E-voucher distribution routing and planning for Syrian refugee camps in Turkey:

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Abstract

The Syria conflict which began as an offshoot of the Arab Spring uprisings, has causes millions of millions of Syrian people displacement who need humanitarian aid in money in addition to in kind aids. The cash based intervention includes voucher, or its electronic version similar to a debit card so called e-voucher. The cost-efficiency of electronic transfers in humanitarian programmes are discussed in the literature.
In this study we investigate the logistics problem of distribution e-vouchers to the Syrian refugee in the southern parts of Turkey by proposing a mathematical optimisation model for the routing of distribution facilities.

Keywords: Humanitarian logistics, E-voucher, Routing

Introduction

The conflict in Syria began as an offshoot of the 2011 Arab Spring uprisings, but it then turned to a civil war; and in the past five years, it has disintegrated into a cauldron of competing rebel groups, terrorist elements, international powers, and religious factions. It is argued as the worst humanitarian crisis since the Second World War, with over a quarter million killed, and half of Syria's 22 million populations displaced from their homes. According to UNHCR report, Turkey has hosted about 3.9 million Syrian refugees since the start of the crisis which is more than any other country in the world. About 260,000 of them reside in 25 camps, and the rest live outside camps, most in urban or peri-urban areas in the southern border of Turkey.

UN seeks $4.63 billion to aid 4.7 million Syrian refugees and host nations. Beside the in-kind distributions, in particular food aid, cash-based interventions play an important role in aiding people on and post-crisis period in humanitarian emergencies as in-kind distributions like seeds, tools, food, non-food items etc. may not always be the most appropriate. They are used to address a range of needs to provide access to food, water, health care, shelter needs, and and other services. The cash based intervention includes voucher, or its electronic version similar to a debit card so called e-voucher. Cash-based responses had been undertaken in Somalia in the past and, for the most part, the results were encouraging. In addition, The cost-efficiency of electronic transfers in humanitarian programmes are discussed in O'Brien et al.(2014).
Cozzolino et al.(2012) categorise disasters by sudden-onset and slow-onset. They further classify them into man-made or with natural causes. Earthquakes, terrorist attacks, droughts, refugee crises are examples of each of these four groups. In humanitarian activities after each type of the aforementioned disasters, there of several players including government, aid agencies, NGO's, military, donors, and logistics companies. The efficiency of logistics operations have been reported to be 50% in some resources while one of the most operations is the *last mile distribution* which deliver aids to beneficiaries. Most of the literature on humanitarian logistics has focused on theoretical models for post crisis activities as evacuation, optimisation of routing and deployment of facilities in distribution of aid.

In this study we investigate the optimal way of distribution e-vouchers to the Syrian refugee camps in the southern parts of Turkey. Once they are distributed, the subsequent money transfers can be performed electronically and therefore, periodic logistics costs and risks are prevented. In the next section the scenario for the registration and distribution of the e-vouchers is explained and the corresponding mathematical model is given.

Problem statement

As depicted in Figure 1, districts in Southeast Turkey host 22 camps currently and this number is expected to increase. In addition to these camps over 95% of the refugees now live in urban areas. Distribution of the e-vouchers for the refugees both inhabited in camps or in urban area would be taken place and it is planned to be accomplished by three ways including *(i)* temporary fixed facilities which include some governmental buildingsand can be assigned for distribution and/or registration purposes, *(ii)* a mobile facilities which comprise a big truck considered as a moving facility, and *(iii)* a mobile vehicle which can perform a door-to-door service for beneficiaries within a predetermined planning horizon. Both the mobile facility and the mobile vehicle are loaded in a permanent facility (in this study the municipality building) is used and served as depot. The mobile facility starts its journey from the first day and should return to the base until the end of the planning horizon. On the other hand, the mobile vehicle travels from the permanent facilities to several cities and returns back to the base at the end of each day during the planning horizon. Its trips are restricted due to the capacity and distance range limitations. Each city that is become a temporary fixed facility or visited either with the mobile facility or with the mobile vehicle can serve several other regions neighbourhood which are identified by defining coverage sets.

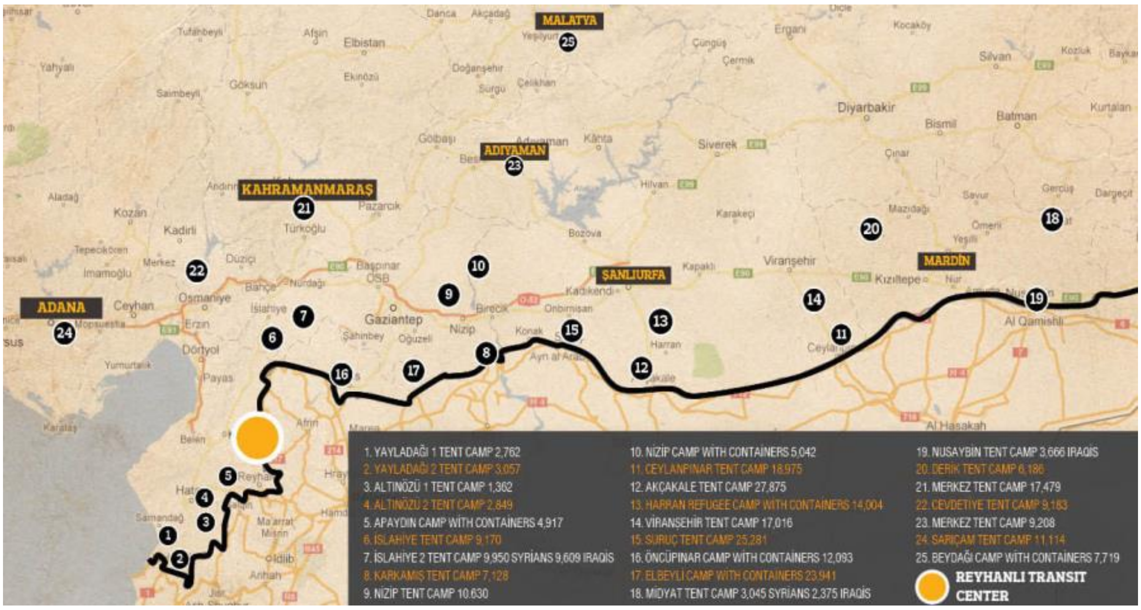

Figure 1. Syrian refugee camps in Turkey

Mathematical programming model

First we introduce our notations for sets, parameters, variables in Tables 1—3 then the mathematical programming model which addresses our problem is given and described afterwards.

Table 1. Sets

$V = \{0,1,\dots,n\}$	: Set of all locations, where 0 denotes the permanent distribution facility.
$G = (V, E)$	: A complete directed graph defined on V.
$S^0 \subseteq V$	: Set of locations that can be served by the permanent distribution facility.
$S_i^1 \subseteq V$	: Set of locations that can be served by a temporary distribution facility at location i.
$S_i^2 \subseteq V$	: Set of locations that can be served by the mobile distribution facility at location i.
$S_i^3 \subseteq V (= \{i\}?)$	: Set of locations that can be served by the distribution vehicle at location i.
V_c	: Set of locations to be served, $V_c = V \setminus S^0$.
$\delta(S) \subseteq E$	: Set of edges with one end in S and the other in $V \setminus S$.

Table 2. List of parameters

p	: Number of temporary distribution facilities we can set up.
c_{ij}^2	: Cost of moving the mobile distribution facility from location i to location j.
c_{ij}^3	: Cost of traveling from location i to location j with the distribution vehicle.
d_{ij}	: Distance between location i and location j.
r_i	: Reward for serving location i.
T	: Number of days in the planning horizon.
R	: Range of the distribution vehicle per day.
p_{ij}	: Risk of an incident on arc (edge? segment) (i,j), where $p_{ij} < 1$.
$\bar{p}$	: Maximum acceptable risk on a route, where $\bar{p} < 1$.

Table 3. List of decision variables

y_i^1	: 1 if a temporary distribution facility is setup at location i, 0 otherwise.
y_i^2	: 1 if the mobile distribution facility visits location i, 0 otherwise.
y_{it}^3	: 1 if the distribution vehicle visits location i on day t, 0 otherwise.
x_{ij}^2	: 1 if the mobile distribution facility moves from location i to location j, , 0 otherwise.
x_{ijt}^3	: 1 if the distribution vehicle moves from location i to location j on day $t \in \{1, \dots, T\}$, 0 otherwise.
z_{ij}^1	: 1 if location i is served by a temporary facility at location j, 0 otherwise.
z_{ij}^2	: 1 if location i is served by the mobile distribution facility at location j, 0 otherwise.
z_{ij}^3	: 1 if location i is served by the distribution vehicle visiting location j, 0 otherwise.

The model aims to maximise a reward that results from distributing or registering refugees in different locations which is seen as the amount of money distributed minus the logistics costs incurred. The distribution of the e-vouchers from the permanent facilities does not incur any significant cost because it is provided from the government. However, the mobile facility and the mobile vehicle have their corresponding unit costs which are proportional to the distance between cities and also the security factor in each of the route segments if they are travelled in.

$$\max \sum_{m\in\{1,2,3\}} \sum_{(i,j)\in E: i,j\in V_c, i\in S_j^m} r_i z_{ij}^m - \sum_{(i,j)\in E} c_{ij}^2 x_{ij}^2 - \sum_{(i,j)\in E} \sum_{t\in\{1,\dots,T\}} c_{ij}^3 x_{ijt}^3 \qquad (1)$$

s.t.

$$\sum_{m\in\{1,2,3\}} \sum_{(i,j)\in E: i,j\in V_c, i\in S_j^m} z_{ij}^m \le 1 \qquad \forall i \in V_c \qquad (2)$$

$$z_{ij}^1 \le y_j^1 \qquad \forall i,j \in V_c: i \in S_j^1 \qquad (3)$$

$$z_{ij}^2 \le y_j^2 \qquad \forall i,j \in V_c: i \in S_j^2 \qquad (4)$$

$$z_{ij}^3 \le \sum_{t\in\{1,\dots,T\}} y_{jt}^3 \qquad \forall i,j \in V_c: i \in S_j^3 \qquad (5)$$

$$\sum_{i\in V} y_j^1 \le p \qquad (6)$$

$$\sum_{t\in\{1,\dots,T\}} y_{it}^3 \le 1 \qquad \forall i \in V_c \qquad (7)$$

$$\sum_{(i,j)\in\delta(0)} x_{ij}^2 \le 2 \qquad (8)$$

$$\sum_{(i,j)\in\delta(k)} x_{ij}^2 = 2y_k^2 \qquad \forall k \in V_c \qquad (9)$$

$\sum_{(i,j)\in\delta(S)} x_{ij}^2 \geq 2y_k^2 \qquad \forall k \in V_c, S \subset V: 0 \in S, k \in V \setminus S \qquad (10)$

$\sum_{(i,j)\in\delta(0)} x_{ijt}^3 \leq 2 \qquad \forall t \in \{1, \dots, T\} \qquad (11)$

$\sum_{(i,j)\in\delta(k)} x_{ijt}^3 = 2y_{kt}^3 \qquad \forall k \in V_c; t \in \{1, \dots, T\} \qquad (12)$

$\sum_{(i,j)\in\delta(S)} x_{ijt}^3 \geq 2y_{kt}^3 \qquad \forall k \in V_c, S \subset V: 0 \in S, k \in V \setminus S; t \in \{1, \dots, T\} \qquad (13)$

$\sum_{(i,j)\in E} d_{ij} x_{ijt}^3 \leq R \qquad \forall t \in \{1, \dots, T\} \qquad (14)$

$\ln(1-\bar{p}) \leq \sum_{(i,j)\in A} \ln\left(1-p_{ij}\right) {x^2}_{ij} \qquad \forall i, j \text{ s.t. } p_{ij} < 1 \qquad (15)$

$\ln(1-\bar{p}) \leq \sum_{(i,j)\in A} \ln\left(1-p_{ij}\right) {x^3}_{ijt}. \qquad \forall t \in \{1, \dots, T\} \qquad (16)$

$x, y, z \in \{0,1\} \qquad (17)$

The objective function (1) maximizes the total amount of money distributed to the refugees. Constraint set (2) ensures that a location can be only served at most once. Constraints (3), (4), and (5) state that if a location is served by a temporary distribution facility, the mobile facility, or the distribution vehicle, the facility or the visit should be in place. The number of temporary distribution facilities to be set up is bounded above by p, as stated in constraint set (6). Constraint set (7) sets an upper limit of one visit by the distribution vehicle on all the locations. Constraint sets (8), (9), and (10) ensure that the mobile facility leaves the permanent facility at most once, visits each location at most once, and every location it visits is connected to the permanent facility. Similarly, constraint sets (11), (12), and (13) ensure that the distribution vehicle leaves the permanent facility at most once each day, visits each location at most once, and every location it visits is connected to the permanent facility. Constraint set (14) sets the maximum distance that the distribution vehicle can travel per day.

Constraint (15) and (17) are the linearized form of the maximum tolerable risk on a route. Note that by using the generic arc traversal variables $x_{ij} \in \{0,1\}$, the probability of no incidents happening on arc (i, j) can be computed as $(1-p_{ij})^{x_{ij}}$. Assuming independence of the probabilities of incidence, the probability that an event occurs on the whole route is $\prod_{(i,j)\in A}(1-p_{ij})^{x_{ij}}$. Hence, the constraint can be stated as

$1-\prod_{(i,j)\in A}\left(1-p_{ij}\right)^{x_{ij}} \leq \bar{p}$ or equivalently,

$1-\bar{p} \leq \prod_{(i,j)\in A}\left(1-p_{ij}\right)^{x_{ij}}. \qquad (a)$

Where $\bar{p}$ is the maximum acceptable risk overall on the logistics operations. (a) is equivalent to (15) by applying the natural logarithm to its both sides . We can easily exclude edges with $p_{ij} = 1$ from the network or set x_{ij}=0 for them. So we have not included such cases (if any) in the model.

Finally, constraint set (16) enforces all decision variables to be binary (with a bit of abuse of notation).

Numerical study with real data

The proposed model is employed for the Kilis city in Turkey which includes a significant number of refugees who are now even more populated than the local residents. Over 200 nodes are identified and classified to be chosen to serve as a permanent facilities (country side and specific districts), Temporary facilities (Schools, camps, hospitals), and mobile vehicle (door-to-door). The rest of other parameters are

- number of period=6 days,
- daily range of mobile vehicle=130 Km,

- Number of permanent facilities p=20 (I just set it as 10% of all Koy & Mahalle nodes which are 193 nodes) you can change it if you think this number is nut reasonable.
- Reliability=$1-\bar{p}$ is set as 0.96

Coverage of S_i^1 is identified as the closest cities whose accumulated population<=500 and its distance is less than 15 Km. The coverage of S_i^2 is identified according the similar rule but with the threshold of 60 people. The mobile vehicle can only serve the city they observe. ($S_i^3 = \{i\}$).

The model is coded in C++ and solved via CPLEX using Concert Technology. The sub tour elimination constraints are handle with Lazycut constraints callback in CPLEX. In addition, We have employed UserCuts callback for fractional solution to compare the their effect of the execution time of the model. The StoerWagner Minimum Cut algorithm has been used to identify the global minimum cut in order to generate the corresponding cuts on the fractional solution.

Table 1 shows a sample result from a subset of nodes with only 30 potential serving/demand nodes. As shown the execution time can be reduced by employing user cuts.

Table 4- A sample small output

Parameter	Without UserCut	With UserCut
T	6	6
N	30	30
#node served	30	30
#nodes served by permanent facility	23	23
#nodes served by mobile facility	0	0
# nodes served by mobile vehicle	7	7
# nodes served	27	27
#nodes set as permanent facility	20	20
#nodes served by mobile facility	0	0
#nodes served by mobile vehicle	7	7
Maximum range travelled/day	5.52986	5.63921
Total distributed money/Voucher	4065.6	4065.6
Objective value	4061.658	4061.58
Execution time	0.53125	0.703125
#times lazycut callback is called	9	15
#cuts added by lazycut callback	342	522
#times User cut callback is called	1	0
#cuts added by Usercut callback	4	0

Conclusion

In this study we have addressed a post disaster humanitarian logistics problem for a man-made slow-onset disaster (crisis). The aim of this study is to maximise the coverage of refugees in Turkey who can benefit from the monetary aid in the e-voucher form.

Encouraging from the successful similar experience for Syrian refugees in Jordan. As the logistics costs in supply chain are high proportion of total costs, an optimal logistics plan would provide a significant savings; that is more money to be distributed to refugees.

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