Solving last-mile distribution problems after major earthquakes

Natural and made man disasters strongly impact population, ecosystems and urban infrastructure. The impacts are even more relevant due to the growth of population in urban areas. Actually, 3,4 billions of people leaves in only 10% of the earth surface, making such areas particularly affected after catastrophes. Moreover, the urban population is already higher than the rural one, and 5 billion people (of 8,3 billion will live in urban areas by 2030 according to the United Nation Organization. The earthquakes that hit Kathmandu in 2015 and Port-au-Prince in 2010 illustrate the consequences of such events: in Kathmandu, the quakes caused the death of 8 000 people and left 17 000 wounded people, while in Port-au-Prince, about 230 000 were killed, 300 000 were wounded and 1,2 million became homeless. Earthquakes were the third type of catastrophe most happen in the world in 2014[1], and the sixth with the most significant impacts[2]. This motivates the study of problems covering the phases of disasters (*i.e.* Preparedness, Response or Reactiveness) and Recovery [5][6]) in case of seismic events.

In this study, we focus on the response phase, in particular the chaotic last-mile distribution after major earthquakes due to its scientific and practical relevance. This type of distribution appears in the operational level of emergencies and consists of a very complex Vehicle Routing Problem (VRP). It worth mentioning that we address the core of the problem with the primordial constraints pointed out in a collaboration with partners of the International Charter on Space and Major Disasters (ICSMC)[3]. The VRP addressed here considers a heterogeneous fleet, multiple trips, multiple depots, accessibility constraints (site dependent constraints) according to the level of impassable routes, and a time window on the depots working time. In addition, fixed and variables costs are taken into account, which correspond respectively to the use of a vehicle and the distances travelled. For short, the problem will be referred as LMDP, meaning Last Mile Distribution Problem. In the practical context, these constraints traduce the following needs. Small and medium size vehicles are used instead of trucks to allow accessing strongly affected regions and for security reasons, which relies on heterogeneous fleet of vehicles. Moreover, multi-trips and multi-depot are required since on emergency, vehicles are used in rotation doing multi-trips to ensure continuity of the service. Furthermore, the chaotic distribution is done by different vehicles of associations, humanitarians, Government, etc, that are loaded in different points of the city. In addition, after analysing the network accessibility for Port-au-Prince quake in 2010 with members of ICSMC, we noticed strongly affected regions, which became inaccessible by the road network (breaking the connectivity of the road network [7]) . This observation made us to include the accessibility constraints to handle the roads conditions according to the type of vehicles.

Given a connected, directed and simple graph G= (V,A), where V and A stand respectively for the distribution points with a demand d_i for each $i \in V$; and the arcs (i,j), representing the passable roads with a length of l_{ij} for each (i,j) $\in$ A. The set M = {1…*m*} of different vehicles is considered, where for each type of vehicle *k*, Q_k, t_k, f_k, r_k, and c_k are respectively, the vehicle capacity, the service time to load and unload a vehicle, a fixed cost, a variable cost and the total cost of passing thought arc (i,j), given by $c_k = l_{ij} \times r_k$. P indicates the set of depots with a working time of T. A pre-processing were done in the graph G in order to consider the accessibility constraints, by taking into account the blockage level of a road (e.g. partially blocked, impassable roads, etc), the road widths (e.g. primary, secondary or tertiary), and the vehicle of types. This allows ensuring that a vehicle of type *k* will travel on roads they can traverse. LMDP consists in determining multi-trips for each vehicle such that vehicles capacity, time window on the depots and demands are satisfied. The goal is to minimize the

[1] EM-DAT – « The International Disaster Database » : http://www.emdat.be/publications
[2] FM Global - Société d'assurance dommages aux biens : http://www.fmglobal-touchpoints.fr/category/anticiper
[3] International Charter on Space and Major Disasters : https://www.disasterscharter.org

total traveling costs (fixed and variable). LMDP is an NP-hard problem since it generalized the classical VRP [3]. Few studies in the literature couple some of the constraints addressed here. We can mention works of [8][9] dedicated to the multi-depot heterogeneous fleet VRP. In [1], a periodic VRP with multi-trip and accessibility restrictions is investigated. Studies [2][3] addressed explicitly the last mile distribution, considering heterogeneous fleet of vehicles, multiple depots and multiple trips, but no accessibility constraints.

To the best of our knowledge, this is the first study to identify and treat the core of last mile distribution efficiently. In particular, the proposed method is able to solve large instances and obtaining also high quality results whenever compared with the best methods for the VRP with multi-attributes in the literature. The hybrid heuristic solves to optimality (whenever possible), a sub-problem of the set partition model, which is enclosed in a Multi-Start Iterated Local Search (MS-ILS). A Randomized Variable Neighbouhood Descent (RVND) is used as local search, where moves like node swaps, relocations, 2-opt, route swaps and route shifts are selected and applied randomly. The computational experiments indicate that the method is able to provide the size of the vehicle fleet and the number of depots. Moreover, multi-trips allow reducing the number of vehicles required to service all demands points and, as a consequence, the fixed costs. For future work, other attributes are planned to be included such as depots capacity, convoy of vehicles for security reasons ensure security, etc.

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