

1.1. Introduction

The objective of the report is to find the best possible solution for an expanding small manufacturing company in deciding whether they must extend their current warehouse space or purchase space either in the city centre, suburb or share a space with another company. The following table describes the client's thoughts for five different criteria against the four alternatives provided.

		Alternatives			
		A1 (Centre)	A2 (Suburb)	A3 (Shared)	A4 (Extend)
Criteria	C1 (public transport links)	Good bus and rail links	Good bus links but no rail links	Poor bus links but good rail links	Excellent bus and rail links
	C2 (parking)	Poor	Good	Excellent	Moderate
	C3 (warehouse space)	Poor	Excellent	Good	Good
	C4 (security)	***	****	***	*
	C5 (cost)	£900,000	£600,000	£300,000	£200,000

Table 1.1: Criteria and Alternatives

1.2. Preliminary Analysis

Considering that the client company is small, it is better to have the warehouse close to the manufacturing unit, for steady and efficient supply of raw materials. Another factor is the type of goods produced by the company. If the company produces perishable and non-hazardous goods, then the warehouse can be located near to the market. However, if the business deals with hazardous items, the warehouse should be kept in industrial areas considering safety regulations.

Primary assumption: Client is manufacturing non-hazardous items, for example a textile manufacturing company.

1.3. **Assumptions and Prioritisation of Criteria**

- i. Cost: Since the company is small and aiming for expansion, choosing a warehouse with optimal(minimum) cost is of prime importance whilst considering all the hidden costs. Apart from the rental cost, the company must consider other hidden costs including maintenance, tax, electricity, and other utilities. The rental price of small industrial warehouses in United Kingdom is around £30 per square feet and proves to be more expensive than larger warehouses (Statista Research Department, May 18, 2022).
- ii. Warehouse space: For an expanding company, the warehouse space should be able to accommodate all the goods and machinery required for the business properly and safely. The ceiling height, floor space and availability of depressed docks for trucks to supply goods should be considered when choosing the warehouse.
- iii. Public transport links: Public transport links plays a vital role in the competitiveness of the business. The warehouse should be accessible to the market and cargo suppliers via excellent highways, rail service, exit ramps and highway interconnectivity. According to the freight and cargo statistics report in UK, 176 billion tonne-kilometre of freight moved in the UK during 2008-2020, of which the share of domestic freight moved by road is 85%. (Statista Research Department, Oct 10, 2022). Assuming that the textile manufacturing company, transports most of its cargo via buses than rails for ease of access to local markets, the public transport links criteria can be sub divided into:
 - 3.1: Public transport via bus links
 - 3.2: Public transport via rail links
- iv. Parking: The parking space in the warehouse should be able to accommodate all the trucks or buses arriving the location. Apart from cargo supplier vehicles, separate space should be considered for employee vehicles and ambulance in case of emergency.

- v. Security: Security refers to protection of goods against theft and unwanted access, and to the security of staff working in the warehouse. Warehouse security contributes significantly to reduction in financial losses and maintaining the brand image among customers and employees. Assessing the information in the above table, the number of stars has been assumed to be ratings of each alternative, were

**** => excellent

*** => good

* => moderate

A warehouse with poor security has been ignored.

1.4. AHP

AHP is a pairwise comparison method which compares the importance of each pair of criteria/alternative relative to each other and decide which one is better and by how much. We make use of a pairwise comparison scale proposed by Thomas L. Saaty (1977, p.246), in converting the qualitative comparisons to a quantitative scale of values between 1-9.

Comparing weights:

	cost	warehouse space	Public transport - bus	Public transport - rail	Parking	Security
cost	1.00	3.00	4.00	6.00	8.00	9.00
warehouse space	0.33	1.00	3.00	5.00	7.00	8.00
Public transport - bus	0.25	0.33	1.00	4.00	5.00	6.00
Public transport - rail	0.17	0.20	0.25	1.00	3.00	5.00
Parking	0.13	0.14	0.20	0.33	1.00	3.00
Security	0.11	0.13	0.17	0.20	0.33	1.00

Table 1.4: AHP weight table

- The criteria are arranged in the order of priority for ease of understanding.
- Cost is moderately more important than warehouse space -> 3
- Cost is relatively between moderate and strong importance to public transport via bus -> 4
- Cost is relatively between strong and very strong importance when compared to public transport via rail -> 6

- Cost is relatively between very strong and extreme importance when compared to parking -> 8
- Cost is extremely important than security -> 9
- The values of all other alternatives when compared to cost will be the inverse of their respective values mentioned above.
- Similarly, the table have been filled for all other criteria.
- The consistency ratio (CR) of the matrix was calculated, to ensure that the values maintain transitivity.

```
> library('MCDA')
> example <- t(matrix(c(1,3,4,6,8,9,
+                      1/3,1,3,5,7,8,
+                      1/4,1/3,1,4,5,6,
+                      1/6,1/5,1/4,1,3,5,
+                      1/8,1/7,1/5,1/3,1,3,
+                      1/9,1/8,1/6,1/5,1/3,1), nrow = 6, ncol = 6))
> pairwiseConsistencyMeasures(example)
$CR
[1] 0.07956622
```

Figure 1.4.1: Checking consistency ratio

CR is below 0.1, which indicates that the weights are consistent.

Comparing alternatives:

The following comparison scale have been used for comparing the alternatives and values were assigned from the Saaty's scale.

Excellent x Good	8
Excellent x Moderate	7
Excellent x Poor	6
Good x Moderate	5
Good x Poor	4
Moderate x Poor	3

Poor and None have been assumed to be equivalent.

Results:

After prioritizing the criteria and deciding the weights, the AHP process uses the Geometric Mean method to calculate the results.

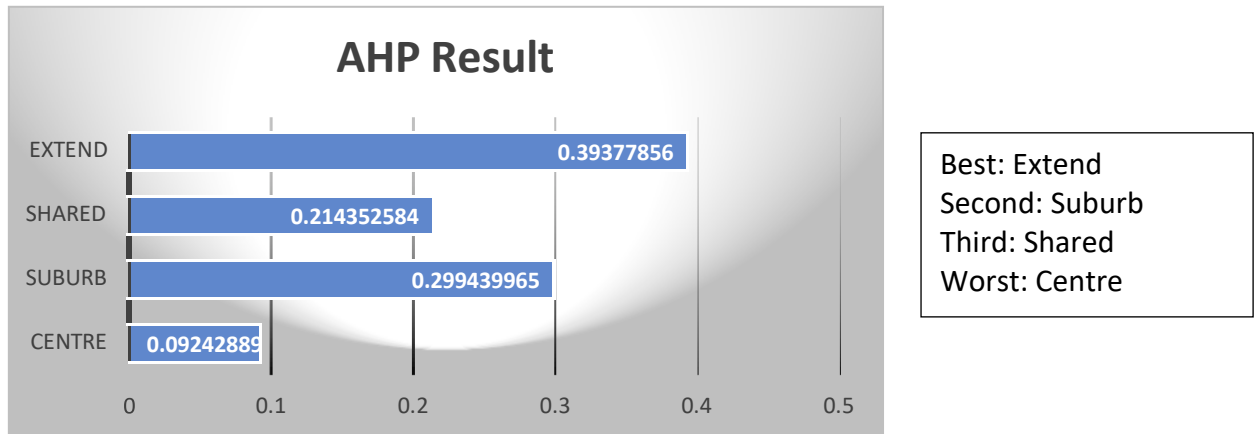


Figure 1.4.2: AHP Result

We can plot a stacked column chart which represents the contribution of each criterion towards the score obtained.

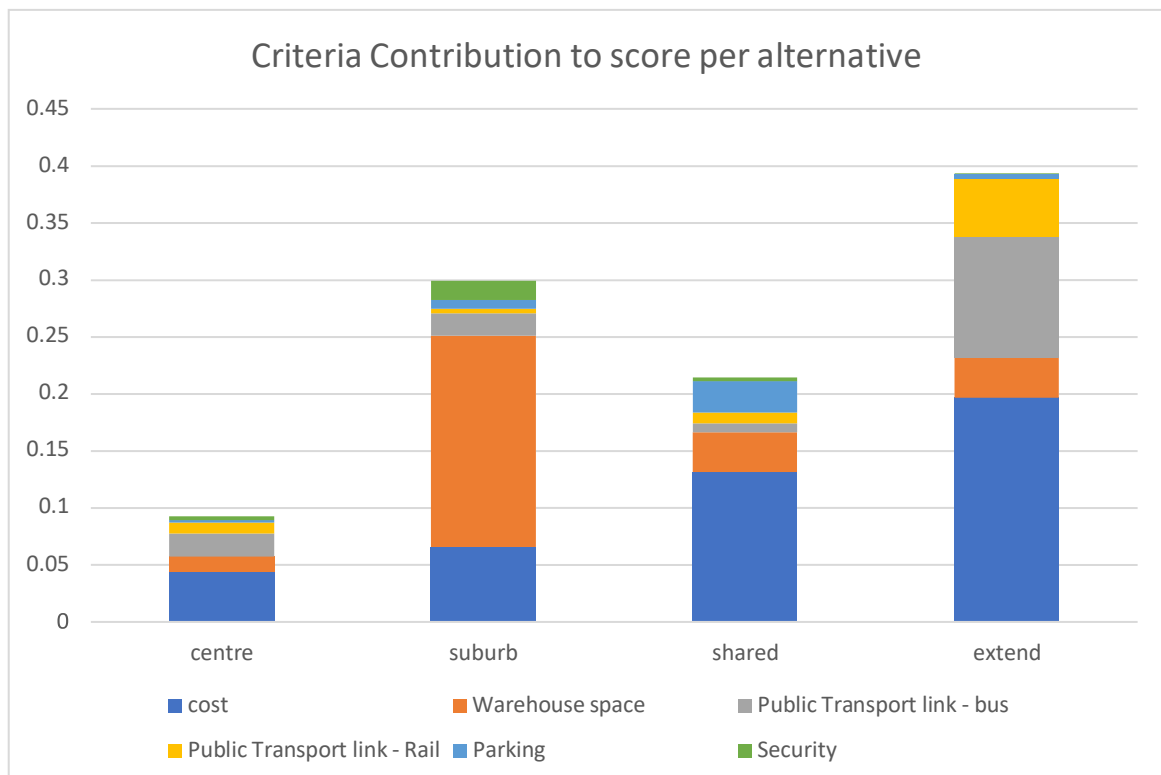


Figure 1.4.3: Contribution of criteria to score per alternative

Analysis:

According to Fig 1.4.2, the best alternative for the company is to extend their existing warehouse and the worst is to purchase in the city centre. The result perfectly aligns with the priorities discussed. Minimisation of cost being the major priority, extend contributes to the least cost whereas city centre the highest. Comparing to other criteria, although extend has moderate parking space and security, it has excellent public transport links both in case of bus as well as rails, and good warehouse space. City centre is the worst in terms of cost, poor parking and warehouse space when compared to all other alternatives.

Further analysis using Fig 1.4.3, depicts that cost contributes the most, followed by public transport links and warehouse space, towards extend being the best alternative. In terms of warehouse space and then cost, suburb can be considered. If the company can compromise slightly on cost and prioritise warehouse space, then suburb can become the best alternative since it also offers excellent security. Shared can be considered as an alternative to suburb as second choice, in terms of cost yet bus links and warehouse space does not contribute significantly.

1.5. TOPSIS

- TOPSIS is an ideal point method for solving multi-criteria decision analysis (MCDA) which assesses each alternative based on their separation from the best ideal solution for each criterion (positive ideal point) and the separation from the worst ideal solution for each criterion (negative ideal point).
- The principle of TOPSIS is that the optimal alternative should have the shortest distance from the positive ideal solution (PIS) and the furthest distance from the negative ideal solution (NIS).

Assumptions:

- Considering the priority of criteria, the weights of each criterion have been assigned as follows:

	cost	public transport-bus	public transport-rail	parking	warehouse space	security
weights	0.35	0.09	0.06	0.12	0.3	0.08

Table 1.5: TOPSIS weight table

Note: Public transport links criteria was subdivided into bus links and rail links. Assuming that the overall weight for public transport links is 15%, bus links have been given 9% and rail links was assigned 6%. The overall weight is greater than that of parking (12%)

- The decision matrix is formulated by converting the qualitative values to quantitative values according to the following scale ranked out of 10.

Excellent	9
Good	7
Moderate	5
Poor	3

Results:

TOPSIS calculates the relative closeness to the ideal solution. The alternative with the highest score is the best solution.

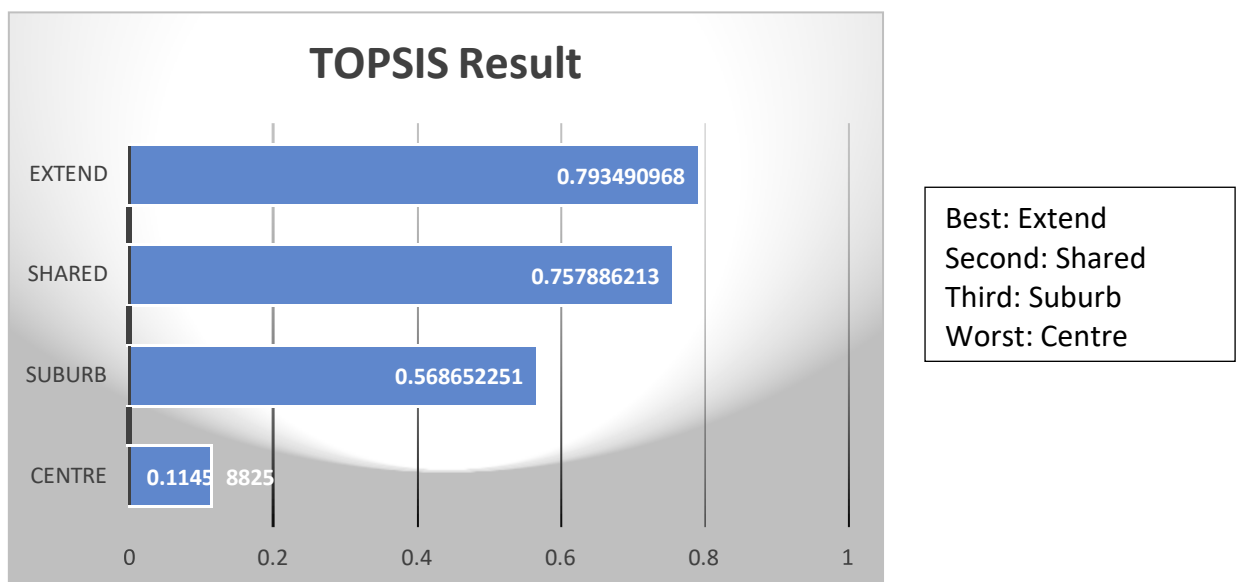


Figure1.5.1: TOPSIS Result

Analysis:

Analysing the excel attached, S_i^+ indicates the distance between each alternative to the PIS and S_i^- indicates the separation from the NIS. S_i^+ is the least and S_i^-

is the maximum for extend. Extend is relatively close to the ideal points, which makes it the best alternative. Centre is the worst solution due to its minimum closeness to the NIS and maximum distance from the PIS. If major priority is given to warehouse space (40%) followed by equal priority for cost (20%) and public transport links (20%), then suburb can become the second-best choice over shared, demonstrated in Fig 1.5.2.

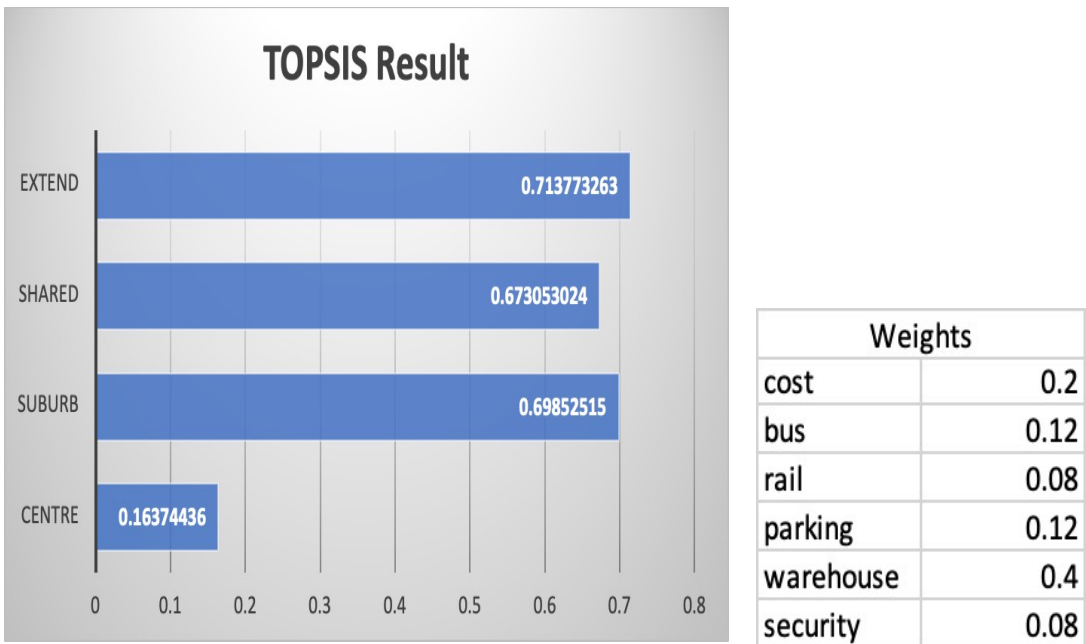


Figure 1.5.2: TOPSIS Analysis after changing priorities

1.6. Final Recommendation

Based on the APH and TOPSIS analysis, the best possible solution for the company to choose a warehouse location is by extending their existing warehouse, whereas it is not suggested to choose the location in the city centre, due to the minimised cost constraint. Suburb or sharing can be considered as other possible secondary options depending upon altering the priorities set. These results have been obtained based on the priorities given to each criterion and is subject to change by altering them according to the company's preferences.

