Deriving rules of thumb for facility decision making in humanitarian operations:

Description of the summary of experimental results

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The file `turkevs2020deriving_experimental_results.csv` is a summary of experimental results from the paper "Deriving rules of thumb for facility decision making in humanitarian operations".

In the paper, we focus on the problem of advance procurement and pre-positioning of emergency supplies at strategic locations in order to better prepare for a disaster. The notation for the instance and solution of the pre-positioning problem is the following:

Sets	
Q	set of facility categories
K	set of commodities
S	set of scenarios
V	set of vertices
E_s	set of edges in scenario $s \in S$

Coefficients	
F_i	$\begin{cases} 1, & \text{if a facility (of any category) can be open at vertex } i \in V \\ 0, & \text{otherwise} \end{cases}$
V_q	volume capacity of a facility of category $q \in Q$ (m^3)
A_q	opening cost of a facility of category $q \in Q$ (€)
V^k	unit volume of commodity $k \in K$ (m^3)
B^k	unit acquisition cost of commodity $k \in K$ (€)
C^k	unit transportation cost of commodity $k \in K$ (€)
V	average speed (km/h)
P^s	probability of scenario $s \in S$
D_i^{ks}	demand for commodity $k \in K$ at vertex $i \in V$ in scenario $s \in S$
R_i^{ks}	$\begin{cases} \text{proportion of pre-positioned commodity } k \in K \text{ that remains usable at vertex } i \in V \text{ in scenario } s \in S, & F_i = 1 \\ -1, & \text{otherwise} \end{cases}$
L_{ij}^s	$\begin{cases} \text{distance from vertex } i \in V \text{ to vertex } j \in V \text{ in scenario } s \in S \text{ (km)}, & (i,j) \in E_s \\ -1, & \text{otherwise} \end{cases}$
A	total budget for opening the facilities (€)
B	total budget for aid acquisition (€)
C	total budget for transportation (€)

Decision variables	
x_{iq}	$\begin{cases} 1, & \text{if a facility of category } q \in Q \text{ is open at vertex } i \in V \\ 0, & \text{otherwise} \end{cases}$
y_i^k	amount of commodity $k \in K$ pre-positioned at vertex $i \in V$
z_{ij}^s	$\begin{cases} 1, & \text{if the facility open at vertex } i \in V \text{ fully meets the demands of vertex } j \in V\text{in scenario } s \in S \\ 0, & \text{otherwise} \end{cases}$

In the paper, we assume that we have only two categories of facilities - small and big ($q = 1$ and $q = 2$ respectively), and only one commodity type ($k = 1$).

The main goal of the paper is to investigate the factors (and their interactions) which have the greatest impact on the choice of facility configuration for inventory pre-positioning in preparation for emergencies. We consider ten factors which are based on the instance characteristics above. In the experiment, we consider all possible level combinations across all characteristics (full-factorial experimental design). Since a lot of instance information is defined randomly (the potential facility locations, choice of scenarios, proportions of aid that remain usable, and the destroyed edges), we construct three replicates for each of the level combinations. This results in an extensive computational study that involves

$$3 \times 3 \times 3 \times 3 \times 3 \times 15 \times 3 \times 3 \times 3 \times 3 \times 3 = 885\,735$$

experimental units, i.e., pre-positioning problem instances.

The table `turkevs2020deriving_experimental_results.csv` has 885 735 rows corresponding to the pre-positioning problem instances included in the study. The table columns list the values of each of the ten factors, some interesting instance information, and some interesting values of the best found solution for the instance, as detailed in the remainder of this document. In the paper, we focus on the percentage of small open facilities, and the numbers of small and big open facilities (colored red below), but we also store some other information so that more insights could be obtained.

Column name	Interpretation	Formula
Factors:		
F	Percentage of potential facility locations: $100F\%$ of random vertices are potential facility locations	$\{0.1, 0.5, 1\}$.
QV	Facility capacities: The capacity V_1 of a small facility is QV times bigger than the volume of the average demand at a vertex in a scenario. The capacity V_2 of a big facility is always 2 times bigger than V_1, $V_2 = 2V_1$.	$\{2, 4, 6\}$
QAV	Facility unit opening costs: This factor represents the ratio between the unit opening cost between a big and a small facility, $QAV = (A_2/V_2)/(A_1/V_1)$.	$\{0.5, 0.75, 1\}$
S	Number of scenarios: S different disaster scenarios are considered, that occur with the same probability $\frac{1}{S}$.	$\{5, 10, 20\}$
R	Average proportion of aid that remains usable: The proportion of pre-positioned aid that remains usable at every potential facility location in every disaster scenario is a random number generated from the normal distribution $\mathcal{N}(R, 0.2)$. If $R = 1$, this means that no aid would be destroyed.	$\{0.5, 0.75, 1\}$
D	Demand graphs: This factor represents the network and demand topology that is defined from a number of case studies and random instances.	{`Chile1`, `Chile2`, `Chile3`, `Chile4`, `Random1`, `Random2`, `Random3`, `Senegal`, `Turkey`, `US1`, `US2`, `US3`, `US4`, `US5`, `US6`}
L	Transportation network damage: In every disaster scenario, $100L\%$ of random edges is destroyed.	$\{0, 0.25, 0.5\}$
AP	Facility budget: The facility budget is $100AP\%$ of an estimated facility budget necessary to meet the expected total demand.	$\{0.5, 0.75, 1\}$
BP	Acquisition budget: The acquisition budget is $100BP\%$ of an estimated acquisition budget necessary to meet the expected total demand.	$\{0.5, 0.75, 1\}$
CP	Transportation budget: The transportation budget is $100CP\%$ of an estimated transportation budget necessary to meet the expected total demand.	$\{0.5, 0.75, 1\}$

Column name	Interpretation	Formula
NR	Index of the problem instance created according to the given values of the ten factors.	$\{1,2,3\}$
Instance information:		
N	Number of vertices.	$\lvert \mathrm{V} \rvert$
ND	Expected number of demand vertices in a scenario.	$\sum_{s \in \mathrm{S}} P^s \sum_{i \in \mathrm{V}} \alpha_i^s$ where $\alpha_i^s = 1$ if demand $D_i^{1s} > 0$, and 0 otherwise.
NF	Number of potential facility locations.	$\sum_{i \in \mathrm{V}} F_i$
$DVIS$	Expected demand volume at a vertex in a scenario.	$\sum_{s \in \mathrm{S}} \frac{P^s}{NDS} \sum_{i \in \mathrm{V}} D_i^{1s} * V^1$ where NDS is the number of demand vertices in scenario s, calculated as above.
DVS	Expected demand volume in a scenario.	$\sum_{s \in \mathrm{S}} P^s \sum_{i \in \mathrm{V}} D_i^{1s} * V^1$
DVS_ND_DVIS	Ratio between the expected demand volume in a scenario, and the product of the number of demand vertices with the expected demand volume at a vertex in a scenario.	$\frac{DVS}{ND * DVIS}$
DVS_VAR	Coefficient of demand volume variation across scenarios (relative standard deviation).	$\frac{\sqrt{\sum_{s \in \mathrm{S}} P^s (DVS - \sum_{i \in \mathrm{V}} D_i^{1s} * V^1))^2}}{DVS}$
A	Facility budget.	Instance coefficient
B	Acquisition budget.	Instance coefficient
C	Transportation budget.	Instance coefficient
A_1	Opening cost of a small facility.	Instance coefficient
A_2	Opening cost of a big facility.	Instance coefficient
MAX_X1	Maximum number of small facilities that the facility budget A enables to be open.	$\left\lfloor \frac{A}{A_1} \right\rfloor$
MAX_X2	Maximum number of big facilities that the facility budget A enables to be open.	$\left\lfloor \frac{A}{A_2} \right\rfloor$

Column name	Interpretation	Formula
Solution information:		
X	Total number of open facilities.	$\sum_{i \in V} \sum_{q \in Q} x_{iq}$
$X1$	Number of small open facilities.	$\sum_{i \in V} x_{i1}$
$X2$	Number of big open facilities.	$\sum_{i \in V} x_{i2}$
$X1\_ND$	Number of small open facilities, normalized by the number of demand vertices.	$\frac{100X1}{ND}$
$X2\_ND$	Number of big open facilities, normalized by the number of demand vertices.	$\frac{100X2}{ND}$
$X1\_DVS\_VAR$	Number of small open facilities, normalized by demand variation across scenarios.	$\frac{X1}{1 + DVS\_VAR}$
$X2\_DVS\_VAR$	Number of big open facilities, normalized by demand variation across scenarios.	$\frac{X2}{1 + DVS\_VAR}$
$X1\_ND\_DVS\_VAR$	Number of small open facilities, normalized by both the number of demand vertices, and the demand variation across scenarios.	$\frac{100X1}{ND * (1 + DVS\_VAR)}$
$X2\_ND\_DVS\_VAR$	Number of big open facilities, normalized by both the number of demand vertices, and the demand variation across scenarios.	$\frac{100X2}{ND * (1 + DVS\_VAR)}$
$X2\_ND\_DVS\_VAR$	Number of small open facilities, normalized by the number of demand vertices	$\frac{100X1}{ND}$
$X1\_MAX\_X1$	Number of small open facilities, relative to the maximum number of small facilities that the facility budget enables to be open.	$\frac{100 * X1}{MAX\_X1}$
$X2\_MAX\_X2$	Number of big open facilities, relative to the the maximum number of big facilities that the facility budget enables to be open.	$\frac{100 * X2}{MAX\_X2}$

Column name	Interpretation	Formula
$X1\_X$	Percentage of small open facilities.	$\frac{X1}{X}$
$X2\_X$	Percentage of big open facilities.	$\frac{X2}{X}$
TOT_CAP	Total storage capacity.	$X1 * V_1 + X2 * V_2$
TOT_CAP_DVS	Total storage capacity, relative to the demand volume in a scenario.	$\frac{100TOT\_CAP}{DVS}$
TOT_CAP_DVS $\_DVS\_VAR$	Total storage capacity, relative to the demand volume in a scenario adjusted by the demand variation across scenarios.	$\frac{100TOT\_CAP}{DVS * (1 + DVS\_VAR)}$
UD	Unmet demand percentage.	$\sum_{s \in \mathrm{S}} P^s \sum_{i \in \mathrm{V}} \sum_{j \in \mathrm{V}} \frac{D_j^{1s}}{\sum_{j' \in \mathrm{V}} D_{j'}^{1s}} (1 - z_{ij}^s)$
$TIME$	Expected response time.	$\sum_{s \in \mathrm{S}} P^s \sum_{i \in \mathrm{V}} \sum_{j \in \mathrm{V}} \frac{\mathcal{L}_{ij}^s}{V} * z_{ij}^s$ where $\mathcal{L}_{ij}^s$ is the shortest path distance between vertices i and j in scenario s, calculated from distance matrix $[L_{ij}^s]$
$PERC\_NF$	Percentage of potential facility locations where a facility is open.	$\frac{100X}{NF}$
$PERC\_TOT\_CAP$	Percentage of total capacity used.	$\frac{100}{X} \sum_{i \in \mathrm{V}} \sum_{q \in \mathrm{Q}} \frac{y_i^1 * V^1}{V_q}$
$PERC\_AID$	Percentage of aid used, i.e., the amount of aid distributed relative to the amount of pre-positioned aid.	$\frac{100}{X} \sum_{i \in \mathrm{V}} \sum_{q \in \mathrm{Q}} x_{iq} \sum_{s \in \mathrm{S}} \frac{P^s}{R_i^{1s}} \frac{\sum_{j \in \mathrm{V}} D_j^{1s} z_{ij}^s}{y_i^1}$
$PERC\_A$	Percentage of facility budget used.	$\frac{100 * (X1 * A_1 + X2 * A_2)}{A}$
$PERC\_B$	Percentage of acquisition budget used.	$\frac{100 * \sum_{i \in \mathrm{V}} y_i^1 * B^1}{B}$
$PERC\_C$	Percentage of transportation budget used.	$\frac{100 * \sum_{s \in \mathrm{S}} P^s \sum_{i \in \mathrm{V}} \sum_{j \in \mathrm{V}} \mathcal{L}_{ij}^s * C^1}{C}$