A Metaheuristic Framework for the Vehicle Routing Problem with Time-Dependent Demands in Humanitarian Logistics

Jorge F. Victoria, H. Murat Afsar, Christian Prins
ICD-LOSI (UMR-STMR CNRS 6279), Université de Technologie de Troyes
12 rue Marie Curie, 10 010 Troyes Cedex, France
{jorge.victoria, murat.afsar, christian.prins}@utt.fr

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1 Introduction

The natural and man-made disasters entail the displacement of affected population [2]. The evacuation plans suggest to the population to flee to the nearest shelters (or emergency meeting points) which are previously identified as safety places to gather the population. These shelters must be supplied of first aid as quickly as possible. If affected people do not receive aid, they tend to flee from these shelters to outside of the affected area. This people fleeing increase the chaos already generated by the disaster and they could propagate an outbreak in future destination areas (unaffected areas) [4].

The need for a quick and timely response leads us to think about Humanitarian Logistics (HL). Thomas and Kopczac [3] define HL as a process of planning, implementing, and controlling the flow, and storage of goods (water, food, clothing, etc.) and materials efficiently, as well as information, from a depot to affected points trying to minimize the damage caused by the disaster. The Vehicle Routing Problem has been solved to manage efficiently the flow of goods in commercial business where the objective, in most of cases, is minimize the cost of distribution. The results obtained in commercial business led researchers to apply this on the humanitarian context where the economic objective goes into the background and the human objective is the focus of the research.

The Capacitated Vehicle Routing Problem with Time-Dependent Demands (TDD-CVRP) in humanitarian logistics problem take into account the displacement of people assuming that at each shelter, it is represented by a linear function $f(t) = \alpha - \beta t$. This continuous decreasing function depends on the initial number of people immediately after the disaster (α) and the number of people fleeing per unit time (β) from a shelter.

2 Problem Description

The TDD-CVRP is defined on a complete directed graph $G = (V, A)$ where V is the set of nodes and A is the arcs set. The depot is represented by 0 and $V' = V \{0\}$. A limited number of homogeneous vehicles must be used. Each vehicle has a limited capacity and autonomy. Each node $i \in V'$ has an initial demand (α_i) and the number of people leaving it (β_i). The travel time between each pair of nodes (i, j) is known and fixed.

The aim is to identify a set of feasible routes so that every node must be visited exactly once and the total satisfied demand is maximized. A feasible route begins and ends at node 0(depot).

TAB. 1 – Results metaheuristic framework

				B&P			Theoretical	GRASP (500-1-1)		ILS (1-500-1)		ELS (1-50-10)		MS-ILS (5-100-1)		MS-ELS (5-20-5)	
V'	**K**	**Q**	**Tmax**	**Z_{LB}**	**Z_{UB}**	**Time(s.)**	**UB**	**Z**	**Time(s.)**	**Z**	**Time(s.)**	**Z**	**Time(s.)**	**Z**	**Time(s.)**	**Z**	**Time(s.)**
25	4	138235	300	405164.95	405164.95	7.76	426740.00	**405164.95**	10.182	**405164.95**	3.597	**405164.95**	3.906	**405164.95**	3.977	**405164.95**	3.513
50	8	141176	450	853219.60	853219.60	1484.28	876360.00	**853219.60**	62.395	**853219.6**	24.939	**853219.6**	18.27	**853219.6**	24.158	**853219.60**	22.046
75	10	163529	675	1206116.44	-	3600.00	1287580.00	1260806.19	161.914	**1260932.10**	57.109	**1260932.10**	62.817	**1260932.10**	64.951	**1260932.10**	70.452
125	14	204201	900	2158880.34	-	3600.00	2262330.00	2225629.06	565.386	2225773.55	298.385	**2225930.41**	277.382	2225773.55	321.884	**2225930.41**	287.223
240	25	225882	900	4359041.28	-	3600.00	4483680.00	4433920.83	4289.302	4434639.56	1516.808	4434433.14	1013.638	4435224.46	1881.824	**4435032.37**	1580.171

3 Solution Method

We present a metaheuristic framework which a Greedy Randomized Adaptive Search Procedure (GRASP), an Iterated Local Search (ILS) and Evolutionary Local Search (ELS) can be executed depending on the number of restarts, number of perturbations and the number of children at each iteration. The Multi-start version of the ILS (MS-ILS) and ELS (MS-ELS) is also performed with the framework. The initial solution is constructed using a best randomized parallel insertion method, four neighborhoods are implemented as local search (LS) procedure and the ejection chain is used as the perturbation mechanism.

4 Preliminary Results

We adapted Golden et al. [1] instances varying between 25 to 240 nodes to test the framework. The instances and results are presented in Table 1. The number of nodes (V'), number of vehicles (K) with a capacity (Q) and autonomy ($Tmax$) per vehicle are the first columns and they are given by the problem. The next three columns are the lower bound (Z_{LB}), upper bound (Z_{UB}) found by an implemented Branch & Price ($B\&P$) algorithm with its respective execution time ($Time(s.)$) in seconds. The theoretical upper bound ($TheoreticalUB$) is obtained sending one vehicle to each node. This is the maximum number of people that can be attended. The following columns are the total satisfied demand (Z) and the total execution time($Time(s.)$) in seconds of each metaheuristic using the framework with a total budget of 500 calls of LS. The number in parenthesis means the parameters used at each case ($numberOfRestarts - numberOfIterations - numberOfChildren$).

The results of B&P algorithm help us to prove that metaheuristics find optimal solutions up to 50 nodes. The MS-ELS finds the best quality solutions (in bold) in all instances and the ELS is, in average, the fastest metaheuristic to find a good solution among the tested.

Références

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