

## **Effectiveness of Front-End Engineering (FEE) in Construction Industry in Malaysia**

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**Abstract:** Throughout of a construction project's life cycle, Front-End Engineering (FEE) is an engineering design approach used to control project expenses and thoroughly plan a project before a fix bid quote is submitted and start of construction phase. FEE lead to a minimum risk of construction project since it practice a pre-project planning and feasibility analysis. This study is conducted to determine significant effectiveness aspects of FEE application in construction industry in Malaysia. Questionnaire was created based on the extensive literature review. There are nine aspects of FEE that have been selected based on previous studies to establish the effectiveness of FEE in construction industry in Malaysia. From the data collection from questionnaire, it will be using a statistical software to analyze the data which is Statistical Package for the Social Sciences (SPSS) for the reliability analysis. Next, Principal Component Analysis (PCA) which adopted from SPSS is use to determine the significant and correlative effectiveness FEE aspects. According to the PCA analysis, three principal components were chosen out of nine principal components since the total variance of the eigenvalues was more than one. As the results the most correlative and significant effectiveness aspects in FEE in Malaysia are (1) constructability, (2) risk analysis and (3) project scope. However, the others FEE aspects were evaluated, but their effects on the analysis were minimal in comparison to the three chosen highest significant FEE aspects. It is intended that this study would benefit other academics and that the outcome would assist construction industry operators in planning and improving their FEE practices.

**Keywords:** Front-End Engineering, Effectiveness, Principal Component Analysis

### **1. Introduction**

Front-End Engineering (FEE) is a basic engineering design used to obtain sufficient information that enable the owners to ensure resources by identify risk and decision making therefore maximize the successful of a project [1]. The term FEE is also known as Front-End Planning (FEP), Front-End Loading (FEL) and Pre-Project Planning [2]. In other words, final success or failure of a project has high percentage determine by the decision that made in this phase. CII [2] stated that projects with

sufficient front-end planning will not always have the high confidence level to success, but for those with insufficient front-end planning will always have the high confidence level to fail.

Throughout a project lifecycle, there are categorized to four main stages which is initiation, planning, execution and closure. It has an inversely relationship with the ability to influence the performance such as cost and time of a project. The ability to influence performance is decreasing rapidly along the project lifecycle. Once a decision had been made in the early stages, it will be more difficult to change at the following stages [3]. Besides that, the lifecycle of a project has a direct relationship with the project cost to change. The cost to change is increasing rapidly along with the project lifecycle. This is because less cost is required during the early stages. The early stage is pre-planning of all aspects such as feasibility and concept study, further proceed to execution stage which require more funds such as funds required for equipment and facilities that need to prepare and support of facilities that need to prepare and support of operational activities [4]. Hence, pre-project planning must be done wisely to reduce overall projects costs, decrease the potential for further expenses changes and optimize the probability of project successful.

Throughout the history of FEE, the research has provided solution to the risk identification correlative with projects. Various application of FEE has been developed based on the research and used by many organizations in related fields. These applications have assisted the organizations to implement a powerful front-end planning process [2, 5]. The FEE applications developed by CII including Project Definition Rating Index (PDRI) for industrial, building and infrastructure, FEP Toolkit, alignment thermometer and Shutdown Turnaround Alignment Review (STAR) [6].

Application of FEE must be used effectively to ensure a good front-end planning of a project. There are some challenges of a FEE study. During execution phase, there will need of many resources such as labors, equipment's and materials. The quantity is set according to the FEE decision that had been made previously. However, there are some unpredictable error or changes will occur. Adjustment of decision need to be made to provide solution for the current problems. FEE could not guarantee the successful of a project but can maximize the probability of successful of a project. Therefore, this study will establish the effectiveness of FEE by identify the most significant and correlative effectiveness parameters.

### 1.1 Scope and limitations of study

This study is focus on establish the effectiveness of FEE in construction industry in Malaysia. A good implementation of FEE application has high potential to lead to a successful of front-end planning of a project. However, FEE cannot guarantee 100% for a project successful as some unpredictable changes will be appear sometimes along the phases of project. Next, there are various FEE application that used by different organizations.

Due to COVID-19, as Malaysia had increasing of cases since the middle of November 2020, government had announce to implement Conditional Movement Control Order (CMCO) in major states of Malaysia. This has led to difficulties and risky to travel if there need some face to face survey or interview with the organizations. Therefore, this study will conduct online survey focus on construction industry player in Johor Bahru district only due to time and cost limitations.

### 1.2 Significant of research

The outcome of this study will summarize the most significant and correlative effectiveness aspects of FEE. From the findings, it could help other researchers in this fields in having more understanding and information about effectiveness aspects of FEE in construction industry in Malaysia. The information also can be used for further study in this area.

## 2. Literature review

According to Abbas, Din, & Farooqui [7], there was plenty that could cause frequent construction delays and effect on expected costs such as inadequate area and site inspections, weather condition and

a poor safety management system. However, insufficient description of scope during FEE was the most significant factor influencing project performance [8]. FEE aspects are the key factor to influence the effectiveness of FEE. In order to determine the significant effectiveness aspects of FEE in the construction industry in Malaysia, the nine FEE aspects was stated by Abbas, Din, & Farooqui [7]. Table 1 listed out the aspect of FEE with their explanation.

**Table 1: Details of FEE aspects**

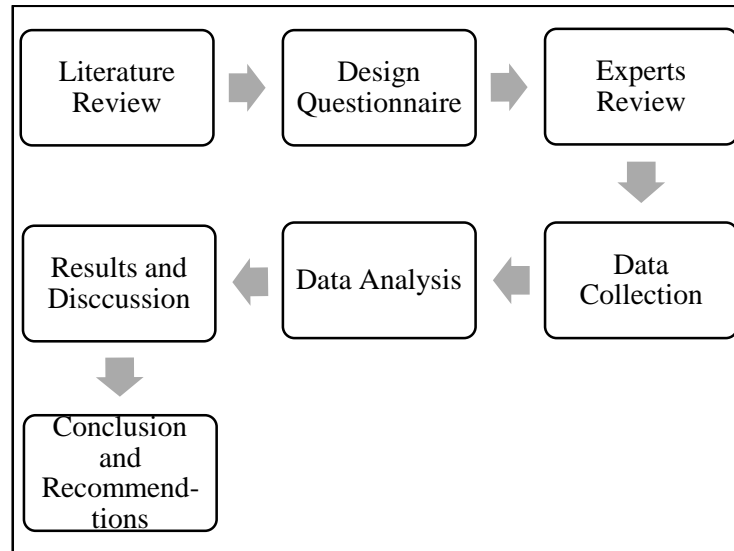
No.	FEE Aspect	Explanation
1.	Scope of project (PS)	The process of a project is specified and ready to be executed quickly [9].
2.	Area & site investigation (ASI)	The geological exploration design method and political and safety issues of the site [10].
3.	Team selection (TS)	Ability and effectiveness of a team to involve and perform in a construction project [11].
4.	Design review coordination (DRC)	Analysis and review of designs according to specifications and requirements among parties [12].
5.	Constructability (CONS.)	Project's conceptual preparation process regarding schedule performance, quality, cost and security [13].
6.	Value engineering (VE)	Identify alternative solutions for project purpose at the lowest possible expenses [14].
7.	Risk analysis (RA)	Probability and consequences of project delays caused by accidents during construction [15].
8.	Safety in design (SID)	The primary implementation of risk analysis and risk management into the project design process [16].
9.	Long lead procurement (LLP)	Early acquisition of material for long periods of procurement [17].

Criteria was then pointed out by Abbas, Din, & Farooqui [7] to the research variables which was the level of involvement of FEE. Hence, each aspects was detailly discussed with their research variables. For PS, provided information of estimated costs, delivery method, procurement policy, master plan preparation, project criteria description. For ASI, offered information on the surrounding environment, offered geological and geotechnical analyses, described specifications for facilities, defined local schedule weather conditions, existence of current underground infrastructure, identified the provision of critical resources, defined political & safety concerns [7].

For TS, offered an efficient coordination approach within the team to promote contractor selection. For DRC, analysis of drawings and measurements, analysis of cost efficiency opportunities, identification of suitable building methods & materials. For CONS., provided appropriate design feedback to prevent modification, to draft control plans, predictions and expenditures, to choose important construction methods and materials, to identify future major building issues. For RA, identification of strict project schedules, identification of inexact cost forecasts and cost escalation of building materials. For VE, identification of high-risk zones, identification of alternative solutions for project work at lower cost and identification of quality assurance and management. For SID, provided design concepts and increase workplace welfare, to avoid the use of unsafe materials, to formulate a health and safety strategy, to propose job methods and sequences, to provide healthy and plannable alternatives. Lastly, for LLP, requirement of a list of lead resources & equipment, identification of processes & proposals for procurement, calculation of costs for material and equipment [7].

### 3. Methodology

This section addresses the analysis methods and data collection strategies. Quantitative method has been chosen to establish the effectiveness of FEE in construction industry in Malaysia. Hence, a survey would be performed through questionnaires spread within various categories of respondents. The methods are simplified via flow chart as seen in Figure 1.



**Figure 1: Flowchart of methodology framework**

Based on the literature review, the different points and information that gathered from it will improve the survey. It is necessarily need to take into account those characteristics in developing a questionnaire to meet the objectives of the study. The questionnaire made up of three sections which are demographic profile, the next part is regarding the general perspective of the respondent on the implementation of FEE and parameters of the effectiveness aspects of FEE. The nine FEE aspects were obtained through literature review from previous studies.

Eight to sixteen experts were the most optimal number to disseminate the questionnaire for review, based on research conducted by Hallowell and Gambatese [18]. The questionnaire was given to twelve lecturers at UTHM who professionals in the building and construction fields in order are to perform the pilot research. This methodology was used in order to resolve the questionnaire so that the respondent could more readily grasp the question. Regarding this study, the data was gathered through questionnaires that had been delivered to construction players who had implemented FEE in Malaysia.

A finite population consists of a set of artifacts or entities which are research objects occupying a specific location [19]. On the basis of this report, the finite population selected is the industry players in Johor Bahru district. A population is so large that it cannot be analyzed easily, so a survey must consist of a few participants. Therefore, it is necessary to provide a precise sample size such that the findings can be correct. The sample size of this study might be found by utilizing Rea and Parker's [20] formula, which estimates the number of individuals on a finite population. The formula is as follows:

$$n = \frac{Z^2[p(1 - p)]N}{Z^2[p(1 - p)] + (N - 1)C^2} \text{ Eq. 1}$$

Where,

Z= standard score in standard deviation units (Z-score)

N= the population size

$p$ = the population proportion

$C$ = the margin of error

The collection of data for this study will be based on quantitative data. For the third section of the questionnaire where the respondents are required to rate the effectiveness criteria of FEE in construction industry, the data will be collected quantitatively by using a Likert Scale. The rating scale is range from 1 to 5 which defines the scale as very low to very high. The questionnaire will be distributed by email to the respondents.

From the data collection from questionnaire, it will be using a statistical software to analyze the data which is Statistical Package for the Social Sciences (SPSS). This program was chosen because it performs the role of entering data and delivering reliable results. Principal component analysis (PCA) will be used in this study to identify the significant parameter for the effectiveness criteria in implementing FEE.

### 3.1 Reliability analysis

Reliability indicates the accuracy of scale estimation, over repeated measures of the same object. Hence, Cronbach [21] developed a reliability coefficient that is widely used in reliability analysis. Taking half the data and calculating the correlation coefficient is an analogous method of separating and computing a correlation. The mean of these claims is equivalent to Cronbach's alpha. In this study, reliability analysis could be implemented by using Cronbach's alpha method with SPSS software which the value is range from zero to one. Hence, the larger the value of alpha coefficient indicates its high reliability.

### 3.2 Principal component analysis (PCA)

Principal Component Analysis (PCA) is a dimensionality reduction technique where the data reduces to a smaller collection of variables which also comprise much of the information. It was a statistical method under the factor analysis which was adopted from the SPSS Statistics. Hence, the concept of PCA is to minimize the number of independent variables of a dataset while maintaining as much knowledge as possible.

Correlation matrixes are frequently used in conjunction with variance-covariance matrixes and Principal Component Analysis (PCA). The following are the steps for performing PCA on the correlation matrix.

- i. Determine the value of the correlation matrix's determinant,  $|R|$ . The correlation matrix determinant must be close to zero in order to execute PCA. This demonstrates the linear dependence of the response variables.
- ii. Verify the independence of the original variables. This test must be performed prior to doing PCA to see whether the response variables are uncorrelated. The steps is as below:

This can be done by testing,  $P=I$ :

Given by  $H_0: P = I$  Eq. 2

$$V = |R| \text{ Eq. 3}$$

Where,

$P$ = Principal component

$I$ = Independent/ uncorrelated

$V = \lambda_1, \lambda_2, \dots, \lambda_p$

For large values of N, we reject  $H_0$  if

$$-a \log V > X^2_{a,p-\frac{(p-1)}{2}} \text{ Eq. 4}$$

$$a = N - 1 - \frac{(2p + 5)}{6} \text{ Eq. 5}$$

Where,

P= total number of parameters

N= total number of subjects

PCA cannot be conducted if  $H_0$  is not rejected. The critical point for chi-square distributions was established using the chi-square distribution table with a significance level of 0.001 and degrees of freedom of  $p(p-1)/2$ .

- iii. Next, determine the number of principal components. 'd' denotes the number of principal components. The number of principal components may be determined by referring at the scree plot of the eigenvalues generated by the SPSS software. A principal component with a value larger than one would be chosen for further investigation. However, eigenvalues approaching zero for principal components can be discarded due to they are not valid for data analysis.

#### 4. Results and Discussion

After experts assessed the questionnaires, changes have been made based on their feedback. The updated set of questions was then issued to construction industry players in Johor Bahru. The process of data analysis begins with the identification of a sample size. Next, followed by reliability analysis of nine parameters regarding the effectiveness aspects in front-end engineering (FEE) which were gathered through literature review from previous studies. Besides that, the Principal Component Analysis (PCA) adopted from SPSS is used to analyze the parameters. Hence, the most significant and correlative parameters of the effectiveness aspects in FEE will be established.

##### 4.1 Determination of sample size

According to CIDB [22], the population size (N) of the construction industry players in Johor Bahru for the year of 2019 was 158. The value of Z-score is 1.96 as the confidence level of 95%. To establish the maximum sample size, the population proportion, p, was set to 0.50, and the margin of error, C, was set to 10% of the sample size. As a result, the degree of precision given as a proportion, d, is 0.10. Hence, the sample size (s) could be calculated as follow.

$$s = \frac{1.96^2 [0.5(1-0.5)] 158}{1.96^2 [0.5(1-0.5)] + (158-1)(0.10^2)}$$

$$s = 59.97 \approx 60$$

Based on Rea and Parker's [20] formula, the sample size obtained is 59.97. As a result, the sample size required to collect data is rounded up to 60 respondents. Sekaran [23] stated that the majority of studies with sample sizes larger than 30 but less than 500 were acceptable. As a result, the requisite number of respondents for questionnaire dissemination is approved.

##### 4.2 Reliability analysis

The term "reliability analysis" relates to the need that a scale accurately represents the construct being measured. Therefore, the reliability analysis has been conducted by using SPSS software in order to obtain the consistency of the parameters.

**Table 2: Cronbach's Alpha value**

No.	FEE Aspect	Mean	Standard Deviation	Cronbach's Alpha
1	Project Scope	4.87	0.343	0.841
2	Area & Site Investigation	3.43	0.851	
3	Project Team Selection	3.52	0.792	
4	Design Review Coordination	3.85	1.246	
5	Constructability	4.00	1.150	
6	Value Engineering	3.90	1.020	
7	Risk Analysis	3.57	1.110	
8	Safety in Design	3.68	0.911	
9	Long Lead Procurement	3.90	1.160	

Table 2 shows the value of Cronbach's Alpha that had been generated from the reliability analysis by SPSS software. The value of standardized Cronbach's Alpha for 9 effectiveness aspects in FEE is 0.841. According to Kline [24], in ability testing, the acceptable value of alpha is above or equal to 0.7. Based on the analysis, the value obtained was exceeded 0.7 which shows that the parameters of the 9 effectiveness aspects in FEE are acceptable and very consistent.

#### 4.3 Results summary

The number of respondents based on their assessment of the effectiveness aspects of FEE is shown in Table 3. The results indicate that the majority of respondents chose scales three to five for the majority of parameters. Only a small percentage of responders chose scales one and two for the aforementioned parameters of FEE aspects.

**Table 3: Summary of results based on the number of respondents**

No.	FEE Aspect	Scale					Total no. of respondent
		1	2	3	4	5	
1.	Project Scope	0	0	0	8	52	60
2.	Area & Site Investigation	0	14	6	40	0	60
3.	Project Team Selection	0	5	25	24	6	60
4.	Design Review Coordination	6	2	9	21	22	60
5.	Constructability	4	4	3	26	23	60
6.	Value Engineering	2	6	4	32	16	60
7.	Risk Analysis	4	7	10	29	10	60
8.	Safety in Design	0	7	16	26	11	60
9.	Long Lead Procurement	4	4	7	24	21	60
Total		20	49	80	230	161	540
Percentage (%)		3.7	9.1	14.8	42.6	29.8	100%

#### 4.4 Data analysis using principal component analysis (PCA)

The independent variables which is these nine aspects of FEE will be examined using PCA, a statistical technique adopted from SPSS. PCA converts all nine FEE aspects into new factors in order to determine the significant and correlative aspect.

The correlation matrix approach may be used in two steps to perform PCA. The first step is to ensure that the correlation matrix's determinant, |R|, is near to zero. Following that, the independence of the original indicators will be determined in order to determine which of the response indicators are independent.

- Step 1: Determinant of correlation matrix, |R|

Based on the result generated from SPSS, the correlation matrix's determinant, |R|, is 0.01. This indicates that the value is close to zero. It demonstrates that linear dependencies exist between the response components. As a result, it satisfies the PCA criteria, and the analysis may proceed.

- Step 2: Verification of hypothesis

The hypothesis that the population matrix is identical to the identity matrix in which all data are multivariate normal must be confirmed. For this survey, there are 9 parameters and 60 respondents. Therefore, p=9 and N=60.

$$\begin{aligned}
 -a \log v &= -\left[ N - 1 - \frac{(2p + 5)}{6} \right] \times \log|R| \\
 &= -\left[ 60 - 1 - \frac{(2 \times 9 + 5)}{6} \right] \times \log 0.01 \\
 &= 110.333
 \end{aligned}$$

Based on the equation, the test statistic is 110.33 while the critical point of the chi-square distribution with p (p-1)/2= 36. The critical point from the chi-square distribution table is 67.985 at the degree of freedom, α= 0.001. As a result, the hypothesis is rejected since the value of the test statistic exceeds the value obtained from the chi-square table where 110.333 > 67.985. Therefore, PCA can be performed.

Table 4 illustrates the value generated from SPSS of the total variance of initial eigenvalues that contributed by 9 components of parameters and the cumulative percentage of initial eigenvalues.

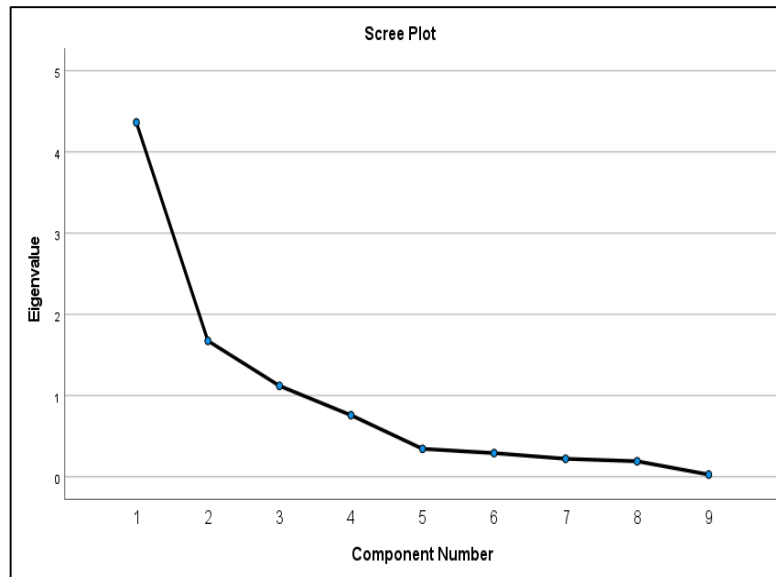
**Table 4: Total variance of initial eigenvalues**

Component	Initial eigenvalues		
	Total	Percentage of variance (%)	Cumulative percentage (%)
1	4.364	48.490	48.490
2	1.675	18.608	67.098
3	1.121	12.456	79.554
4	0.759	8.438	87.992
5	0.345	3.835	91.827
6	0.293	3.251	95.078
7	0.222	2.472	97.550
8	0.192	2.135	99.685
9	0.028	0.315	100.000

According to Table 4, the largest number of eigenvalues greater than one was 4.364 with a percentage of variance 48.49% for principal component (PC) one. However, PC two has a considerable decrease in eigenvalues, with just 1.675 eigenvalues accounting for 18.608% of the entire variance. The

number of eigenvalues in PC three was 1.121, and they account for 12.456% of the entire variance, bringing the cumulative to 79.554%. Additionally, PC four to nine demonstrates that the total variance of initial eigenvalues is close to zero where the total variance of the following eigenvalues was 1.839 with the percentage of variance 20.446%.

Figure 2 shows the scree plot generated from SPSS which illustrates the eigenvalue of the 9 components of the FEE effectiveness aspects parameter.



**Figure 2: Scree plot for the parameters of the effectiveness aspects in FEE**

According to the scree plot in Figure 2, principal components one to three have a value larger than one and might be used as the analysis's main component. However, for PC four to nine, the eigenvalue was near to zero. As a result, these components can be omitted from data analysis because they are not genuine. Thus, only three components are chosen for further analysis, and the coefficient matrix for these three components was listed in Table 5.

**Table 5: Component score of coefficient matrix**

FEE aspects parameter	Component		
	1	2	3
Project Scope	-0.013	0.309	<b>0.852</b>
Area & Site Investigation	0.678	0.468	0.266
Project Team Selection	0.626	0.484	-0.253
Design Review Coordination	0.777	-0.515	0.131
Constructability	<b>0.847</b>	-0.211	-0.011
Value Engineering	0.828	-0.267	-0.022
Risk Analysis	0.662	<b>0.501</b>	0.142
Safety in Design	0.685	0.419	-0.443
Long Lead Procurement	0.773	-0.564	0.162

Table 5 shows three component scores of coefficient matrix derived from SPSS software. Each parameter has a unique component score, and the parameter with the highest value closest to one is regarded the most significant. The remaining characteristics are still addressed, but have a lesser

influence when compared to the critical values. In this section, the highest of the score of coefficient matrix for each component will be selected.

According to the total variance of the eigenvalues in Table 4, nine major components were identified, although only three had a value eigenvalue larger than one were selected. The most significant and correlative parameters had component score coefficient matrix values that were closest to one [25]. The most significant and correlative aspects parameter for PC one is constructability. Furthermore, the most significant and correlative aspects parameter for PC two is risk analysis. Lastly, the most significant and correlative aspects parameter for PC three is project scope. These results are summarized in Table 6.

**Table 6: The summary of PCA findings**

FEE aspects parameter	Component		
	1	2	3
Project Scope	-	-	0.852
Area & Site Investigation	-	-	-
Project Team Selection	-	-	-
Design Review Coordination	-	-	-
Constructability	0.847	-	-
Value Engineering	-	-	-
Risk Analysis	-	0.501	-
Safety in Design	-	-	-
Long Lead Procurement	-	-	-

Table 6 illustrates the summary of results based on the analysis. It shows that the most significant and correlative effectiveness aspects in FEE in Malaysia by using principal component analysis (PCA) method are (1) constructability, (2) risk analysis and (3) project scope. Hence, these three FEE aspects are the most significant and correlative effectiveness aspects in FEE.

## 5. Conclusions

This study conducted in order to determine significant effectiveness aspects of front-end engineering (FEE) in construction industry in Malaysia. From the analysis, there are three highest correlative and significant effectiveness aspects of FEE has been identified. From PCA analysis, it can be concluded that the most correlative and significant effectiveness aspects of FEE were (1) constructability, (2) risk analysis and (3) project scope. Hence, the objectives of establish the effectiveness of Front-End Engineering (FEE) in construction industry in Malaysia has been fulfilled by identified the correlative and significant aspects in FEE.

Recommendation is used to provide suggestions for further study that may be conducted. These recommendations are likely to improve the research process, allowing for the generation of more valuable data. To determine the significant and correlative of the parameters, other statistical method may be apply in any future research. Statistical methods such as regression analysis is focus on the relationship between a dependent variable and one or more independent variable. For an instance, how will age of person (dependent variable) affect the health status and anxiety level (independent variable). By apply this statistical method, researcher could relate the relationship between the dependent and independent variable of their study which it is difficult to explain in other ways. Hence, researcher may justify the relationship and results by this statistical method.

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