MELOGIC PROJECT: Effects of critical ESHFP characteristics on supply time

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In the following, we have implemented the proposed heuristic algorithm for solving the ESHFP in Matlab R2015a on a PC equipped with a 2.0GHz Intel Core i7-4510U and 4 GB of RAM. We validated implementation correctness by solving various problem instances and verifying all intermediate and final results obtained. The initial validation experiments also indicated that the proposed heuristic develops efficient supply plans. The study of the problem and algorithm deals with discussing the effects of key problem characteristics on supply time

To this direction, we developed a problem generator that creates multiple problem instances. Subsequently, we solved the generated problems using the proposed heuristic algorithm. The test problems resulted from generating the entire range of input data related to the following 5 categories: (a) Supplies, (b) Supply points, (c) Demand points, (d) Available vehicles, and (e) Road network. Specifically:

- the *Total Demand* in pallets at all shelters is generated from the normal distribution $N(30, 2^2)$. A generated *Total Demand* is accepted only if it is higher than 25 pallets. Subsequently, we transform this demand into volume (m^3).
- the number of supply points is generated from the discrete uniform distribution U (2,5).
- the coordinates of the supply points are generated from the uniform distribution U (0,20), under the constraint that their Euclidian distance from the origin (0,0) is between 0 and 20.
- the number of demand points is either equal or twice the number of supply points, their coordinates are generated from the uniform distribution U (0,50) under the constraint that their Euclidian distance from the origin (0,0) is in the range between 30 and 50.
- the number of clusters is generated from the discrete uniform distribution U (1,3) taking also into account that it should be less or equal to the number of demand points.

- the number of vehicles for each problem is generated from the discrete uniform distribution $U\,(2,5)$; the coordinates of the vehicles' originating locations are generated from the uniform distribution $U\,(0,20)$ under the constraint that their Euclidian distance from the origin (0,0) is between 0 and 20.
- vehicle capacities are created in such a way that the total *Total Demand* is 10%, 20%, 30%, 40%, 50%, 100%, 200% of vehicles' total capacity.
- the vehicle mean speed is generated from the uniform distribution $U\,(45,55)$ km/h.
- the travel time between two nodes is computed by their Euclidian distance divided by vehicles' mean speed.

The inputs of the experimental study and their levels are presented below.

1) *"B"* is the ratio of the number of demand points over the number of supply points. This parameter quantifies the balance between supply and demand nodes:

$$B = \frac{\#\,of\ demand\ points}{\#\,of\ supply\ points}, \quad B = 1{,}2 \tag{1}$$

2) *"T"* is the ratio of total demand over total supply, both measured in the same unit (e.g m^3). This parameter quantifies tightness of supply:

$$T = \frac{Total\ Demand}{Total\ Supply}, \quad T = 0.05, 0.1, \dots, 0.9, 0.95 \tag{2}$$

3) *"D"* is the ratio of total demand over the total capacity of vehicles, both measured in the same unit (e.g. m^3). Parameter D quantifies fleet adequacy. Additionally, D provides an indication of the number of trips needed per vehicle (on an average sense):

$$D = \frac{Total\ Demand}{Total\ Capacity}, \quad D\ =\ 0.1, 0.2, 0.3, 0.4, 0.5, 1, 2 \tag{3}$$

4) Parameter "σ" quantifies the distribution of supplies among supply points. More specifically, it quantifies whether:

    4.a. supplies are distributed (almost) uniformly among supply points ($\sigma^2 = low$)

    4.b. supplies are distributed non-uniformly among supply points ($\sigma^2 = high$)

$$\sigma^2 = \sum_{c \in C} s_c^2 \tag{4}$$

where $C = \{1, \dots, m\}$ is the set of types of supplies to be supplied and s_c the corresponding deviation for each commodity $c \in C$, which is computed as follows:

$$s_c = \sqrt{\frac{1}{s-1}\sum_{i=1}^{s}\left(s_i^c - \frac{d_c}{s}\right)^2}$$

In the above definition, s_i^c, $c \in C, i \in S$ is the units of commodity c provided at supply point i, $d_c, c \in C$ is the total demand for commodity $c \in C$ (in units) and s is the number of supply points.

The results of the experiments are presented in four graphs, corresponding to the four combinations of the values of the two parameters σ^2 and B ((high, low) $\times$ (1,2)) respectively. In each of these graphs, both parameters T and D vary along their specified ranges.

The results of the first set ($\sigma^2 = high, B = 1$) are shown in Figure 1. As expected, D affects significantly the total supply time when it varies from 1 to 2. In the latter case the vehicles need to make almost twice as many trips as in the former. For$D < 1$, i.e. when the total demand is less than the total capacity of available vehicles, the effect of D on total supply time is less significant, since fewer trips need to be executed in order to satisfy a low total demand. Furthermore, as expected, total supply time appears to be greater for higher values of T, for which supply quantities are tighter.

In the second set of experiments, the supplies are distributed more uniformly ($\sigma^2 = low$) among supply points and there is an equal number of demand and supply points ($B = 1$). The results are shown in Figure 2. Similarly to the previous set, for $D = 2$ the total supply time increases. On the other hand, for $D < 1$, the effects of D on the total supply time are more pronounced. Moreover, as it can be observed in Figure 2, for higher total supply (compared to the total demand) the total supply time reduces. This is because in the specific case the available vehicles need to visit less supply points to collect the total demand. On the other hand, when total demand increases and tends to be equal to total supply, the available vehicles need to execute more trips and visit more supply points for collecting the necessary supplies to satisfy the total demand, resulting in higher total supply time. The positive effect of lower σ^2 is apparent in the case of low T.

In the third set of experiments, the supplies are distributed non-uniformly ($\sigma^2 = high$) among supply points and the number of demand points is twice the number of supply points (B= 2). Figure 3 shows that the total supply time is slightly higher in comparison to the first two set of experiments due to the higher number of demand points. Moreover, due to higher σ^2, vehicles need to visit more supply points in order to collect the necessary supplies. Similarly to the first two sets of experiments, the total supply time increases when the total demand increases (compared to the total capacity), since in this case the vehicles need to make more trips to collect the total demand.

In the fourth set of experiments, the supplies are distributed more uniformly ($\sigma^2 = low$) among supply points and the number of demand points is twice the number of supply points ($B = 2$). Similarly to the third set, since $B = 2$ the total supply time is higher compared to the cases with $B = 1$ due to the increased number of demand points (see Figure 4). Additionally, the increase of total demand over total supply clearly affects total supply time, which in this case increases, since vehicles need to execute multiple trips. Finally, lower σ^2 decreases total supply time.

Overall, it can be observed that $Total\,Supply\,Time$ reveals almost the same behavior (shape) for all sets of experiments. For instance, for $D = 0.1$ to $D = 0.5$ there is a slight fluctuation of *Total Supply Time*. On the other hand, *Total Supply Time* achieves a minimum for $D = 1$, and increases steeply for $D = 2$. When $D = 1$, on average, the algorithm, due to its construction, uses more vehicles (compared to the case when $D < 1$) to satisfy the *Total Demand* (for $D < 1$, the algorithm may not use all available vehicles). Less vehicles leads to fuller vehicles and increased loading/unloading times per vehicle, leading to longer supply. For $D = 2$, most (or all) vehicles make multiple trips, resulting in long supply time.

For parameters $B, T$and, σ, we can conclude the following:

- When the number of demand points is higher than the number of supply points (as quantified by B), *Total Supply Time* is increased due to increased routing time, as expected
- The increase of *Total Demand* over *Total Supply* (as quantified by T) causes an increase of *Total Supply Time*, as shown in Figures 1-4, because the number of supply points to be visited increases in order to collect the necessary quantities, and thus route duration increases
- When supplies are distributed more uniformly among supply points (σ^2 low) *Total Supply Time* is in generally lower. This is because vehicles may visit less supply points, in order to collect the necessary supplies.

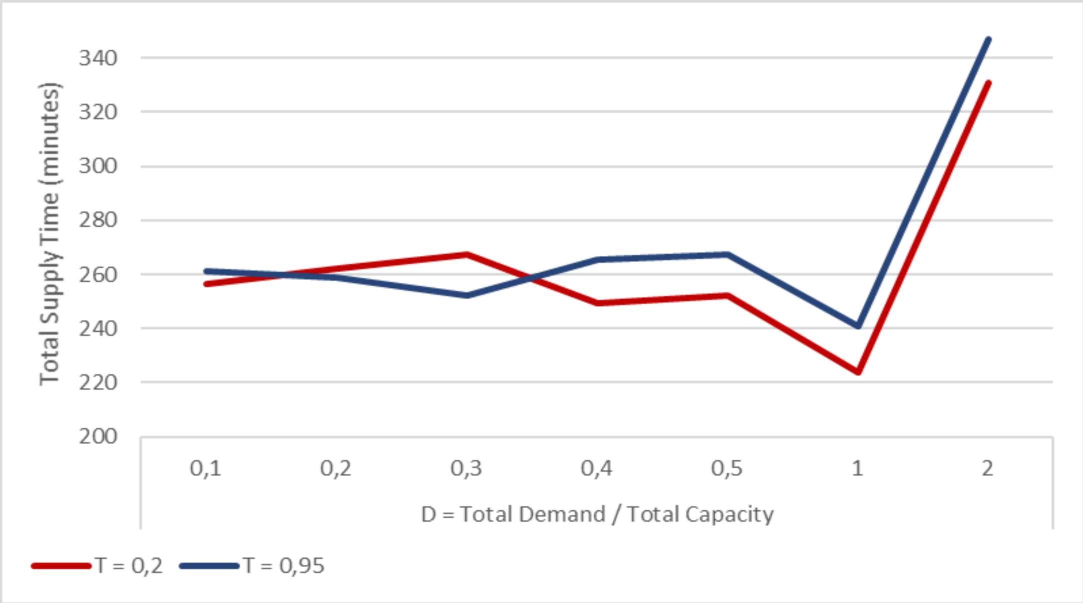

Figure 1: *Results for* $B = 1, \sigma^2 = high$

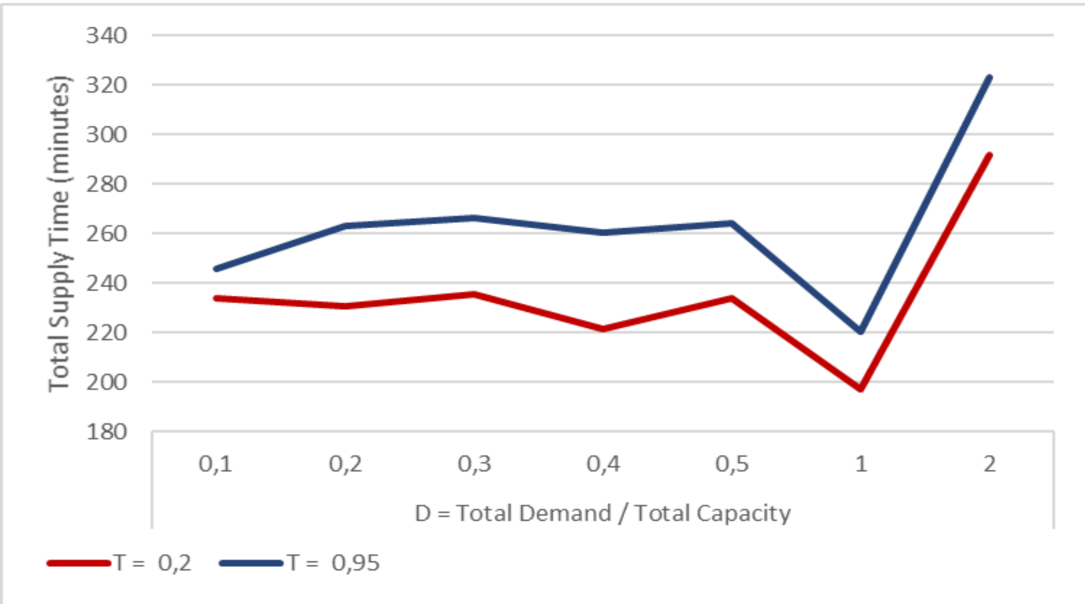

Figure 2: *Results for* $B = 1, \sigma^2 = low$

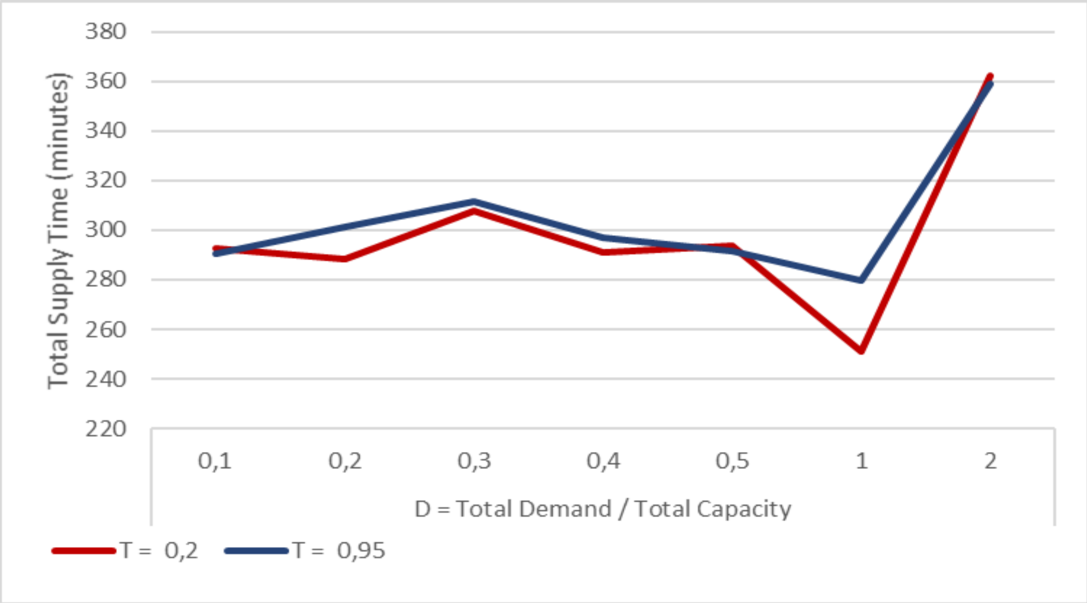

Figure 3: *Results for* $B = 2$, $\sigma^2 = high$

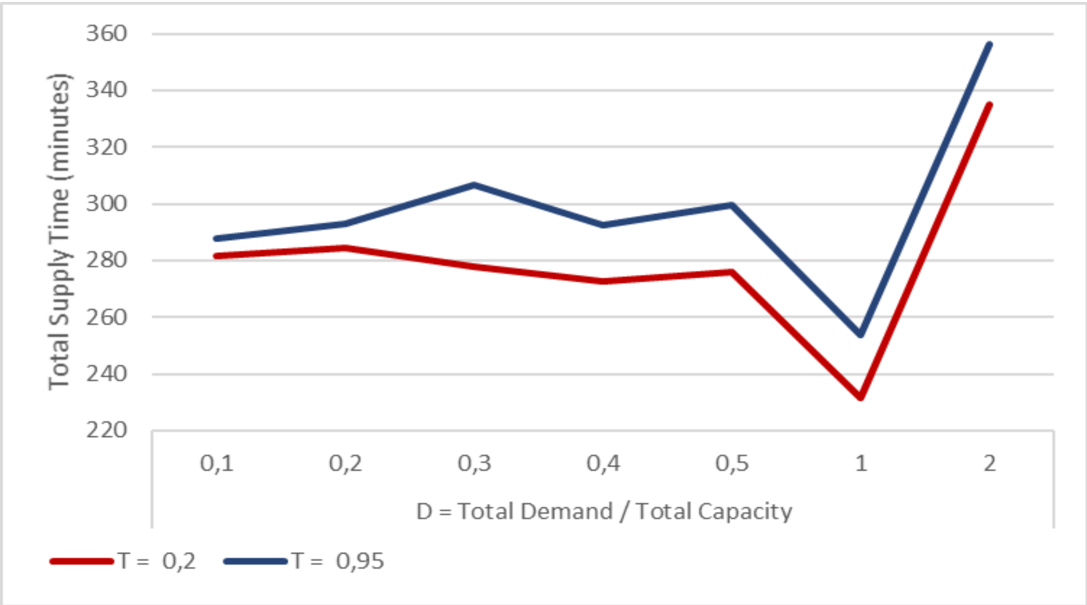

Figure 4: *Results for* $B = 2$, $\sigma^2 = low$