Structured Strategic Decisions through the Analytical Hierarchy Process: A Case Study of the Selection of Warehouse Location for WFP in Ethiopia

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Summary: This thesis developed a multi-attribute model to help the World Food Programme in the optimization of warehouse location in the Somali region of Ethiopia. The methodology used uses the Analytic Hierarchy Process which facilitates the use of qualitative information for optimization purposes. The model can be scaled in order to be used, first, in other geographical regions and second, as a guide for strategic decisions with the presence of imperfect information.

KEY INSIGHTS

1. There is no perfect answer when dealing with multiple attribute decisions, rather a set of tradeoffs the decision maker must consider.

2. The process of understanding what factors comprise a decision, as well as understanding the relative importance of each factor, is as important as the overall decision.

3. Sensitivity analysis with multiple attribute decisions is crucial to develop the level of intuition required to effectively make the tradeoffs.

Introduction

Providing humanitarian relief is a supply chain intensive operation, and improvements in supply chain efficiency directly impact the ability to help the millions of people in need. Strategic decisions have a tremendous effect on the efficiency of the supply chain, but the lack of readily available data endemic to logistics operations in developing regions, combined with the unpredictability of humanitarian events and the perpetual scarcity of resources, force humanitarian logisticians to frequently make strategic and tactical decisions on the basis of intuition without sufficient fact driven analysis.

Our research uses the Analytic Hierarchy Process, a multiple attribute decision model that provides structure to decisions where there is limited availability of information, to enable superior
strategic decision making using estimates and qualitative data. This is demonstrated by determining the location of additional warehouse capacity for the World Food Programme, the world’s largest food aid provider, in the Somali Region of Ethiopia. Locating a warehouse requires the evaluation and synthesis of multiple attributes to make a determination, but with limited time, resources, and effort, making an effective decision can be a challenge. Below we go through the Analytic Hierarchy Process’s four step process, deconstruction, prioritization, scoring, and normalization, detailing how we implemented this model for our effort.

**Deconstructing the Goal Statement**

The first step in the Analytic Hierarchy Process identifies the criteria upon which the decision of where to place an additional warehouse should be based. It also identifies the potential alternatives, in this case the potential locations being evaluated. We worked collaboratively with the World Food Programme to define criteria through a series of brainstorming sessions and external research. We settled on a list of five criteria for evaluating the quality of a warehouse location. These were ‘Adequacy of Infrastructure’, ‘Location’, ‘Transportation’, ‘Cost’, and ‘Regional Stability’. We then further deconstructed three of these criteria that were hard to evaluate into an additional tier of ‘attributes’, coming up with the model below, where the criteria/attributes outlined in orange are the end-nodes that will be evaluated during the scoring phase.

The final piece of this phase was to identify all of the warehouse alternatives, which were determined entirely by the WFP team. They came up with a list of nine alternatives, all alternatives being at the city level to ensure as consistent a set of metrics for scoring as possible.

With the goal statement deconstructed into a hierarchal framework, the World Food Programme team established relative priorities using pairwise comparison matrices, prioritizing each criteria or attribute within a cluster (as seen in Figure 3) relative to its parent function using a scale of 1-9. This means that all criteria are evaluated relative to their importance to the goal statement, and all attributes are evaluated on the basis of their relative importance to the parent criteria (e.g. for Infrastructure Attributes, Security is measured relative to the other three attributes in that cluster relative to their importance in determining the overall adequacy of infrastructure’.)
Priority Normalization

From the completed pairwise comparison matrices we normalized the priorities to come up with relative priorities for each criteria/attribute within a cluster. Additionally, this method allowed us to look at the consistency index of each matrix; the common heuristic is that a matrix exhibiting a consistency index less than .10 is desired. Based upon the consistency and a ‘sanity check’ we conducted with the WFP, we collaboratively adjusted some of the priorities in an iterative process until we achieved consensus that these were relatively accurate. To determine the overall contribution of an attribute we multiplied the priority of the attribute within its cluster by the priority of the attribute’s parent criteria within the primary cluster. The following figure shows the results of the prioritization exercise.

![Figure 4 - Importance of Criterion/Attributes in Overall Decision Pareto](image)

Proximity to Beneficiaries is the most significant factor in making a determination, and this model exhibits the common Pareto distribution, where a few factors comprise the majority of the decision process. In this instance, the top five factors constitute 82.56% of the overall decision. With this knowledge in mind the ability exists to conduct an abridged version of this analysis if necessary where only the top five criteria/attributes are evaluated, achieving relatively accurate results with less than half the analysis. This also signals that the potential may exist to use these top five as a heuristic for similar evaluations.

Scoring

Once the problem was fully deconstructed and the relative priorities were identified and normalized, we identified an approach for evaluating each of the alternatives at the end node. To do so we developed a data collection plan to ensure that each end node has a specific metric. The metrics were created with a focus on three key criteria, making sure it was easily acquired, scalable to other areas beyond the Somali Region of Ethiopia, and relevant to the problem at hand.

Developing the data collection plan occurred in an iterative fashion, as different sources of information were identified, validated, or discarded when proved to be unreliable or irrelevant. The plan became much more qualitative as it was built out, relying extensively on a series of surveys completed by field officers in the locations with existing warehouses, and then using that data to create estimated values for the three newly proposed warehouse locations, using whatever data we had available as a proxy combined with our own intuition.

![Figure 5 - Final Data Collection Plan](image)

Evaluation

With the scoring data collected, we then normalized all of the scores, multiplied them by the priority for each end node, and aggregated the information to create an overall fitness score for each alternative. Normalizing them relative to the highest scoring alternative we come up with the following:
<table>
<thead>
<tr>
<th>Alternative</th>
<th>Normalized Fitness Score</th>
</tr>
</thead>
<tbody>
<tr>
<td>Jijiga</td>
<td>100%</td>
</tr>
<tr>
<td>Nazareth</td>
<td>98%</td>
</tr>
<tr>
<td>Degehabar</td>
<td>92%</td>
</tr>
<tr>
<td>Dire Dawa</td>
<td>92%</td>
</tr>
<tr>
<td>Kebridehar</td>
<td>83%</td>
</tr>
<tr>
<td>Gode</td>
<td>83%</td>
</tr>
<tr>
<td>Fik</td>
<td>75%</td>
</tr>
<tr>
<td>Mustahil</td>
<td>71%</td>
</tr>
<tr>
<td>Warder</td>
<td>69%</td>
</tr>
</tbody>
</table>

Figure 6 - Priority Percentages of each Alternative

Based upon these scores, we can see that there is a strong level of stratification with a fairly constant reduction in scoring between an option and its next best alternative. Given the range of normalized scores from 69% up to 100% we can say with a high level of confidence that the choices are sufficiently segregated for the purpose of evaluation.

**Sensitivity Analysis**

To gain a deeper level of understanding into the workings of the Analytic Hierarchy Processes decisions in selecting an optimal warehouse location, we ran a series of variations to the model.

Regional Stability was the most challenging criteria to obtain reliable data for. Therefore, we chose to evaluate the impact of changing the relative priority of Regional Stability. As Figure 7 shows, as the relative priority of Regional Stability increases, Nazareth overtakes Jijiga as the highest ranked location. These results provide us significant insight into why Nazareth was selected as the second selection, as it is located in the most stable area of any of the locations.

As Proximity to Beneficiaries was the most important end-node we looked at the impact of modifying its relative priority.

From this we can see some general trends that more remote locations scored much higher in proximity to the beneficiaries, but much lower in areas surrounding infrastructure and Access to Ports. This shows the tradeoff that is truly central to the decision, in that areas closer to the beneficiaries tend to lack adequate infrastructure. Knowing this, the WFP will have to choose between the two when selecting a warehouse location.
Conclusions

In addressing a complex multiple attribute decision there is rarely one single approach or solution that is 'correct'. Rather, it is in the ability to structure the decision in a fashion that encourages critical thinking and allows for intuition to be developed that the Analytic Hierarchy Process derives its value. In understanding this we can come to some clear conclusions about the factors that a decision of this nature should be based upon, as well as determining a list of locations in a ranked format to assist with implementation.

The main contribution of this model is not necessarily the solution of the best warehouse location. Instead the three main contributions of our model are the ability to promote critical thinking about the strategic decision, the formalization of factors for analysis, and the exercise of open team discussion and collaboration. These three contributions can be derived by the application of this model in any other strategic decision where there is lack of quantitative information.