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A model for strategic selection of feeder management systems: A case study

Hsing Hung Chen [a], Amy H.I. Lee [b,*], He-Yau Kang [c]

[a] Faculty of Management and Administration, Macau University of Science and Technology, Avenue Wei Long, Taipa, Macau, China
[b] Department of Industrial Management, Chung Hua University, No. 707, Sec. 2, Wu Fu Rd., Hsinchu 300, Taiwan
[c] Department of Industrial Engineering and Management, National Chin-Yi University of Technology, 35, Lane 215, Sec. 1, Chung San Rd., Taiping, Taichung 411, Taiwan

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ABSTRACT

The move to integrating distribution management system (DMS) and feeder management system (FMS) in China is becoming the main trend in recent years, in addition to upgrading and rebuilding existing energy management system (EMS) and DMS. However, with increasing complexity in the social environments along with rapidly changing technologies, how to select a suitable contractor and a FMS project is becoming an important issue for electric power companies. This paper first briefly introduces FMS and then lists its critical success criteria. A model that applies a multi-criteria decision-making (MCDM) method, an analytic network process (ANP) associated with benefits, opportunities, costs and risks (BOCR), is constructed to help power companies to select the most suitable FMS project.

1. Introduction

The power industry in China has now entered into a new era of large power networks, large power generations, large unit capacity, large voltage transmission/distribution, and highly automatic control systems. To maintain a secure and economic operation for such huge power systems, some advanced power system control facilities and technologies, such as energy management system (EMS) and distribution management system (DMS), have been introduced into business operations since 1995. EMS includes fundamental functions of generation scheduling and network analysis, like transient stability analysis and voltage stability analysis [1]. DMS is to monitor network security and to manage voltage and reactive power for 35 kV and above sub-transmission networks or 10 kV radial distribution networks [2]. In average, a supervisory control and data acquisition (SCADA) or an EMS/DMS system can run no more than ten-years in China. Accordingly, most of the existing SCADA systems in China have reached the end of their life, and the power companies have a heavy task to either update or rebuild the SCADA systems. In addition, for area power network, the network reconfiguration, maintenance scheduling, tap control of the tap change under load transformer and capacitor switching are mainly concerned. Therefore, some special functions for area network dispatching centers are being developed in recent years, and some off-line management functions such as automated mapping/facilities management/geographic information system (AM/FM/GIS) are also considered to be developed. The AM/FM/GIS, combined with customer information system, load management system and automatic dispatching system, forms an integrated computer management information system, which is called feeder management system (FMS). It is predicted that the move to an integration of DMS and FMS in China will become the main trend in the near future. Therefore, it is essential for electric power companies to select the most appropriate contractor and FMS project in today's complex social environment and rapidly changing technological environment. It is surprised that no research has ever tackled such an important issue in power industry before. In order to fill the vacancy, this paper finds the critical success criteria of the FMS and constructs an evaluation model to help power companies in selecting the most suitable FMS project.

There are several common contract methods. The lowest bid tendering method (LBT), featuring simple tendering procedures and non-controversial issues, makes it one of the most popular contract awarding methods for international procurement, especially for state-run projects [3]. However, due to changes in the industrial environment and the trend of global competition, decision-making models that only consider the price may no longer

Abbreviations: AGC, automatic generation control; AM/FM/GIS, automated mapping/facilities management/geographic information system; ANP, analytic network process; BOCR, benefits, opportunities, costs and risks; CI, consistency index; CR, consistency ratio; DMS, distribution management system; EMS, energy management system; ERP, enterprise resource planning; FMS, feeder management system; GUI, graphic user interface; LBT, lowest bid tendering method; MAT, most advantageous tendering; MCDM, multi-criteria decision-making; RTDB, real-time database; SCADA, supervisory control and data acquisition; TCP/IP, transmission control protocol/internet protocol.

* Corresponding author. Tel.: +886 35186582.
E-mail address: amylee@chu.edu.tw (A.H.I. Lee).

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meet the needs of the competitive industrial environment. The most advantageous tendering method (MAT) does not only consider the price, it also prevents malicious price-lowering competition and enables the company to obtain a well qualified contractor [4].

In response to the adoption of MAT method in the FMS project, the characteristics of project management and variant facets of their critical success criteria will first be introduced in the subsequent sections. Conventional AHP and ANP usually adopt pairwise comparison of criteria to rank the final priority. However, considering the aspects of benefits, opportunities, costs and risks of an alternative, and synthesizing the positive criteria of benefits and opportunities and the negative criteria of costs and risks with rating calculation by a method such as additive, subtractive and multiplicative is a more comprehensive and instinctive way in daily life. Accordingly, ANP with BOCR is applied in the paper to handle positive and negative criteria all together in public-oriented projects.

The rest of this paper is organized as follows. FMS and its critical success criteria are examined in Section 2. The ANP model with BOCR for evaluation and operation of FMS projects is constructed in Section 3, and a real case is examined in Section 4. Discussions and conclusions are provided in the last section.

2. Feeder management system and its critical success criteria

FMS, an important IT project in power industry, is one of the resolutions many enterprises have resorted to in the 21st century. This has been a result of increased complexity of environment, global competition, and rapid changes in technology. However, when firms are faced with investment or business planning decisions, a number of factors influence the decision. EMS or DMS, one of the most important IT systems in the power industry, has been gaining the universal attention for the last two decades. In order to efficiently organize and manage the operations of power systems, a five-leveled structure of power system dispatching centers in China is adopted [5]. At the top level, there is a national dispatching center in charge of coordination between different regions. At the second level, there are six regional power networks including central China (CC), northeast China (NE), north China (NC), east China (EC), northwest China (NW) and south China (SC) regional power networks, and each of them consists of several provincial power systems. Generation scheduling and security monitoring are the major concerns in these levels of control centers, which are also called EMS (a SCADA/AGC system). The third level is the provincial control centers. Below each provincial network, there are subtransmission systems or distribution networks. Some big city or urban area stands as the center for this kind of network. At the lowest level are the country networks, which cover wide rural areas. All of the last three levels of control centers, which are called DMS (a SCADA system), are to monitor network security and to manage voltage and reactive power for 35 kV and above sub-transmission networks or 10 kV radial distribution networks. Generally speaking, EMS/DMS has a ten-year life period in China. Most of the power companies with existing SCADA systems are faced with an imminent task to update or rebuild their SCADA since the current systems are reaching the end of their life. The original SCADA will be replaced by a new generation of EMS/DMS. This new EMS/DMS will undoubtedly be with an open and distributed structure. The operation system, graphic user interface (GUI), real-time database (RTDB) and computer network communication, UNIX, X-Window/Motif, TCP/IP and remote terminal unit will comply with international standards. For area power network, the maintenance scheduling, network reconfiguration, tap control of the tap change under load transformer and capacitor switching are the major concerns. Therefore, some special functions for area network dispatching centers should be developed in near future [6]. In addition to the above functions of DMS in dispatching centers, some off-line management functions also gain attention. Some area electric power supply bureaus are introducing automated AM/FM/GIS for the needs of ordinary management. FMS, an integrated computer management information system, is formed by combining the AM/FM/GIS with customer information system, load management system and automatic dispatching system. FMS integrates resources of existing distribution management systems to build up an overall distribution feeder automatic system in order to (1) remotely control/monitor normal-open and normal-close power distribution systems; (2) cut off the normal-open feeder when a fault occurs, isolate the fault area and finally restore the power supply to the blackout area (fault identification and service restoration); and (3) help power dispatchers to improve power supply quality and reliability through variant technologies about advanced feeder automation. It is clear that the move to the integration of DMS and FMS in China will become the main trend in the years to come.

LBT was the most popular contract methods for state-run projects for more than two decades. However, in terms of time, quality, satisfaction, on-site safety and disputes on public contract fulfillment, MAT is more effective than LBT [4]. The clients believe that MAT will end up with higher project cost than LBT, but also has a lower possibility in the change of budget. Consequently, the overall effectiveness of the MAT method has gained positive recognition among the participant groups of public work [4]. Three subjects, which are tender system, evaluation committee system, and evaluation process, are generally considered to be the direction of improvement on MAT method, and are, therefore, applied in the selection of FMS project in this paper. If a procurement entity adopts MAT, which is a multi-criteria bid evaluation procedure, the contractor with a tender that fulfills the criteria set forth in the tender documentation and whose proposal is the most advantageous to the entity will win the tender. Bingi et al. [7] suggested that implementing a SCADA is a careful exercise in strategic thinking, precision planning, and negotiations with departments and divisions. It is important for companies to be aware of certain critical issues before implementing any SCADA project. Careful consideration of these critical success criteria will ensure a smooth rollout and realization of full benefits of the project. Use ERP implementation in China as an example. Yusuf et al. [8] show respondents' opinions on ERP implementation difficulties in Chinese enterprises. Most of respondents thought "support of top management" was the most important issue to decide implementation's fate. "Costly and time-consuming", "cultural differences", "technical complexity", and "lack of professional personnel" were also ranked as very serious problems. Only "inner resistance" was identified as a moderate trouble by respondents [8].

If the procurement entity adopts the MAT method, the entity shall establish a procurement evaluation committee, which shall be composed of 5–9 members who have relevant professional knowledge about the project being carried out. The evaluation committee's duties are [4]:

1. Setting or approving the evaluation criteria and the evaluation method;
2. Conducting the evaluation of tenders;
3. Aiding the entity in explaining matters related to the evaluation criteria, the evaluation process, or the result of evaluation.

Furthermore, the evaluation items for MAT may be, but not limited to, technology, quality, function, management, commercial terms, track records, contract performance, price, financial plan and any other items that matters to the function or benefit of procurement. Therefore, it is considered that the evaluation committee will make the selection on a fair basis to choose the tender that is the most advantageous to the procuring entity. The members of the evaluation committee must have full knowledge about the entity's requirement and to avoid a purchasing process that are not transparent. Based on previous literatures [4,8–11] and the evaluation of the committee, the most important factors for the FMS project are as follows. Under benefits, there are criteria: functionality (to what extent the completed product complies with all functionality targets including all planned features), reliability (to what extent the completed product meets all reliability objectives like accuracy, number of errors in the product, and quality, etc.), and usability (to what extent the completed product meets user friendly characteristics like ease of use, automated, easy to repair, and easy fault identification, etc.). The criteria under opportunities are extension and expansion (to what extent the completed product meets the traits of easy expansion including scan point number, hardware and software, and site numbers), learning and innovation (quick and easy access of technology and information for all related personnel), and flexibility (compatibility of hardware support, good application software to provide ability to interface, supporting and managing files and performing storage, retrieval, manipulation and transmission functions). Under costs are criteria: bidding price (proposed project bidding price), extra capital spending (estimated extra expenditure in addition to the bidding price), and performance bond (guarantee from a contractor for satisfactory completion of a project). The criteria under risks are: commercial terms (additional requirement by commercial terms), technical complexity (inadequacy in advanced technologies), and cultural differences and inner resistance. In order to select the best FMS project in the subsequent real case study, the authors constructed a BOCR framework with twelve critical success criteria, which will be presented in Section 4.

3. Analytic network process (ANP) associated with BOCR

The ANP, proposed by Saaty [12], is a generalization of AHP, a simple, mathematically based multi-criteria decision-making tool to deal with complex, unstructured and multi-attribute problems. A network may be more suitable to represent the complexity of the problem, which must be solved by the ANP. One of the general theories of the ANP, which was also proposed by Saaty [12], let decision makers to deal with the benefits, opportunities, costs, and risks (the BOCR merits) of a decision. A network can consist of four sub-networks: benefits, opportunities, costs, and risks. A systematic ANP model with BOCR is proposed in this section. For a more detailed explanation of each of the steps, please refer to Saaty [12] and Lee et al. [13,14]. The steps are summarized as follows:

Step 1. Form a committee of experts and define the project selection problem.

Step 2. Construct a control network for the problem. A control network, as depicted in the first half in Fig. 1, contains strategic criteria, the very basic criteria used to assess the problem, and the four merits, benefits, opportunities, costs and risks.

Step 3. Determine the priorities of the strategic criteria based on conventional ANP [12].

Step 4. Determine the importance of benefits, opportunities, costs and risks to each strategic criterion. A five-step scale is used, and the values of each scale is assigned to be very high, 0.42; high, 0.26; medium, 0.16; low, 0.10; and very low, 0.06 [15–17].

Step 5. Determine the priorities of the merits using the results from step 3 and 4. Calculate the priority of a merit by multiplying the score of a merit on each strategic crite-

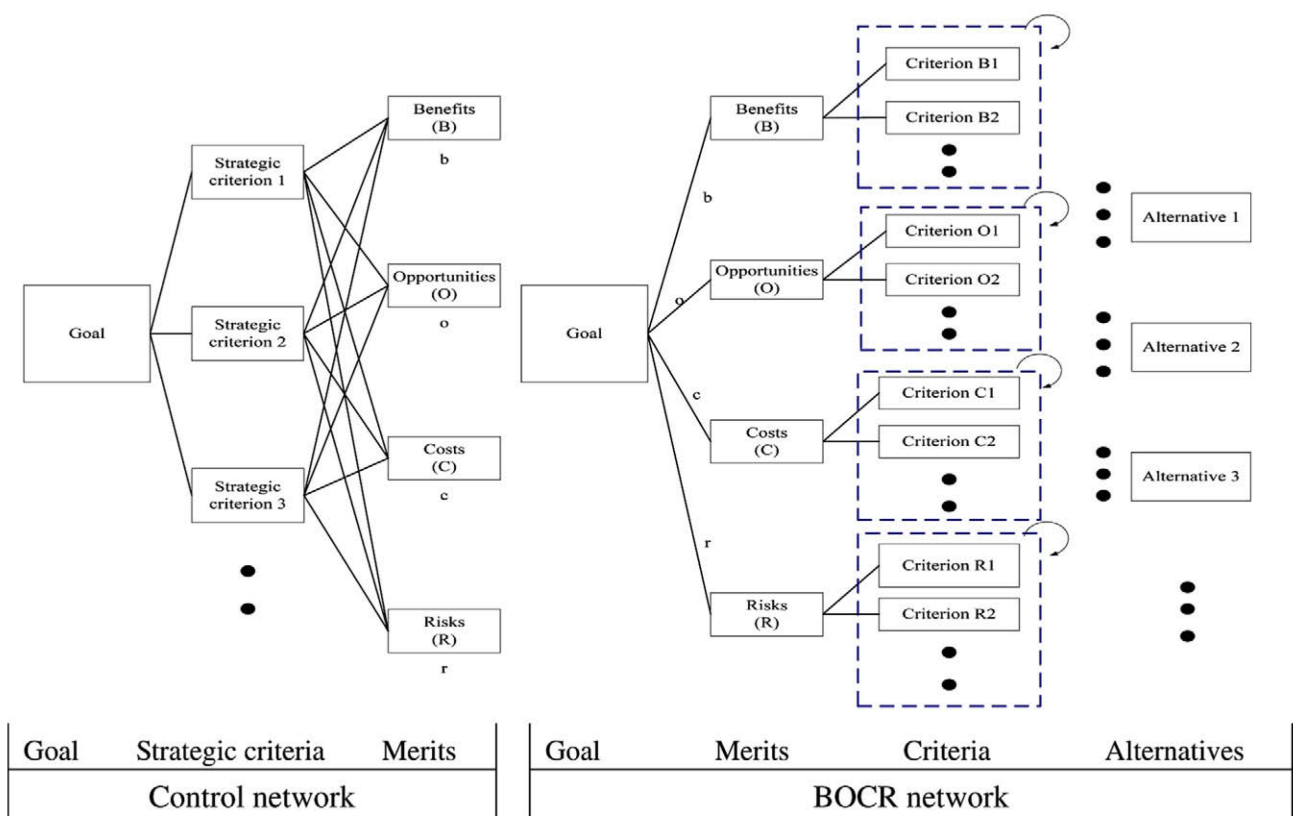

Fig. 1. The ANP with BOCR.

rion from step 4 with the priority of the respective strategic criterion from step 3 and summing up the calculated values for the merit. Normalize the calculated values of the four merits, and obtain the priorities of benefits, opportunities, costs and risks, that is, *b*, *o*, *c* and *r*, respectively.

Step 6. Decompose the project selection problem into a network with four sub-networks: benefits (B), opportunities (O), costs (C) and risks (R), as depicted in the second half in Fig. 1.

Step 7. Formulate a questionnaire based on the BOCR network to pairwise compare the criteria with respect to the same upper level merit, and the interdependence among the criteria with respect to the same upper level merit.

Step 8. Calculate the relative priorities in each sub-network based on the ANP.

Step 9. Calculate the priorities of alternatives for each merit sub-network. Using the priorities obtained from step 8, form an unweighted supermatrix, a weighted supermatrix and a limit supermatrix for each sub-network by ANP, which is proposed by Saaty [12].

Step 10. Calculate overall priorities of alternatives by synthesizing priorities of each alternative under each merit from step 9 with corresponding normalized weights *b*, *o*, *c* and *r* from step 5. There are five ways to combine the scores of each alternative under B, O, C and R [15,18].

In order to elucidate the proposed model clearly, the model integrated with twelve critical factors described in Section 3 will be applied in a real case study in the subsequent section to help select the best FMS project.

4. Case study

An anonymous power company in China willing to select the best FMS project was used as an example to examine the practicality of the project selection model. In the first step, seven senior managers, including technology development manager, research manager, operations manager, marketing manager, purchasing manager, dispatching manager and controller, contributed their professional experience and formed the evaluation committee. Their first task was to select critical success criteria. The committee also confirmed the firm's strategic criteria as performance, business drivers and marketing need, based on previous literatures and practical experiences [4,8,11]. The relationship of FMS project among goal, strategic criteria, merits, criteria and alternatives is structured by evaluation committee as shown in Fig. 2.

The first level of the control network contains the goal, the selection of the best FMS project. In the second level, three strategic criteria are considered; namely, *performance*, *business driver*, and *market need*. *Performance* concerns the capabilities of the technology for delivering the expected results in variant processing environments such as functionality and usability. *Business drivers* are defined as business expectations of the firm assessed by business managers, engineers or developers, for instance, time to business operations, learning and innovation, liability and costs. *Market need* considers whether the firm possesses advanced technology to satisfy customer needs in compared with other competitors. In the third level, there are four merits: benefits (B), opportunities (O), costs (C), and risks (R). The purpose of the control network is to calculate the priorities of the four merits.

The BOCR network has the same goal as the control network does, and the purpose of this network is to calculate the priorities

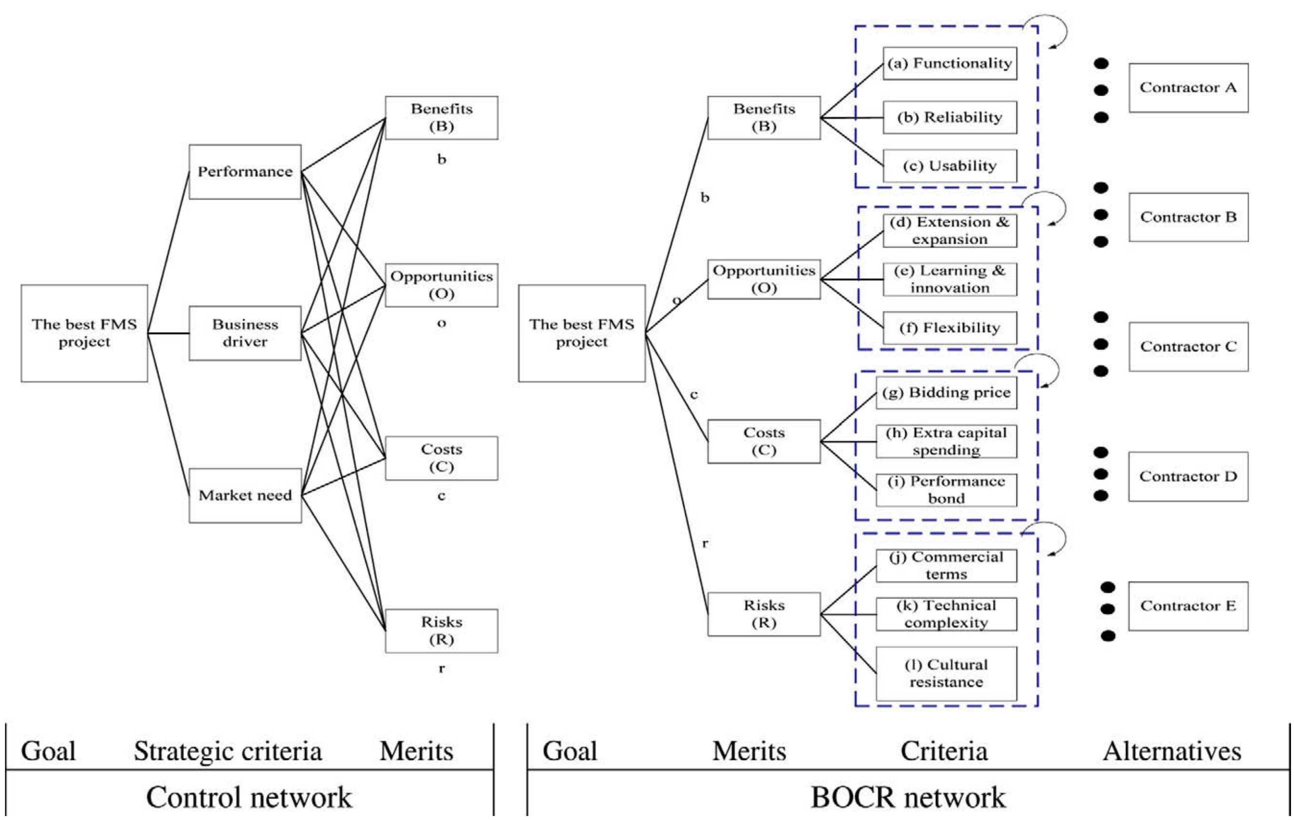

Fig. 2. The framework for FMS selection.

of alternatives. The second level of the network composes of the four merits. The BOCR network can be further divided into four sub-networks: *benefits* sub-network, *opportunities* sub-network, *costs* sub-network, and *risks* sub-network. In the third level of the network, twelve selected criteria in Section 2 are applied here to evaluate each FMS project. Under *benefits* merit, there are three criteria, group factors (a) through (c). Under *opportunities* merit, there are three detailed criteria, group factor (d), (e) and (f). Group factors (g), (h) and (i) are the criteria of *costs* merit, and group factors (j), (k) and (l) are the criteria of *risks* merit.

Nine tenders intended to take part in the FMS bidding procurement; however, only five tenders passed the bidder's qualification examination, and they are represented as contractor A, B, C, D, and E. Contractor A and D are joint-ventured companies from both local and foreign companies, while contractor B and C are foreign companies from Europe and the USA, respectively. Contractor E is a domestic company.

A questionnaire is constructed, and the members of the evaluation committee are invited to contribute their professional experience. Based on the collected opinions of the experts and the proposed model, the performance of the five contractors can be generated.

In the first part of the model, experts are asked to evaluate the priorities of benefits, opportunities, costs and risks. Based on each expert's opinion, a pairwise comparison matrix is formed to evaluate the three strategic criteria, and the priorities of the strategic criteria are calculated. The consistency property of the matrix is also examined. Delphi method is applied to obtain a consensus among the members. The final pairwise comparison of the experts on the three strategic criteria with respect to the goal is as shown in Table 1.

Table 1
Comparison matrix for the strategic criteria.

	Performance	Business driver	Market need
Performance	1	2	5
Business driver	1/2	1	3
Marketing need	1/5	1/3	1

An eigenvector, w_{s1}, and an eigenvalue, $\lambda_{\max}$, are calculated using the eigenvalue method [19].

$$w_{s1} = \begin{matrix} \text{performance} \\ \text{business driver} \\ \text{market need} \end{matrix} \begin{bmatrix} 0.581 \\ 0.309 \\ 0.110 \end{bmatrix} \quad \text{and} \quad \lambda_{\max} = 3.0064$$

The eigenvector shows the priority of the three strategic criteria assessed by the experts. The consistency property of the matrix is defined and calculated by consistency index (CI) and consistency ratio (CR) as follows [19].

$$\mathrm{CI} = \frac{\lambda_{\max} - n}{n - 1} = \frac{3.0064 - 3}{3 - 1} = 0.0032,$$
$$\mathrm{CR} = \frac{\mathrm{CI}}{\mathrm{RI}} = \frac{0.0032}{0.58} = 0.0055,$$

where n is the number of items being compared in the matrix, and RI is random index of similar size [19]. Since CR is less than 0.05, the comparison matrix is consistent.

Next, experts are asked to assess BOCR according to strategic criteria by the five-step scale. The ratings of the four merits on strategic criteria by Delphi method and the normalized priorities of BOCR are shown in Table 2.

In the second part of the model, the priorities of the alternatives under each merit are calculated. There are four sub-networks, namely benefits, opportunities, costs, and risks. The relative importance weights of criteria with respect to the same upper level merit, the interdependence priorities among the criteria that have the same upper level merit are calculated using the Delphi pairwise comparison results. The priorities of criteria, without considering the inter-relationship among criteria, are shown in the third column of Table 3. The inter-relationship, the synthesized priorities of criteria are shown in the last column of Table 3.

The importance of criteria in making the FMS project selection should be understood by the management. Under the benefits merit, the most important criterion, out of the three criteria, is usability, with a priority of 0.557. This means that the major benefit concern for the firm in having the FMS project is to have a good system to operate. Under the opportunities merit, extension and expansion (0.534) is the most important criterion. This implies that a system that can be extended and expanded in the future is essen-

Table 2
Priorities of benefits, opportunities, costs and risks.

	Performance (0.581)	Business driver (0.309)	Marketing need (0.110)	Priorities	Normalized priorities
Benefits	Very High	Very High	High	0.4024	0.3877
Opportunities	Medium	High	Very High	0.2195	0.2115
Costs	High	Very High	High	0.3094	0.2981
Risks	Low	Low	Medium	0.1066	0.1027

Table 3
Priorities of merits and criteria.

Merits	Criteria	Priorities (no interdependence)	Priorities (with interdependence)
Benefits (0.3877)	(a) Functionality	0.260	0.261
	(b) Reliability	0.106	0.182
	(c) Usability	0.633	0.557
Opportunities (0.2115)	(d) Extension and expansion	0.557	0.534
	(e) Learning and innovation	0.123	0.182
	(f) Flexibility	0.320	0.283
Costs (0.2981)	(g) Bidding price	0.581	0.514
	(h) Extra capital spending	0.110	0.141
	(i) Performance bond	0.309	0.345
Risks (0.1027)	(j) Commercial terms	0.272	0.199
	(k) Technical complexity	0.608	0.691
	(l) Cultural resistance	0.120	0.110

tial for the firm. Under the costs merit, bidding price (0.514) is the major concern. Under the risks merit, technical complexity (0.691) is the problem the firm worries most about. This means that the firm concerns more about the possibility that it does not have adequate technologies and capability to handle the system.

The performance results of different contractors under various criteria, however, are collected from each expert individually in order to limit the number of pairwise comparisons [19]. All criteria, except bidding price, extra capital spending and performance bond, are qualitative criteria and are rated in a range from zero to a hundred. For the criteria under benefits and opportunities merits, the higher the score, the better the performance of the contractor is. On the other hand, for the criteria under risks merit, the higher the score, the worse the performance of the contractor is. Bidding price, extra capital spending and performance bond are quantitative criteria under costs merit. The larger the estimated amount is, the worse the performance of the contractor is. The synthesized performance value of each contractor on each criterion is calculated by geometric averaging the results from all the experts. The results are shown in Table 4. These performance values are further transformed into a number between zero to one by dividing the performance value of a contractor on a criterion by the largest performance value among all contractors on the same criterion. The above performance values of contractors and the priorities of criteria (with interdependence) are synthesized to obtain the overall performance of each contractor under each merit. The normalized performances of contractors under the four merits are calculated as shown in Table 5.

The final ranking of the alternatives are calculated by the five methods to combine the scores of each alternative under B, O, C and R. The results are as shown in Table 6. Under all five methods of synthesizing the scores of alternatives, contractor D (a joint-ventured company) ranks the first. While contractor B (a European company) and contractor E (a domestic company) always stay respectively as the fourth and the last contractors, contractor A (a joint-ventured company) and contractor C (a US company) take turns in the ranking of the second and the third. Under multiplicative priority powers, and multiplicative methods, contractor A is the second best, and contractor C is the third. However, under probabilistic additive and subtractive methods, the opposite is true. In addition, under additive method, both contractor A and contractor C have the same ranking of the second best. Such a result is because the overall performances of the two contractors are very similar, and the final scores of the two contractors are not significantly different under all the methods of calculation. The two joint-ventured organizations, by integrating resources from both the cost-effective local company and the technology-oriented foreign company, perform better than the other contractors. In MAT bidding, this kind of joint-ventured entity usually dominates the market since it has advanced technologies with reasonable price. In addition, a joint-ventured organization not only helps local company upgrade its technologies but also reduces culture conflicts from inner resistance. A comparison of the performances between contractor D and A shows that contractor D performs better in both the benefits and opportunities merits, but the opposite is true in the costs and risks merits. The final priorities of contractor D and

Table 4
Qualitative and quantitative results of different criteria under different contractors.

Criteria	Contractor A	Contractor B	Contractor C	Contractor D	Contractor E
Functionality	79.676	86.924	80.160	82.093	68.412
Reliability	79.320	81.493	84.043	81.135	71.803
Usability	88.365	90.666	87.636	88.519	84.225
Extension and expansion	79.360	83.042	85.637	83.649	71.302
Learning and innovation	81.449	78.122	75.155	84.764	64.525
Flexibility	83.669	84.648	87.764	87.316	75.367
Bidding price	1.3040	1.5556	1.4631	1.3347	1.2190[a]
Extra capital spending	180.2	310.0	246.1	152.5	237.2[b]
Performance bond	64.0	159.5	149.9	78.8	116.8[b]
Commercial terms	75.835	80.224	81.645	78.679	75.955
Technical complexity	78.831	84.254	89.257	77.212	67.829
Cultural resistance	58.186	65.241	70.816	50.948	42.572

[a] In billion of RMB.
[b] In thousand of RMB.

Table 5
Priorities of alternatives under four merits.

Alternatives	Merits	
	Benefits (0.3877) Normalized	Opportunities (0.2115) Normalized
Contractor A	0.18671	0.18025
Contractor B	0.19707	0.19360
Contractor C	0.21462	0.21213
Contractor D	0.21081	0.21918
Contractor E	0.19079	0.19483

Alternatives	Merits					
	Costs (0.2981)			Risks (0.1027)		
	Normalized	Reciprocal	Normalized reciprocal	Normalized	Reciprocal	Normalized reciprocal
Contractor A	0.16523	6.05227	0.23851	0.17327	5.77123	0.22947
Contractor B	0.22414	4.46148	0.17582	0.19676	5.08223	0.20208
Contractor C	0.20372	4.90872	0.19345	0.21006	4.76045	0.18928
Contractor D	0.18090	5.52797	0.21785	0.21670	4.61474	0.18349
Contractor E	0.22601	4.42449	0.17436	0.20320	4.92122	0.19568

Table 6
Final synthesis of priorities of alternatives.

Alternatives	Synthesizing methods									
	Additive		Probabilistic additive		Subtractive		Multiplicative priority powers		Multiplicative	
	Priority	Rank	Priority	Rank	Priority	Rank	Priority	Rank	Priority	Rank
Contractor A	0.2052	2	0.4443	3	0.0435	3	0.2049	2	1.1756	2
Contractor B	0.1905	4	0.4311	4	0.0303	4	0.1903	4	0.8651	4
Contractor C	0.2052	2	0.4466	2	0.0458	2	0.2036	3	1.0639	3
Contractor D	0.2119	1	0.4527	1	0.0519	1	0.2116	1	1.1787	1
Contractor E	0.1872	5	0.4278	5	0.0269	5	0.1870	5	0.8094	5

A under multiplicative method are 1.1787 and 1.1756, respectively. Such performances are not significantly different. However, note that due to the nature of the multiplicative method, the importance of the four merits (b, o, c and r) does not take effect in this calculation. Taking into account the different importance of the four merits in the other four calculation methods, contractor D performs significantly better than contractor A because contractor D makes higher scores in the benefits and opportunities merits, which have a combined weight of 0.6858 ($b + c = 0.3877 + 0.2981$).

5. Conclusions

With increasing complexity in social environments along with rapidly changing technologies, adopting MAT to select the best project has a great potential since it does not only consider the price, but also concerns variant facets of projects. In this paper, critical factors for the success of a FMS are generated first. An ANP with BOCR model is then used to facilitate the FMS selection. After theoretically analyzing and practically evaluating the FMS projects through the proposed process, practitioners can fully understand the expected performance of each FMS project under benefits, opportunities, costs and risks. The best project under the complex and dynamic environments can finally be selected. Our future research will examine whether the project selected can keep a firm operating efficiently and innovatively.

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