Robust Decision Support System for Dynamic Vehicle Routing Problem

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The basic necessity in freight transport is to ship goods from depots to geographically dispersed points. With this requirement, a combinatorial optimization problem arises, which is known as Vehicle Routing Problem (VRP). Usually, the VRP is classified in four types:

Customers, travel times and/or demands

	Deterministic	*Stochastic*
Static	• All inputs are know beforehand • Time is not taken into account	• Inputs are known as stochastic variables and revealed during the route • Recourse function
Dynamic	• All inputs are known beforehand • Some inputs depend on time	• Inputs are known as stochastic variables and revealed during the route

The a-priori route is changed

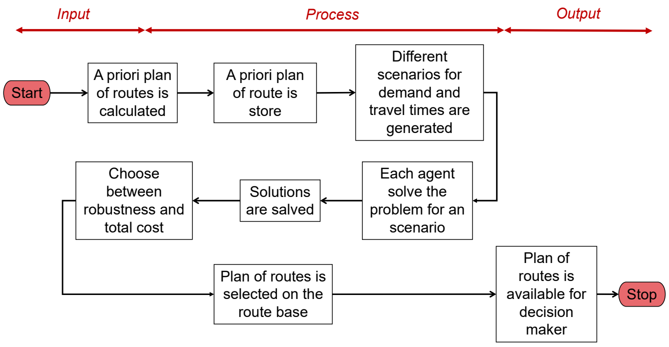
In today's economy, the dynamic and stochastic version has received more attention, especially because:

- customers desire more flexibility and fast fulfilment of their orders;
- inherent uncertainties arise;
- new tools such as on-board computers and communication systems have been developed.

Problem definition and solution approach

We consider the Dynamic VRP as a dynamic and stochastic type, where the demands and travel times are stochastic variables and revealed dynamically. The problem consists of planning optimal vehicle routes to service a number of locations in the presence of dynamic inputs. The problem is modelled using a graph where nodes represent stochastic demand and arcs represent stochastic travel times. The capacity of each vehicle is limited and routes for each vehicle begin and end at a specific depot node. A route is defined as the set of arcs followed by a vehicle, and a plan is a set of routes servicing all customers exactly once.

Our proposed solution approach to solve the dynamic and stochastic VRP is represented as follows:



At the beginning of the operation's day, stochastic information about the inputs (demands and travel times) are known. We use this stochastic information and the metaheuristic Simulated Annealing to create the first a priori plan of routes, or a priori route for each vehicle. The a priori plan of routes is store in a Route Base.

Afterwards, we exploit the stochastic information using Monte Carlo Simulation to generate different scenarios for the demands and travel times. The idea is to predict information about demands and travel times more accurately. So, it is not necessary to update the a priori plan of routes when the real information regarding demands and travel times is revealed. Every scenario is an agent, and each agent solves the problem for the scenario also using Simulated Annealing. The solution for each scenario is also store in the Route Base.

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Following, the decision maker chooses between two parameters: total cost and robust planning. According to this choice the best plan of routes is selected in the Route Base, using the robust cost function. Finally, the selected plan of routes is available to the decision maker.

To serve as an enabler for choosing the importance of the two parameters total cost (ω_1) and robust planning (ω_2) we develop a robust cost function:

$$\bar{J}_v(x) := \left\{ \underbrace{\sum_{v \epsilon V} \sum_{k=1}^{|x^v|-1} \omega_1 \left(c_{ij} \middle| i = x_k^v, j = x_{k+1}^v \right)}_{\text{Cost of the first stage}} + \underbrace{\omega_2 \sum_{s \epsilon S} \frac{F_s(x) - F_{s0}(x)}{|S| - 1}}_{\text{Cost of the second stage}} \right\}$$

Our objective is to develop and implement an Agent-based Decision Support System that uses this approach to solve the dynamic and stochastic vehicle routing problem, where demands and travel times are stochastic variables and revealed dynamically during the execution of the a priori plan of routes. So, the objective of this system is to provide managers with a solution that

- allows for a certain range of a priori unknown demand and travel time changes without changing the solution structure of the problem;
- reduces the total cost of the routes as much as possible;
- displays the trade-off between a priori optimality and robustness.

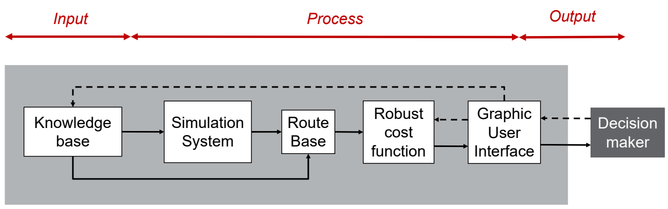
For that, the structure of the Agent-based Decision Support System is:

- a Data Base to store all the data required by the dynamic and stochastic vehicle routing problem (locations of the logistic provider, locations of the customer, transportation costs, fleet data, etc.);
- a Data Base Management System to update the information stored in the Data Base and also to generate the scenarios;
- a Model Base, which contains the algorithm to generate the a priori plan and the pool of plans;
- a Robust Cost Function to choose between robust planning and total cost;
- a Graphic User Interface (GUI) supporting the window-based dialogs to define and update data and visualize the problem and the results.

Methodology

To develop the Agent-based Decision Support System we use the methodology named System Development Methodology, proposed by Nunamaker et al. (1990). In this methodology, there are three main steps to develop a system, and each step includes research issues.

In the first step, we construct a meaning research question, investigate the functionalities and requirements of the system and study other disciplines for others ideas and approaches to solve the Dynamic VRP. In the following second step, the Agent-based Decision Support System is constructed in three stages: develop a system architecture, analyze, design and build the system. Finally, once the Agent-based Decision Support System is developed, we evaluate the system in a last step.



Agent-based Decision Support System's Structure

Expected Outcome

The developed Agent-based Decision Support System will support managers on effective decision-making in the Vehicle Routing Problem. It will provide a robust solution which allows some disturbances in the inputs, without replanning and extra costs.