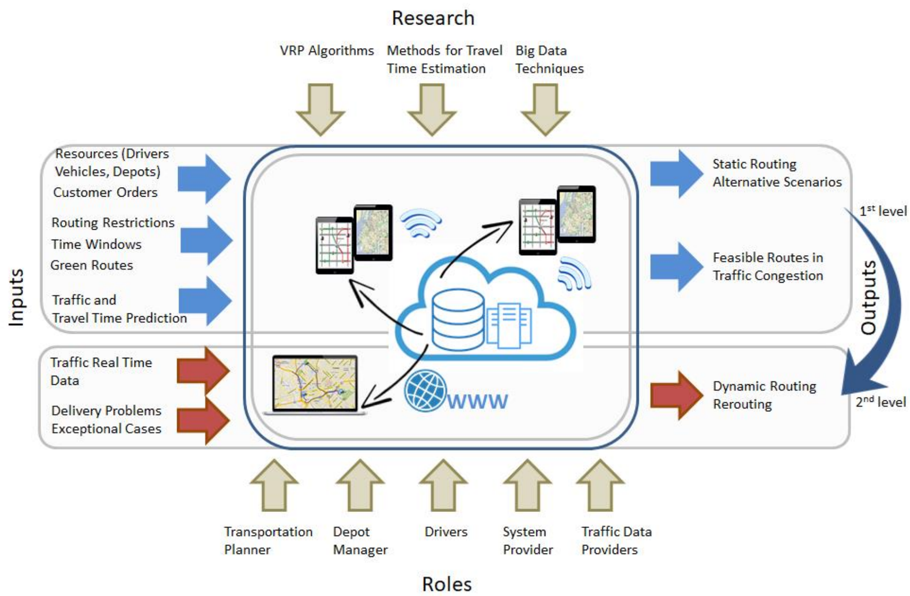

Figure 3 Overview of the Vehicle Routing and Scheduling System Design Concept

Real time data of traffic and exceptional cases can be collected using big data techniques in order to re-route the vehicles during deliveries, as accidents and delays can cause delivery problems which eventually lead to penalties. This functionality refers to the Dynamic VRP (DVRP) and is distinguished as a second level routing in Figure 3.

The main roles involved, contributing and using directly the software are: i) transportation planners and depot managers, who receive the outcome of the software, edit the created solution, and finally provide the initial routing of vehicles and scheduling of deliveries, ii) drivers, who receive the routing and scheduling in a front-end device, such as tablets and mobile devices, iii) system providers, which is the IT company, providing all the above functions and applications, as well as, maintaining and supporting the software, and finally iv) traffic data providers, who support the whole procedure, by providing the appropriate data for travel time prediction and dynamic routing.

The technical solution of the system is based on the cloud computing concept, as the system runs on the cloud under the responsibility of the system provider. Every user of the routing and scheduling system can access its functionality as a software service (SaaS).

4 Conclusions and Further Research

This paper presents the development phases and the conceptual design of an integrated web-based software solution to support transportation operations of contemporary logistics companies in order to effectively schedule their deliveries under various parameters and time dependent constraints.

The methodological approach for system implementation is presented in Figure 2. According to the first phase (preparation phase), the "state of the art" has concluded to the conceptual design of the system, presented in Figure 3. In addition, business process models of transportation and logistics companies have been developed in order to conduct requirements analysis of the system and to investigate the parameters and constraints of the static and dynamic VRP. The analysis of business processes will drive the design specifications of the new system in the third phase of the research. State of the art results, along with requirements analysis will be the input for the development of algorithms for the static and dynamic vehicle routing and scheduling problem, as well as for the development of big data methods for traffic data collection and processing. The first and the most important note that can be made for further research is the design of system's architecture and the implementation of a prototype for testing and validation purposes (third phase of the research approach) and later the implementation of the final system (fourth phase).

The final outcome of the presented approach and conceptual design will be an innovative system for vehicle routing and scheduling in urban environment, which is characterized by heavily and often unpredictable traffic congestion. The system's innovative characteristics include the formation of the time dependent vehicle routing and scheduling problem, taking into consideration various parameters and restrictions like traffic congestion, working hours and state regulations in a holistic way, the algorithms for solving this problem and the forecasting methods for the calculation of travel times. Finally, the service provision through a web-based interface will make the system globally accessible, user friendly and relatively easy to implement even in smaller scale logistics companies.

Acknowledgments

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