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USE OF MULTI-CRITERIA DECISION ANALYSIS FOR LOCATION DECISION: DEVELOPING A RISK REACTION SPECTRUM

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ABSTRACT

The location of any business facility plays a pivotal role in the success of the business and it is one of the major considerations in subjects such as business strategy, operations management and economics. This paper proposes the use of Multi-criteria Decision Analysis, as an effective means of tackling the crucial location decision for a manufacturing plant. An exploratory case of a strawberry syrup manufacturer is investigated and a ranking of three speculative locations where the company can establish their new strawberry syrup production plant is presented here. To evaluate the effectiveness of MCDA in determining the optimum set of locations for the plant, extensive sensitivity analyses were carried out with all the criteria involved, and this further supported the findings of the three most possible locations. Finally, the paper proposes the development of a risk continuum based on extreme risk preferences, which can be used as a tool to determine the ranking of the alternatives based on the risk preference and attitude. The paper showed the potential of the MCDA as an effective tool in location decisions, presents a tool to incorporate diversity in decision maker preferences, and then sets the stage for further research in this specific branch.

JEL Classifications: C3, M2, D7 and D8
Keywords: Location Decisions, Decision Making, Multi-criteria Decision Analysis, MCDA, Evidential Reasoning.
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INTRODUCTION

The determination of the location of a production/manufacturing plant plays a very important role, both for business studies (Brush et al., 1999) and for economics (Blair and Premus, 1987). Proper location of a manufacturing plant determines how long the raw materials and the produced good need to travel, how skilled the workforce are, how efficient the operations of the factory is, etc. (Brush et al., 1999). An appropriate location is determined by various tools present, both qualitative and quantitative. All these tools base themselves on few critical factors, which are qualitative and quantitative in nature (Townroe, 1972).

Notable among the tools based entirely on quantitative factors are Distance Models, Transportation Networks, Hierarchy Models and Flow Models (Beckman, 1968). These models are concerned with the distances - from the market and from the source of the raw materials, costs of transportation and other measurable factors. But based on experience, accounting for only the quantitative is not enough (Townroe, 1972). The decision maker needs to factor in the importance of the qualitative factors as well, most importantly his own preference and intuition as well as political stability, local advantage etc. Furthermore, the fact that there exists a correlation between different alternatives when a decision maker undertakes a decision needs to be factored into the analysis, which has been ignored by the popular Prospect theory (Nwogugu, 2005). This study points out the need to consider decision making and risk assessment as multi criteria processes, and develop on the existing rigidity of the prospect theory.

Unfortunately all these tools focus on the variability of one or two factors at a time, keeping everything else constant, wherein their drawbacks lie (Sorenson and Baum, 2003). The final decision depends of the manager's knowledge of the factors, tools and tradeoffs. This paper presents a means of giving managers a more holistic picture of the alternatives at hand based on the important available criteria and also the individual risk preferences, aiding them in taking more balanced decisions. The paper starts with the discussion of the existing

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literature on location decision making and how it can be a multi-criteria decision making problem, and goes on describe the location case at hand, and finally presents the analyses along with a concluding remark for the decision maker and also a direction for future research.

LITERATURE REVIEW

The start of the paper discusses the outlying problem of the popular location decision making tools is the integration of both quantitative and qualitative factors influencing the location decision. The biggest benefit of multi-criteria decision analysis (MCDA) is that it can be used to solve problems involving both quantitative and qualitative criteria. As such, it can incorporate more details in location selection problem, not only profit maximization (Gamboa and Munda, 2007). MCDA is a means of ranking the alternatives for a decision maker by means of understanding the preferences, the aims and the tradeoffs of the decision maker, both for the qualitative and the quantitative criteria (Belton, 2001).

Although research is not abundant in this subject field, there are relevant studies in similar circumstances which can be used to show the validity of the use of MCDA in this paper (Smith and Junginger, 2011). An MCDA methodology has been used in the selection of a country for Foreign Direct Investment (FDI) based on criteria which are very similar to the ones used for this paper. In addition to this, other papers follow the methodology which can be applied to location decision problems. The steps in consideration are the identification of the relevant criteria, the identification of alternatives, collection of the data for these alternatives, and then ranking them in order of their performance (Smith and Junginger, 2011). Other relevant studies show that problems related to the location of any facilities involve criteria which are not only quantitative and qualitative in nature, but their performances are contradicting each other, which makes the use of MCDA a very effective contextual tool, as shown by different studies (Boffey and Karkazis, 1993; Hale and Moderg, 2003 and Tuzkaya *et al.*, 2008). As such, it can be concluded from the existing literature that for the problem in hand for this paper, an MCDA approach will be relevant and useful.

In terms of risk preferences of the decision makers involved, a study that determines whether risk attitude (averse or preferred) has an observable effect on auditor judgments, and tests the predictions of a Multiattribute Preference Model (that reflects the decision maker's attitude towards risk) lends substance to the case study undertaken in this paper (Farmer, 1993). Decisions involving targets on multiple evaluation attritbutes under uncertainty have also been modeled (Bordley & Kirkwood, 2004). Here uncertainty refers to the presence of a certain level of risk associated with the performance targets. Some studies have also highlighted the swing of decision makers optimal alternatives based on the risk preference standpoints (Chiles and McMackin, 1996). On similar lines, the works of Smith and Junginger (2011), Boffey and Karkazis (1993) and Tuzkaya *et al.* (2008) have presented the risk preferences of the decision maker, but had the gap of comprehending what would have happened to the optimum set of alternatives if the risk preferences would have reversed. In essence, to look into the scenario in this manner of perspective – changing risk preferences while observing the changes in the result would be further strengthening the decision making model through a manner of sensitivity analyses, as proposed by the work of Pidd (2003) and Savage (2012).

Two of the common MCDA methods are Multi-attribute Value Theory (MAVT) and the Multi-attribute Utility Theory (MAUT). Both of them base their assumptions on some form preferential or utility independence as well as constant tradeoffs (Belton and Stewart, 2002). The advantage of these methods is that they are simple, transparent and allow the results and the recommendations to be documented easily. But then, because of the assumption of constant tradeoffs, they tend to give extreme results. Also the decision maker is either unwilling or may not be able to give information on their preferences, utilities and tradeoffs (Stewart and Losa, 2003). This is the case for this problem, since the paper is directed as a proposal to use MCDA for solving a location problem. In such case, the level of uncertainty and practicality involved, it would not be feasible to obtain exact judgments (Guo *et al.*, 2007). Therefore, this paper focuses on the use of Evidential Reasoning approach, which is practically focused and deals with both the qualitative and quantitative data equally as well as the other approaches, but does not need satisfy the strict rules of the other approaches. For obtaining the results, the software Intelligent Decision Systems (IDS) is used which has proven itself in different studies to be very good ER software (Yang and Xu, 2002).

METHODOLOGY AND CASE DESCRIPTION

Research Rationale

For this paper, an exploratory case study approach has been used. The rationale for using the case study approach is to assess the fertility of the tool proposed not only for academia, but also for a more hands on

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approach. An inductive method of reasoning was used for the exploratory analysis in order to determine the effectiveness of the use of MCDA for the location decision problems from the learning and outcomes from the case at hand (Dul and Hak, 2007; Yin, 2011).

Case Description

Haque Confectionaries is part of the Haque Brothers Industries Limited operating in Bangladesh for over 64 years. They focus on the production of quite a few biscuit brands based on different flavours and also a good range of wafers (Haque Group of Industries, 2012). Initially they used to import their raw materials, especially fruit syrups and flavors from abroad. One of their most popular products is the strawberry wafer; also some of their biscuits and candies are based on the flavor of strawberry. As such, one of their biggest imports is the strawberry syrup (Haque Group of Industries, 2012).

Recently, the strawberry research in Bangladesh has come up with a breed of Strawberry which can be grown in the soil of the Rajshahi Region. This development was done by the Botanical Research body in Rajshashi University, and studies in 2007 showed that the soil can support the growth of strawberry (Ara *et al.,* 2009) and another study in 2008 showed the development of a new breed of strawberry which can be grown for commercial purposes in large numbers (Karim *et al., 2011*). As such, the market for strawberries is thriving in the country and the yield is large enough to make a strawberry syrup manufacturing plant feasible. This would not only reduce the costs of raw materials for the Haque Confectionaries, but will also add to the economy in terms of lesser imports and more employment.

Hence, the case analysis aims to come up with three speculative sites, which may be suitable places for the location of the new strawberry syrup manufacturing plant. The ranking of these three sites are based on criteria which mainly fall under the categories of physical factors, human based factors and government subsidies (Beckman 1968). Due to the speculative nature of the study, any organizational partnership or agreement was not necessary with the Haque Confectionaries, and the interviews were collected for purely academic purposes. Thus there was no obligation from the part of the researchers or the organization to share the details of the findings or applying the findings of the research into practice.

Decision Makers Preferences

One of the novelties of this paper was to come up with a spectrum between the extreme risk attitudes of the decision maker, consisting of the overall scores of all the alternatives, and showing how these scores change with the changes in decision makers' risk preferences. As such, the MCDA was run on risk neutral scenarios, and then the preferences were plugged in for both the extreme risk taking decision maker and the extreme risk averse decision maker, which were obtained from extensive interviews with the decision making teams of the organization.

DEVELOPING THE MCDA MODEL

Modeling Assumptions

For this paper, few generic assumptions are taken for the ease of problem definition. The assumptions are given as below:

1. The raw material, which is the strawberries, is taken to be from one region – Rajshahi – in Bangladesh. This assumption is justified due to the fact that only one region has so far been found in the country which has soil and the weather conditions to support strawberry plantations.
2. The market is also taken to be in one region, as the plant that manufacture the wafers and candies are cluttered together in one area of the capital (Haque Group of Industries, 2012).
3. The variation of storage cost is not significant in different destinations, and so can be ignored.
4. Due to electricity supply crisis, the assumption is taken that the plant will have self-generated electricity (Sajjadur, 2010)

Criteria definitions

For the MCDA problem, a very clear definition of the criteria is very important. This is because when the final list of three alternatives will be made, the calculation will be thoroughly based on the alternatives' performances in these criteria. As was mentioned in earlier parts of the paper, the major criteria identified were the physical factors, human based factors and government subsidies. These criteria, with descriptions of how they were

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measured are given in the Appendix A. The sub-criteria chosen are those that can be seen as having highest influence in a location decision (MacCarthy and Atthirawong, 2003), and all of them are shown below:

TABLE 1. BREAKDOWN OF CRITERIA FOR THE MCDA

Major Criteria	Sub-Criteria	Type of Criterion
Site/Physical Cost Factors	Proximity from Raw Materials	Cost Criteria
	Proximity to Market	Cost Criteria
	Land Price	Cost Criteria
	Number of Godowns	Benefit Criteria
	Utility Availability	Benefit Criteria
Human Based Cost Factors	Transportation Cost of Raw Materials	Cost Criteria
	Transportation Cost of Finished Goods	Cost Criteria
	Agglomeration Tendency	Benefit Criteria
	Average Labor Wage	Cost Criteria
	Literacy Rate	Benefit Criteria
	Number of College Students	Benefit Criteria
	Kilometers of Metal Roads	Benefit Criteria
	Population of the Region	Cost Criteria
Government Factors	Development Projects	Benefit Criteria
	Political Stability	Benefit Criteria

Initial and Satisficed Alternatives

The initial set of alternatives chosen was all the sixty four districts of Bangladesh. It can be seen that sixty four alternatives are too many choices for the decision maker, and as such, the initial alternatives are filtered by satisficing of some criteria. This would make not only the collection of the data easier, but also the calculation and data processing less messy (Beim and Lévesque, 2006). The criteria taken into consideration and their justification are given below:

TABLE 2. CRITERIA AND VALUES USED FOR SHORTENING THE INITIAL LIST OF ALTERNATIVES

Criteria	Condition	Value
Distance to market	Equal to or Less Than	250 km
Distance from raw materials	Equal to or less than	300 km
Population	Equal or less than	2,000,000
Literacy Rate	Higher than	25%
Number of college students	Higher than	21000

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These criteria were initially chosen to satisfy because they deemed to be the major important factors for the decision maker. Distances to market and from the raw material are important because then the total transportation cost as well as the time for the raw material to reach the plant and the time for the syrup to reach the manufacturing plant are reduced. Also the differences of the values is because of syrup liquid is too valuable and fragile to carry than the picked strawberries. For the case of the population, any districts having a value higher than 2,000,000 will be too dense to establish a plant, and would lead to further congestion and pollution. The literacy rate is obviously important to ensure a pool of skilled labor, as well as the number of college students.

Data Collection

After the satisficing of the initial set of alternatives to ten, further data was collected regarding all the criteria. The data collection was from websites of Bangladesh Government (District Portals, 2011) as well as from a non-government institute website (Districts of Bangladesh, 2010). The data on political stability and government factor was collected with the help of online survey given to local and regional business men and entrepreneurs in the major focus districts. The questionnaire was developed on the recommendations on the study by Hoque and Hopper (1997), where they suggested few specific factors relevant to Bangladesh which can be sued to determine a level of political stability. Also, for further verification of the data, on field survey reports were analyzed. Data on political stability was gathered by going through newspaper articles keeping in mind the number and level of violent crimes that has been committed in the areas of concern. The data are shown in Appendix B.

Data Preprocessing

For the fifteen criteria selected, the scales are defined to be local for nine of them, one of them is defined as truly global, and the other five partially global. The scales are given in the following table:

TABLE 3. TYPE OF SCALES FOR EACH CRITERIA

Criterion in Consideration	Type of Scales
Proximity to Market	P.Global
Proximity from Raw Materials	P.Global
Land Price	Local
Gas Supply	Local
Number of Go-downs	P.Global
Transportation cost of raw materials	Local
Transportation cost of finished goods	Local
Number of Industries	Local
Average Labor wage	Local
Literacy Rate	Global
No. of College Students	P.Global
Kms Of Metal Roads	Local
Population	P. Global
Development Projects	Local
Political Stability	Local

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Some explanation is necessary to define what a partially global scale is, as it is one of the novelties of this paper. Basically the paper focuses on the problem which is faced by a company in Bangladesh. Initially all the districts were chosen as alternatives, so the alternative set was collectively exhaustive. So, for criteria where the highest score is the highest value from that initial list, then the scale can be termed as global, as the data from all the regions will definitely point at the highest and the lowest values possible. But if the use of the model is further considered in an international context, outside the boundary of Bangladesh, then these alternatives are not anymore collectively exhaustive, which makes them local again. So the criteria which fall under this category are named as partially global.

After the data evidence collected has been put into partial value functions based on respective global, local and partial global scale, the data is preprocessed both in the proportional method and standard 0-1 transformation. This is normally included in the processing done by the IDS software used, but this is done manually to check whether there are any abnormal data present and also to check for dominance. The graphs showing performances of each alternative in the respective criteria is attached with the Appendix C. It shows that none of the alternatives are dominant either on the concordant or the discordant principles, emphasizing on the fact that there is no 'best' dominant solution outright, and hence further justifying the multi-criteria decision analysis (Stewart and Losa, 2003).

One important aspect of this study is that the fact that not all decision makers has the same risk preferences were incorporated by the authors, whereby both facilitated the interview of a risk taker and a risk seeking decision maker and answered a questionnaire designed to evaluate the importance (and subsequently weights) they assigned to each of the criterion. In effect, there were now multiple risk averse decision makers and risk seeking decision makers, and the data was normalized in order to generate risk adjusted values. The values for a risk neutral decision maker were assigned based on the linear graphical relationship.

The weights are assigned based on pairwise comparison, where the most important criteria per category are recognized (Beckman 1968). The detail comparisons and the weights set are shown below:

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TABLE 4. DETERMINING THE WEIGHTS OF EACH CRITERIA

Site/Physical Factors		
Land Price	1	Most Important Criteria
Proximity to Market	1.5	times as less important as Land Price
Proximity to Raw Materials	2	times as less important as Land Price
Gas Supply	5	times as less important as Land Price
Number of Godowns	8	times as less important as Land Price
Human - based Cost Factors		
Transportation cost of raw materials	1	Most Important Criteria
Transportation cost of finished goods	1	Most Important Criteria
Average Labour Wage	1.2	times as less important as Transportation Costs
Population	1.5	times as less important as Transportation Costs
KMs of metal road	2	times as less important as Transportation Costs
No. of College Students	3	times as less important as Transportation Costs
Literacy Rate	3.5	times as less important as Transportation Costs
Number of Industries	7	times as less important as Transportation Costs
Government Factors		
Political Stability	1	Most Important
Development projects in food industry	3.5	times as less important as Political Stability

Major Criteria Comparison

Physical Costs	1	Most Important
Human Based	2	times as less important as Physical Cost
Government	3	times as less important as Physical Cost

RESULTS FROM THE MCDA MODEL

Results

The results of the analysis are presented below that illustrates the differences based on the different risk preferences:

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FIGURE 1. RISK PREFERENCE SPECTRUM FOR ALL THE ALTERNATIVES FOR MCDA

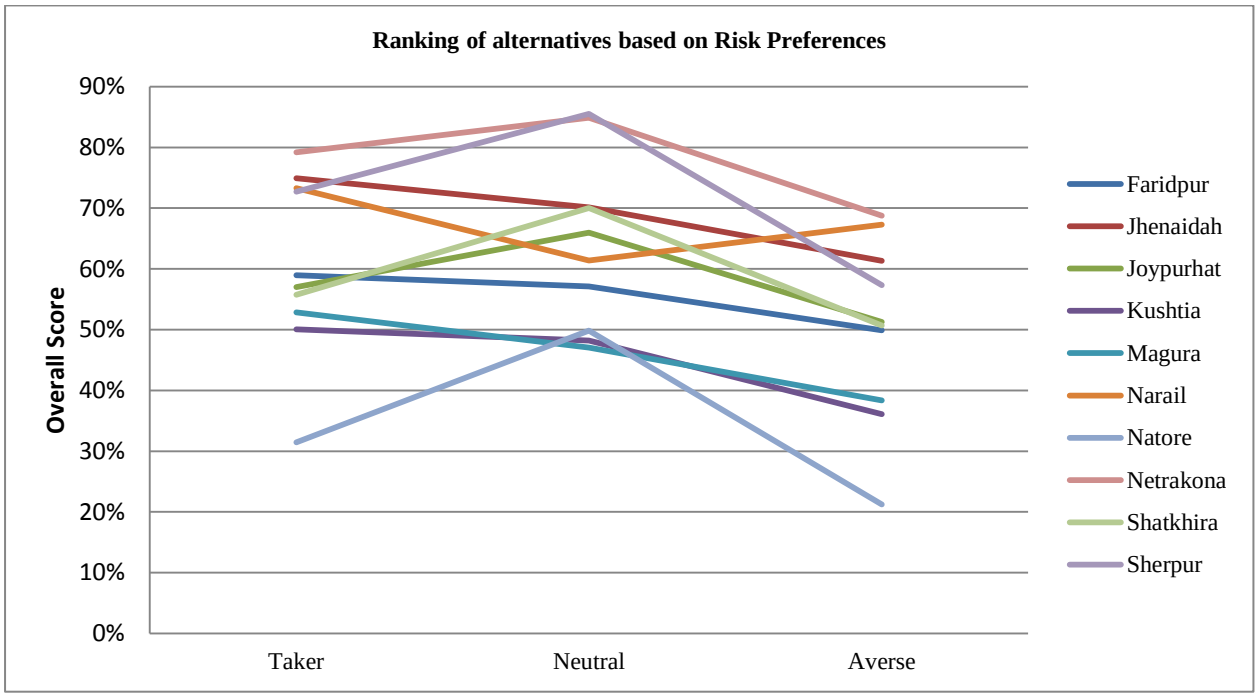

TABLE 5. OVERALL PERFORMANCE OF ALL THE ALTERNATIVES FOR DIFFERENT RISK NATURES

	Taker	Neutral	Averse
	Overall Score		
Faridpur	59%	57%	50%
Jhenaidah	75%	70%	61%
Joypurhat	57%	66%	51%
Kushtia	50%	48%	36%
Magura	53%	47%	38%
Narail	73%	61%	67%
Natore	31%	50%	21%
Netrakona	79%	85%	69%
Shatkhira	56%	70%	51%
Sherpur	73%	86%	57%

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It could be observed that the reason for such ranking was because of high scores for Netrakona, Sherpur and Jhenaidah in Site/Physical Cost Factors and Government Factors in comparison to other locations. Among the top three, Netrakona was chosen because of its high performances in Land Price, Gas Supply, Proximities, Transportation Costs, Development Projects and Political Stability.

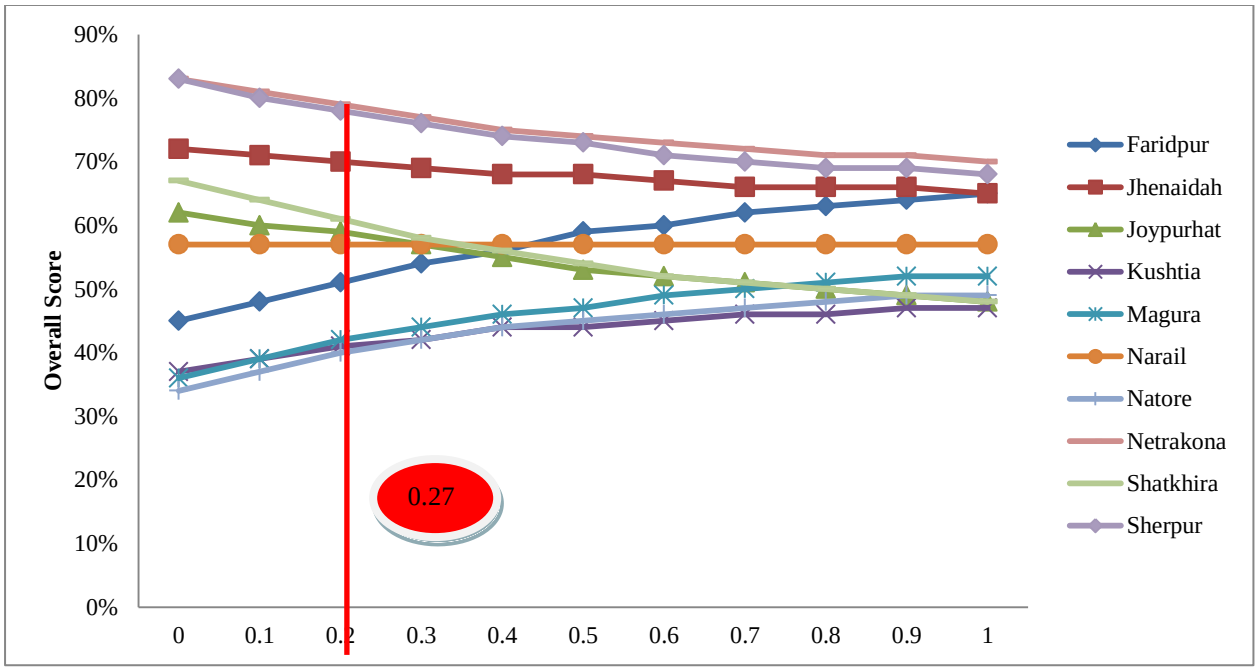
Sensitivity analysis

Sensitivity analysis on the risk neutral scenario of all the alternatives based on changing the weights of the criteria which were initially used to come to the final ranking were carried out in order to overcome the problem with the assumed weights (Steele et al., 2009). The weights are initially changed for the three major criteria and the performances of the ten alternatives are taken into consideration. And then the weights for sub-criteria for the major criteria are changed accordingly for completeness (Hodgkin, Belton and Kouluri, 2005). The limitation for this paper would be that all the possible combinations of the sensitivity analysis could not be done as this would be too time consuming and beyond the scope of this paper.

From the first set of analyses with the major criteria, it can be seen that the changing the weights even to extremes will not change the initial ranking of the best three locations, only they affect the scoring of the locations, and for the case of Site/Physical Factors, only the order of the ranking is changed, although the top three locations remain the same.

The second set of analysis with all the fifteen sub-criteria shows that for the criteria Proximity to Market, Transportation Costs, Labour Wage, Literacy Rate, Population, Development Projects and Political Stability, even the maximum deviation of weights, the ranking stays the same. For the factors Proximity to Raw Material, Gas Supply and Kilometers of Metal Road, the ranking again stays the same, but the order of the preferences are changed. One of the representative graphs are given below:

FIGURE 2. REPRESENTATIVE SENSITIVITY ANALYSIS GRAPH FOR ALTERNATIVES STAYING THE SAME AFTER CHANGING THE WEIGHTS



Finally for the factor Number of Godowns, Faridpur comes up to the third position, replacing Jhenaidah, and for the factor Land Price, Joypurhat comes up replacing Jhenaidah. This can be seen in the following two graphs:

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FIGURE 3. REPRESENTATIVE SENSITIVITY ANALYSIS GRAPH FOR ALTERNATIVES CHANGING SLIGHTLY AFTER CHANGING THE WEIGHTS

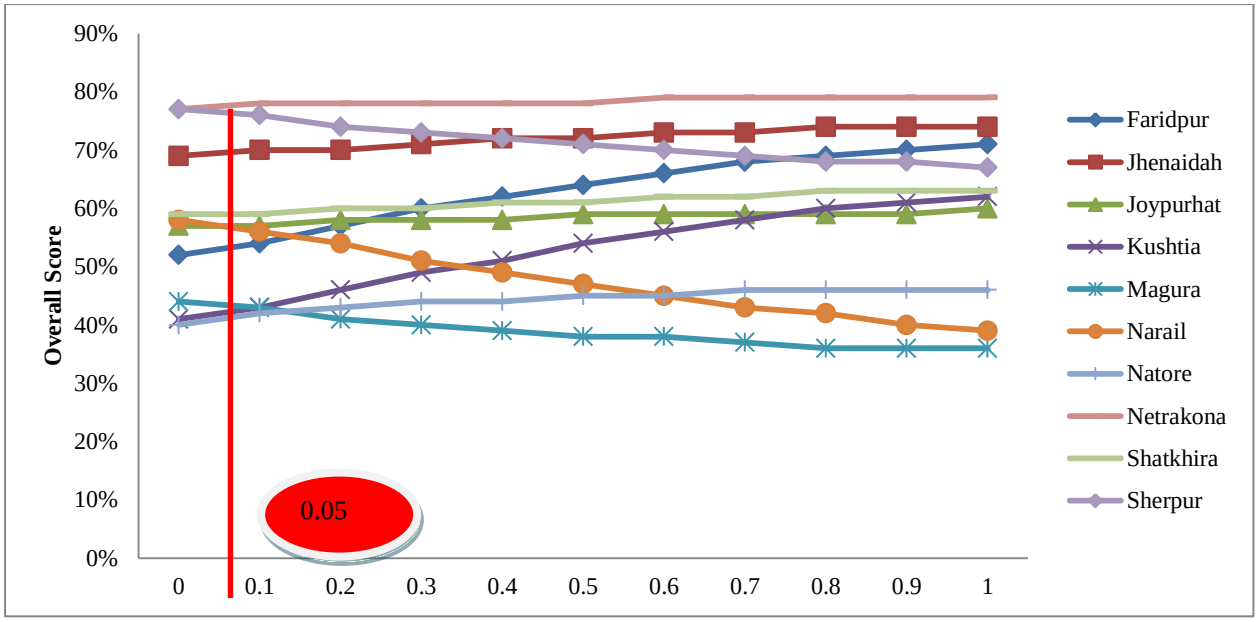
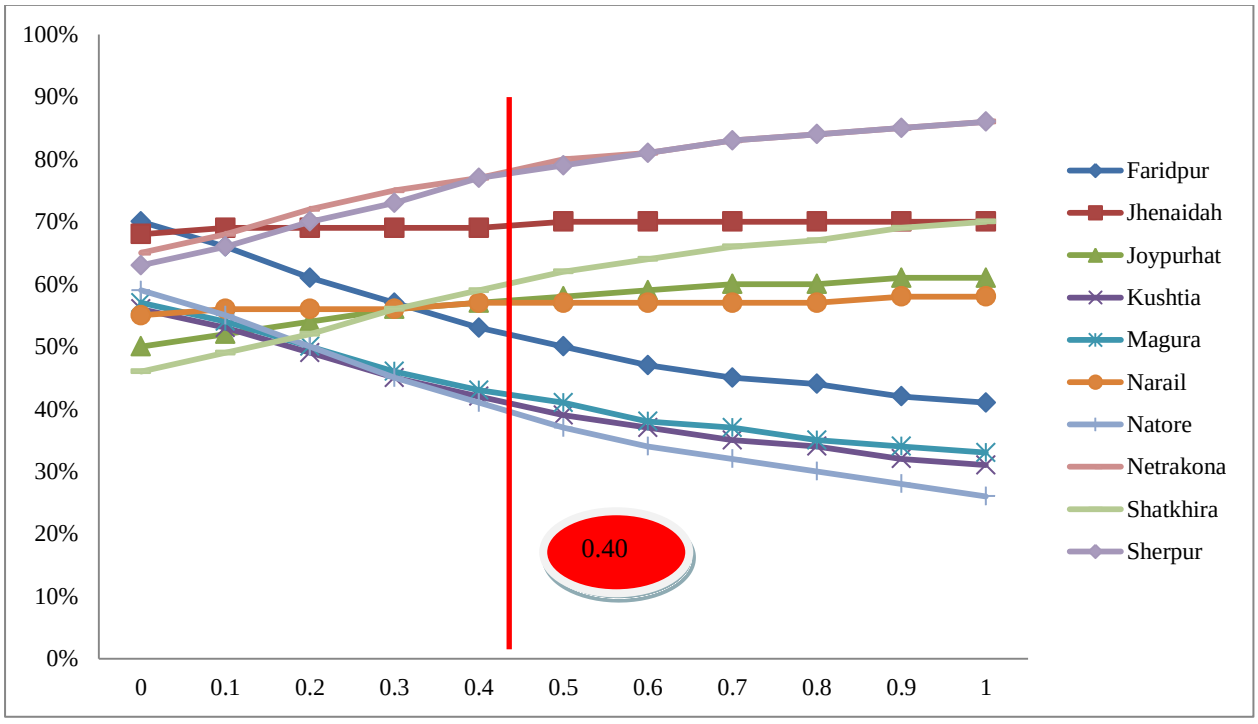


FIGURE 4. REPRESENTATIVE SENSITIVITY ANALYSIS GRAPH FOR ALTERNATIVES CHANGING SIGNIFICANTLY AFTER CHANGING WEIGHTS



For the risk taking and risk averse preferences of the decision maker scenarios, the sensitivity analyses yielded the same set of results, confirming the fact that the weights conferred upon were independent of the decision makers risk preferences, rather focusing on the importance of the criteria involved, as according to the literature of the pairwise comparison (Hodgkin, Belton and Kouluri, 2005).

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Recommendations for the case

Based on these sensitivity analysis, it can be concluded that the initial ranking based on the criteria are good enough for the location decision because the ranking does not change even after changing the weights much. Although for three criteria, the ranking did change, and so it would be suggested to the decision maker to consider the options of Faridpur and Jhenaidah to do further sensitivity analysis, and also to gather more information regarding these two locations so to ensure whether either of them should be included when speculating the possible location of a strawberry syrup plant.

OUTCOMES OF THE RESEARCH AND FURTHER DIRECTIONS

This paper is based on the use of Multi-criteria Decision Analysis to find out a ranking of three locations which are suitable for the placement of a strawberry syrup manufacturing plant for Haque Brothers Industries Limited. Normally decisions for location is taken by other methods and not much have been done using MCDA, and as such, this paper initially sets out to justify the use of MCDA in such a context.

For the problem that has been described in this paper, it is recommended for the decision maker to carry out a bit more extensive and collectively exhaustive set of sensitivity analysis so as to make sure that everything has been taken into account. This would include changing the weights of more than one criteria at a time and see what happens to the ranking. Also, there were four assumptions taken when creating this model, as including these factors in the study was beyond the scope of this paper. So the decision maker is encouraged to get details with these criteria as well and see what happens to the final ranking, so that the final decision is taken on very concrete evidence. Finally, if the company is thinking of establishing a plant, a further financial feasibility study is recommended, because the aspect of cost, possibilities of loan, tax structure, and the discounted returns have not been looked into in this model or the paper. As such, a detailed financial model of the top three ranked alternatives can give the decision maker one choice of a location to base the final decision on.

The paper proves that MCDA can indeed act as a good tool to zero in on a location for a business or economic unit for an organization, but it also suggests use of extensive sensitivity analysis to make sure of the completeness of the study. And the paper also introduces the use of a risk reaction spectrum, a form of sensitivity analyses for the whole MCDA model which involves carrying out the decision for a risk neutral decision maker, and for a similar context, an extreme risk averse decision maker and an extreme risk taking decision maker. This will in turn provide the decision maker not only with a ranking of locations to set up a business unit, but it will also provide a decision maker to evaluate his/her risk standpoint and then generate a set of results simply from the spectrum graph provided. As such, the result of this analysis has increased versatility in terms of having the results of different sorts of decision makers incorporated in the spectrum.

Finally, this paper has just highlighted the usability of MCDA to determine the location of a business unit. Further research can be carried out in order to further develop an effective tool incorporating MCDA as a location decision making tool, satisfying the underlying assumptions of MAUT and MAVT. Also another direction of further research that this paper brings to attention is the further development of this risk reaction spectrum, which was a novelty suggested in this paper. The development of such a continuum will help in making a concrete decision on the location choice, regardless of the decision makers preference, and can a new set of sensitivity or scenario analyses for MCDA.

APPENDIX A: DESCRIPTION OF THE CRITERIA SELECTED FOR THE PAPER

Physical factors:

- *Proximity to Market and from Raw Materials:* The distance from the market is calculated and the cardinal value is used to measure the performance.
- *Land Price:* The performance of alternatives is measured in an ordinal scale of five values: *Very High, High, Medium, Low and Very Low.*
- *Number of Go-downs:* It is important to know about the storage facilities because higher loads of the raw material can be brought in using economically efficient transport, reducing the manufacturing costs.
- *Utility Availability:* With the initial assumption that the electricity needed to run the plant will be generated by the company itself, this criterion is measured in terms of gas supply availability. An ordinal scale is used, which has values from best to worst such as: *Excellent, Improved, Developing and Acceptable.*

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Human Based Cost Factors:

- *Transportation cost of raw materials and finished goods:* Similar to the proximity factor, these are measured in terms of the costs.
- *Agglomeration Tendency:* Whenever there are many industries clustered in one area, it is a good idea to establish a factory in that area as the benefits of an industrial area can be shared by many industries. These benefits can be in terms of utilities, common production materials, common repair facilities, industrial carrier truck parking, good pool of labor etc. (MacCarthy and Atthirawong, 2003). For this paper, the number of industries in a certain area is taken into account.
- *Average Labor Wage:* The average labor age differs from different parts of the country, and it is a cost factor.
- *Literacy Rate and Number of College Students:* The higher the literacy rate of an area, the better trained and educated the workforce. It is measured in terms of percentage of the population.
- *Kilometers of Metal Road:* This is an interesting criterion. A higher value for this criterion will mean that the carrier trucks can travel faster and more smoothly, leading to lesser travelling and also lesser need for maintenance.
- *Population:* Largely populated and dense areas are bad for factory set-ups, as it becomes harder for the plants to dispose of their waste products and also increases the level of pollution. As such, even governments encourage plants to be set up in areas away from populated zones. (MacCarthy and Atthirawong, 2003).

Government Factors

- *Development Projects in Food Sector:* Similar to the agglomeration tendency, development projects in the food sector will actually have a positive effect in both improving the quality of the strawberry syrup and also the cost of it.
- *Political Stability:* This is another very important factor of location of an industry or a plant in Bangladesh, as the political situation sways quite a lot in the country, leading to strikes, road blockages and many other problems which disrupt a smooth production schedule. This criterion is measured in the ordinal scale, where values from best to worst are: *Very Stable, Stable, Somewhat Stable, Unstable and Very Unstable*.

APPENDIX B: DATA COLLECTED FOR THE SATISFICED ALTERNATIVES

FIGURE 5. DATA ON CRITERIA FOR ALTERNATIVES PART 1

		Proximity to Market	Proximity from Raw Materials	Land Price	Gas Supply	Number of Godowns
Alternatives	Faridpur	101	217	High	Excellent	32
	Jhenaidah	178	168	Medium	Improved	30
	Joypurhat	249	116	Low	Acceptable	24
	Kushtia	183	122	High	Improved	34
	Magura	150	194	High	Improved	11
	Narail	130	247	Low	Excellent	10
	Natore	210	46	Very High	Developing	16
	Netrakona	158	277	Very Low	Improved	29
	Satkhira	240	285	Very Low	Developing	28
	Sherpur	188	247	Very Low	Developing	20

FIGURE 6. DATA ON CRITERIA FOR ALTERNATIVES PART 2

		Transportation cost of raw materials	Transportation cost of finished goods	Number of Industries	Average Labor wage	Literacy Rate
Alternatives	Faridpur	4356	3196	14	8457	37.44
	Jhenaidah	3937	4037	16	8487	25.95
	Joypurhat	3649	4979	7	7214	60.29
	Kushtia	3693	4303	14	9878	90.9
	Magura	4435	3995	10	7414	28.5
	Narail	5315	4145	10	7164	35.65
	Natore	2838	4478	11	8028	27
	Netrakona	4389	3199	8	8478	34.94
	Satkhira	5058	4608	23	8959	30.35
	Sherpur	4249	3659	5	6851	32.4

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FIGURE 7. DATA ON CRITERIA FOR ALTERNATIVES PART 3

		No. of College Students	Kms Of Metal Roads	Population	Development Projects	Political Stability
Alternatives	Faridpur	48502	441	1,714,496	16	Somewhat Stable
	Jhenaidah	49167	450	1,579,490	98	Very Stable
	Joypurhat	30230	110	844,818	5	Unstable
	Kushtia	67614	264	1,713,224	3	Very Unstable
	Magura	33744	73	811,160	43	Very Stable
	Narail	30024	89	689,021	1	Very Unstable
	Natore	42586	266	1,521,359	26	Somewhat Stable
	Netrakona	48854	141	1971240	164	Very Stable
	Satkhira	55813	244	1,843,194	24	Somewhat Stable
	Sherpur	25682	149	1246511	159	Very Stable

APPENDIX C: GRAPHS SHOWING CHECK OF DOMINATION IN PREPROCESSED DATA

FIGURE 8. CHECKING FOR A DOMINANT ALTERNATIVE THROUGH PROPORTIONAL TRANSFORMATION

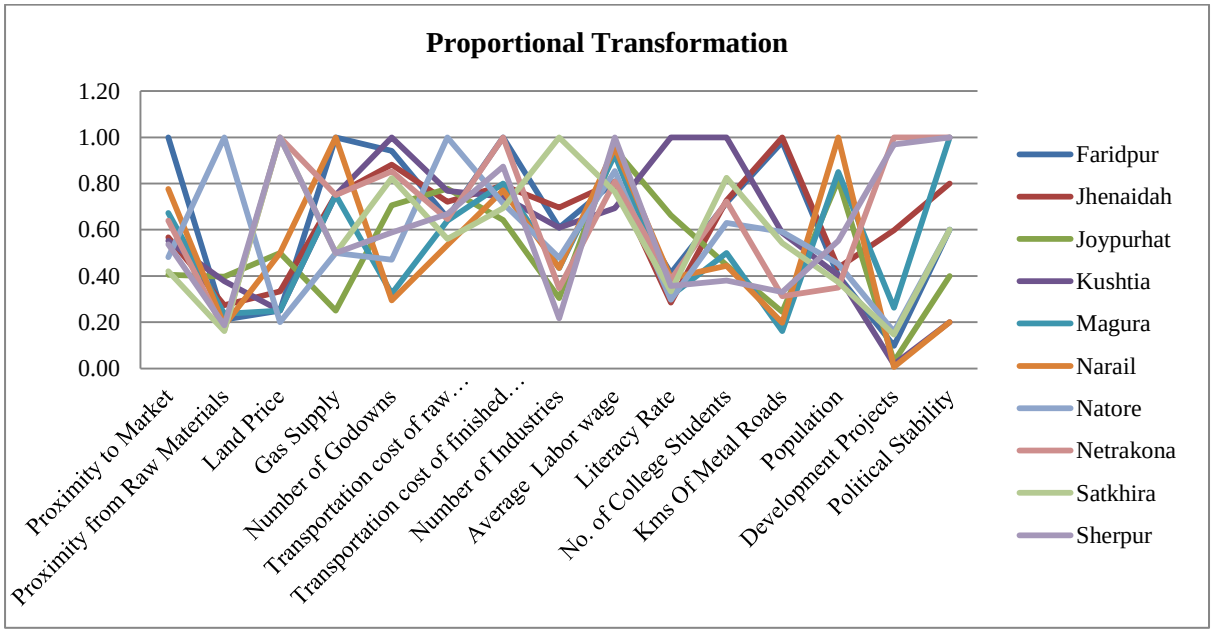

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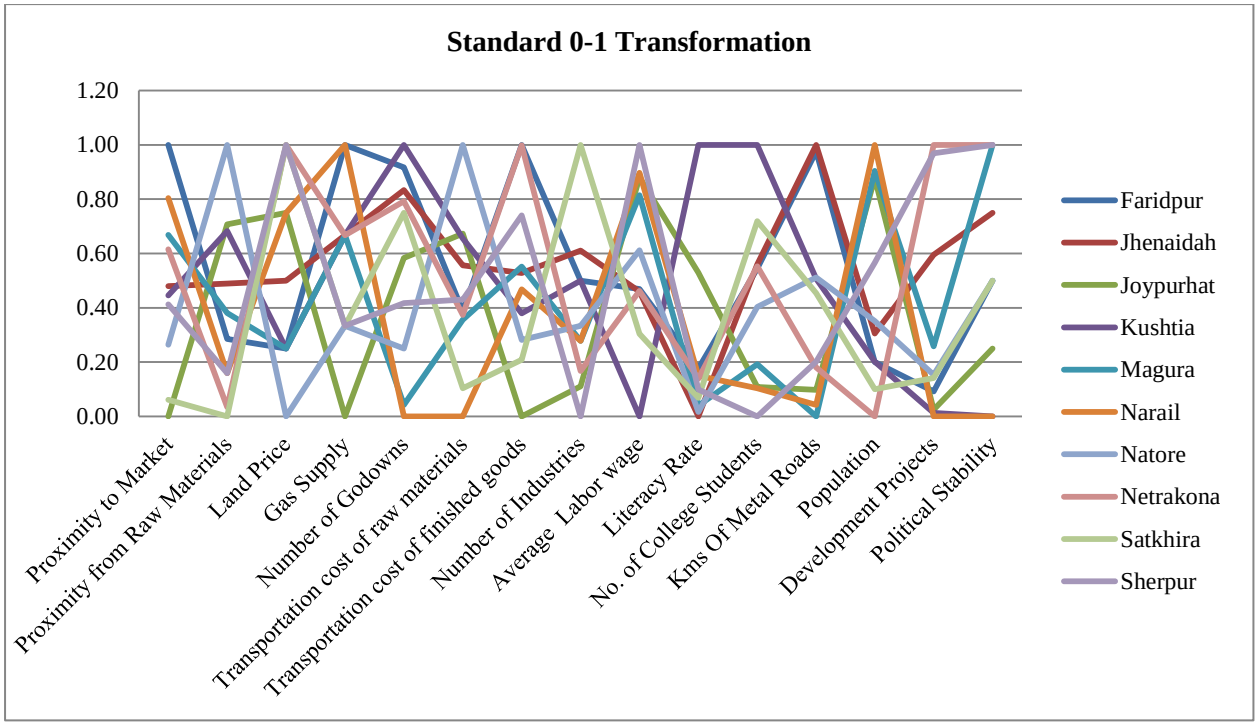
FIGURE 9. CHECKING FOR A DOMINANT ALTERNATIVE THROUGH STANDARD 0-1 TRANSFORMATION



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