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# The Usage of Influence Diagram for Decision Making in Textiles

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**Abstract**

Naturally, managers are frequently faced with decision making processes. The optimal solution of the decision making process rises to the for which in itself depends on the number of decision alternatives and state of the worlds which in themselves may affect the decision alternatives. The scenarios or possibilities faced in decision problem are interlaced to a graphical technique commonly refered to as decision tree to which managers confer to be guided. In this study, the influence diagram, which is similar to a decision tree but also provides room for the decision maker to include extra information about the relationships between variables, is reviewed. An example decision problem is used to show the usage of the influence diagram within the context of Textiles industry.

**Keywords:** decision, decision tree, influence diagram, interaction, textiles

## 1. Introduction

Decision making is the process of choosing the appropriate the decision alternatives which is anticipated to contribute highly to the solution, in order that a certain goal is achieved or a problem is deciphered. The decision process includes distinct steps which lead to the desired results. As such, the decision process consists of steps that include identifying the problem, identifying the state of the worlds on which the decision maker may or may not have control, determining the alternatives relevant to the solution of the problem and the advantages derived from these alternatives, assigning the probability values of the uncontrollable elements, if possible, and choosing the optimal alternative in line with the collected data, and finally using certain decision criterias to solve a payoff matrix. A detailed study of techniques employed in decision making problems can be found in many decision theory and management science books (Wald, 1950; Barnard et al, 1953; Sezen, 2004; Meredith et al, 2002; Clemen, 1996).

In literature there are number of studies related with influence diagrams and decision tree from different scientific areas. Yavuz et al (2007) uses decision tree to select a global manufacturing facility and provides the influence diagram of the problem; In their study the emphasis is made on that decision makers should not ignore the influence of qualitative factors such as stability, labor skill, etc. in addition to economic factors related to host country for the location of a factory. Tabernier et al (2010) shows that the influence diagram can be used for representing complex systems and applies the graphical technique to understand the environmental impact of atm. Carriger et al (2011) proposes an influence diagram approach for ecological risk-based decisions about pesticide usage. Bielza et al (2011) reviews of representation issues and modelling challenges with influence diagrams, particularly looks at the representation of asymmetric decision problems including conditional distribution trees, sequential decision diagrams, and sequential valuation networks. Ünal et al (2007) reviews the decision making techniques in apparel industry and shows its importance for Textiles. In their study the usual decision making process is applied to solve the problems such as new investments and purchase of new sewing machines, furthermore the decision tree representation of the problems are drawn and interpreted but the usage of the influence diagram is not mentioned.

In this study, two of the graphical techniques used to solve decision problems are studied, namely, the Decision Tree and the Influence Diagram. Firstly, these graphical techniques are reviewed and then an example from a Textiles industry is put to the test.

## 2. Materials and Method

In this study, a data set provided by Reynolds and Lancaster (2007) for a small sized textiles company is studied. Although supplied data set is genuine, the company name was changed. Reynolds and Lancaster (2007) shows the decision making process under uncertainty for a small company, examplifies the Bayesian approach to solve the decision process via decision tree. In our study one of the aim is to make a contribution to their study and also to researchers, managers, and decision-makers, by showing the usage of the Influence Diagram and its suitability to Textiles' decisions.

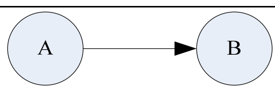
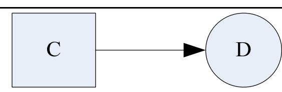
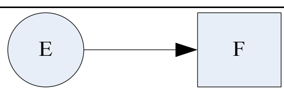
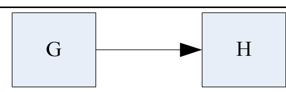
The Decision Tree can be defined as a graphical technique that evaluates all possible decision alternatives, all state of the worlds that may have an impact on these decision alternatives, and every single possible consequence based on the combination of state of worlds and decision alternatives. The Decision Tree also provides the decision-maker to see the decision problem clearly through geometrical symbols such as lines, squares, circles (Sezen, 2004). The elements of the Decision Tree are decision nodes, chance nodes, branches with payoff values and probabilities of the state of the worlds (Meredith et al, 2002). During the solution phase of a decision tree, expected values are calculated for each decision scenario and added to decision tree (Gordon et al, 1983).

The Influence Diagram presents decision problem in the form of a non-circular, directed graphic derived from nodes and directed arcs that interconnect with these nodes (Howard and Matheson, 2005). The problem is presented in three levels which are relational, functional and numerical (Smith et al 1993). It is a fact that when a decision tree have too many decision alternatives and chance variables, it turns into a very complex structure. Influence Diagram is an approach suggested by Howard and Matheson (2005) in order to present a type of statement that summarizes the general structure of the problem, and not an unclear tree form and also carrying the functional relationships between the variables. The different relational levels for the influence diagrams are summarized in the following paragraphs.

*Relational Level on Influence Diagram:* Variables in the problem are symbolized by various node types and the decision problem elements presented through non-circular graphic consisting of nodes and directed arcs that interconnect with the nodes (Diehel and Haimes, 2004). In the relational level of influence Diagram, basically three types of nodes and two types of arc are used.

- *Decision node*; symbolized by a square or rectangular. It represents variables under a decision-maker's control and modeling of decision alternatives the decision-maker has.
- *Chance node*; symbolized by a circle or an ellipse. It represents the random variables and therefore the uncertainty included in the problem.
- *Value (utility) node*; symbolized by a diamond shape. It models the quality that will identify the best decision to be accepted, and generally represents the anticipated benefit of the consequence.
- *Conditional arc*; is the arc directed towards the chance node or the value node. An arc pointing at the chance node implies that chance node probability is conditionally dependent on the input node. An arc directed to a value node partially identifies the value of the node along with input node outcomes.
- *Informational arc*; is the arc directed to a decision node. When a decision node is decided upon, the decision-maker is aware of the consequences of the previous decision or the uncertain variable. Different arc samples in Influence Diagrams are shown in Table 1 (Diehel and Haimes, 2004).

Table 1. A summary of different directed arcs in influence diagrams

| | |
|---|---|
|  |  |
| The probabilities associated with chance variable B depend on the outcome of chance variable A. | The probability of chance variable D depends on decision variable C. |
|  |  |
| The decision maker knows the outcome of chance variable E when decision F is made. | The decision maker knows the decision G when decision H is made. |

As it can be seen in Table 1, an arc referring to a chance variable represents the presence of a conditional probability distribution for the chance variable at the end of the arc. An arc pointing to a decision variable expresses what is already known by the decision-maker at the time when an event related to this decision variable is chosen. Finally, the arc that is directed towards the value node determines the definition set of utility function (Howard and Matheson, 2005).

Functional Level on Influence Diagram: At this level, alternatives for each decision node and probability distribution and likelihoods for every chance node are determined (Diehel and Haimes, 2004).

Numerical Level on Influence Diagram: This is the level where real numbers relating to probability function and utility values are determined (Diehel and Haimes, 2004).

Relationships Between Nodes on the Influence Diagrams: Figure 1, reflects a simple single stage decision situation's influence diagram that includes chance, decision and value nodes. Decision alternatives are $d_1$ and $d_2$, and the chance node has the outcomes $x_1$ and $x_2$. The arcs show that the chance node is independent from the other nodes. Thus, only $P(x_1)$, $P(x_2)$ probabilities are assigned. The utility function $u(d_i, x_j)$ depends on both decision and chance nodes (Virtanen et al, 2004).

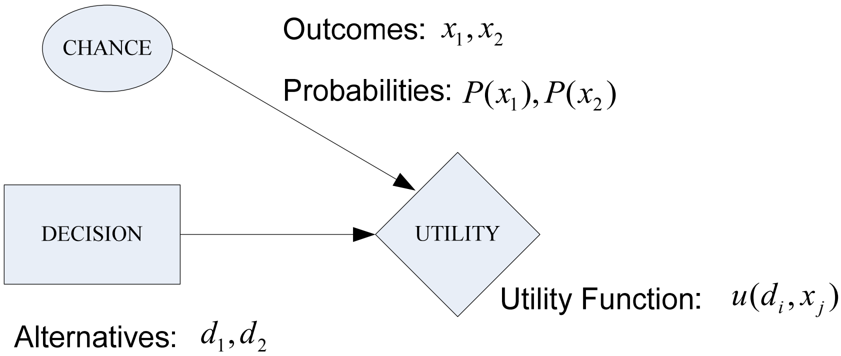



Figure 1. A single stage influence diagram

Solution Process of Influence Diagram: The first solution approach suggested for the influence diagram is to reach the solution by converting the influence diagram into a decision tree and solving this tree as suggested by Howard and Matheson. However this approach brings the problem that the number of variables in the problem increases almost exponentially and thus, calculation effectiveness evantually decreases. In the technique developed by Shachter (1986), nodes in the influence diagram are deleted one by one till the one node that shows the expected utility remains, afterwhich the expected utility value is calculated. The solution process includes a series of transformations that Shachter (1986) calls value-preserving reduction. A node will be said to be removed from the diagram if it is eliminated through some value preserving reduction. There are two kinds of reductions; remove nodes and reverses arc.

Node Removal Process: The chance and decision node removals are based on Olmsted's studies, but are really just the basic steps in evaluating a stochastic dynamic program (Bellman, 1957). The arc reversal processes are realized in accordance with the Bayes' Theorem (Shachter, 1986) as follows:

- *Barren Node Removal***:** A chance or decision node will be called a barren node if it is a sink, that is, it has no successors. No matter what value is assigned to the barren node variable no other node is affected, so it may be removed from the diagram.
- *Chance Node Removal:* Given that chance node $i$ directly precedes the value node and nothing else in an oriented, node $i$ may be removed by conditional expectation.
- *Decision Node Removal:* In the influence diagram, when it is known that all barren nodes have been removed, the decision node $i$ is the conditional predecessor of value node and all other conditional predecessors of value node are informational predecessors of node $i$ , then node $i$ will be removed by maximizing expected utilitiy, conditioned on the values of its informational predecessors.

Arc Reversal Process: Given that there is an arc (i, j) between chance node i and j, but no other directed (i, j) path, arc (i, j) can be replaced by arc (j, i). Both nodes inherit each other's conditional predecessors. In order to reverse an arc that is directed from chance node i to chance node j, firstly, conditional probability functions associated with node i and j are multiplied, then the share of random variable i in this multiplication (which is called marginal) is obtained and this marginal is associated with variable j, and finally, the multiplication value is divided to the marginal, and the result is associated with variable i. In the solution process of influence diagrams, how the nodes relate to their predecessors and consequents are really important. Steps included in the approach developed by Shachter (1986) to solve influence diagram are as follows (Clemen, 1996):

1. Initially, it should be checked whether the influence diagram is ready for solution. For this purpose, firstly, it should be made sure that there is only one single value node (or a series of value nodes that feed into one "super" value node) in the influence diagram and that there are no cycles. Later, the influence diagram is checked for barren nodes and if there are any, they are removed.

2. If a chance node exists with the value node as its successor, remove this chance node with the modified transformation. If any nodes remain in the diagram return to step 2.

3. If there exists a decision node that is a direct predecessor of the value node are informational predecessors of the decision node, remove this decision node with modified transformation and eliminate any barren nodes. If any nodes remain in the diagram return to step 2.

4. Find a chance node i that is a direct predecessor to the value node such that it has no decision node successors.

5. Find a chance node j that is a direct successor of i such that there is no other directed path between i and j reverse the arc between i and j. If chance node i has any other successors repeat step 5.

6. Remove chance node i with the modified transformation. If any nodes remain in the diagram return to step 38.

After removing a node of any kind, arcs that are directed from the predecessor of the removed node are added to the consequents of the removed node (Owens et al, 1997).

In the following section, the decision tree and influence diagram approach will be shown for a Textile companies decision making process.

**3. Results and Discussion**

In this study a data set prepared by Reynolds and Lancaster (2007) for a small sized company is investigated in detail. In their study, Reynolds and Lancaster (2007) examines the techniques used in making prospective marketing estimations for small companies and they mention the utility of Bayesian decision making for these estimations. For this purpose, they provide a decision problem cautioning that due to commercial worries, original name of the company and name of the export country was changed. The company from which the data gathered is a small textiles company that operates in The United Kingdom. The company produces carpets. The currency involved is the English pound. A special type of carpet they produce is sold for a price of £32 per square meter in the U.K. The product of the company is considered to fall into the category of luxury commerce item in the United Arab Emirates and sold for a price of £56. Since the product is accepted to be a luxury item, the prices are influenced by the state of economy in export country. The company management is expecting a recession (decline) in the U.A.E. economy. It is stated by company authorities that the next 12 months are important for the orders placed. There is an economical recession (decline) anticipation based on local inflation and low commercial values. The company will export its product immediately or it will wait for another 6 or 12 month to do it. The executives of the carpet company foresee three different scenarios for the U.A.E. These are stable economical conditions, slightly worse condition and severely bad conditions. The pay-off matrix for the problem and probabilities assigned by the company authorities for economical state are given in Table 2. In each cell are profit values that can be gained under various conditions of state of nature and decision alternatives are displayed.

Table 2. Pay-off matrix for Quality Wilton Ltd. (£)

| | | **State of Natures** | | |
|---|---|---|---|---|
| | | **Economical State Same (A) (P=0.40)** | **Economical State Slightly worse (B) (P=0.30)** | **Economical State Severely Bad (C) (P=0.30)** |
| **Actions (Decision Alternatives)** | **Export now** | 2726000 | 1870000 | -711000 |
| | **Export with a 6 months delay** | 2357000 | 1694500 | 900500 |
| | **Export with a 12 months delay** | 210000 | 1425000 | 766000 |

For this matrix whose result matrix is given in Table 2, decision tree drawn by Insight Tree Software from Visionary Tools and the full solution of the tree are presented in Figure 2. According to the results obtained from the decision tree, the optimal solution has turned out to be the "export with a 6 month delay" option.

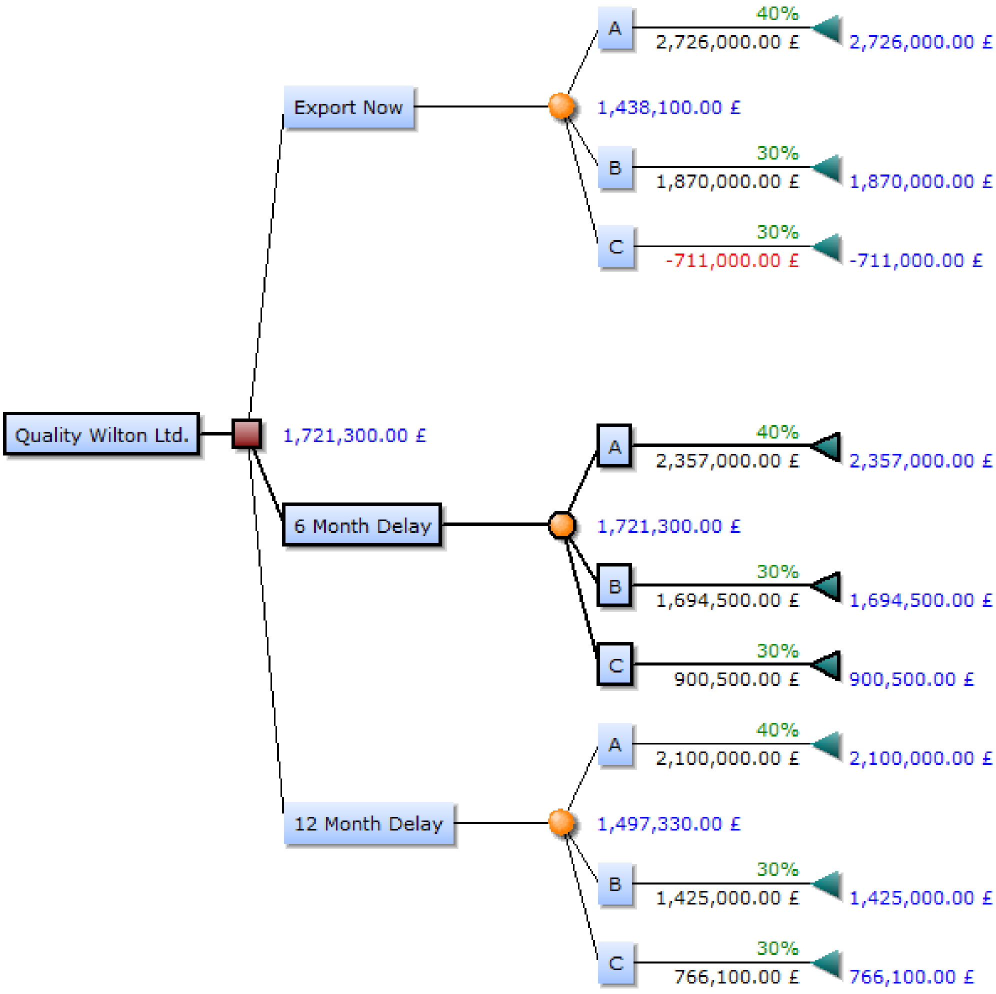



Figure 2. Decision tree and optimal solution for Quality Wilton Ltd.

If the company chooses this option, then the expected monetary value is £1,721,300.

The same problem can be solved with the influence diagram approach, also. To do so, the first step would be to express the problem graphically at relational level. Accordingly, the influence diagram for Quality Wilton Ltd.'s decision problem is displayed in Figure 3.

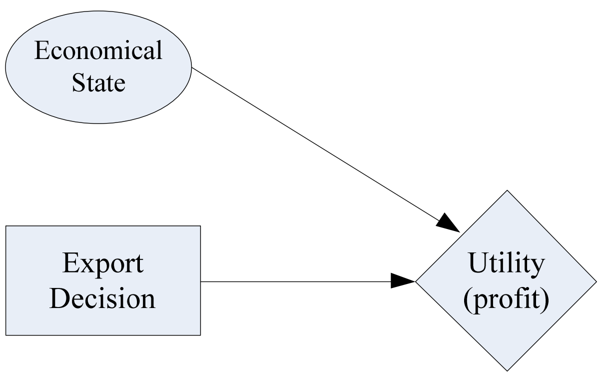



Figure 3. Influence diagram for Quality Wilton Ltd. (relational level)

Arrangement of functional level and numerical level information are given in the next part as the 2nd and 3rd steps to complete the expression of the problem.

*Functional Level*:

Alternatives for export decision (alternatives for decision node):

- Export now
- Export with a 6 months delay
- Export with a 12 months delay.

Probability values for economical state (probability values for chance node):

- Probability of economical state staying the same 0.40
- Probability of economy slightly worse 0.30
- Probability of economy going severely bad 0.30.

*Numerical Leve*l is shown in Table 3.

Table 3. The numerical level's data table for Quality Wilton Ltd.

| | Economical State Same (A) | Economical State Slightly Worse (B) | Economical State Severely Bad (C) |
|---|---|---|---|
| **Export now** | 2726000 | 1870000 | -711000 |
| **Export with a 6 months delay** | 2357000 | 1694500 | 900500 |
| **Export with a 12 months delay** | 210000 | 1425000 | 766000 |

Once the three levels of the problem are completely unfolded as above, the solution phase of influence diagram begins. The solution table shown in Table 4 is generated by applying the steps in the solution process mentioned before. As can be seen by examining the table, the optimal policy is the same as the optimal policy reached through the decision tree, and is to export with a 6 months delay and make a profit of 1,721,300 £ since it is the expected monetary value.

It is natural for the two solutions to point to the same result, because there is no change in the conditions. The greatest asset of presenting the problem with the influence diagram approach is that the graphical expression for the problem is brief and simple (as can be easily seen in Figure 3). In the decision tree approach, the fact that all details about the problem are given on a graphical display may cause the problem to look even more complicated. On the other hand, dependency relations among variables in the problem can be seen in the relational level of the influence diagram much more clearly than in the graphical display of decision tree. Finally, solution table presents the calculations more neatly and clearly on decision tree.

Table 4. The influence diagram solution table for Quality Wilton Ltd.

| Export Decision (İK) | Economical state (ED) | Utility (v) | Probabilities for Economical States P(ED) | v*P(ED) | Utility Value after Chance variable is removed (v1) | Optimal policy |
|---|---|---|---|---|---|---|
| **Now** | Same | 2726000 | 0.40 | 1090400 | | |
| **Now** | Slightly worse | 1870000 | 0.30 | 561000 | 1438100 | |
| **Now** | Severely bad | -711000 | 0.30 | -213300 | | |
| **6 months delay** | Same | 2357000 | 0.40 | 942800 | | 1721300 |
| **6 months delay** | Slightly worse | 1694500 | 0.30 | 508350 | 1721300 | & |
| **6 months delay** | Severely bad | 900500 | 0.30 | 270150 | | 6 Months |
| **12 months delay** | Same | 2100000 | 0.40 | 840000 | | |
| **12 months delay** | Slightly worse | 1425000 | 0.30 | 427500 | 1497330 | |
| **12 months delay** | Severely bad | 766100 | 0.30 | 229830 | | |

## 4. Conclusion

Even though decision trees are very useful graphical techniques in which all the elements of a decision problem are shown in a single graphics, they also brings along a complexity due to the fact that all decision alternatives to emerge are shown all in one place. If there are too many decision alternatives and state of the worlds then the decision tree can quickly become very big and complex. The Influence diagram, however, is out of this complexity, and is useful to see the general outline or elements of the decision making problem that is faced. Notably, it is useful because it includes little statistical information, instead, it briefly presents general details of the problem and elements that affect the company's decision-making process. Influence diagram, which executives, who want to plan their future by seeing a broader outline of the problem, but not all of its elements, can easily use, can present the same mathematical solution as the decision tree. In addition, influence diagrams have the strength of showing dependency relations among variables. The influence diagrams are not difficult to draw and the managers in Textile industry may benefit from the influence diagrams since the graph retains the functional relationships between the variables in decision problem.

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