SUPPLY CHAIN OPTIMIZATION MODELS IN THE AREA OF OPERATION

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Abstract: Main idea of this paper is to choose both suitable and applicable operations research methods for military logistic support in the area of operation. Proposed model is based upon Combined Joint Task Force-7 data as the interim U.S. military formation in Iraq between June 2003 and May 2004.

Keywords: Supply chain, optimization, operations research, heuristics.

1 INTRODUCTION

Optimization of supply chain in the area of operation can be viewed as an effort to find the best distribution solution. The level of logistical support generally depends on time and resources as key factors for optimization. The Operational Decision-Making Process (ODMP) should include an appropriate design of an optimal distribution model as early as possible. In case the distribution dependent system components are stationary (e.g. bases, security stations) the so-called ex-post optimization has to be put into consideration.

The main idea of this paper is to find suitable methods of operations research which could be used to design a distribution strategy for a fixed (non-movable) structure. Models were generated and tested using WinQSB 2.0. The authors set as a restrictive condition the fact that the Euphrates river does not influence the model proposal.

2 OPTIMIZATION MODEL – GENERAL SCENARIO PREMISE

For a model of fixed structure case a scenario of Joint Security Stations (JSS) around the city Baghdad (Iraq) area was chosen. The JSS originally combat outposts are resistant sites established to support and back the Combined Joint Task Force 7 (CJTF-7). JSS were dislocated around the Joint Operations Area (JOA) to manage effective control among the city. As a basis a plan of given area (resized for paper layout purposes) was chosen. Left bottom corner represents two-dimensional Cartesian coordinate system (x,y) zero.

From the point of view of distribution strategy optimization the operations research provides two applicable methods:

- Method for optimal distribution system structure (Object Localization models – e.g. distribution centre localization);
- Method for transportation routes optimization (Optimal distribution chain between system elements – typically Travelling Salesman problem).

Cost optimum does not need to be the only criteria however its use is the most common because it reflects travelling distance/time savings. For object localization there will be searched its Cartesian coordinates (x,y) in proper units. In case there are geographically oriented databases available the coordinates could be acquired by the use of algorithms which are commonly implemented in the geographic software. Even the distance matrix Fig. 1 suitable for the network graph construction can be generated.

![Distance matrix example](image)

2.1 Object localization model

By this model a 2D object localization method will be applied. General premise for a localization model:

Let \(i=1,2,...m\) new objects which connect to \(j=1,2,...n\) existing places so that costs for their connection are minimized. In case we search for an optimal distribution depot (warehouse) the distribution system model called “single object localization” is employed [2]. I.e. we need to place one object \(m=1\) which will connect to \(n\) existing elements (JSS). That means we search for coordinates of this new object \(N=(x,y)\) which will connect with elements with known coordinates \(M_j=(x_j,y_j), j=1,2,...,n\). In the data input-table Tab. 1 we can ignore the columns that are concerned with flows between existing facilities (if there are any) here all flows are from the existing facilities to the new facility.
Generally there are 3 types of distance model measures [2]:

- Rectilinear - objective function:
  \[ \text{min} z = \sum_{j=1}^{n} \left( |x - x_j| + |y - y_j| \right) \]  
  \[ (1) \]

- Euclidean - objective function:
  \[ \text{min} z = \sum_{j=1}^{n} \sqrt{(x - x_j)^2 + (y - y_j)^2} \]  
  \[ (2) \]

- Squared Euclidean - objective function:
  \[ \text{min} z = \sum_{j=1}^{n} w_j \left( (x - x_j)^2 + (y - y_j)^2 \right) \]  
  \[ (3) \]

The rectilinear distance measure is used for warehouses or cities which were designed in the form of a rectangular grid. The Euclidean distance measure is used where a straight line route is possible. The squared Euclidean distance measure is used where a straight travel is possible but where it is needed to omit excessive distances (squaring a
large distance number results in larger distance number and recall that we use the distance number in the objective which we are trying to minimize.

This model proposal tests and compares all three distance measures.

Tab. 2 Rectilinear distance summary

<table>
<thead>
<tr>
<th>New Facility</th>
<th>X Axis</th>
<th>Y Axis</th>
</tr>
</thead>
<tbody>
<tr>
<td>DC</td>
<td>7</td>
<td>6.50</td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td>68</td>
</tr>
</tbody>
</table>

Tab. 3 Squared Euclidian distance summary

<table>
<thead>
<tr>
<th>New Facility</th>
<th>X Axis</th>
<th>Y Axis</th>
</tr>
</thead>
<tbody>
<tr>
<td>DC</td>
<td>8.49</td>
<td>6.27</td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td>68</td>
</tr>
</tbody>
</table>

Tab. 4 Euclidian distance summary

<table>
<thead>
<tr>
<th>New Facility</th>
<th>X Axis</th>
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</tr>
</tbody>
</table>

The result of an optimal placement of the distribution centre (DC) is an area defined by boundary lines. That particular area shows where the cost function is minimized - the cost of potential supply will therefore be minimized. As mentioned above, the deployment of this model must be preceded by consideration about how the distribution will be done. Whether supply will be transported on roads or, for example air (mostly straight line flight – e.g. helicopter dropping material). This decision will set conditions for the problem formulation. Fig. 3 shows all three DC locations with respect to the existing JSS. It is not really crucial to determine the DC position 100% accurately (the data is probably not accurate enough anyway). Instead the grey triangle indicates the approximate region where it would be sensible to site the DC.

Fig. 3 Localization results diagram with costs

2.2 Optimal distribution chain between system elements

If it is not possible for any reason to use the services of a distribution center (typically the deteriorated security situation in the neighborhood), it is essential to find another way to supply the JSS. Usually it is necessary to get along with a limited transport capacity. The following model considers a helicopter fully occupied with the entire amount of
specific supply items (e.g. pharmaceuticals, antidotes, etc.), which comes into the area and flies gradually dropping supplies to all JSS. What will be its flight plan in order to minimize the route? This model example can be characterized as a so-called Traveling salesman problem (TSP), which is defined as follows. The map [Fig. 2] shows 10 JSS and the table Tab. 5 shows distances between each of them. Traveling salesman problem solution determines the order of visits of individual cities, each city has to be visited just once, the final length (price ticket, ...) has to be the shortest and the salesman (helicopter) returns to the starting point. The problem belongs to the category of Non-linear programming with a typical computational complexity. Even for a small number of nodes number of solutions is high and grows exponentially. Therefore, we will try to find other approach, however not ensuring hundred percent certainty of the shortest part, which may lead to a sufficient suboptimal solution. In the next step an optimal helicopter’s route is counted.

As mentioned above the table Tab. 5 indicates aerial distances between each of the ten JSS (V1-V10). It represents the input matrix for software solutions. In the next step a proper algorithm for the calculation tasks is chosen [1]:
- Closest neighbor method.
- Heuristics.
- Two-way heuristics.
- Branch and bound method.

Each algorithm provides a different result because of its nature arising from different approach. Based on the testings a two-way heuristics algorithm proved to be the most cost effective (see Tab. 6).

The optimal route solution is in the order V1, V3, V2, V5, V8, V6, V10, V4, V9, V7. The total distance will be using Two-way heuristics 32 Km.

### 3 CONCLUSION

This paper deals with the use of operations research methods in the operational area logistic support. The paper demonstrates two ways of optimization. First example applies non-linear programming object localization method the second uses the Travelling Salesman Algorithm for aerial supply logistic support. Presented findings and proposed approach will be further elaborated in author’s Ph.D. thesis.
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References


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