Article citation info:
CHUA SJL, ALI AS, ALIAS AB. Implementation of Analytic Hierarchy Process (AHP) decision making framework for building maintenance procurement selection: Case study of Malaysian public universities. Eksploatacja i Niezawodnosc –Maintenance and Reliability 2015; 17 (5): 7–18.

Shirley Jin Lin CHUA
Azlan Shah ALI
Anuar Bin ALIAS

IMPLEMENTATION OF ANALYTIC HIERARCHY PROCESS (AHP) DECISION MAKING FRAMEWORK FOR BUILDING MAINTENANCE PROCUREMENT SELECTION: CASE STUDY OF MALAYSIAN PUBLIC UNIVERSITIES

ZASTOSOWANIE PLATFORMY PROGRAMISTYCZNEJ WSPOMAGAJĄCEJ PODEJMOWANIE DECYZJI, OPARTEJ NA PROCESIE HIERARCHII ANALITYCZNEJ (AHP) W POSTĘPOWANIU PRZETARGOWYM NA UTRZYMANIE BUDYNKÓW. PRZYPADEK MALEZYJSKICH UCZELNI PUBLICZNYCH

In this paper, the proposed Analytic Hierarchy Process (AHP) based decision making framework was implemented and validated for its capability, applicability and validity in assisting building maintenance personnel to select the most appropriate procurement method. The decision making framework was developed based on AHP technique and principles. Expert Choice Software was employed as the development tool where the shortlisted criteria and alternatives were integrated within the framework. The validation process was carried out through a structured interview with nine public universities selected. The evaluations revealed that majority of the interviewees perceived that the framework developed was good (65%) and excellent (21%) in terms of capability, applicability and validity. The proposed decision making framework introduced expected to be a useful tool for maintenance organization that can assist them in decision making on selecting the most appropriate procurement method.

Keywords: *analytic hierarchy process, building maintenance management, procurement strategy alternative, procurement selection criteria, public university.*

W niniejszej pracy przedstawiono platformę programistyczną wspomagającą podejmowanie decyzji opartą na procesie hierarchii analitycznej (AHP). Po wdrożeniu zaproponowanegoframeworku, weryfikowano jego wydajność, przydatność oraz wiarygodność jako narzędzia wspierającego pracowników utrzymania budynku przy wyborze najodpowiedniejszej metody przetargowej. Platformę opracowano w oparciu o technikę i zasady AHP. Jako narzędzia programistycznego użyto Expert Choice Software, za pomocą którego integrowano z frameworkiem wybrane kryteria i alternatywy. Weryfikację przeprowadzono na podstawie strukturalizowanego wywiadu z wybranymi dziewięcioma uczelniami publicznymi. Otrzymane oceny wykazały, że większość badanych postrzegało opracowaną platformę jako dobrą (65%) lub doskonałą (21%) pod względem wydajności, przydatności i wiarygodności. Przewiduje się, że proponowany framework wspomagający podejmowanie decyzji będzie stanowić użyteczne narzędzie doboru odpowiednich metod przetargowych dla instytucji zajmujących się obsługą techniczną.

Słowa kluczowe: *proces hierarchii analitycznej, zarządzanie utrzymaniem budynków, alternatywna strategia przetargowa, kryteria wyboru zamówienia, uczelnia publiczna.*

1. Introduction

Maintenance management to the private and the public sector has been rapidly changing throughout the years due to several factors which include the enhancement of sophisticated technology, globalization and change of economy [13, 48]. The economy of Malaysia has been planned on the basis of five-year strategic plan since independence. Construction industry plays an important role to the economy of Malaysia in generating wealth and improving the quality of life for Malaysians through the translation of government's socio-economic policies into social and economic infrastructure and buildings [10]. The increase in supply of building will lead the increase in the amount invested in building maintenance. Lateef [18]claimed that the allocation for repair and maintenance works in Malaysia is grossly inadequate to meet the ever-growing demand for the maintenance backlog even the government consistently increases allocation to the maintenance sector. The former Prime Minister of Malaysia, Dato' Seri Abdullah Ahmad Badawi stated that Malaysia was losing billions of ringgit due to the poor maintenance of buildings and amenities. He further highlighted that there were weaknesses in the management and maintenance of public facilities [46]. Many academic organizations view building maintenance management as a burden rather than as a value-added strategy[20]. Maintenance management is not regarded as part of the top management function or duties but as an operational function. It only receives management attention when everything has gone wrong.

Public facilities are indeed very essential to a nation. Thus, this research will be mainly focusing on maintenance management of public universities in Malaysia. University buildings are factor of production

[19]. It is essential for education building to plan effective building maintenance management because the facility condition of education building directly impact teaching and learning [22]. Therefore, an improvement in maintenance management processes is very critical for universities in Malaysia. Public universities in Malaysia are categorized into three groups; Research Universities, Focused Universities and Comprehensive Universities. So far, there are 20 public universities in Malaysia, which comprise 5 research universities, 4 comprehensive universities and 11 focused universities.

Selecting an appropriate procurement strategy for building maintenance is a very critical decision in building maintenance management. It is claimed that it is a complex and intimidate task to the client and the client's advisers to select the most appropriate procurement method[12].Procurement is vital since it sets the basis for cooperation between clients and contractors[31]. This statement is true for the local, regional or global project in scope. Procurement method selection becomes a very significant task for clients because employing an inappropriate procurement method may lead to project failure[8, 30].

The adoption of an appropriate sourcing strategy in building maintenance will not only help the good functionality of the building, the mechanical and electrical elements but also in achieving cost savings, higher comfort levels, better economic rent of the building space, elevated corporate image a sustainability of the building[41]. Morledge *et al.* [28]pointed out that their research led them to believe that relatively few professionals fully understood the differences between the various procurement systems and would be unable to make sensible recommendations as to which system would be most appropriate for a specific project. In fact, the amplification of demand on quality services for building or space, changes in business environment and the ever evolving market trend resulting in an emergence of various procurement strategies. Thus, the tasks of decision-makers to select the most appropriate procurement method becoming more challenging.In this respect, a more systematic selection framework is much needed. This paper reports a study conducted among public universities in Malaysia on the development of procurement selection framework based on Analytic Hierarchy Process (AHP) technique and principles. The proposed decision making framework is implemented and validated for its capability, applicability and validity and the results are presented in this paper.

2. Determination of procurement strategy alternative and procurement selection criteria

Procurement is defined as "an organizational system that assigns specific responsibilities and authorities to people and organizations" while maintenance procurement as "the process by which required maintenance works are carried out" [1, 9, 24, 47]. Maintenance work range from very large maintenance projects to a very small maintenance task. Subsequently, many different types of procurement methods have been developed to overcome the weaknesses of the existing procurement method and meet the range of service's requirement. The types of procurement method identified through literature review for building maintenance were listed as below [3, 4, 9, 14, 35, 41, 47]:

I Direct Labour or In-house

In-house is the management process of performing a service by in-house staffdirectly employed by organisationsto run and maintain the building[14, 29].The client organisation usually employ direct labour under the terms of conventional employee relationship to monitor and control the performance of maintenance [5, 29, 45]. Williams [45]highlighted that presentlythere were very less organisations that employ 100% in-house operation but if it really exists, it is not on a large scale.According to Sheng [41], in-house strategy is deemed to be the most fundamental and traditional strategy for the delivery of property management and maintenance services.The operation staffs who are employed directly by the organization are recognized as part of the organization with no existence of service contract tying the relationship together except the ordinary employment contract. Through in-house strategy, the assigned property manager will need to plan, execute, coordinate and control the team members' work. Internal communication will take place both laterally and vertically.

II Outsourcing

Hui and Tsang [14] explained that outsourcing is a whole package of support function is off-loaded to an external service provider. Sheng [41] stated that outsourcing prepares the organization to engage an external specialist for the provision of certain specialized trade of service under contract basis.Outsourcing can trade of service under several types of contract which include:

1) Outsourcing by Lump Sum Contract.
2) Outsourcing by Measured Term Contract.
3) Outsourcing by Specialist Term Contract.
4) Outsourcing by Day work Term Contract.
5) Outsourcing by Tendered Schedule Term contract.
6) Outsourcing by Repair and Maintenance Contract.
7) Outsourcing by Cost Reimbursement Contract.
8) Outsourcing by Service Level Agreement.

Outsourcing has increasingly become an important approach that can significantly assist organizations to leverage their skills and resources to achieve greater competitiveness [21, 34, 44]. Lau and Zhang [21]stated that outsourcing strategy enable organizations to gain competitive advantage through cost reduction and improved responsiveness to changing business environment and market demand. This is agreed by [3, 42]that outsourcing is a supply strategy often chosen as a means of increasing organizational effectiveness and efficiency.

III Out-tasking

Out-tasking is defined as "a management process whereby specific tasks, as opposed to a whole package of support function in the case of outsourcing, are performed by a contractor"[14, 16]. According to Hui and Tsang [14], the company usually employs a small number of staff to serve as coordinators between internal customers and the external service provider when outsourcing is practised. This is in contrast to out-tasking where the internal staff members play a proactive role of planning and initiating service activities and leading the external service provider for delivery of the needed service. Thus, the internal personnel are fully responsible for the consequences of out-tasking.

IV Public Private Partnership (PPP)

Public Private Partnership (PPP) is "a partnership or strategic alliance has been formed between the organization and service provider based on a sharing of the responsibility for the delivery and performance of the service, including the sharing of the benefits arising from any efficiency gains and cost savings" [3, 4].

V Total Facilities Management (TFM)

An entire scope of services are packaged togetherand externalized to a solitary supplier which gets to be completely in charge of themonitoring, control, delivery and accomplishment of executionobjectives which relate to operational benefit [3, 4].

VI Traditional

Straub [43]stated that maintenance projects mostly adopted traditional procurement method where three to five competitive bids are solicited and the lowest tender price will be selected. Espling and Olsson [11] claimed that traditional procurement produce low productivity, litigation, an adversarial environment and a reduced ability to absorb technological and business process innovations.

VII Partnering

Espling and Olsson [11] defined partnering as "a managerial approach used by two or more organizations to achieve specific business objectives by maximizing the effectiveness of each participant's resources". The approach is based on mutual objectives, an agreed method of problem resolution and active search for continuous measurable improvements [6, 11]. Partnering is becoming increasingly used for procurement of maintenance services [35].Partnering requires changing traditional relationships to a shared culture without regard to organizational boundaries. The relationship is based on dedication to common goals, trust and an understanding of each other's individual expectations and values. Expected benefits include cost effectiveness and improved efficiency, the continuous improvement of quality products and services and increased opportunity for innovation. It should be noted that these types of arrangements do not create a business partnership [35].

As this research mainly focusing in assisting the universities organization that wishes to outsource the services, direct labour which is known as in-house was excluded in this present study.

Masterman [27] claimed that many clients had been selecting procurement systems in a cursory manner simply based upon subjective past experience and the conservative decisions and some client even employ a specific procurement strategy by default without making a deliberated choice. Although past experiences may be an essential factor that influences the selection of procurement strategy, but experiences and solutions to problems retrieved from past projects may not be applicable to the current projects because each building has its own distinct characteristic. In addition, Love *et al.* [25] highlighted that owners who have similar nature do not certainly have similar needs. In fact, the needs rely on many factors and are usually specific to the particular project. Some researches highlighted that it is essential to establish a list of procurement selection criteria before various procurement methods were evaluated. The procurement selection criteria should reflect the requirements and characteristics of the client, project and external environment [2, 17, 26]. There are 26 criteria identified from literature review, which are divided into three main categories that are clients' requirement, project characteristic and external environment or factor which can be referred to Table 1.

In order to derive a particular set of procurement method and procurement selection criteria for public universities in Malaysia, postal questionnaires survey was conducted with all the public universities in Malaysia. The assessment criteria and alternatives for selection are evaluated by the maintenance personnel in public universities in Malaysia. The main purpose of evaluation is to eliminate those criteria and alternatives that are considered less or not important for the development of the decision making framework.

Likert scale and ranking analysis were employed. In order to derive a set procurement selection criteria that were considered essential, only those procurement method and criteria obtained both mean rating and mode equivalent to or above 4, which were considered as important and very important according to likert scales of 5 (from which 1 indicate "least important" to 5 indicate "very important") were included in this study for the proposed decision making framework.

The mean is computed by adding up all the scored and dividing by the number of scores ($M=\sum X/N$) [23]. It is essential to calculate a mean to rank the variables. Mode is known as the most common category whereby the score most frequently exist in a distribution.

There are only 19 criteria will be considered for the development of decision making framework. On the other hand, the procurement methods that are considered as most commonly used (percentage of cases more than 50%) and categorized as important and very important with both mean rating and mode equal or above 4 will be considered for the proposed decision making framework. The procurement selection criteria and procurement option that were selected are provided in Table 2.

3. Analytic Hierarchy Process (AHP)

The Analytic Hierarchy Process (AHP) is "a theory of measurement through pairwise comparisons and relies on the judgments of experts to derive priority scales" [37]. Ibbs and Chih [15]stated that the first steps of AHP are to develop a hierarchy of criteria and to identify all possible alternatives. AHP uses a pairwise comparison procedure whereby a decision maker is required to compare all alternatives with respect to evaluation criteria in turn. The decision maker's preferences are presented in a ratio scale and are combined into an overall rating. The basic steps for conducting study using AHP are as follow [33, 36, 38–40]:

Table 1. Procurement Method Selection Criteria

Criteria			
C 1	**Client Requirement and Characteristics**		
C 1.1	Experience contractor availability	C 1.11	Involvement of owner in the project
C 1.2	Quality level	C 1.12	Working relationship
C 1.3	Knowledge of the strategy	C 1.13	Intuition and past experience
C 1.4	Degree of responsibility	C 1.14	Client in house technical capability
C 1.5	Client's financial capability	C 1.15	Price or cost certainty
C 1.6	Price competition	C 1.16	Risk allocation or avoidance
C 1.7	Time Certainty	C 1.17	Dissatisfaction with previous process
C 1.8	Speed	C 1.18	Degree of complexity
C 1.9	Public accountability	C 1.19	Degree of flexibility
C 1.10	Clarity of scope		
C 2	**Project Characteristic**		
C 2.1	Existing building condition	C 2.2	Project size
C 3	**External environment/ factor**		
C 3.1	Objective or policy of organization	C 3.4	Political issue/constraint
C 3.2	Government policy	C 3.5	Cultural differences
C 3.3	Dispute and arbitration		

Table 2. Selected procurement selection criteria and procurement options for the proposed decision making framework

Procurement Selection Criteria	Mean	Mode	Procurement method used in universities	Mean	Mode	Percent of Cases
Experience contractor availability	4.71	5	Outsourcing by Repair and Maintenance Contract	4.06	4	82.4%
Existing building condition	4.59	5	Outsourcing by Specialist Term Contract	4.18	4	76.5%
Objective or policy of organization	4.53	4	Outsourcing by Tendered Schedule Term Contract	4.12	4	70.6%
Quality level	4.47	5	Outsourcing by Measured Term Contract	3.94	4	64.7%
Government policy	4.41	4				
Knowledge of the strategy	4.41	5				
Degree of responsibility	4.41	5				
Client's financial capability	4.41	5				
Price competition	4.35	4				
Time Certainty	4.35	4				
Speed	4.35	4				
Public accountability	4.29	4				
Clarity of scope	4.29	4				
Involvement of owner in the project	4.24	4				
Working relationship	4.24	5				
Project size	4.18	4				
Intuition and pass experience	4.12	4				
Client in house technical capability	4.06	4				
Price or cost certainty	4.00	4				

(a) Define the problem and determine its goal.
(b) Structure the hierarchy with the decision-maker's objective at the top with the intermediate levels capturing criteria on which subsequent levels depend and the bottom level containing the alternatives.
(c) Construct a set of n × n pair-wise comparison matrices for each of the lower levels with one matrix for each element in the level immediately above. The pairwise comparisons are made using the relative measurement scale. The pair-wise comparisons capture a decision maker's perception of which element dominates the other.
(d) There are n (n−1)/2 judgments required to develop the set of matrices in step (c). Reciprocals are automatically assigned in each pair-wise comparison.
(e) The hierarchy synthesis function is used to weight the eigenvectors by the weights of the criteria and the sum is taken over all weighted eigenvector entries corresponding to those in the next lower level of the hierarchy.
(f) After all the pair-wise comparisons are completed, the consistency of the comparisons is assessed consistency ratio (CR) calculated by the formula below [7, 9, 36]:

Consistency Ratio (CR) = Consistency index (CI)/ Random Index (RI)

Where CI = $(\lambda max - n)/(n-1)$, with n the number of elements, λmax = the maximum eigenvalue of the comparison matrix and RI = the consistency index of a randomly generated reciprocal matrix within a scale of 1 to 9. The consistency ratio (CR) is acceptable if it does not exceed 0.10. Repeat and review the judgment if the CR is greater than 0.10.

4. Proposed decision making framework

The proposed decision making framework was developed based on Multiple Criteria Decision Making (MCDM) particularly Analytic Hierarchy Process (AHP). The framework employed AHP techniques and principles using Expert Choice 11 software as the development tool. The development of decision making framework using AHP mainly focused on two important components that are the possible assessment criteria and the alternatives available for selection whereby the assessment criteria were used to evaluate the alternatives as shown in Figure 1.

There are three basic principles of the AHP which include the principle of constructing hierarchies where a complex system was structured hierarchically by decomposing the elements into constituent parts according to essential relationships towards a desired goal which can make the whole system well understood, the principle of establishing priorities where priority of elements in a decision problem is established to make pairwise comparison that is to compare the elements in pairs against a given criterion and finally the principle of logical consistency to ensure that elements are grouped logically and ranked consistently according to a logical criterion [36]. Logical consistency ensures that elements are grouped logically and ranked consistently according to a logical criterion.

The AHP implementation steps of the framework will be simplified by using the Expert Choice professional software that is available commercially and designed for implementing AHP. Expert Choice 11 software was employed as a development tool to assist in developing the decision making framework. Expert Choice software offers a model view containing either a tree view or cluster view of the decision hierarchy. Expert Choice allows the decision maker to re-examination and revises the judgments for all level of the hierarchy and shows where inconsistency exists and how to minimize it in order

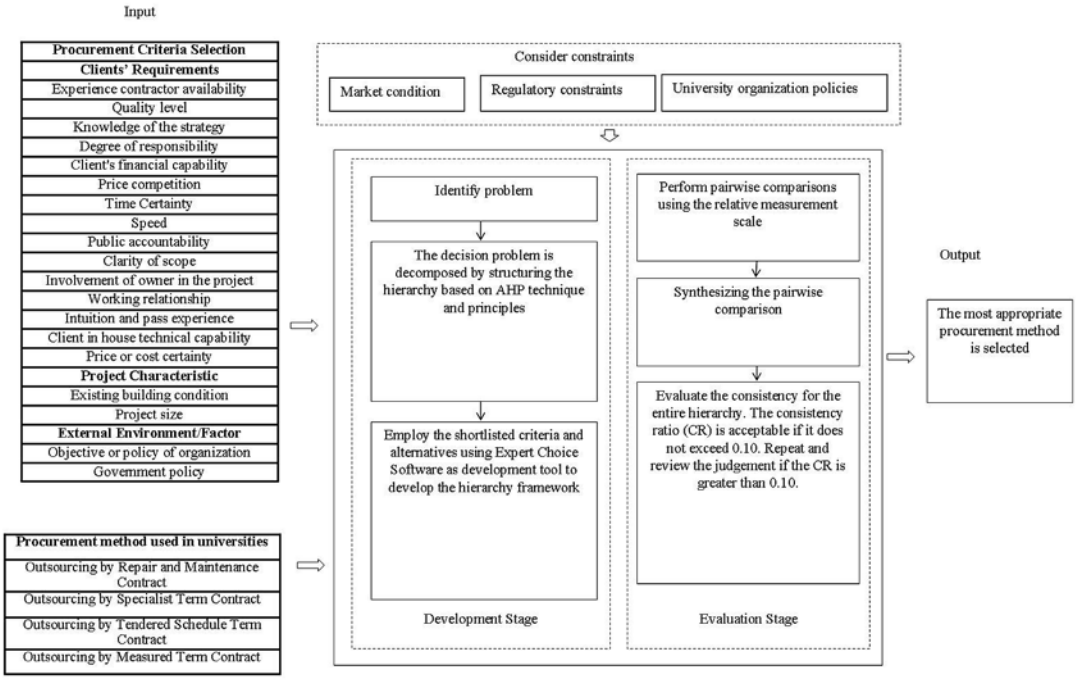

Fig. 1. Decision Making Framework for Procurement Method Selection of Building Maintenance Management for Public Universities

to improve the decision. The inconsistency value will be shown once the judgment is done.

5. Research design and methodology

Structured interview was conducted to validate the framework developed. The framework produced was demonstrated to the interviewees. Then, the interviewees were asked to run the framework and were asked to evaluate the framework in terms of capability, applicability and validity. Structure interview is chosen so that the researcher can explain the framework in detail to the respondents, clarify any doubts arises by the interviewees and at the same time the researcher able to examine the level of understanding of the respondents towards the topic and the framework. All the interviewees were explained and asked the same questions in the same manner to standardize in order to make it easier to repeat the interview and provide a reliable source of qualitative data.

As mentioned previously, the total populations of public universities in Malaysia are 20, comprise of 5 research universities, 4 comprehensive universities and 11 focused universities. However, there are only 17 universities replied in the postal questionnaires survey. The interviewees for the structured interview were selected from the universities that have responded in the postal questionnaires survey. There were 9 universities equivalent to 52.9% selected from 17 uni-

Table 3. Interviewees Profiles

Name of Universities	Nos. of Interviewees	Position	Experience (years)
Research Universities			
University RA	3	Head of Civil Engineering Division	20
		Head of Contract & Quantity Surveying Division	30
		Quantity Surveyor	10
University RB	1	Assistant Head of Quantity Surveying Department	17
University RC	1	Head of Contract Department	31
Comprehensive Universities			
University CA	1	Head of Contract Management And Cost Control Section	12
University CB	1	Acting Senior Facilities Engineer	7
Focussed Universities			
University FA	1	Head of Quantity Surveying Department	10
University FB	1	Deputy Director of Facility and Estate Management Department	25
University FC	1	Head Department of Building Maintenance Section	11
University FD	1	Deputy Director of Development & Facilities Management Department	23

Table 4. All vector of priorities for main criteria, sub criteria and alternative

Level 1: Goal	Select the most appropriate procurement method of building maintenance management services for public university																		
Level 2: Main Criteria	Clients' Requirements (C1)															Project Characteristic (C2)		External Environment or Factor (C3)	
Vector of Priorities	0.300															0.100		0.600	
CR	0.00															0.00		0.00	
Level3: Sub Criteria	C1.1	C1.2	C1.3	C1.4	C1.5	C1.6	C1.7	C1.8	C1.9	C1.10	C1.11	C1.12	C1.13	C1.14	C1.15	C2.1	C2.2	C3.1	C3.2
Vector of Priorities	0.071	0.068	0.042	0.023	0.025	0.092	0.070	0.040	0.017	0.168	0.063	0.065	0.078	0.070	0.109	0.875	0.125	0.125	0.875
CR	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.00	0.00	0.00	0.00
Level 4: Alternatives	Vector of Priorities																		
Outsourcing by Repair and Maintenance Contract	0.532	0.053	0.079	0.063	0.216	0.265	0.046	0.06	0.118	0.116	0.091	0.426	0.055	0.250	0.250	0.250	0.250	0.250	0.250
Outsourcing by Specialist Term Contract	0.061	0.585	0.219	0.501	0.112	0.265	0.147	0.619	0.487	0.245	0.266	0.111	0.532	0.250	0.250	0.250	0.250	0.250	0.250
Outsourcing by Tendered Schedule Term Contract	0.095	0.121	0.200	0.120	0.350	0.094	0.296	0.215	0.118	0.073	0.091	0.171	0.213	0.250	0.250	0.250	0.250	0.250	0.250
Outsourcing by Measured Term Contract	0.312	0.242	0.503	0.316	0.322	0.375	0.511	0.107	0.276	0.567	0.552	0.292	0.200	0.250	0.250	0.250	0.250	0.250	0.250
CR	0.02	0.04	0.05	0.04	0.04	0.05	0.05	0.04	0.06	0.07	0.09	0.07	0.02	0.00	0.00	0.00	0.00	0.00	0.00

**CR= Consistency Ratio*

Table 5. Vector of overall priorities with respect to main criteria

Main Criteria	Clients' Requirements (C1)	Project Characteristic (C2)	External Environment/Factor (C3)	Vector of Overall Priorities
Vector of Priorities	0.300	0.100	0.600	
CR	0.00	0.00	0.00	
Alternatives	Vector of Priorities			
Outsourcing by Repair and Maintenance Contract	0.203	0.250	0.250	0.240
Outsourcing by Specialist Term Contract	0.273	0.250	0.250	0.255
Outsourcing by Tendered Schedule Term Contract	0.18	0.250	0.250	0.236
Outsourcing by Measured Term Contract	0.344	0.250	0.250	0.269
CR	0.07	0.00	0.00	0.03

**CR= Consistency Ratio*

versities responded. The 9 universities are selected from the 3 main categories of universities so that this research covers different type and category of university. Piaw [32] highlighted that in qualitative research, the sample size is usually small and 5 subjects are accepted if the demography data are same. Besides, Musa [29] research on determining the best options for Facilities Management (FM) service delivery in UK shopping centers, which also integrated AHP and Expert Choice in developing the framework did 5 interviews on shopping complexes for validation of his research framework. Thus, 9 universities are considered satisfactory and accepted because the evaluation done by the 9 universities were quite equivalent. The interviewees' profiles are tabulated in Table 3 according to the 3 main types of public universities categories.

In the structured interview, the interviewees were first requested to do a pair-wise comparison with the assessment criteria and procurement option which was stored in Expert Choice software as an interview instrument. This Expert Choice software instrument offers a questionnaire with scale of 1 to 9 to perform pair-wise comparison. The judgments can be performed in three ways by numerical, verbal and graphical in Expert Choice software. The interviewees were requested to perform pair-wise comparisons for all levels of hierarchy in the framework produced. This instrument brings a lot of advantages in terms of time saving, simple, easy to be explained and understand as well as well-structured.

Once the interviewee obtained the proposed procurement method from the framework, the interviewee requested to rate the Decision Making Framework for Procurement Method Selection of Building Maintenance Management for Public Universities in terms of capability, applicability and validity. Each evaluation form was labeled with distinctive reference number (UM/FBE/BHA1100007/FBF/0XX) at the right top to identify which university gave what evaluations and comments. The interviewees can also provide comments, cop and sign the form after evaluation done. The example of evaluation form as shown in Appendix A.

6. Results and discussion

The validation process was carried out through structured interviews with 9 universities selected. The interviewees were selected from the maintenance and facilities' maintenance management department of university. The interview commenced on 9th of April 2013 and lasted on 9th of May 2013. The structured interview took exactly one-month time. The interview was scheduled so that two to three universities were interviewed in a week. The interviewees had at least five-year experiences in selecting procurement method for building maintenance work and had been involved in the decision-making process.

In the proposed method, the interviewees are first requested to do a pair-wise comparison with the assessment criteria and procurement

Table 6. Summary results to compare all interviewees' priority vector to select the most appropriate procurement method for different type of building maintenance services

Priority Ranking	Universities, Maintenance Services and Vector of Priorities				
	University RA	University RB	University RC	University CA	University CB
	Maintenance of Water-proofing System	Maintenance of Air-conditioning Services	Housekeeping	General Repair Work	Roof Repair Work
1	EEF (0.600)	PC (0.540)	CR (0.481)	CR=EEF (0.444)	PC (0.667)
2	CR (0.300)	EEF (0.297)	EEF(0.405)	CR=EEF (0.444)	CR (0.222)
3	PC (0.100)	CR (0.163)	PC(0.114)	PC (0.111)	EEF (0.111)

EEF=External Environment or Factor, CR=Clients' Requirement, PC=project characteristic

Table 7. Summary results to compare all interviewees' priority vector to select the most appropriate procurement method for different type of building maintenance services

Priority Ranking	Universities, Maintenance Services and Vector of Priorities			
	University FA	University FB	University FC	University FD
	Building Cleaning	Maintenance of electrical system	Maintenance of road	Maintenance of Lift
1	EEF (0.528)	CR = PC(0.455)	CR (0.427)	EEF (0.600)
2	CR (0.333)	CR = PC(0.455)	EEF (0.318)	PC=CR (0.200)
3	PC (0.140)	EEF (0.091)	PC (0.254)	PC=CR (0.200)

EEF=External Environment or Factor, CR=Clients' Requirement, PC=project characteristic

Table 8. Vector of Overall Priorities for the Four Alternatives and Ranking of the Alternatives

Alternatives	Vector of Overall Priorities	Rank
University RA		
Outsourcing by Repair and Maintenance Contract	0.240	3
Outsourcing by Specialist Term Contract	0.255	2
Outsourcing by Tendered Schedule Term Contract	0.236	4
Outsourcing by Measured Term Contract	**0.269**	**1**

Table 8. Vector of Overall Priorities for the Four Alternatives and Ranking of the Alternatives

University RB		
Outsourcing by Repair and Maintenance Contract	0.300	2
Outsourcing by Specialist Term Contract	**0.432**	**1**
Outsourcing by Tendered Schedule Term Contract	0.108	4
Outsourcing by Measured Term Contract	0.160	3
University RC		
Outsourcing by Repair and Maintenance Contract	0.235	2
Outsourcing by Specialist Term Contract	0.349	1
Outsourcing by Tendered Schedule Term Contract	**0.216**	3
Outsourcing by Measured Term Contract	0.201	4
University CA		
Outsourcing by Repair and Maintenance Contract	**0.289**	**1**
Outsourcing by Specialist Term Contract	0.274	2
Outsourcing by Tendered Schedule Term Contract	0.225	3
Outsourcing by Measured Term Contract	0.213	4
University CB		
Outsourcing by Repair and Maintenance Contract	0.238	3
Outsourcing by Specialist Term Contract	0.164	4
Outsourcing by Tendered Schedule Term Contract	0.251	2
Outsourcing by Measured Term Contract	**0.347**	**1**
University FA		
Outsourcing by Repair and Maintenance Contract	0.266	2
Outsourcing by Specialist Term Contract	0.181	3
Outsourcing by Tendered Schedule Term Contract	0.169	4
Outsourcing by Measured Term Contract	**0.384**	**1**
University FB		
Outsourcing by Repair and Maintenance Contract	0.223	3
Outsourcing by Specialist Term Contract	**0.367**	**1**
Outsourcing by Tendered Schedule Term Contract	0.264	2
Outsourcing by Measured Term Contract	0.146	4
University FC		
Outsourcing by Repair and Maintenance Contract	0.235	3
Outsourcing by Specialist Term Contract	0.227	4
Outsourcing by Tendered Schedule Term Contract	**0.293**	**1**
Outsourcing by Measured Term Contract	0.246	2
University FD		
Outsourcing by Repair and Maintenance Contract	0.245	2
Outsourcing by Specialist Term Contract	**0.295**	**1**
Outsourcing by Tendered Schedule Term Contract	0.222	4
Outsourcing by Measured Term Contract	0.238	3

Table 9. Procurement Methods Comparison (Actual versus Proposed)

No.	University	Type of building maintenance services	Actual Procurement method used	Procurement Method proposed by the Framework	Similarity
1	RA	Maintenance of Waterproofing System	Outsourcing by Measured Term Contract	Outsourcing by Measured Term Contract	√
2	RB	Maintenance of Air-conditioning Services	Outsourcing by Repair and Maintenance Contract	Outsourcing by Specialist Term Contract	X
3	RC	Housekeeping	Facilities Management Condition of Contract	Outsourcing by Specialist Term Contract	X
4	CA	General Repair Work	Outsourcing by Repair and Maintenance Contract	Outsourcing by Repair and Maintenance Contract	√
5	CB	Roof Repair Work	Outsourcing by Measured Term Contract	Outsourcing by Measured Term Contract	√
6	FA	Building Cleaning	Outsourcing by Measured Term Contract	Outsourcing by Measured Term Contract	√
7	FB	Maintenance of Electrical System	Outsourcing by Repair and Maintenance Contract	Outsourcing by Specialist Term Contract	X
8	FC	Maintenance of Road	Outsourcing by Tendered Schedule Term Contract	Outsourcing by Tendered Schedule Term Contract	√
9	FD	Maintenance of Lift	Outsourcing by Specialist Term Contract	Outsourcing by Specialist Term Contract	√

Table 10. Nine universities evaluation towards Decision Making Framework for Procurement Method Selection of Building Maintenance Management for Public Universities

No.	Evaluation Question	Rating				
		Very Poor	Poor	Satisfactory	Good	Excellent
1	The capability of the framework			11%	75%	14%
1.1	How well the framework in supporting the decision process?			2 (22%)	7 (78%)	
1.2	How reliable the assessment procurement selection criteria employed in the framework?			1 (11%)	8 (89%)	
1.3	How well the framework reflect the real situation in decision making process for procurement method selection?			1 (11%)	7 (78%)	1 (11%)
1.4	How useful was the Expert Choice software employed in the framework?				5 (56%)	4 (44%)
2	The applicability of the framework			10%	63%	27%
2.1	How relevant the framework in selecting the most appropriate procurement method?				6 (67%)	3 (33%)
2.2	How appropriate was the assessment criteria employed in the selection process?			1 (11%)	7 (78%)	1 (11%)
2.3	How appropriate was the framework to act as an alternative decision making for a supporting system?			1 (11%)	6 (67%)	2 (22%)
2.4	How relevant was the framework in improving the existing decision making process?				7 (78%)	2 (22%)
2.5	How relevant was the framework in term of:-					
2.5.1	Speed			3 (33%)	4 (44%)	2 (22%)
2.5.2	Flexibility			1 (11%)	4 (44%)	4 (44%)
2.5.3	Consistency				6 (67%)	3 (33%)
3	The validity of the result			33%	50%	17%
3.1	How convinced were you with the result produced by this framework?			3 (33%)	4 (44%)	2 (22%)
3.2	How confident were you in using the result as a selection making process in real situation?			3 (33%)	5 (56%)	1 (11%)
Overall score		**0%**	**0%**	**14%**	**65%**	**21%**

option which was stored in Expert Choice software. All the pair-wise comparison judgments made in Expert Choice software were synthesized to obtain vector of priorities. Table 4 showed all the vector of priority for main criteria, sub criteria and alternatives for University RA in selecting procurement method for maintenance of waterproofing. All main criteria judgments consistency ratio (CR) were 0.00 that were less than 0.10 (<0.10) which represent good consistency while Table 5 revealed vectors of priorities for the alternatives with respect to the main factor and alternatives' vector of overall priorities. The vector of overall priorities for the four alternatives as shown in Table 5 indicated that outsourcing by measured term contract (0.269) which obtained the highest of vector of overall priorities is the best procurement method for maintenance of waterproofing in University RA.

Similarly, the assessments were done by other 8 public universities and hence 9 procurement methods were successfully derived. The interviewees' decisions on vector of priorities for main criteria were different in selecting procurement method for different type of building maintenance services. Table 6 and Table 7 showed the summary results to compare all interviewees' priority vector to select the most appropriate procurement method for different type of building maintenance services. It can be seen in Table 6 and Table 7 that owners of a similar nature do not necessarily have similar needs. In fact, the needs are usually specific to the particular project. The vector of overall priorities for the four alternatives and ranking of the alternatives were shown in Table 8.

Table 9 compares the proposed and the actual procurement method used. From Table 9, out of 9 assessments conducted there were 6 matching and 3 non-matching. For all the 6 matching universities' respondents stated that they were satisfied with the result proposed by the framework. While for the non-matching, the University RB interviewee stated that the proposed procurement method was very suitable as the maintenance work for air-conditioning services required specialist to carry out. The University RC interviewee also claimed that the proposed framework was very useful and a new knowledge for him to make a more deliberate decision compared with the decision made previously. On the other hand, the respondent of University FB clarified that she was satisfied with the proposed framework as the maintenance of the electrical system should be done by specialists who are certified. The interviewees admitted that the selection of the procurement process proposed was decided on a judgmental basis which was not simply based on previous experience and perception. Clients may suffer if their selection simply based upon biased past experience and the conservative decisions of their in-house experts[30]. Although past experiences may be an essential factor that influences the selection of procurement strategy, but experiences and solutions to problems retrieved from previous projects may not be applicable to the current projects because each building has its own distinct characteristic. Thus, the proposed decision making framework will be capable to assist the decision-makers to select the most appropriate procurement method as the decision maker able to derive his set of important criteria in the selection according to the characteristics of the building.

Once the judgments completed and obtained the proposed procurement method from the framework, the interviewees were requested to rate the decision making framework in terms of capability, applicability and validity. The summary of the evaluations done by the 9 universities were shown in Table 10. The results revealed that majority of the interviewees perceived that the decision making framework developed was good (65%) and excellent (21%) in terms of capability, applicability and validity in assisting the decision-makers to select the most appropriate procurement method in building maintenance work. In terms of capability, the majority (75%) of the interviewees considered that the framework has the capability to assist them to select the most appropriate procurement method and 89% of the interviewees conceived that the assessment procurement selection criteria employed in the framework were reliable. In addition, majority of the interviewees (78%) also perceived that the framework was well in supporting the decision process and reflect the real situation in the decision-making process for procurement method selection.

In evaluating the applicability of the framework, 63% of the interviewees considered the framework had good applicability and 27% of the interviewees conceived that the framework had excellent applicability in selecting the most appropriate procurement method. Majority thinks that the framework was good (78%) and excellent (22%) in improving the existing decision making process. The results also indicated that the framework was good (67%) and excellent (22%) to act as an alternative decision making for a supporting system.

In terms of evaluating the results obtained from the framework, the interviewees conceived that the results obtained were good (44%) and excellent (22%) in convincing them to employ the result obtained. There were 56% (good) and 11% (excellent) of the interviewees were confident in using the result as a selection making process in real situation.

7. Conclusion

The proposed framework was well received by the interviewees and they admitted that the selection of the procurement process proposed was decided on a judgmental basis which was not simply based upon previous experience and perception. The evaluations done by the 9 universities regarding the proposed decision making framework revealed that majority of the interviewees perceived that the Decision Making Framework for Procurement Method Selection of Building Maintenance Management for Public Universities developed was good (65%) and excellent (21%) in terms of capability, applicability and validity in assisting the decision-makers to select the most appropriate procurement method in building maintenance work. Thus, the proposed decision making framework will be capable to assist the decision-makers to select the most appropriate procurement method.

Acknowledgement:

The authors gratefully acknowledge the financial support of the University of Malaya Research Grant (UMRG), grant no RG183/12SUS established at the University of Malaya, Sustainability Science Research Cluster.

References

1. Adekunle, S.O., D. Michael, M.A.K. Malik, M. Peter, and R. Steve. Construction project procurement routes: an in-depth critique. International Journal of Managing Projects in Business 2009; 2(3): 338-354.
2. Ambrose, M.D. and S.N. Tucker. Matching a Procurement System to Client and Project Needs: A Procurement System Evaluator. in W055/W065 Triennial Symposium on Customer Satisfaction. 1999.

3. Ancarani, A. and G. Capaldo. Supporting decision-making process in facilities management services procurement: A methodological approach. Journal of Purchasing and Supply Management 2005; 11(5–6): 232-241.
4. Atkin, B. and A. Brooks, Total Facilities Management. 2nd ed. 2005, Oxford: Blackwell Publishing Ltd.
5. Barret, P. and D. Baldry, Facilities Management: Towards Best Practice. 2nd ed. 2003, Oxford: Blackwell Publishing Ltd.
6. Bennett, J. and S. Jayes, Trusting the Team: The Best Practice Guide to Partnering in Construction. 1995, Reading: Centre for Strategic Studies in Construction, The University of Reading.
7. Cheung, S.O., T.I. Lam, M.Y. Leung, and Y.W. Wan. An analytical hierarchy process based procurement selection method. Construction Management and Economics 2001; 19(4): 427-437.
8. Chua, D., Y. Kog, and P. Loh. Critical Success Factors for Different Project Objectives. Journal of Construction Engineering and Management 1999; 125(3): 142-150.
9. Chua, S.J.L., A.S. Ali, and A.B. Alias. An Analytic Hierarchy Process (AHP) Decision Making Framework for Procurement Strategy Selection in Building Maintenance Work. Journal of Performance of Constructed Facilities 2013.
10. Construction Industry Development Board (CIDB), Construction Industry Master Plan Malaysia 2006-2015. 2007, Malaysia.
11. Espling, U. and U. Olsson. Part II. Partnering in a railway infrastructure maintenance contract: a case study. Journal of Quality in Maintenance Engineering 2004; 10(4): 248-253.
12. Hashim, M., M.C.Y. Li, N.C. Yin, N.S. Hooi, S.M. Heng, and T.L. Yong, Factors influencing the selection of procurement systems by clients, in International Conference on Construction Industry 2006 2006: Padang, Indonesia: 1-10.
13. Horner, R.M.W., M.A. El-Haram, and A.K. Munns. Building maintenance strategy: a new management approach. Journal of Quality in Maintenance Engineering 1997; 3(4): 273-280.
14. Hui, E.Y.Y. and A.H.C. Tsang. Sourcing strategies of facilities management. Journal of Quality in Maintenance Engineering 2004; 10(2): 85-92.
15. Ibbs, W. and Y.-Y. Chih. Alternative methods for choosing an appropriate project delivery system (PDS). Facilities 2011; 29(13): 527-541.
16. Kleeman, W.B. Out-tasking: More Widespread than Outsourcing in the USA. Facilities 1994; 12(2): 24-26.
17. Kumaraswamy, M.M. and S.M. Dissanayaka. Developing a decision support system for building project procurement. Building and Environment 2001; 36(3): 337-349.
18. Lateef, O.A. Building maintenance management in Malaysia. Journal of Building Appraisal 2009; 4(3): 207–214.
19. Lateef, O.A. Case for alternative approach to building maintenance management of public universities. Journal of Building Appraisal 2010b; 5(3): 201–212.
20. Lateef, O.A., M.F. Khamidi, and A. Idrus. Building maintenance management in a Malaysian university campuses: a case study. Australasian Journal of Construction Economics and Building 2010a; 10(1/2): 76-89.
21. Lau, K.H. and J. Zhang. Drivers and obstacles of outsourcing practices in China. International Journal of Physical Distribution & Logistics Management 2006; 36(10): 776-792.
22. Lavy, S. and D.L. Bilbo. Facilities maintenance management practices in large public schools, Texas. Facilities 2009; 27(1): 5-20.
23. Leech, N.L., K.C. Barrett, and G.A. Morgan, IBM SPSS for Intermediate Statistics : Use and Interpretation. 4th ed. 2011, New York: Taylor & Franciz Group.
24. Love, P.E.D., Z. Irani, E. Cheng, and H. LI. A model for supporting inter-organizational relations in the supply chain. Engineering Construction and Architectural Management 2002; 9(1): 2-15.
25. Love, P.E.D., M. Skitmore, and G. Earl. Selecting an Appropriate Procurement Method for the Construction Process: An Empirical Study. Construction Management and Economics 1998; 16(2): 221-233.
26. Luu, D.T., S.T. Ng, and S.E. Chen. A case-based procurement advisory system for construction. Advances in Engineering Software 2003a; 34(7): 429-438.
27. Masterman, J.W.E., An Introduction to Building Procurement Systems. 1992, London: Spon Press.
28. Morledge, R., A. Smith, and D.T. Kashiwagi, Building Procurement. 1st ed. 2006, UK: Blackwell Publishing Ltd.
29. Musa, Z.N., Determining the Best Options for Facilities Management(FM) Service Delivery in UK Shopping Complex, in School of the Built Environment 2011; Liverpool John Moores University: Liverpool: 309.
30. Ng, S.T., D.T. Luu, and S.E. Chen. Decision Criteria and Their Subjectivity in Construction Procurement Selection. The Australian Journal of Construction Economics and Building 2002; 2(1): 70-80.
31. Pesamaa, O., P.E. Eriksson, and J.F. Hair. Validating a model of cooperative procurement in the construction industry. International Journal of Project Management 2009; 27: 552–559.
32. Piaw, C.Y., Buku 1: Kaedah Penyelidikan. 2nd ed. 2011, Malaysia: McGraw-Hill Companies.
33. Pirdashti, M., A. Ghadi, M. Mohammadi, and G. Shojatalab. Multi-Criteria Decision-Making Selection Model with Application to Chemical Engineering Management Decisions. World Academy of Science, Engineering and Technology 2009; 49: 54-59.
34. Quinn, J.B. and F.G. Hilmer. Strategic outsourcing. Sloan Management Review 1994; 35(4): 43-55.
35. Royal Institution of Chartered Surveyors (RICS), Building maintenance: strategy, planning and procurement, in RICS guidance note 2nd edition 2009; Royal Institution of Chartered Surveyors (RICS): UK.
36. Saaty, T.L., Decision making for leaders : the analytical hierarchy process for decisions in a complex world. 1982, United States of America: Lifetime Learning Pub. 286.
37. Saaty, T.L. Decision making with the analytic hierarchy process. International Journal of Services Sciences 2008; 1(1): 83-98.
38. Saaty, T.L. Highlights and critical points in the theory and application of the Analytic Hierarchy Process. European Journal of Operational Research 1994a; 74(3): 426-447.
39. Saaty, T.L. How to Make a Decision: The Analytic Hierarchy Process. Interfaces 1994b; 24(6): 19-43.
40. Saaty, T.L. How to make a decision: The Analytic Hierarchy Process. European Journal of Operational Research 1990; 48: 9-26.
41. Sheng, L.C. Overview of In-house and Outsourcing Strategies for Property Maintenance and Management Services. The Malaysian Surveyor 2012; 47(1): 54-56.
42. Steane, P.D. and D.H.T. Walker. Competitive tendering and contracting public sector services in Australia – a facilities management issue. Facilities 2000; 18(5): 245-255.

43. Straub, A. Performance-based maintenance partnering: a promising concept. Journal of Facilities Management 2007; 5(2): 129-142.
44. Weston, R. It's hard to buck outsourcing tide. PC Week;7/15/96 1996; 13(28): 1.
45. Williams, B., Facilities Management in the UK. 2003, Kent: Building Economics Bureau Ltd.
46. Wong, J., Billions wasted, in The Star 2006: Kuching, Malaysia.
47. Wordsworth, P., Lee's Building Maintenance Management. 4th ed. 2001, Britain: Blackwell Science.
48. Zawawi, E.M.A., S.N. Kamaruzzaman, A.S. Ali, and R. Sulaiman. Assessment of building maintenance management in Malaysia: Resolving using a solution diagram. Journal of Retail & Leisure Property 2010; 9(4): 349–356.

Shirley ChuaJin Lin
Azlan Shah Ali
Anuar Bin Alias
Faculty of Built Environment,
University of Malaya,
50603 Kuala Lumpur, Malaysia.
Emails: shirleychua88@um.edu.my, shirleychua01@yahoo.com