# Investigation of the Effect of Decision Matrix on Industrial Engineering Students' Descision Making Skills

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**Abstract:** Business world expects engineers to make accurate and reliable decisions on complex problems in multiple environments. Engineers need to rely on scientific techniques and be reliable in their decision-making processes. In this study, decision matrices were used as a method of multi-criteria decision making. This study was carried out with the participation of 37 engineering faculty students. At the first phase, students were given multi-criteria problems and they were expected to decide these problems intuitively and then check their decisions by using decision matrix. In the second phase, the relationship between the engineering students' decision making skills and decision making styles was examined. Data were obtained from Melbourne decision making questionnaire and decision matrix for 4 different scenarios by using survey method. No significant relationship was found between students' Melbourne test results and decision matrices results. The correlation between students' Melbourne questionnaire results and decision matrices results was found to be very low. These results indicate that engineering students will change their intuitive decisions on different real life problems if they use decision making tools like decision matrices. Using decision matrices will enable engineering students to give more realistic decisions about real life problems according to given criteria.

**Keywords:** Decision-making; Decision matrix; Decision-making style; Problem solving; Multi criteria decision making

## I. Introduction

The decision is a process that goes through various stages. The stages of the decision-making process should be known in order to reach an effective decision (Karakaya, 2003). Decision-making is to choose the most appropriate one for the purpose of the decision-maker in the face of various alternatives.There are many factors affecting this process. These are objectives, decision-makers, natural conditions, options, the results of options and choosing among options (Tekin, 2004). The characteristics of the decision-maker are the most important factors in decision-making. If the decision maker uses his/her own intuition, belief and imitation skills together with scientific methods, his/her decision will probably be correct and the results will be positive.In multi-choice situations, there may be different approaches to decision-making due to the complexity of the situation.

Various models are used in engineering decision making. These models are classified as: decision-making under certainty, decision-making under uncertainty, decision-making under risk, decision-making under partial knowledge and decision-making under competition (Sezen, 2004).

### I.1.Decision matrix in multi criteria decision making

Decision matrix is a simple and useful tool to be used in multi criteria problems. Decision matrix-based methods are perhaps one of the most popular decision-making approaches used in industry. It is potentially effective and simple to use and has no drawbacks. For effective usage of decision matrix, the rating factors should be determined as objectively as possible and the weighting factors should be determined to reflect the priority among the design criteria. The method should help to make an appropriate decision rather than dictate the decision. The final decision should not be made solely on the results of the decision matrix. The value of a decision matrix is that it forces us to consider various alternatives carefully and thoughtfully. It is important to recognize that there is a certain uncertainty and subjectivity that can lead to faulty results in choosing the best choice. An important lack of the decision matrix method is that it does not take into account of uncertainty.

The columns in the matrix indicate the criteria in the given problem and the rows indicate the alternatives. Decision matrix in multi criteria situations is the process of finding a meaningful indicator from multidimensional data in order to evaluate alternatives (Doğan, 1985; Cheney, 2009; Heo et al.2012; Ho, 2008). Multi-Criteria decision-making (MCDM) problems have 3 types which are selection, classification and ranking (Vassilev, 2005). Selection problems; to determine the best among the alternative purposes, or to make the best choice from a set of difficult or equal weights with many alternatives. Briefly, the right alternative is to be selected from within the alternative set. Classification Problems; alternatives are classified according to specific criteria or preferences. The aim is to bring together alternatives that show similar characteristics and behaviors. Ranking Problem; alternatives can be measured or identified from good to bad in sequencing problems (Yıldırım & Önder, 2014). Today, new decision-making methods are preferred in cases where there are multiple criteria such as industrial enterprises, engineering design and production processes, defense industry, material selection and procurement, construction sites, patient treatment methods selection, socio-scientific issues (Öztel, 2016., Kul et al. , 2014).

Decision matrices are used in many areas, especially engineering areas, which require multiple decision-making. Therefore, decision-making skills of engineering students need to be supported.

## II. Materials and Methods

Problems of this study;

1. Do decision matrices have an impact on the use of decision matrix for industrial engineering students to make decisions in multiple situations?
2. Is there a relationship between the decision-making styles of industrial engineering students and the decisions that they make by using decision matrix?

**Method:** The research design is composed of a mixed method, in which quantitative data is supported by qualitative data.

**Participants:** The study group consisted of 37 students studying in the industrial engineering department of engineering faculty of a private university.

### II.1 Data Collection Tools

#### II.1.1. Melbourne Decision Making Scale

Melbourne Decision Making Questionnaire was developed by Mann et al. (1998). The Melbourne Decision Making Scale is divided into two parts. The first part aims to determine self-esteem (self-confidence) in decision making. It consists of six items and items 1, 3, 5 are straight; Items 2, 4, 6 are reverse coded. Scoring is done as "True" response gets 2 points, "Sometimes True" response gets1 point, "Not True" response gets 0 points. The maximum score that can be obtained from the scale is 12. High scores indicate high self-esteem in decision-making. Second section consists of 22 items and measures decision-making styles. Second part consists of 4 types of decision making style namely, Vigilance(careful) decision making style, Hyper vigilance (avoidant) decision-making style, Procrastination (procrastination) decision-making style and Buck Passing (panic) decision-making style (Taşgit, 2012).

#### II.1.2. Decision matrices

In this research, 4 matrices were used for 4 problems. The criteria and options of the matrices were prepared by the researcher. In determining the weights of the criteria, the most important (percentage maximum), equally significant (same percentage value) and least significant (minimum percentage) were given. When scoring options, the best solution (maximum score), equal value solution (equal score) and least valuable solution (minimum score) were determined. Below is an example matrix.

The Ministry of Energy wants to store the energy obtained. There are 4 different methods for this. These;

a. Energy storage in chemical bonds (Hydrogen storage)
b. Compressed air energy storage
c. Pumped Storage Hydro Power Station
d. Lead acid batteries

Which one would you prefer? Why?

### II.2. Research Application

In the first stage of the study, Melbourne Decision Making Scale was given to the students. The students were asked to complete the Likert type scale. In the second stage, students were asked to decide 4 problems without using matrix. In the third stage, they were asked to decide by using decision matrices.

**II.3. Application of Matrices**

The criteria and options of the problems are given to the students. Firstly, the students determined their percentage weight by 100 (10%, 30%... etc.) according to the criteria and then gave 1 to 4 points according to the importance of the options. Then they multiplied the points in that row by the % weight of each criterion and reached the total score. The highest score has been that student's decision. Sample calculation of the Decision Matrix method is as below (Ustasüleyman 2009; Akkaya, 2004).

Table 1: Sample Calculation of the Decision Matrix Method

| **Criteria** | **Weight** | **Options** | | | |
|---|---|---|---|---|---|
| | | Option 1: Energy storage in chemical bonds (Hydrogen storage) | Option 2: Compressed air energy storage | Option 3: Pumped storage Hydro power station | Option4: Lead acid batteries |
| Energy storage capacity | %20 | Average ( 2 ) 40 | Average (2) 40 | Good ( 3 ) 60 | Very good( 4 ) 80 |
| Space required for storage | %10 | No special features ( 4 ) 40 | Enough underground Like a cave ( 2) 20 | Sufficient space( 2 ) 20 | No special features ( 4 ) 40 |
| Cost per KWh of storage | %30 | 2.42 tl( 1 ) 30 | 1.54 tl( 3 ) 90 | 1.32 tl ( 4 ) 120 | 1.98 tl( 2 ) 60 |
| Security risk | %40 | Fire risk 40 ( 1 ) | No risk( 4 ) 160 | Flood risk ( 3 ) 120 | Chemicals can be absorbed and mixed with groundwater ( 2 ) 80 |
| | Total 100 | 150 | 300 | **320** | 260 |

**II.4. Data Analysis**

SPSS 16.0 program was used for data analysis. Whether the data was distributed normally was examined among the factors of maintaining the same decision (not changing the decision from the beginning to the end by using two methods which are intuitive and decision matrix) and self-esteem levels of decision making, Vigilance(careful) decision making style, Hyper vigilance (avoidant) decision-making style, Procrastination decision-making style and Buck Passing (panic) decision-making style.

Kolmogorov-Smirnov test was used for the normality test because the number of participants was greater than or equal to 30 (37). When data were examined in Table 1, it was found that the significance values were close to 0 and indicated that the data were not distributed normally. The distributions were found to be unsuitable for normal distribution and nonparametric tests were used such as Mann-Whitney U, Kruskal-Wallis test and Pearson product-moment correlation analysis (Spearman test) (Büyüköztürk et al., 2012). The significance of the data was tested at $p < 0.05$ and the results were presented in table.2.

Scoring of Decision Matrices; It was scored according to the industrial engineering students' intuitive (without using decision matrix) decisions and the decisions taken by using decision matrices to find out whether there was a change between two methods in 4 different problem scenarios. According to this;

There was no decision change in all 4 scenarios will get 0 point,
1 decision was changed in 4 scenarios will get 1 point,
2 decisions were changed in 4 scenarios will get 2 point,
3 decisions were changed in 4 scenarios will get 3 point,
All decisions were changed in 4 scenarios will get 4 point.

## III. Results

Decision-making skills of multi-media decision matrix of engineering students and their scores from the Melbourne scale were analyzed and their relationships with each other were determined. The findings are presented in tables and graphs.

Table 1: Normality Test Findings

| | | Self-esteem | Vigilance style | Hyper vigilance style | Procrastination style | Buck Passing style |
|---|---|---|---|---|---|---|
| **Kolmogorov-Simirnov Statistics** | 0 | 0,313 | 0,246 | 0,316 | 0,134 | 0,206 |
| | 1 | 0,264 | 0,178 | 0,171 | 0,332 | 0,336 |
| | 2 | 0,193 | 0,309 | 0,209 | 0,183 | 0,184 |
| | 3 | 0,172 | 0,241 | 0,269 | 0,183 | 0,175 |
| | 4 | 0,175 | 0,878 | 0,253 | 0,314 | |
| **Kolmogorov-Simirnov Sig** | 0 | 0,11 | 0,877 | 0,10 | 0,200 | 0,200 |
| | 1 | 0,71 | 0,861 | 0,200 | 0,005 | 0,004 |
| | 2 | 0,200 | 0,935 | 0,200 | 0,200 | 0,200 |
| | 3 | 0,200 | 0,750 | 0,92 | 0,200 | 0,200 |
| | 4 | - | - | - | - | - |

As seen in the Table 1, the kurtosis and skewness values and branch and leaf graphs and Q-Q graphs were examined whether the data were distributed normally or not. Finally, it was concluded that the data were not distributed normally.

Table 2: Kruskal-Wallis, Mann-Whitney U and Pearson Correlation test results

| | **Kruskal-Wallis Test** | | **Mann-Whitney U** | | | **Pearson Correlation Test** | |
|---|---|---|---|---|---|---|---|
| | **Chi square** | **Asymp. Sig** | **Mann Whitney U** | **Z** | **Asymp. Sig (p value)** | **Pearson(r)** | **Sig(2 tailed)** |
| **Self-esteem decision making** | 3,632 | 0,458 | 6,500 | -1,368 | 1,171 | -0,153 | 0,365 |
| **Vigilance decision making style** | 6,051 | 0,195 | 1,000 | -2,353 | 0,19 | 0.122 | 0,299 |
| **Hyper vigilance decision making style** | 1,627 | 0,804 | 13,000 | -0,096 | 0,923 | 0,207 | 0,219 |
| **Procrastination decision making style** | 4,987 | 0,289 | 9,500 | -0,746 | 0,456 | 0,016 | 0,932 |
| **Buck Passing decision making style** | 5,779 | 0,216 | 12,000 | -0,280 | 0,780 | 0,296 | 0,076 |

Consequently, Kruskal-Wallis test was performed from nonparametric tests for the data that were not normally distributed. When the significance (Asymp. Sig) value was examined in the test statistics, a significant relationship was not found. This result indicates that when used MCDM tools like decision matrix for decision making the first decision taken by intuitive method will be differentiated significantly.

Furthermore, the median distributions of the data were examined by Mann-Whitney test and significant values were found. According to Mann-Whitney U-test results shown in Table 2, there is no significant difference between industrial engineering students' decision-making styles ($p > 0.05$).

Correlations between keeping the same decision with the self-confidence and decision making styles were tested. When test data were examined very low level of correlations were found among maintaining the same decision (not changing the decision from the beginning to the end by using two methods which are intuitive and decision matrix) and self-esteem decision making, Vigilance(careful) decision making style, Hyper vigilance (avoidant) decision-making style and Buck Passing (panic) decision-making style. In literature, correlations below 0.3 were considered very low (negligible) levels. Very low level of correlations show that the decisions made by using the decision matrix and the decisions taken by heuristic methods differ significantly from each other which will power the need of giving formal education to engineering students. It is shown that engineering students can make more realistic decisions by using MCDM tools such as decision-making matrix to solve their real life problems. Only a high-level of positive correlation (0,932) was found between maintaining the same decision and Procrastination decision-making style.

## IV. Conclusions & Discussions

There are several studies in the literature examining the importance of decision-making matrix in decision-making. Goh and Richards (1997) found that solving a robot selection problem for a company through group decision-making reduces the risk of making high-cost investment decisions. Goh and Richards (1997) stated that solving a robot selection problem for a company through group decision-making would reduce the risk in making a high-cost investment decision. Yu et al. (2000) used matrices in order to make the decision to re-operate electrical and electronic devices that have completed their economic life or to evaluate them without causing environmental pollution. Yu et al. (2000) used the matrix to make the decision to re-use electrical and electronic devices that have completed their economic life or to evaluate them without causing environmental pollution. Vincent and Bogatyreva (2005) used the matrix in group decision making and Multi-media Management System selection.

Krishnamurty et al. (2008); Chen et al. (2013) stated the importance of scientific and reliable decision making in various stages of engineering design and production process and stated the importance of decision matrices in these processes. In contrast, research (Earl et al., 2005) reported that they are not motivated enough to choose approaches that are of importance through experience such as decision matrices in everyday life. One of the main reasons is that adaptation of decision-making methods to each new problem needs to be adapted (Reich 2010). It often requires a deep transformation of the practices and habits of companies; time, knowledge, human resources and technologies involved in the implementation of these have high costs (Jetter, 2006).

As a result of the study;

1. No significant relationship was found between heuristic decision making and matrix decision making.
2. These results show that the decisions made using the decision matrix and the heuristic decisions differ significantly from each other.
3. This shows that engineering students can make more realistic decisions by using MCDM tools such as decision-making matrix.
4. Correlations between decision-making confidence and decision-making styles and the maintaining the same decision were examined. According to the correlation test results, it was found that there is no significant relationship (except Procrastination decision-making style) between the intuitive abilities of decision making by using decision matrices.
5. The causes, reasons and data reliability of high level of correlation between maintaining the same decision and Procrastination decision-making style needs to be studied for future studies.

Overall, the data show that the inclusion of the decision matrix in engineering education programs creates a value-added experience for students. Given the positive impact of the decision matrix on student performance, it is proposed to include a part of the curriculum.

Finally, the decision matrix combines different assessment options in a common denominator, allowing decision makers to make an objective assessment.

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