Multi-period Hub Location Problem with Serial Demands: A Case Study of Humanitarian Aids Distribution in Lebanon

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Abstract

In this paper, we address the problem of humanitarian aids distribution across refugee camps in war-ridden areas from a network design perspective. We show that the problem can be modeled as a variant of multi-period hub location problem with a particular demand pattern resulted by the user's behavior. The problem has been motivated by a case study of Lebanese experience in Syrian war refugee accommodation. We elaborate on the complexity and real-life constraints and, propose a compact formulation of a mathematical model of the problem. We then show that modeling the problem using a Benders paradigm drives $\mathcal{O}(n^3)$ variables of the original compact model unnecessary in addition to the constraints that are being projected out in a typical Benders decomposition. Additionally, we identify several classes of valid inequalities together with efficient separation procedures leading to a cut-and-Benders approach. Our extensive computational experiments on the case study with real data as well as randomly generated instances proves the performance of proposed solution methods.

Keywords: Hub-and-spoke network design, distribution, humanitarian aids, refugees, mateheuristics.

1. Introduction

The emergency situations including wars and natural disasters introduce fragility for civilians and occurrence of urgent requirements. Loosely speaking, in cases of natural disasters, today's technology is to a high extent able to foresee many natural phenomena. However, when it comes to a war situation, an anticipation and prediction of its duration is very difficult as it may last unexpectedly long. Therefore, any predictive/preventive plan becomes less realistic.

Generally speaking, in cases of natural disasters, in many cases the impacted geographical region is relatively restricted. As a consequence, a reconstruction can be started immediately, or relatively very quickly in the aftermath of the event and people will be able to return to their residential areas afterwards; while, in a war condition, everything is of a different nature. In wars, damages are propagated and distributed very quickly across a relatively very wide area. The longer the war lasts, the less becomes the likelihood of any quick return of the refugees back to their homes (those fled out of the region[1]). This is mainly due to the deteriorated economic conditions hindering the reconstruction until a stability is re-established in that political and economic ecosystem. Till then, the UNHCR-recognized refugees are entitled to some supports including humanitarian aids to overcome their essential needs.

A most recent case of this situation is already happening in Syria where a multitude of players have got involved and the situation developed since the unrest in the aftermath of the so called *Arab Spring* has turned into a full-fledged chaotic and asymmetric war spread over a wide region from the south approaching the capital of Iraq, from the east to the boarder villages in Lebanon and up until the Jordanian boarders. According to the UNHCR[2], Syrian war has caused 6.6 million internally displaced persons, 13.1 million people in need inside Syria and 2.98 million people in hard-to-reach and besieged areas. Table 1 reports the

[1]Here, unless said otherwise, by the word '*refugee*' we refer to those who had to leave their homes and seek residing elsewhere due to the war condition, independent of being recognized/registered as refugees by the UNHCR or not.

[2]http://www.unhcr.org/syria-emergency.html

statistics reported by the UNHCR[3]. It must be noted that this only concerns the registered refugees and not all-inclusive.
One observes that Lebanon, together with Turkey account for more than 80% of refugees, although when it

Location Name	Source	Data date	Population	
Turkey	Government of Turkey, UNHCR	18 Oct 2018	63.7%	3,587,930
Lebanon	UNHCR	30 Sep 2018	16.9%	952,562
Jordan	UNHCR	24 Oct 2018	11.9%	672,578
Iraq	UNHCR	30 Sep 2018	4.4%	250,184
Egypt	UNHCR	30 Sep 2018	2.3%	131,504
Other (North Africa)	UNHCR	15 Mar 2018	0.6%	33,545

Table 1: Total Persons of Concern by Country of Asylum.

comes to the registered refugees only. According to the sources within the Lebanon, in 2017, this number reached 1.5 million, which stands for a government estimation accounting for both UNHCR-registered and non-registered displaced Syrians.
Lebanese Republic is a country of 6.082 million population neighbor with two countries, with almost half of its borders faced to the Mediterranean Sea **??**. Even though the country neither is located in the most peaceful neighborhood in the world nor its political conditions are the most stable one around the globe, the main mode of transport is road for domestic transportation. Moreover, due to the geographical topology and environmental barriers and conditions, the country does not run any known railway system. Although the country's dimensions are quite limited to an area of 10,452 km^2, the hilly nature of territory causes long travel time between pairs of theoretically close locations. Therefore imposing accessibility issue for distribution networks is needed in many cases. Since the start of war in Syria, the population of Lebanon has increased by a factor of 25.6% by Syrians, 0.5% by Palestinian refugees from Syria and 0.6% by Lebanese returning from Syria. In Lebanon, according to the UNHCR, life is a daily struggle for more than a million Syrian refugees, who have little or no financial resources. Around 70% live below the poverty line. There are no formal refugee camps and, as a result, Syrians are scattered throughout more than 2,100 urban and rural communities and locations, often sharing small basic lodging facilities with other refugee families in overcrowded conditions[4].
Lebanese authority have divided Lebanon into 26 districts. Every district represent location of a camp. Historically, for the almost half a million Palestinians living in camps in Lebanon, there has been a number of Distribution Centers (DC) serving those camps across the country.

In general, there is a Main Warehouse (MW), which acquires the nutrition and other essential requirements, needed for developing packages in the form of baskets of given amount of calories, to be sent to the consumers, living in camps. The preparation of packages are to be done in MWs. Once the packages are formed, depending on the distribution plan, they are loaded on a fleet of trucks and LGVs and are sent to the selected regional DCs. The regional DCs are represented by hub nodes in the model. The next morning, trucks start from the regional DCs and from there, they are deployed to selected points of delivery (the delivery points, other way of saying the refugees camps, are the nodes which are represented by the "spoke nodes" in the model). The delivery points (spoke nodes) are to be visited in a sequential order. every unloaded truck will be discharged from the rest of the operation/itinerary and will leave the fleet immediately. At the end of the day, there must not be any truck left fully or partially loaded. It must be noted that among the locations to be served (the centroid) there are locations with access issues for the trucks; therefore such points are served directly from the DCs using chartered services through a third-party service provider. These points are represented by "isolated nodes" in the model. Once a node received its services (in one, two or three days, depending on the planning), the node will no more be considered as a potential spoke(or spur)

[3]https://data2.unhcr.org/en/situations/syria
[4]http://www.unhcr.org/syria-emergency.html

node until the end of the current planning horizon.
The objective is to identify the location of a subset of hub nodes (DCs) in each period of the horizon and establish a network with a multi-level structure. The demand of every node at each period is a percentage of the whole demand during the entire planning horizon and depends on the number of antecedent visits to the same node during the same planning horizon. Flow is unidirectional, only from the Main Warehouse (MW) to its final destination. The fleet of transporters is assumed to be homogeneous.

1.1. Contribution and scope

The prime focus of this paper is to propose a network structure for distribution of humanitarian aids for Syrian refugees in Lebanon. The objective of this work is mainly improving the quality of services provided by the UNHCR, by assuring the frequency of service and receiving the demands in time. Besides, another motivation and objective of this work is to propose an exhaustive planning of distributing the demand in the network while optimising the use of available resources, as well as improving the benefits of service providers, in terms of reducing the cost of service provision and the use of navigation fleet (mainly by optimising the use of the capacity of transporters in every trip) to let service providers eventually serving more camps and refugees by providing them with packages of humanitarian aid. This work has been inspired by a thorough investigation of the matter and a close collaboration with the relevant decision makers of the sector. From the theoretical and modeling point of view, this model generalized the previous models of Hub Location Problem by introducing a Multi-Period Hub Location Problem with Serial Demands (MPHLPSD) wherein the demand volume at the n-th visit is proportional to the n-th term of a sequence of number representing human behavior. We propose the first compact mixed integer programming formulation for this problem and show that if Benders decomposition is seen from the perspective of a modeling tool, $\mathcal{O}(n^3)$ variables can be dropped from the formulation, in addition to the constraints being projected out in Benders fashion. Several classes of effective valid inequalities and efficient separation routines are proposed in order to turn the solution approach into a very efficient cut-and-Benders method reporting a significantly accelerated convergence. For the case at hand, we report the optimal location of DCs to be used in Lebanon. An extensive computational experiments on randomly generated instances of various sizes, confirms computational efficiency of the proposed solution framework and viability of the proposed technique. (Dufour et al., 2018; Mohammadi et al., 2019; Zhalechian et al., 2018; **?**; Monemi and Gelareh, 2017)

2. Summary and Conclusion

We proposed the first *Multiperiod Hub Location Problem with Serial Demand (MPHLPSD)* accommodating user's demand pattern, and formulated it as a MILP. We showed that the problem of distributing humanitarian aids could be formulated as such a problem. We further showed that a Benders formulation of problem can help getting rid of some unnecessary variables and benefit from logical relationships among variables. Several classes of valid inequalities and efficient separation routines have been identified, which resulted in an efficient branch-and-cut and Benders approach capable of solving relatively lager size instances, which are far too challenging for general-purpose solvers. We also showed that while a general-purpose solver is often unable to even find a feasible solution for instances of this problem, such a solution can be generated easily and be used to warm start our branch, cut and Benders method. On a set of randomly generated instances we have tested our solution algorithm and the obtained numerical results, compared to the results obtained from CPLEX, showed a great success. Also, on a real-life case study we reported optimal solution and it revealed some very interesting observations. As a future interesting aspect, one may think of investigating the outcome of applying this method of planning the delivery network, to analyse whether following this plan may also have any direct effect on the everyday life of refugees residing on the covered camps or not.

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