# An Application of the Analytical Hierarchy Process (AHP) for Safety measurement in Malaysian Construction Industry

**Samad Doostdar[1], Zubaidah Ismail[2],**

[1,2] Civil Engineering Department, University of Malaya, 50603 Kuala Lumpur, Malaysia
Correspond to samaddoostdar@yahoo.com (S. Doostdar), zubaidahjka@gmail.com (Z. Ismail),

**ABSTRACT;** Analytical Hierarchy Process (AHP) is a famous method amongst Multi Criteria Decision Making (MCDM), set up by Saaty in 1980. AHP can be determined as a methodology of hierarchical analysis following reasonable decision making with make simpler a difficult crisis. Decision making in systems of Safety management concerned multipart challenges. AHP is process for get better the composite decisions understanding with analyzes of the problem in a structure of hierarchy. The integration all of applicable decision criteria, their pair wise judgment permits the decision maker to establish the trade-offs amongst objectives.

In recent years, Malaysian's economy and infrastructure development have significantly and rapidly risen. The construction industry continues to play a major role in this development as many construction activities have been carried out to meet the high demands of the expansive market. However, the construction industry has faced a wide range of challenges, one of which is the frequent occurrences of accidents at the workplace. An effective safety program can substantially reduce accidents because it can help management to build up safer means of operations and create safe working environments for the workers. Furthermore, by having an effective safety programs, good safety culture can be embedded in organization because it can encourage mutual cooperation between management and workers in the operations of the programs and decisions that affect their safety and health.

The focus of this research is development methodology of Analytics Hierarchy Process (AHP) in construction safety factors and investigates the levels of some effective elements in SMS in Malaysian construction industries.

***Keywords:*** *Safety Management System, Construction Management, Analytic Hierarchy Process (AHP), safety factors,*

## 1. INTRODUCTION

To extend and experiment the theoretical models, Analytic Hierarchy Process (AHP) are take on develop successively, observe and refine the assessment models of theoretical election. The easy ranking method applies a questionnaire of self-completion postal, posted to a big group of experts in industries of construction and specialized who have information and construction Industries experience for gathering information.

Analytical Hierarchy Process (AHP) is the most famous methods amongst Multi Criteria Decision Making (MCDM), set up by Saaty in 1980. AHP can be determined as a methodology of hierarchical analysis following reasonable decision making with make simpler a difficult crisis (Saaty 2006).

Decision making in systems of Safety management concerned multipart challenges. In cooperation tangible and intangible criterion requires to be first choice in a procedure of decision making. Intangible criteria for example factors of political and social take preference over criteria of tangibles for instance elements of economic and technical. AHP is process for get better the composite decisions understanding with analyzes of the problem in a structure of hierarchy. The integration all of applicable decision criteria, their pair wise judgment permits the decision maker to establish the trade-offs amongst objectives.

A main power of AHP is the pair-wise judgment where the factors influence of a special stage over those of a lower level is considered; the judgment is according to an opinion of expert's and skill gained from the examination and constant of organization performance learning. Other AHP benefit is the capability to examination the judgments constancy. This ratio of reliability is significant to make sure the decisions were dependable and the last decision is ended well.

## 2. LITERATURE REVIEW

Over time, AHP has established to be a very adaptable decision making process. Saaty is the AHP method designer. Vaidya, O.S. and Kumar, S. (2006), offer a good primer on AHP along with a wide range of projects where AHP was productively performed. T.L. Saaty and M.S. Ozdemir (2003), feature the AHP application on a variety of problems. Such as, Stannard, Barry, S. Sajjad Z. and Earl S. Rosenbloom (2006) show examples of AHP in ability planning related to challenges. There are many AHP applications in a range of fields and control for example in Customer Relationship Management (Barbarosoglu & Yazgac, 2000; Colombo & Francalanci, 2004), manufacturing Tam, C.M., Fung, W.H. and Chan, P.C. (2001), financial statements assessment . Dikmen, I., Birgonul, M.T. and Han, S. (2007) risk assessment in construction, Yi, K.-J. and D. Langford (2006)shows Scheduling-Based safety and Risk Estimation, Yu, R., and Tzeng, G.H. (2006), improvement of Soft Computing Method in decision making.

Wang, S.Q., Dulaimi, M.F., and Aguria, M.Y. (2004) Developed Risk Management framework in construction safety system and Williamson, A., Feyer, A., Cairns, D., Biancotti, D., (1997), developed new

method for safety measurement in construction. Influencing safety factors in Malaysian construction projects investigated by Zubaidah, I., and Samad, D and Zakaria. H, (2012).

There is no using AHP confirmation in model of management studies expected at helping users choose a suitable decision model.

The Analytic Hierarchy Process (AHP) is a practice of mathematical decision making that permits attention of both qualitative and quantitative field of decisions. It decreases compound decisions to a one-on-one comparisons sequence, and next step synthesizes the consequences. Evaluating to other methods like status or rating technique, the AHP employ the human skill to measure single alternatives belongings.

## 3. RESEARCH OBJECTIVES;

The objective of this research is to justify the best practices safety factors in of safety management in the construction industry; then to Evaluation and development methodology of Safety Management System by AHP in order to installing a safety framework in Malaysian construction industries and verify and draw inferences on how effective is the safety management and/or programs in Malaysian construction sites, to investigate the levels of some key elements in safety management in construction industries. Finally recommend some of the best practices in safety management for construction industry.

## 4. METHODOLOGY OF ANALYTICAL HIERARCHY PROCESS (AHP)

The research Methodology designed in five steps which are including; the first step was to List of relevant attributes were selected and collected based on previous studies of various studies in Safety Management System,

In next step a questionnaire was designed based on Saaty table for finding significant safety factors in Malaysian construction projects, The developed questionnaires sent to 50 relate companies and also Preliminary interviews were conducted with 150 responders. In next step, the important weights for factors and attributes were determined and it's categorized in criteria's, sub-criteria's and alternatives.

From the result of data categorizing to measure the effectiveness of SMS was invented, this model is based on Analytical model or AHP, in the next steps pair-wise comparing of factors and weighting of significant factors was done, at the result of Model if Accident rate is reduced or minimized then in last step can implement Safety Management System.

## 5. DATA COLLECTION

A variety of methodologies were adapted in order to reflect the different aspects of construction sites and to reflect overall project objectives. A pilot study was carried out and necessary amendments were made to the instruments before the main research started.

The safety compliance measure was tested with using several safely rating. The questionnaire and interview were designed and examined with samples of expert managers, safety managers, construction consultants and Academic experts. Adjustments to the procedure for administering these were made to ensure effective date collection.

The three modes in data collection used were:

- Interview with contractor & consultants & experts
- Questionnaire Method (based on saaty table)
- Evaluation of safety records
- Accident analysis

## 6. DATA CATEGORIZING

This survey was carried out involved 50 companies and auditing of SMS was done through interviews with 150 responders by using Safety Management System questionnaires form in area of Kuala Lumpur, Serdang, Bangi, Kajang and Johur Bahru of Malaysia. The data was analysed t-test to obtain the value of conformance. (Table1) shows categorizing of AHP criteria's;

**Table 1,** Data categorizing

| Criteria | Sub Criteria |
|---|---|
| **Equipments & Structures** | Equipment acquisition and maintenance |
| | Supported by technical control and information system |
| | Good communication |
| | Appropriate supervision |
| | Personal attitude |
| | Feedback on outcome of work |
| **Policy & Management** | identify integral part of performance |
| | Cost effective improvement in performance |
| | Safety policy |
| | Freedom to make decision |
| | Implementation of safety suggestion |
| | Clear and realistic of goal |

| | |
|---|---|
| | Safety rules and regulations |
| **Safety of Work Environment** | Evaluation of environmental factors |
| | Challenging work |
| | Safety issues in environment work |
| | Monitoring |
| | Mechanical integrity and effect on environment |
| | Safe work practices |
| | Providing safety environment |
| | Understanding kinds of waste produced during constructional activity |
| | Efficiency of system and its impact on environment |
| | after construction phase |
| **Techniques & Resources Planning** | Risk assessment |
| | Adequate and appropriate resources |
| | Contractors training |
| | Occupational safety program |
| | Emergency planning during hazard |
| | Cost effectiveness of techniques |
| | Time needed for given task |
| | Cost of modern and good technique |
| **System & Procedures** | Involvement in operational process |
| | Knowledge of risk process |
| | Incident investigation and analysis |
| | Compliance audition response |
| **Program & Training** | Training of personnel |
| | Organization arrangement |
| | Legal control |
| | Program evaluation |
| | Appropriate safety education and training |

## 7. ANALYZING BY AHP MODEL;

The same as mentioned at Saaty in 1990 stated the Analytic Hierarchy Process (AHP) is a multi-criteria decision making (MCDM) method and is regarded as an expressive approach for making a decision. The MCDM problem faces with choices such as the top or suitable option choice from numerous possible applicants, subject matter to some criterion or quality. Facing a problem of MCDM, a factors and criteria diversity are first planned, the significant issues and criterion recognition need a number of aspects for main choice or influencing. Those issues or criterion with high level are guessed to be critical.

In this research, Analyzing by AHP is according to six steps which based on Data frequency will explain each step;

### 7.1. First the Decision Problem Organization

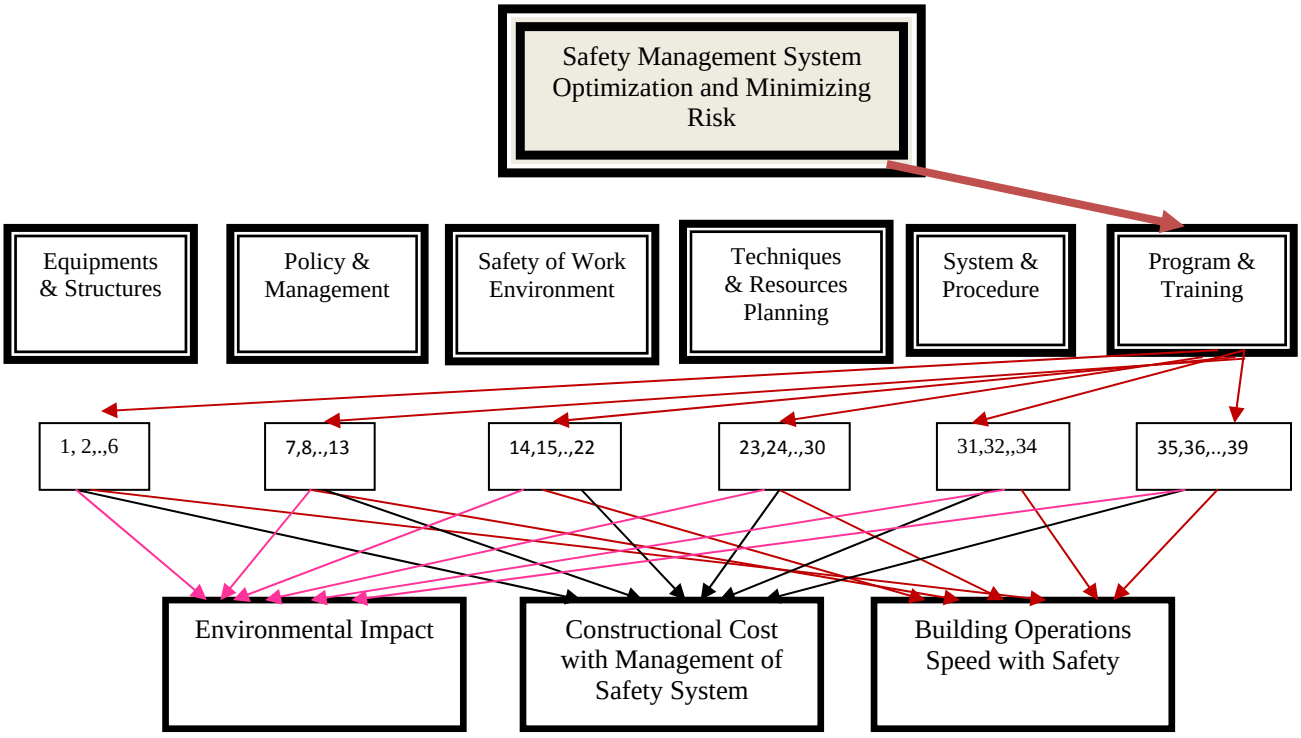
Consequently in the first stage is to structure the problem decisions at a hierarchy. The decision goal is choosing the greatest equipment for systems of Safety management, is at the hierarchy top level. Then of the criteria level consists that related to this aim and the bottom one shows the options to be estimated.

In this research is using the AHP approach at first step to select a group of significant elements to the achievement of several project objectives and providing a model for future and using of this model in another part of the world. According to hierarchy and model for evaluation these factors are chosen that their tables will be explained in the following part.

### 7.2. Second: Arrangement the Analytical Decision Hierarchy due to the Problem

The AHP second stage is to arrangement the decision problem to a model of hierarchical. This includes the decision problem analysis into fundamentals considering to their ordinary qualities. Here, the hierarchies represent the aspects for choose systems of intelligent building controlling. The peak cluster is the goal choice, following this part is the factors selection and at last criteria election which increase from the objectives. (Figure1).

**Figure 1,** arrangement the decision problem for Analytic Hierarchy Process




### 7.3. Third: Pair-wise Assessment Matrices Construction

Thus in this third stage, the assessments are being created to get the main choice of the options by relevant to each of principle and per criteria weights with respect to the aim. The pairing assessment weight of result is achieved by consistency examination, where the ratio of consistency is not as much of 0.1, that time it can be accepted.

#### 7.3.1. Pair Wise Comparative Questionnaire between Criteria's

The super matrix was multiplied by weights of clusters. Because the clusters environment, construction field, social and economic have equal importance, the super matrix values were multiple and Equipments & structure is obtained 0.391 in compare with the other criteria that it means it is 0.391 time more important between the chosen of criteria. Therefore, policy & management is highest contributing factor and equipments & structure are the lowest contributing factor; with 0 missing judgments which is acceptable. (Table2).

**Table 2,** Pair Wise comparative between criteria's

| | Equipments & structure | Policy & Management | Safety of work environment | Techniques & resources planning | System & procedures | Program & Training |
|---|---|---|---|---|---|---|
| Equipments & structure | 1 | 1/8 | 1/6 | ¼ | 1/3 | 1/5 |
| Policy & Management | 8 | 1 | 3 | 5 | 2 | 6 |
| Safety of work environment | 6 | 1/3 | 1 | 4 | 3 | 5 |
| Techniques & resources planning | 4 | 1/5 | ¼ | 1 | 2 | 1/3 |
| System & procedures | 3 | 1/2 | 1/3 | ½ | 1 | 1/2 |
| Program & Training | 5 | 1/6 | 1/5 | 3 | 2 | 1 |

**7.3.2. Weight of Pair Wise Comparative Questionnaire between Criteria**

Table 3 shows, Pair wise comparison between selective sub-criteria of per-criteria based on interview with experts, In fact this part of study investigate and comparison between criteria of equipment acquisition & maintenance, supported by technical control & information system, good communication, appropriate supervision, personal attitude and feedback on outcome of work. Answers in questionnaire is summarised in the table; all average is based on expert's answers.

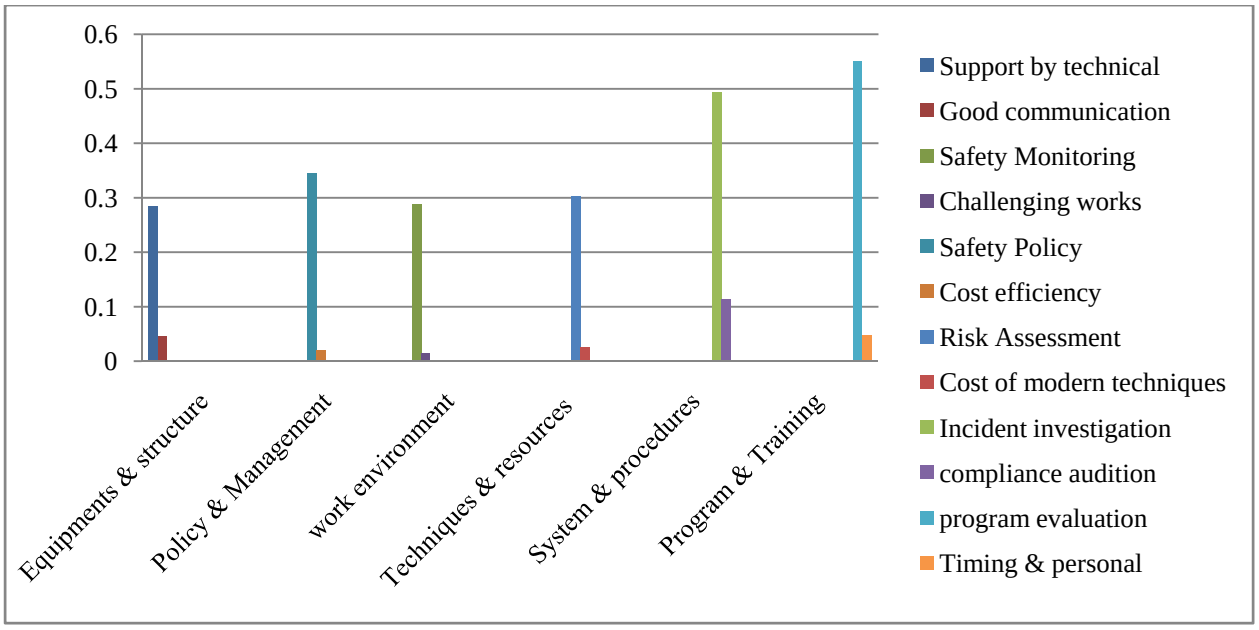
**Table 3,** Categorical Factors Weights

| | Equipments & structure | Policy & Management | Safety of work environment | Techniques &resources planning | System & procedures | Program & Training | Weight |
|---|---|---|---|---|---|---|---|
| Equipments & structure | 0.0370 | 0.0537 | 0.0336 | 0.0181 | 0.0322 | 0.0153 | 0.031 |
| Policy & Management | 0.2962 | 0.4301 | 0.6060 | 0.3636 | 0.1935 | 0.4603 | 0.391 |
| Safety of work environment | 0.2222 | 0.1433 | 0.2020 | 0.2909 | 0.2903 | 0.3836 | 0.256 |
| Techniques & resources planning | 0.1481 | 0.0860 | 0.0505 | 0.0727 | 0.1935 | 0.0255 | 0.097 |
| System & procedures | 0.1111 | 0.2150 | 0.0673 | 0.0363 | 0.0967 | 0.0383 | 0.095 |
| Program & Training | 0.1851 | 0.0716 | 0.0404 | 0.2181 | 0.1935 | 0.0767 | 0.130 |

**7.4. Fourth: a Priorities Vector or Factors Weighting Estimation in the Matrix**

The ratio of reliability is measured significant as it ultimately able to manage bias estimation made by the field professional that tending to their own individual knowledge, through the pair wise comparison procedure. This is principally for background of professional in certain regions may highly control the procedure of assessment, Figure2 shows the highest and lowest contributing factor to SMS in each group of criteria's; with 0 missing judgments, which is acceptable,

**Figure 2**, Factors weighting in the Matrix, The Highest and Lowest contribution factors in SMS



### 7.5. Fifth: Checking the constancy quantity of the Matrix

As decision makers are frequently conflicting in their judgments, the AHP method integrate professional inconsistencies into the model and supply the decision maker with a these variation determine. An examination of constancy can be worked to calculate the relation constancy to determine the matrices, and such a compute refers to the judgement reliability index matrices.

In this research an examination of constancy could be worked to calculate the relation constancy to determine the matrices, and such a compute refers to the judgement reliability index matrices;

#### 7.5.1. Relative weights for the Equipment and Structure factors

The relative weights for the factors are as follows: supported by technical control & information system (0.284), appropriate supervision (0.260), equipment acquisition & maintenance (0.226), feedback on outcome of work (0.116), personal attitude (0.069) and good communication (0.045). It can be inferred from obtained result that technical control & information system is the highest contributing factors to safety management system and the good communication is the lowest contributing factor to SMS. With 0 missing judgments, this is acceptable.

#### 7.5.2. Relative weights of Policy & Management factors;

According to table of Policy & management weight, the weight of Safety policy criteria is 0.345 between Identify integral part of performance, Cost effective improvement in performance, Safety policy, Freedom to make decision , Implementation of safety suggestion , Safety rules & regulations and Clear and realistic of goal. This comparison is shown Safety policy is the most significant between all of them based on experts view in Malaysia.

#### 7.5.3. Relative weights of Environment factors;

The relative weights for the safety of work environment factors are as follows: evaluation of environmental factors (0.236), challenging work (0.015), safety issues in environment work (0.064), monitoring (0.287), mechanical integrity and effect on environment (0.062), safe work practices (0.11), providing safety environment(0.069), understanding kinds of waste produced during constructional activity (0.078) and efficiency of system and its impact on environment after construction phase (0.079). It can be Monitoring is the highest contributing factor to SMS and the Challenging work is the lowest contributing factor to SMS; with 0 missing judgments, which is acceptable.

#### 7.5.4. Relative weights of techniques & resources factors;

The relative weights for the techniques & resources factor are as follows: risk assessment (0.303), adequate & appropriate resources (0.225), contractors training (0.098), occupational safety program (0.183), emergency planning during hazard (0.085), cost effectiveness of techniques (0.051), time needed for given task (0.029), and cost of modern & good technique (0.026). It can be inferred that risk assessment is the highest contributing factor to SMS and the Cost of modern & good technique is the lowest contributing factor to SMS.

### 7.6. Sixth: the Mean Calculation of those Ratings Relative Weights by an Acceptable Consistency Degree

A final vector of priority is considering from the aggregate matrix, in fact characterized the possible alternatives preferences by valuation of all the criterion and sub-criteria. Though, the final step of main vectors choice was not calculated here.

In this research consist the computation of the signify weights of relative Local weight and Global weight approximated with authority on each hierarchy level considering to the prioritisation of AHP factor;

#### 7.6.1. Computation Weighting Of Policy and Management

| | Local Weight | Global weight |
|---|---|---|
| Identify integral part of performance | 0.026 | 0.01 |
| Cost effective improvement in performance | 0.019 | 0.007 |
| Safety policy | 0.345 | 0.135 |
| Freedom to make decision | 0.151 | 0.059 |
| Implementation of safety suggestion | 0.084 | 0.033 |
| Safety rules & regulations | 0.261 | 0.102 |
| Clear and realistic of goal | 0.114 | 0.045 |

### 7.6.2. Competition Weighting Of Safety of Work Environment

| | Local Weight | Global Weight |
|---|---|---|
| Evaluation of environmental factors | 0.236 | 0.06 |
| Challenging work | 0.015 | 0.004 |
| Safety issues in environment work | 0.064 | 0.016 |
| Monitoring | 0.287 | 0.074 |
| Mechanical integrity and effect on environment | 0.062 | 0.016 |
| Safe work practices | 0.11 | 0.028 |
| Providing safety environment | 0.069 | 0.018 |
| Understanding kinds of waste produced during constructional activity | 0.078 | 0.02 |

### 7.6.3. Competition Weighting Of Techniques & Resources

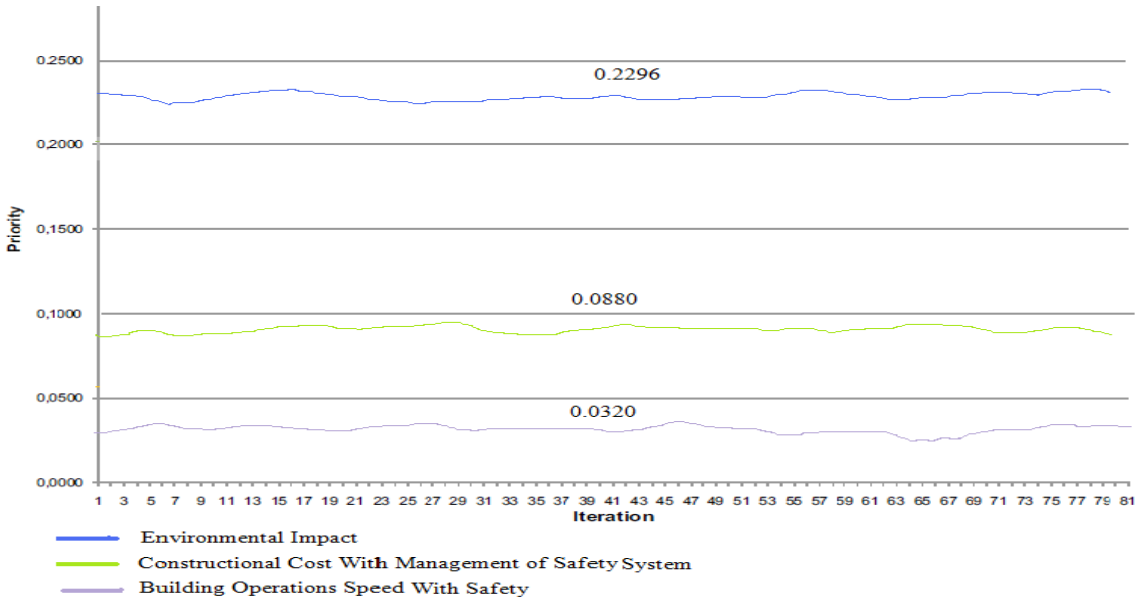
| | LOCAL WEIGHT | GLOBAL WEIGHT |
|---|---|---|
| Risk assessment | 0.303 | 0.029 |
| Adequate & appropriate resources | 0.225 | 0.024 |
| Contractors training | 0.098 | 0.009 |
| Occupational safety program | 0.183 | 0.018 |
| Emergency planning during hazard | 0.085 | 0.009 |
| Cost effectiveness of techniques | 0.051 | 0.006 |
| Time needed for given task | 0.029 | 0.003 |
| Cost of modern & good technique | 0.026 | 0.002 |

## 8. RESULT AND DISCUSSION;

This section highlighted the results of sensitivity analysis to explore the number of experts need for surveying. In the normal process of AHP the weighted factors is multiplied by it and then raised to very big power, until the system's row values converge to the same value for each column of the matrix. This is the power method (Saaty, 2003). In this study, the results of sensitivity analysis realized that there was no difference between rankings of criteria, when the weighted factors were raised to smaller power.

These results can be arranged as the cumulative results. It is presents the first criteria cover more of priority results, also other criteria with remind, in this remaining value of each criterion is very small. [Figure 3],

**Figure 3,** Value of effective factors in Safety Management System in Malaysian Construction projects



The AHP model was developed and validated by quantifying the factors that lead to shortcomings in safety management system of industrial construction to Support and develop total operations and future program. The multifaceted model is ergonomically and mathematically sound; which can be applied in any work environment of industry and similarity condition of climate. The purpose of the study was to establish another technique to predict and prevent shortcomings in SMS in industrial construction. The research will be a great contribution to the prevention of shortcomings and to the construction industry Safety program. The model will aid in risk assessment and shortcoming prevention. It is recommended to use the model in SMS Protection training and Management.

## REFERENCES


AbouRizk, S. and Er, K.C. (2004) “Implementing a structured risk analysis process: experiences and lessons learned”, Proceedings of the Specialty Conference on Leadership and Management in Construction, Hilton Head, South Carolina, 305–312.

Barry, S. Sajjad Z. and Earl S. Rosenbloom. (2006), “Application of Analytic Hierarchy Process in Multi-Objective mixed integer programming for Airlift capacity planning”, Asia-Pacific Journal of Operational Research (APJOR), vol. 23, issue 01, pp. 61-76

Baradan, S. and M. A. Usmen (2006). "Comparitive Injury and Fatality Risk Analysis of Building Trades." Journal of Construction Engineering and Management 132(5): 533-539.

Cheng, E.W.L., and Li, H. (2005), "Analytic Network Process Applied to Project Selection", ASCE Journal of Construction Engineering and Management, 131(4), pp. 459-466

Dikmen, I., Birgonul, M.T. and Han, S. (2007) “Using fuzzy risk assessment to rate cost overrun risk in international construction projects”, International Journal of Project Management, 25(5),pp. 494-505.

Gambatese, J. A., M. Behm, et al. (2005). "Viability for Designing for Construction Worker Safety." Journal of Construction Engineering and Management 131(9): 1029-1036.

Reddy, M., Pratt, W., Dourish, P., & Shabot, M. M. (2003). Sociotechnical requirements analysis for clinical systems. Methods of Information in Medicine, 42, 437-444.

Saaty, T.L, (1980) The analytical hierarchy process, McGraw-Hill, New York, U.S.

Saaty, T. L. (2005), "Theory and Applications of the Analytic Network Process: Decision Making with Benefits, Opportunities, Costs, and Risks", USA: RWS Publications.

Saaty, T.L., and Niemira, M.P. (2006), "A Framework for Making Better Decisions", Research Review, 13(1), pp. 44-48.

Tam, C.M., Fung, W.H. and Chan, P.C. (2001) Study of Attitude Changes in People After the Implementation of a New Safety management System: the Supervision Plan, Construction Management and Economics, Vol.19, pp.393-403.

T.L. Saaty and M.S. Ozdemir. Why the magic number seven plus or minus two. Mathematical and Computer Modelling, 38:233–244, 2003.

Vaidya, O.S. and Kumar, S. (2006), “Analytic Hierarchy Process: An Overview of Applications”, European Journal of Operational Research, 169(1), pp. 1-29.

Yu, I., Kim, K., Jung, Y. and Chin, S. (2007). “Comparable Performance Measurement System for Construction Companies.” Journal of Management in Engineering, 23(3), pp. 131-139.

Yu, R., and Tzeng, G.H. (2006), "A Soft Computing Method for Multi-Criteria Decision Making with Dependence and Feedback", Applied Mathematics and Computation, Elsevier Inc., 180(1), pp. 63-75.

Wang, S.Q., Dulaimi, M.F., and Aguria, M.Y. (2004), "Risk Management Framework for Construction Project in Developing Countries", Construction Management and Economics, 22(3), pp. 237-252.

Wuebker, L. J. (1986). Safety locus of control as a predictor of industrial accidents and injuries. Journal of Business and Psychology, 1(1), 19-30.

Zubaidah, I., and Samad, D and Zakaria. H, (2012), Factors influencing the implementation of a safety management system for construction sites, Journal of Safety science, 50(3), pp, 418-423.