Procurement Factors Analysis and Scenario Simulation for the Next Generation Radio Monitoring System

Pei-Keng Sun[a], and KuangChiu Huang[a]
Institute of Telecommunications Management, National Cheng Kung University [a]

***Abstract* —Modern digital radio monitoring systems procurement is a complicated and critical task for National Communication Commission (NCC) to execute with various issues to be considered. An expensive system affects efficiency of spectrum management, and it will be operated for more than ten years. Therefore, a thorough study to figure out key factors of procurement is necessary. This research adopts Analytic Network Process (ANP) method to analyze key procurement factors from both academia and industry, and then simulates two scenarios to forecast potential procurement outcomes. The findings of this research are designed to assist the NCC in evaluating, designing and executing a suitable radio monitoring procurement project.**

I. INTRODUCTION

The existing analog monitoring equipment has been used for more than fifteen years. Therefore, the NCC in Taiwan is planning to replace the existing system. However, the procurement of radio monitoring equipment includes huge amount investment with complex procedures, and the facilities must be endurable to operate for ten to fifteen years. Due to the heterogeneity of the equipment, this research discusses key factors which affect the "Next Generation Radio Monitoring System Procurement."

This study took references from interviews and related research papers to build our research model. By means of the model, it expects to find key factors that could affect the NCC's decision-making, and to figure out ranks of factors by experts' opinions. Yet the procurement is still in the planning, this study assumes two scenarios to simulate the outcomes in difference situations and expects to enhance usefulness of our research by providing a complete analysis.

II. LITERATURE REVIEW

This section consists of two categories of literatures. First one defines factors and their terminologies. Second one explains the reasons why this study chooses ANP as a decision-making methodology.

A. Factors

Factors of our ANP model are collected and selected from two sources. First, the Article five of "Regulations for Evaluation of the Most Advantageous Tender:" there are eight key factors (technology, quality, function, management, commercial terms, past achievements in contract performance, price, financial plan, and any other matters related to the function or benefit of procurement) of evaluation items for selecting the most advantageous tender. Second, literatures mention about related procurement factors. This research classifies different terminologies of factors from past studies into previous definitions. The results indicate that technology, quality, past achievements in contract performance, and price are more important than other factors while a procurement project carrying on.

B. Decision-Making by ANP

Past studies adopted ANP as their methodology to calculate factors' weights and ranks for achieving their research goal [1]-[2]. Owing ANP not only offers a clear research model but also analyzes questionnaire data systematically. It provides a suitable methodology to construct research model via expert interviews, as well as to figure out the weights and ranks of each factor. Therefore, we chose ANP as the research method to pairwisely compare dimensions and factors from expert questionnaires.

III. SYSTEM COMPARISON

This section compares monitoring system by hardware and software to gain some insight of their differences and improvements.

A. Hardware

According to the Request for Proposal (RFP) of the "Radio Spectrum Monitoring Project" of the Directorate General of Telecommunication (DGT), the existing radio monitoring systems are composed by remote monitoring stations (RMS) and mobile monitoring stations (MMS). The systems analyze analog signals by monitoring medium frequency (MF), high frequency (HF), very high frequency (VHF) and ultra-high frequency (UHF) for their major tasks. In other words, the radio frequencies (RF) range that the systems monitored is from 300 kHz to 3 GHz.

In order to monitor complex digital communication messages, the NCC must upgrades and replaces the existing equipment to monitor digital signals [3]. As the functions of the existing systems, the next generation systems are designed with fixed monitoring stations (FMS) and mobile monitoring stations (MMS) to monitor radio frequencies. The new systems monitor MF, HF, VHF, UHF, and super high frequency (SHF), [4].That is, the RF, in the range of 300 kHz to 30 GHz, is broader than the existing systems. TABLE I lists differences of hardware.

Corresponding author:fj9321@gmail.com
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TABLE I
HARDWARE COMPARISON OF EXISTING SYSTEMS AND NEXT GENERATION SYSTEMS

	Existing system	Next generation system
Signal type	analog signals	analog and digital signals
Frequency range	from MF to UHF	from MF to SHF

B. Software

The software structure of existing systems adopts client-server structure for data communications, users communicate between clients and servers to execute monitoring tasks through specific port numbers and software (shown as Fig. 1). However, the inconvenient issue is that it is hard to exchange data via heterogeneous systems from different vendors. To overcome this issue, there are two proposed data communication solutions: web-based structure and three-tier structure [5].

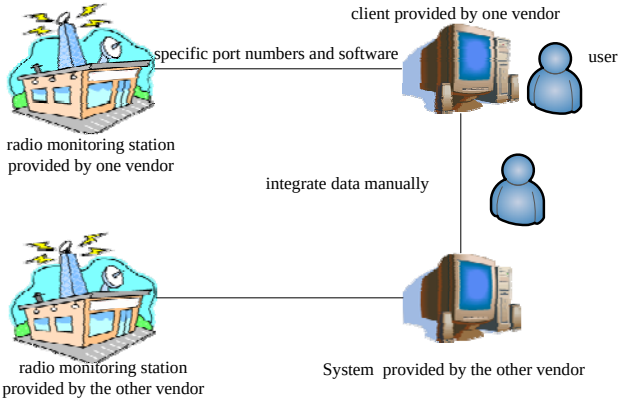

Fig. 1. Client-Server Structure

The concept of web-based structure is to design a web supported program, operators can use a web browser, without installing any software on their computer, to execute radio monitoring tasks by connecting to the application server (shown as Fig. 2). The advantages of the structure are that the systems become easier to be updated and maintained, but it needs vendors to design another new product and to redesign the original software for satisfying users' requirement [5].

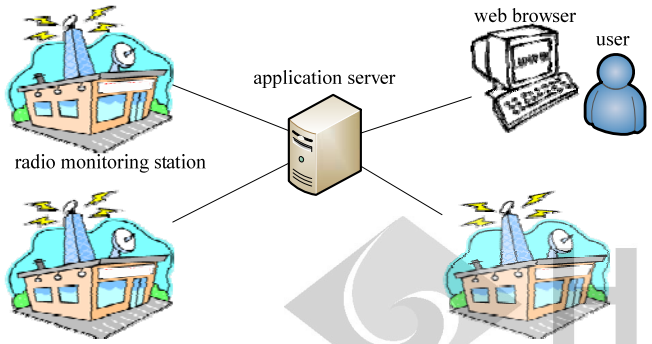

Fig. 2. Web-Based Structure

The concept of three-tier structure contains three-tiers: user interface (UI), radio monitoring functionalities (RMF), and measurement server (MS), with two interfaces: application programming interface (API) and generic interface (GI) (shown as Fig. 3). The structure could provide standardized interfaces, which is convenient for data exchange, and flexible for each standardized layer to update. In order to offer the open platform for integrating heterogeneous equipment together, vendors have to provide the related document and source code of two interfaces [5]. TABLE II lists differences of software.

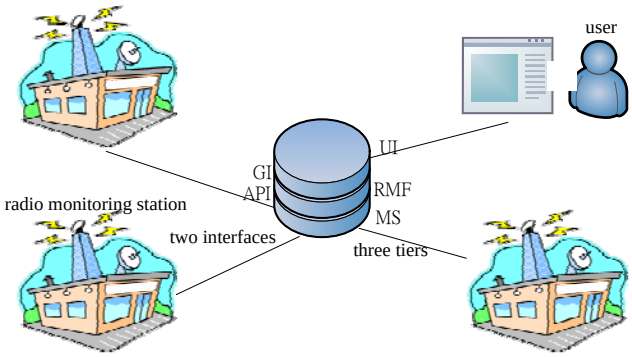

Fig. 3. Three-Tier Structure

TABLE II
SOFTWARE COMPARISON OF EXISTING SYSTEMS AND NEXT GENERATION SYSTEMS

	Existing system	Next generation system
Software structure	client-server	web-based or three-tier

IV. METHODOLOGY

Methodology has two sections: first one is Delphi Method which investigates and arranges experts' opinion; second one is ANP which adopted by this study.

A. Delphi Method

The Delphi Method suggested researchers use the Knowledge Resource Nomination Worksheet (KRNW) to find out experts first. In order to have an overall perspective of the essential domain experts, KRNW divides experts into different domain of expertise, for examples: academics, practitioners, and government officials. This method used five steps to identify experts and invite them into our study (shown as Fig. 4) [6]:

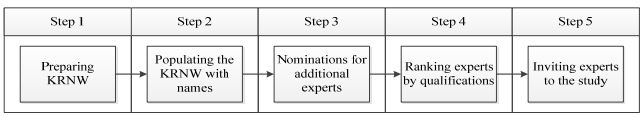

Fig. 4. Steps of Delphi Method

First of all, this study separates the experts into academics and government officials. Second, it fills the names of experts into type and organization. Third, it contacts with experts on KRNW and asks experts nominate other experts who are not on the list. Fourth, it classifies experts and ranks experts by different category. Fifth, it invites experts to

participate in team of experts.

B. Analytic Network Process

ANP, developed and presented by Professor Thomas L. Saaty, assumes that factors may have a relationship of interdependent and feedback, so-called network models. Researchers can use following five steps to conduct the research (shown as Fig. 5) [7, 8].

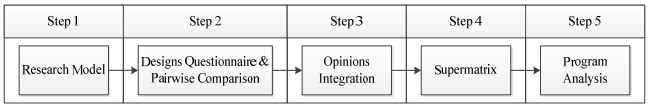

Fig. 5. Steps of ANP

First, it constructs a research model, which is including research objective, dimensions, and factors. Second, it designs questionnaire and compares various factors pairwisely based on the research model; third, it compiles the information obtained from questionnaires. Fourth, it constructs supermatrix from the data results, calculates relative factors' weights, and exams whether the Consistency Ratio (C.R.) comply with the standard. Fifth, it decides to choose and use which analysis program. For the purpose of more correct and accurate results, this study chooses Super Decision, the specific ANP computing software designed by Dr. Saaty and his research team, to calculate results from expert questionnaire.

V. Research Results and Analysis

There are three sections in research results and analysis. First one introduces the experts' background, compiles the outcome from interviews, then building a research model. Second one conducts expert questionnaire, then divides the experts into different domains and analyses the outcome from the expert questionnaire. Third one simulates two scenarios and provides an evaluation process which makes this study clearer and more complete.

A. Expert Interviews

This study interviews academia respondents and government officials. The former represents scholars who participate in "Next Generation Radio Monitoring Systems Build Plan and Optimization Analysis" research team. The latter represents government officials of the NCC who involved in the procurement project.

The information this study has been collected from interviews indicates that our model consists of three dimensions with eight factors (shown in Fig. 6). First dimension is "commercial terms" which contains two factors, "procurement contract" and "maintenance contract," that the NCC can control and modify. Second dimension is "monitoring systems" which contains three factors, "quality," "functionality" and "price," related to the system. Third dimension is "supplier" which composed of three factors, "technology," "project management" and "past achievements in contract performance," related to the supplier's or the bidder's behavior and ability.

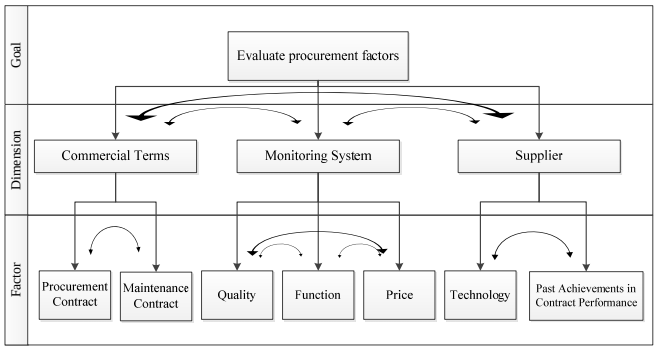

Fig. 6. Research Model

B. Questionnaire Analysis

Before preparing for the expert questionnaire, this research follows the opinions obtained by interviews and builds the relationship between dimensions and factors. The respondents choose from academics (research team members) and officials (the NCC involved in the project). There are six scholars and eleven officials, with 17 respondents totally. The integrated raw data pass consistency test, namely the C.R. of those data are less than 0.1. TABLE III shows the weights of each factor which consists of academia opinion, officials' opinion, experienced experts' opinion, and overall opinion.

TABLE III
Factors' Weights

Factors \ Type	Academics	Officials	Experienced	Overall
Procurement contract	0.131	0.163	0.190*	0.149
Maintenance contract	0.193*	0.154	0.179	0.171
Quality	0.177	0.186*	0.154	0.184*
Function	0.095	0.152	0.087	0.128
Price	0.062	0.061	0.051	0.061
Technology	0.172	0.132	0.158	0.147
Project Management	0.063	0.062	0.077	0.063
Past achievement in contract performance	0.108	0.091	0.104	0.098

*: represents the most important factor in that category

According to the outcome of data analysis, there are five points to be addressed. First, quality is the most important factor and price is the least important to overall experts. Next, the academia perspective reflects that the maintenance contract is the most important factor. Third, the officials' opinion illustrates that quality is the most important factor. Forth, the experienced experts' opinion indicates that procurement contract is the most important factor. Fifth, monitoring system, includes quality, function, and price, is important among all dimensions.

C. Scenario Simulations

The procurement is still in the planning stage; therefore, based on our ANP model, this study assumes two scenarios to simulate the outcomes with difference situations and adopts the weights from questionnaire analysis. The first scenario takes traditional idea into account; while the second scenario takes overall perspectives into consideration. Scenario 1 assumes that three different vendors with their features in systems--quality, function, and price. Scenario 2 assumes that vendors have their strength within three dimensions.

In scenario 1, Supplier A provides the best quality, lowest function, but expensive system; supplier B provides better quality, fair function, and lowest price; whereas supplier C provides lower quality, fair function, and the most expensive systems. The factors' scores are depicted in TABLE IV.

TABLE IV
FACTORS' SCORES AND WEIGHTED SCORES IN SCENARIO 1

Factors \ Suppliers	A	B	C
Quality (0.184)	8 (1.472)	6 (1.104)	4 0.736)
Function (0.128)	4 (0.512)	8 (1.024)	6 0.768)
Price (0.061)	6 (0.366)	4 (0.244)	8 (0.488)
Score	(2.350)	(2.372)	(1.992)
Rank	2	1	3

The numbers within the parentheses represent weighted scores.

The outcome shows that supplier B obtains the highest weighted scores although it provides the highest price. According to this result, there is no doubt that better quality and function of systems are more important than low cost. Lower price is no longer dominant radio monitoring market.

In scenario 2, supplier A provides the most useful commercial terms, and lower level of monitoring system, and fair supplier's ability; supplier B provides fair commercial terms, better monitoring system, but lower supplier's ability; while supplier C has poor commercial terms, fair monitoring system, and better supplier ability. The factors' scores are depicted in TABLE V.

TABLE V
FACTORS' SCORES AND WEIGHTED SCORES IN SCENARIO 2

Dimensions \ Suppliers	A	B	C
Commercial terms (0.320)	8 (2.560)	6 (1.920)	4 (1.280)
Monitoring system (0.373)	4 (1.492)	8 (2.984)	6 (2.238)
Supplier (0.308)	6 (1.848)	4 (1.232)	8 (2.464)
Score	(5.900)	(6.136)	(5.940)
Rank	3	1	2

1. The weight of each dimension comes from the sum of its factors.
2. The numbers within the parentheses represent weighted scores.

The outcome shows that supplier A receives the highest scores. There are two possible reasons why system is the most important matter for the NCC to consider: first, building a system which is highly reliable, easy to maintain, and easy to upgrade as its primary tasks; second, monitoring system are important than commercial terms and suppliers' capability.

VI. CONCLUSION

This study offers a clear set of constructs, factors and weights to take a comprehensive evaluation from both academia and government officers. This study figures out the weights of each factor: quality has the highest weight and price is the least important factor to evaluate procurement in the overall questionnaire analysis. Among all dimensions, monitoring system receives the highest weight. This paper also assumes two scenarios to simulate potential situation. Scenario 1 reflects that providing the lowest price might not win the bids anymore, and scenario 2 reflects that providing the better monitoring system to overcome supplier's ability and commercial terms may wins the bids. This research can provide factors of radio monitoring study and procurement forecasting to assist not only the NCC's procurement project but also national communication regulatory authorities in other countries with a complete process.

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