Infomobility and Vehicle Routing Problem

Transportation Models of goods

Giuseppe Salvo, Luigi Sanfilippo
Technology and Economy of Transport
University of Palermo
Palermo, Italy
giuseppe.salvo@unipa.it; luigi.sanfilippo@unipa.it

***Abstract*—The research of optimization techniques in the system of goods distribution from warehouses to final users (vehicle routing problem), made considerable savings on the total cost of transport and, consequently, on the final cost of goods, and produced the models applicable to other operating environments (e.g., transport for disabled people, school, municipal waste collection). The analysis conducted on the different models developed under the VRP highlights the support that these models can give on the infomobility of goods.**

Keywords-Infomobility of goods; Model of Vehicle Routing Problem; Models of DRAI; Logistic Operator; Mutimodal Transport Operator; Transport of goods

I. INTRODUCTION

The distribution of goods, delivery to a clients set or pick up of goods by one or more deposits, made with suitable transport, causes many problems. In particular, transport takes place in urban areas, deposits are located in the peripheral areas (suburban); customers are all in the urban area and vehicles used are mainly by road. In pick-up and delivery of goods lie the problems of vehicle routing and scheduling.

In fact, the adoption of standard operating procedures which make extensive use of vehicle techniques routing allow sizing of fleet and driving staff, with positive effects on business management. On the other hand the reduced availability of time on the part of customers to receive the goods requires a careful scheduling of deliveries.

The solution of a transporting goods problem in a predetermined time interval requires the determination of a trips set, all with original and final destination at the depot and carried out by various vehicles of the fleet, so as to meet the demands of customers, respecting operational service constraints and minimizing the overall cost for the transport.

In recent years, thanks to the numerous technological advances, the Vehicle Routing Problem (VRP) [9] has been an active area of Operational Research. New approaches, new models and faster solution algorithms were developed as a result of more accurate techniques, (e.g., Asymmetric Vehicle Routing Problem AVPR [9]; Capacitated Vehicle Routing Problem CVRP [9]; Traveling Salesman Problem TSP [14]; Green Vehicle Routing Problem G-VRP [1]). The application of these approaches for solving vehicle routing problems is very useful in solving various problems (e.g., transport services disabled, school buses, on-demand, etc.). Much still needs to be done to determine the extent how the traffic information can help operators to solve logistical problems of routing and scheduling.

Development of Operations Research models increasingly specialized is accompanied with proliferation of devices that, using information technology and communications (ITC), are able to expand the user's knowledge, leading to better decisions. As part of the transport activity, this involves, e.g., the knowledge of the congestion state of the network, the possibility of modifying in real time the route according to the changed conditions of the road network, the possibility, on the part of the customer to monitor the arrival of the goods pending. The availability of extensive and detailed information occurs affecting the structures of the VRP algorithms, giving origin to a continuous "loop".

The objective of this work is to analyze the interaction in the transport of goods, between mobile information systems (e.g., devices, information technologies, communication protocols, etc.) and VRP models available in the literature.

To this end, in Section II, it will be taken into account the needs of logistics operators to see how goods transportation changed and what are new requirements, passing in review the main traffic service and their usefulness in the transport of goods.

In Section III, we will analyze the mathematical models for the transport of goods. In particular, we will focus on the problems DRAI (Dynamic Routing And Inventory), collection and delivery of goods, giving a classification of variable according to topology, type of goods, demand, kinds of decision, constraints/objectives, costs, solving approach. It will also analyze some of VRP models that offer the advantages of lower costs and better management of transport, in order to verify whether these models have among the explicit variables elements infomobility.

In Section IV, we will comment on the analysis results, formulating hypotheses, for the integration of the already known models with the explicit variables related to the availability of information on the road network state, and monitoring of the fleet.

II. THE NEEDS OF LOGISTICS OPERATORS

The factor which has made necessary a different approach toward the transport activities are:

- **Compression of time in the supply chain**. The shortening of the transfer of information within the chain has highlighted the relative slowness of the process of physical transfer of goods. It is obvious that effort have been focused on this process to make it faster and more reliable.
- **Control of the transport process**. In the effort of reduction in transit times in the supply chain, strict control of goods has become an inevitable requirement. Satellite vehicle positional system, system for the control in various links in the chain of the specific goods (tracking and tracing), systems for continuous communication with various units are indispensable tools today.
- **Dissemination of outsourcing logistics and evolution of operators**. The assignment to third parties by companies of their logistics activities has created a new market of the logistics operators. So in most cases not more carriers that perform the simple activity from origin to destination, but logistic operators can manage with tools, reality quite complex, requiring the ability to integrate with various systems of the client companies or other actors in the world of transport (customs, ports, etc.).
- **Diffusion of the Internet**. Even in the transport sector, as in many areas Internet has opened up new opportunities that require ability to adapt to the new technologies. The e-commerce further strengthens the compression of time, but it also poses considerable problems of reorganization to reach a new market in a competitive way. The availability of portals (market places) dedicated specifically to the various modes of transport offers new tools to operate more efficiently.

The modern production processes resulted in a significant increase in demand for logistics and is more frequent in the case of manufacturing companies that make outsourcing, relying on established companies or applying spin-off of the business that deals with the logistics. Cost, time and quality are the basis of service, but the primary factor of success for a logistic enterprise is a service "tailored" to the customer. To be able to offer a service “ad hoc” we need a particular focus on the Human Resources, on the *Information and Communication Technology* (ICT). In particular, for logistic operators that operates as MTO (*Multimodal Transport Operator*), the availability of effective ICT tools to communicate with customers and other transport operators has a real strategic value [11].

Most of the "traditional" problems in the transportation of goods derive from the need to maintain continuous contact workers with staff on board, with customers and suppliers, as well as databases and service companies such as customs, insurance companies and banks. This also means a wide and full cooperation between all actors in the supply chain such as intermodal shipping companies, intermodal operators, terminal operators and transport providers (land/sea/air) for the exchange of all data of transport fundamentals to handle the shipping [13]. An adequate system of telecommunications is the support for the exchange of electronic documents to allow the tracking and control of shipments to foster the development of a "just-in-time" ensuring effective efficiency of the logistics cycle considerably higher than that now obtainable [8].

The use of telecommunications networks, Internet and the introduction of the exchange data electronically help to pursue some primary objectives as:

- Reduction in production of paper documents;
- Reduction in time sorting the delivery documents;
- Reduction in procedural costs;
- Acceleration in cash flows;
- Reduction in errors and misinterpretations;
- Reduction in time and costs of storage;
- Information about the products location during transport;
- Optimization in use of means of transport;
- Information and documents;
- Contribution to the creation of statistical data on transport at national / international level.

Therefore, it is essential providing a flow of information to ensure the fulfillment of the objectives listed above with particular reference to traceability of load, timely communication with forecast delivery date, and billing system on computer, agreed with customer, clear and standardized [12]. The same exchange of information must be provided by operator intermodal to its customers assuring certainty and timeliness in supply data using both mainframes and operating systems on a PC.

Only upon reaching these goals the intermodality will expand its incidence rate in the world of transport and reducing the negative weight of some serious infrastructure.

Several studies conducted in Europe (Davies, et al. [4] and Golob and Regan [7]) have examined the effects of the use of ICT in transport processes of goods, in the field of e-commerce in particular is analyzed the influence of the use of technology information and communication technologies (ITC) on the organization of transport. In particular, the use of seven technologies:

1. Satellite or radio based communication (S/RC);
2. AVL technologies;
3. AVI systems, including PrePass transponders;
4. EDI;
5. Vehicle maintenance software (VMS);
6. Routing and scheduling software (R/SS);

7. CB radio (CBR).

This analysis was based on the results of a survey of transport operators with the aim of:

a) Exploring the extent to which ICT is used by businesses.
b) Checking that the transporters believe it is important to use the ITC.
c) Identifying the efficiency of the fleet in terms of return empty running.
d) Identifying sources of backloads.
e) Analyzing the methods used to find backloads.
f) Identifying the benefits and barriers to the view of the drivers' trade in goods.

A first major finding from the survey, confirmed by a similar study conducted on a sample of transport companies of southern Italy, address the issue of management of empty running and significant impact on the total cost of transport. Less than 5% of companies are part of a network for the exchange of transport orders that allows them to reduce the distances with empty vehicles. The investigation demonstrated how ICT, although recognized as an important tool, is only partly used to support technical activities (planning vehicle routing, vehicle tracking, vehicle telematics) and how the perception of the informatics support is only limited to accounting matters.

III. Mathematical models for transport of goods

A. *Problems DRAI*

The logistics distribution, namely organization and implementation of physical distribution of goods, must also include, for example, the management of possible intermediate storage, handling from warehouse to vector and vice versa, the bargaining of times and modes of delivery goods to the customer. Mathematical models for this kind of issues must give a description integrated to whole process of physical distribution and consider, in addition to transport costs, other logistical costs such as those related keeping goods in the warehouse (*inventory costs*) and materials handling (*handling costs).* These models are described by Tinarelli [25], in case of single destination, and in Anily and Federgruen [26], in case of multiple destinations. Below, will be considered models that refer to problems characterized by at least the following three aspects:

- The need to define the paths that must be followed by the transport of goods;
- The existence of costs related to the quantity or value of the goods in question;
- The presence of dynamic aspects that require repeated decisions during a given time interval.

The problems that fall within the context defined will be referred to here after as problems DRAI (Dynamic Routing and Inventory). The problem DRAI, concern how to manage the supply of customers geographically distributed during a given time interval, considering issues relating to both the transport and the management of the warehouses. DRAI's in problems, it is assumed that the transport takes place via rubber and that time departure, loads and locations are subject to decision. It is also supposed that deployment task rather than collection occurs. In the context defined above, decision makers that make a problem DRAI must answer at least the following questions:

- When the shipments are made, in other words, when you have to load the vehicles and when they are visited customers;
- How much load in each vehicle and how much deliver to each customer;
- Which path should be followed by each vehicle to serve its customers.

The literature has lots of articles speaking about *Pick up and Delivery* (PD), especially if the application is affected by conditions of uncertainty, in terms of geographical location of customers and/or terms of the amount of goods required. Interesting problems of PD are analyzed by Savelsbergh and Sol [18]. A classification of DRAI problems in literature is described in Table 1.

TABLE I. CLASSIFICATION OF DRAI PROBLEM

Topology			
Distribution Structure	one to many	many to many	
Types of goods			
Number	one	many	
Demand			
Knowledge	known	uncertain	unknown
Variability in time	constant	variable	
Distribution	uniform	not uniform	
Kinds of Decisions			
Domain	time	frequency	
Constraints / Objectives			
Vehicle capacity	equal	different	
Storage capacity	infinite	over	
Storage capacity customers	infinite	over	
Number of vehicles	known	decision variable	non-binding
Cost			
Warehouse	conservation	lost sales	shuffle
Transport	fixed	proportional to the distance	proportional to number of stops
Solving Approach			
Decomposition	time	regions - routes	
Grouping	time	frequency	position
Models / Algorithms	exact	approximate	

 ISBN: 978-1-61208-269-1

B. Models of DRAI

The models considered here are well suit to problems where demand is almost constant or varies slowly over time. There are two dominant schools that study the models in the frequency domain. The first of these is the so-called *Continuous Approximation* (CA), while the second refers to the *Fixed-Partition Policies* (FPP).

Both schools are based on some of the following results, which allow the assessment (asymptotically) the length of paths.

1. Assuming it is worth the triangle inequality, minimum length Z of a closed path that from the central warehouse allows you to visit all customers in a particular region satisfies (1).

$$\max\left\{L^*(N), \frac{2}{|N|}\sum_{i\in N} d_i\right\} \le Z \le 2\min_{i\in N} d_i + L^*(N) \le d_i + L^*(N) \tag{1}$$

   where N is the set of customers to visit, d_i is the distance of the client from the warehouse and L* (N) is the minimum length of a Hamiltonian path between customers in N.

2. If the set customers is partitioned according to any policy RP in R regions each, that containing q customers, the minimum value ZRP of the lengths sum of the paths of customer visit, meets (2).

$$\frac{2}{|q|}\sum_{i\in N} d_i \le Z^{RP} \le \frac{2}{|q|}\sum_{i\in N} d_i + 2\,d_{max} + \sum_{j\in R} L^*(N(j)) \tag{2}$$

   where N (j) is the set of customers in region j.

If the distance between any pair of customers is Euclidean, whatever policy of partition RP, (3) is true

$$\sum_{j\in R} L^*(N(j)) \le L^*(N) + \frac{3}{2}P^{RP} \tag{3}$$

where P^{RP} is the length of perimeters of regions in which it was divided the area containing all customers to visit.

If the distance between any pair of customers is Euclidean and they are distributed on a compact region of the plane at random and independent, (4) is the result on the asymptotic length.

$$\lim_{|N|\to\infty} \frac{L^*(N)}{\sqrt{|N|}} = \beta \tag{4}$$

where β is a constant that dependent on the law of random distribution of customers.

In the case of Euclidean distances, if there are policies for which the term PRP increases with order less than O (|N|), the above observations allow us to affirm that the sum of the lengths of shortest paths that cover all customers with probability 1, asymptotically (5).

$$\lim_{|N|\to\infty} Z^{RP} = \frac{2|N|}{q} E(d) \tag{5}$$

where E(d) is the average distance of customers from the warehouse.

The length of the minimum Hamiltonian path, which covers all customers grows with the square root of the number of the same, while, if it is determined the maximum number of clients per path, the sum of the lengths of multiple paths necessary to cover the totality of customers grows linearly.

C. 9.4.2 The Continuous Approximation

This class of models offers a hierarchical approach to DRAI problems solving. The basic principle is that many specific data can be neglected, retaining the ability of analytical model to provide useful solutions. The discrete data, when sufficiently numerous, may be approximated by continuous functions so as to develop simple (but plausible) models. The solution process is to define a cost function to be minimized. This includes all relevant costs along the distribution cycle, which can be summarized as follows:

- Physical handling of goods: transport in strict sense, preparation and packaging of the lots to be dispatched;
- Storage: cost of renting facilities dedicated to storage, cost related to expectation of goods.

The cost function under realistic conditions (such as economies of scale in goods flow) is a concave function. Concave functions have many local optima, which makes it difficult to determine the global optimum. Two important consequences of the concavity are: justifies the use of the approximation by continuous functions, and leads to solutions of "all or nothing". The main hypotheses underlying the Continuous Approximation approach are: the demand varies slowly with time, the geographical distribution of consumers varies slowly in space, the total cost can be expressed as the sum of costs of small components (disjoint) of the total region.

An extensive review of the literature on Continuous Approximation is provided by Langevin, et al. [16] and Federgruen and Simchi-Levi [19].

D. The Fixed-partition policies

Baseline scenario for the Fixed-partition policies, are as follows:

- Topology: one to many, with Euclidean distances approximately;
- Question: constant over time and uniform in space;
- Constraints: both on the capacity of vehicles on their number;

- Inventory costs: storage (possibly different depending on the customer), fixed of reorder;
- Transport costs proportional to the length of the routes, fixed costs;
- Solutions: heuristics, asymptotically optimal of the number of customers.

Φ is the set of all policies FPP. Determine a strategy that minimizes the cost Φ respecting the constraints defined above is clearly NP-hard, since it must still determine the minimum Hamiltonian circuits. But taking advantage of structural properties the cost average value expression over the long term is shown that it is possible to define, without having to determine simultaneously Hamiltonian paths and frequency of clients access, a partition in regions, with probability 1, asymptotically optimal in the number of customers.

Instead of *Fixed-Partition Policies* spoken Anily and Federgruen [28] and Bramel [20].

E. Problems Routing and Scheduling in the distribution of goods

Below, we describe different characteristics of the problems routing and scheduling freight, considering key components of this problem - road network, customers, stores and vehicles - various operational constraints that may be imposed in construction of travel, and finally, possible objectives to be pursued in the optimization. The road network used for the transport, normally is described by a graph whose edges represent road sections passable and whose vertices correspond to remarkable points of the network, i.e., at intersections and at points where they are localized customers and deposits. Each customer is characterized by:

- Vertex of road graph;
- Amount of goods, possibly of different types, which must be delivered and / or collection;
- Intervals of time, also referred to as time windows, in which can be served;
- Time loading and unloading;
- Any subset of vehicles that can be used to serve him.

If you cannot fully meet the demand of transport associated with all customers, some of them or are not served or are only partially. To this end are generally defined priority levels of service between customers. The travels for customers service have origin and destination in one or more deposits located in the vertex of the road graph.

The number and types of vehicles of each deposit, as well as the amount of goods that each store is capable of treating, may depend on the deposit. The transportation of goods is made using a fleet of vehicles that can be fixed or variable in size. The truck drivers are subject to restrictions of trade union different.

Other limitations are given by Erdogan and Miller-Hooks [1] in Green Vehicle Routing Problem. The G-VRP seeks to find at most m tours, one for each vehicle, that starts and ends at the depot, visiting a subset of vertices including AFSs when needed such that the total distance traveled is minimized. Vehicle driving range constraints that are dictated by fuel tank capacity limitations and tour duration constraints meant to restrict tour durations to a pre-specified limit Tmax, apply.

Travel must meet a number of operational constraints, arising from the nature of the transport operation, the quality of the desired service and employment contracts of staff. In any moment the quantity of goods loaded on each vehicle may exceed the respective load capacity. The travel can include both pick-up and delivery of goods, or only one of these activities. The visit to the customer must be made within relevant time windows or can also be defined as a maximum total duration of journey. To this end, a complete graph whose vertices are the vertices of network corresponding to and deposits is defined, starting from the road network. For each pair of vertices i and j of the graph, there is an arc whose cost c_{ij} is the cost of the shortest path, in terms of distance or travel time, between the two vertices, measured on the original road network. In some cases the problem does not explicitly refer to a road network: the vertices (customers and deposits) are determined exclusively by their coordinates in a plane and the costs c_{ij} of the graph are defined by the Euclidean distance between the vertices i and j. These problems, known as Euclidean problems are obviously symmetrical and have the property of triangularity. The objectives that can be pursued in the solution of a problem of freight transport are numerous, including:

- Minimization of the total cost of transport (depending on the total distance traveled and/or time travel) and the fixed costs associated with the use of vehicles and crews;
- Minimization of vehicles numbers and/or drivers necessary;
- Balancing of the various paths from the point of view of the distance traveled or the workload associated;
- Minimization of the penalties associated with non- or partial service to customers.

Extensive surveys on the problems of vehicle routing and scheduling were presented by Laporte [24], Fisher [17], and Toth and Vigo [10] [14]. An annotated bibliography of these problems has been proposed by Laporte [15]. There are also available studies on the subject of comprehensive volumes such as Toth and Vigo [9].

Methods of solution metaheuristics for the standard version of the VRP were compared by Bianchessi and Righini, [5], in particular Tarantilis, et al. [6] analyzing various models (Type of moves employed; Intermediate infeasible solutions; Solution-attributes stored in tabu list; Tabu tenure; Diversification; Intensification).

Definitions and formulations of the performance in distribution, or rather about effectiveness (that extent they are satisfied with the goals of rapid deployment) and equity, (ie the extent to which all recipients receive a similar service), are discussed by Huang, et al. [2]. They demonstrated that the efficiency is the total travel time for selected routes, the efficacy is the measure of which calculates the speed and sufficiency of deliveries, the equity is the measure the spread in service level across nodes.

R. Bachmann and Langevin [3] developed an algorithm with few data (cost of delivering a load to each store and cost per stop in that region); this algorithm provides a viable solution and considers the decrease in capacity of trailers.

F. *Models and exact algorithms for the VRP*

The *Asymmetric Capacitated Vehicle Routing Problem* (ACVRP) is linked to *Bin Packing Problem* (BPP), which requires to determine the minimum number of identical containers (bins), each with capacity D, necessary to contain a given set of objects, the j-th of which is characterized by a non-negative weight d_j.

It is known in fact that in the particular case where $c_{ij} = 0$ for all $(i, j) \in A$, $i \neq j$, $i \neq 0$, and $c_{0j} = 1$ for all $j \in V \setminus \{0\}$, and ACVRP equivalent to BPP. Note that if the value of the optimal solution of the BPP associated to ACVRP (from (6) to (12)) is greater than K, the ACVRP have no solution. A linear programming model for whole ACVRP can be obtained using $(n+1)^2$ x binary variables, one for each arch of the complete graph. The variable x_{ij} takes the value 1 if and only if the arch (i, j) and in the optimal solution assumes value 0 otherwise. For each $S \subseteq V \setminus \{0\}$, and $\sigma(S)$ the minimum number of vehicles needed to serve all customers in S, i.e., the value of the optimal solution of the BPP with set of objects S. Note that $\sigma(V\setminus\{0\}) \leq K$. It therefore has the following formulation:

$$z=\min \sum_{i\in V}\sum_{j\in V} c_{ij}x_{ij} \quad (6)$$

$$\sum_{i\in V} x_{ij}=1 \qquad \forall j\in V\setminus\{0\} \quad (7)$$

$$\sum_{i\in V} x_{i0}=K \quad (8)$$

$$\sum_{j\in V} x_{ij}=1 \qquad \forall i\in V\setminus\{0\} \quad (9)$$

$$\sum_{j\in V} x_{i0}=K \quad (10)$$

$$\sum_{i\in S}\sum_{j\in S\in} x_{ij}\geq\sigma(S) \qquad \forall S\subseteq V\setminus\{0\} \quad S\neq\emptyset \quad (11)$$

$$x_{ij}\in\{0,1\} \qquad \forall i,j\in V \quad (12)$$

G. *Lower bounds and exact algorithms*

Being the TSP a relaxation of VRP, it is evident that any lower bound valid for TSP is also valid for VRP. Considering the symmetric version of the problem is possible to perform a relaxation which requires the computation of a spanning tree of minimum cost (*Shortest Spanning Tree*, SST) of undirected graph in place of arborescence. A "lower bound" alternative is given by the cost of the same SST on the graph G plus the cost of the K cost arcs. A second type of "lower bound" for ACVRP considering the graph extended, oriented and complete.

Thoth and Vigo [14], Fischetti, et al. [21] Cornuejos and Harche, [23], and Fisher [22] presented review that offer relaxations of the Lower bounds and exact algorithms.

H. *The method of Clarke-Wright*

The algorithm of Clarke-Wright [9] is one of the first attempts to solve VRP with capacity constraints (CVRP). The algorithm starts from a solution no admissible where every guest is served in a different journey. Trips are then iteratively combined considering the saving s_{ij} (13), in terms of cost of travel, which can be achieved by serving two customers in one trip instead of leaving them in two separate trips.

$$s_{ij}=c_{0i}+c_{i0}+c_{0j}+c_{jo}-(c_{0i}+c_{ij}+c_{j0})=c_{i0}+c_{0j}-c_{ij} \quad (13)$$

Depending on the construction method of travel, it obtain two distinct versions of the algorithm (sequential and parallel), but in both cases the pairs of customers are taken into account for the possible union of travel which contain them to decreasing values of saving associated with them.

The sequential version of the algorithm of Clarke and Wright builds a trip at a time, adding a new customer at the beginning or at the end of the trip, as long as no other customer can be inserted without violating the constraint on the ability or has reached the end of List of saving.

The most widespread version of the algorithm of Clarke and Wright is parallel, where the list of saving is examined only once, and if both the couple's current customers are at the beginning or at the end of two trips and if the union of the two trips is eligible for the capacity constraint, the travel to which customers belong are merged into one trip, as long as the list of saving is not full. One can change the algorithm of Clarke and Wright in order to consider operational constraints also extremely complex, just merely do the unions of travel leading to a new journey admissible.

I. *The algorithm of Fisher and Jaikumar*

Fisher and Jaikumar [9] proposed an algorithm for CVRP based on a reformulation of the problem as a Generalized Assignment (*Generalized Assignment Problem*, GAP) non-linear, which determines an allocation of eligible customers to a number of trips and the objective function which takes into account the cost of sequencing customers in each trip. In the approach proposed, the non-linear the objective function is approximated by a linear function. The method of solution is of the type called a *cluster-first-route-second* and is decomposed into two phases.

In the first phase, customers are partitioned into subsets (clusters), eligible from the point of view of capacity constraint, solving a GAP with the objective function

 ISBN: 978-1-61208-269-1

linearized. During the second stage, the final solution is obtained by sequencing of the customers of each subset using an algorithm (from (14) to (17)) for the resolution of TSP.

$$\min \sum_{k=1}^{k} f(y_k) \quad (14)$$

$$\sum_{i \in V \setminus \{0\}} d_i y_{ik} \leq D \qquad k=1,\ldots,K \quad (15)$$

$$\sum_{k=1}^{k} y_k = 1 \qquad \forall i \in V \setminus \{0\} \quad (16)$$

$$y_{ik} \in \{0,1\} \qquad i \in V \setminus \{0\}, k=1,\ldots,K \quad (17)$$

where $y_{ik} = 1$ if and only if the i customer is assigned to the subset k and $f(y_k)$ is the cost of sequencing optimal customer assigned at the k trip, that is, the value of the optimal solution of TSP associated with the vertices of the subset $N_k = \{ i \mid y_{ik} = 1\} \cup \{O\}$. The focus of the algorithm is constituted by the construction of the linear objective function nonlinear f (y_k).

A possible way to construct this approximation is based on the determination of K customers (or points) *seed* the, i_l,..., i_K, associated with vehicles 1, ..., K. The γ_{ik} coefficients are calculated as the insertion cost of customer on journey from warehouse to seed i_k and back. Due to the strong influence of seed on the placement of customers to different subsets made by the GAP, the choice of the set of seed is an extremely delicate phase heuristic Fisher and Jaikumar.

J. *Finishing techniques based on local search*

The solutions obtained by heuristic algorithms can often be improved using post-optimization procedures (called *local search*) based on movements of customers or exchanges of arcs. The algorithms of local search iteratively evaluate eligibility and cost of all solutions of the surroundings of the current solution, saving the best feasible solution found. If the cost of the best solution of the surroundings is lower than the current solution, it runs the transfer or exchange associated with it and it becomes the new current solution.

The algorithm terminates when no solution of the surroundings current has lower cost than the current. The difference between current and new solution cost (18) is easily obtained considering only arcs removed from the current solution and those inserted in the new solution.

$$\Delta^{i}_{ab} = \left(c_{\pi(a)a} + c_{a\sigma(a)} + c_{b\sigma(b)}\right) - \left(c_{\pi(a)\sigma(a)} + c_{ab} + c_{a\sigma(b)}\right) \quad (18)$$

The procedures of local search easily are generalized so as to consider displacements of more than two clients or exchanges of more than two arcs. These generalizations produce better solutions.

IV. CONCLUSIONS AND FUTURE WORK

Highlighting the interaction of ITS and goods transportation was essential to analyze the needs of logistics operators and the primary objectives that they pursue, describing goods transportation models in order to identify the main problems of the operators (DRAI; VRP). Defining a wide scenery of the models in the literature was useful for making a classification according to the following parameters: topology, type of goods, demand, kinds of decision, constraints/objectives, costs, solving approach.

During the study, we analyzed models for goods transportation that interacted with ITS. These models have shown that the implementation of ITS not only reduces costs, but also facilitates an efficient organization and management of goods. Further studies could be developed to identify the extent to which the use of certain instruments of ITS vary some elements of a supply chain.

A future work could include the study of fleet management, understood as tracking and tracing of vehicles that usually use the following services:

- Mobile terminals management;
- Fleet management and their list;
- Management of the position requests for terminal or fleet;
- Visualization of the terminal position on the map;
- Management of the terminal lists of a specific fleet;
- The introduction of this elements as decision variables in the VRP, would achieve more accurate results.

In particular, it seem to be a priority:

1. Knowledge of road network portion passable in function of the geometric characteristics vehicle and emissions into the atmosphere of own engine;
2. Monitoring of average speeds along the network arcs used in the assigned itinerary to update the generalized cost of transport (at least for the travel time);
3. Possibility to reserve the use of spaces for parking dedicated to the loading / unloading of goods, so as to reduce the search time of parking, to reduce the delay on the current traffic produced by illegal parking, and ultimately, reduce the crew of each vehicle.

The use of mathematical models of routing and scheduling that considers the variables described above, could yield further improvements in business management.

REFERENCES

[1] S. Erdogan and E. Miller-Hooks, "A Green Vehicle Routing Problem," Transportation Research Part E, vol. 48, pp. 100-114, January 2012;

[2] M. Huang, K. Smilowitz, and B. Balcik, "Models for relief routing-Equity, efficiency and efficacy," Transportation Research Part E, vol. 48, pp.2-18, January 2012;

[3] R. Bachmann and A. Langevin, “A vehicle routing cost evaluation algorithm for the strategic analysis of radial distribution networks,” Transportation Research Part E, vol. 45, January 2009;

[4] I. Davies, R. Mason, and C. Lalwani, “Assessing the impact of ICT on UK general haulage companies,” International Journal of Production Economics, vol. 106, pp. 12-27, March 2007;

[5] N. Bianchessi and G. Righini, “Heuristic algorithms for the vehicle routing problem with simultaneous pick-up and delivery,” Computers & Operations Research, vol. 34, pp. 578-594, February 2007;

[6] C.D. Tarantilis, G. Ioannou, and G. Prastacos, “Advanced vehicle routing algorithms for complex operations management problems,” Journal of Food Engineering, vol. 70, pp. 455-471, October 2005;

[7] F. Golob Thomas and C. Regan Amelia, “Trucking industry adoption of information technology- a multivariate discrete choice model,” Transportation Research Part C: Emerging Technologies, vol. 10, pp. 205-228, June 2002;

[8] R. Danielis, “Domanda di trasporto merci e preferenze dichiarate,” Franco Angeli, Milano 2002;

[9] P. Thot and D. Vigo, “Vehicle Routing Problem,” SIAM monographs on discrete mathematics & applications, Philadelphia, 2002;

[10] P. Thot and D. Vigo, “Models, relaxation and exact approaches for the capacited Vehicle Routing Problem,” Discrete Applied Mathematics, vol. 123, pp.487-512, 2002;

[11] Ministers of Transport (ECMT), European Commission (EC), “Terminology on combined transport, United Nations, New York and Geneva,” 2001;

[12] Politecnico di Milano - Dipartimento di Economia, “Indagine sull’Evoluzione Strutturale delle Imprese della Logistica in Italia,” Assologistica, 2001;

[13] O. Baccelli, “La Mobilità delle Merci in Europa: Potenzialità del Trasporto Intermodale,” Egea, 2001;

[14] P. Thot and D. Vigo, “Exact Algorithms for Vehicle Routing,” in T. Crainc and G. Laporte, Eds. Fleet Management and Logistic, 1-33 Kluwer Accademic Publisher, Boston, 1998;

[15] G. Laporte “Vehicle routing,” M. Dell’Amico, F. Maffioli, and S. Martello, Eds. Annotated Bibliographies in Combinatorial Optimization, Wiley, Chichester, U.K, 1997;

[16] A. Langevin, P. Mbaraga, and J.F. Campbell, “Continuous approximation models in freight distribution: an overview,” Transportation Research B, vol. 30, pp. 163-188, 1996;

[17] M.L. Fisher, “The Vehicle routing,” in M.O. Ball, T.L. Magnanti, C.L. Monna, and G.L. Nemhauser, editor Network Routing, Vol. 8 Handbooks in Operation Research and Management Science, pp 1-33, North-Holland, Amsterdam, 1995;

[18] M.W.R. Savelsbergh and M. Sol, "The general pickup and delivery problem," Transportation Science, vol. 29, pp. 17-29, 1995;

[19] A. Federgruen and D. Simchi-Levi, “Analysis of Vehicle Routing and InventoryRouting Problems,” in Handbooks in Operations Research and Management Science, M. Ball et al., Eds. 297-371, North Holland, Amsterdam, 1995;

[20] J. Bramel and D. Simchi-Levi, “A location based heuristic for general routing problems,” Operations Research, vol. 43, pp. 649-660, 1995;

[21] M. Fischetti, P. Thot, and D. Vigo “A Branch-and-Bound Algorithm for the Capacited Vehicle Routing Problem on direct graphs,” Operation Research 42(5), pp 846-859, 1994;

[22] M.L. Fisher, “Optimal Solution of Vehicle Routing Problem Using Minimum k-Trees,” Operation Research 42(4), pp 626-642, 1994;

[23] G. Cornuejos and F.Harche, “Polyhedral Study on the Capacitated Vehicle Routing Problem,” Mathematical Programming 60(1), pp 21-52, 1993;

[24] G. Laporte, “The Vehicle routing problem: An Overview of Exact and Approximate Algorithms,” European Journal of Operational Research 59, pp 345-358, 1992;

[25] G.U. Tinarelli, “La gestione delle scorte nelle imprese commerciali e di produzione,” Etas Libri, Milano 1992;

[26] S. Anily and A. Federgruen, “One warehouse multiple retailer systems with vehicle routing costs,” Management Science, vol. 36, pp. 92-114, 1990.

 ISBN: 978-1-61208-269-1