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Power planning in ICT infrastructure: A multi-criteria operational performance evaluation approach ☆

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ABSTRACT

It is critical for information and communications technology (ICT) companies to carry our effective power planning, in order to support the growing number of services they provide, and this traditionally relies on the tacit knowledge and experience of senior staff. The loss of such domain knowledge resulting from the retirement of staff is an important issue for organizations such as Chunghwa Telecom (CHT), the largest ICT operator in Taiwan. This study thus develops a systematic power planning model using a multi-criteria operational performance evaluation. A group version of the fuzzy repertory grid and fuzzy TOPSIS approaches is applied to elicit a set of evaluation criteria that senior staff agree on, and then the priorities of the telecom rooms are evaluated against this. In addition, a new factor, reflecting the attitudes of the decision makers with respect to the degree of strictness, is defined to determine the superiority and inferiority of each alternative compared to the others. Furthermore, a novel decision aggregation strategy regarding the degree of variation among decision makers is proposed, and a quantitative assessment is carried out to analyze its impact on the ranking results in an objective manner. The proposed model may help ICT organizations to more effectively manage their power resources, and thus obtain competitive advantages.

1. Introduction

Since the United States broke up AT&T in 1984 and instigated another round of telecommunication deregulation in 1996 aimed at increasing competition among service providers worldwide, each country that signed the WTO (World Trade Organization) has promoted the liberalization of its telecoms markets, and also allowed or relaxed domestic and foreign investment in their domestic industries. Chunghwa Telecom (CHT), which became a private company in 2005, is the largest mobile operator in Taiwan, with an annual revenue of NT$192.46 billion (US$6.41 billion) and 34.8% market share in total mobile customers (CHT annual report, 2011). CHT recently orientated its development toward information and communications technology (ICT) services and systems, with the aims of designing the best network resources, developing green and cloud applications, and building good relationships with customers. According to an article published in Taiwan News in July 2012, the National Communications Commission (NCC) of Taiwan has proposed a plan to implement the last mile network infrastructure in order to foster the competitive advantages of local firms. Efficient resource allocation thus plays an important role in CHT's ICT strategic management.

Power resources are critical to support all kinds of ICT infrastructures, and energy efficiency is increasingly important in this area [1]. In order to expand its business scale, CHT has developed various core telecom services, utilizing power resources to gain operational experience as well as increased revenues. Many organizations face imbalances between power capacity and demand, which is either too small or too big for their needs, driving up energy costs, and thus reducing the funds available for more strategic activities. In addition, due to the limited availability of land, and increasing awareness of environmental protection and health issues in Taiwan, the construction of new telecom rooms is one of the toughest obstacles for international vendors when attempting to obtain a power infrastructure that meets their precise size requirements. However, as many prior studies have shown, telecom rooms play an increasingly critical role in ICT infrastructure, such as enabling firms to develop a cloud computing environment and data centers [1,2]. Effective plans for appropriately allocating power resources in telecom rooms need to take many issues into consideration, such as the budget, time, and labor constraints.

In the past few years, CHT has adopted an intuitive approach to making power planning decisions, which mainly depends on the work experience of senior staff. However, this involves a high level

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of subjectivity, which means that well-grounded solutions may not always be obtained. In addition, as a result of privatization, a large number of older employees are about to retire, and CHT will soon lose these valuable sources of knowledge. CHT thus requires a systematic and/or mathematical model to solve what is essentially a multi-criteria decision making (MCDM) problem. In this study, we develop a novel model of power planning for CHT's telecom rooms, named P^2M, based on the senior staff's tacit domain knowledge and experience. We conduct a retrospective analysis in which the senior staff are invited to systematically evaluate the operational performance of the present telecom rooms using an MCDM approach. In this way, their valuable expertise can be acquired and shared, thus helping to develop the model in an effective and efficient manner.

To achieve this research aim, we apply a group version of the widely used repertory grid (RG) and MCDM approaches to elicit a set of evaluation criteria that the senior experts agree on, and then rank the priorities of telecom rooms against this. In particular, TOPSIS (Technique for Order Preference by Similarity to Ideal Solution) is applied due to its better ability to provide positive and negative decision reference points, i.e., ideal positive and negative solutions, compared to traditional MCDM methods [3]. To handle the decision problem in a more realistic fashion, fuzzy RG and fuzzy group TOPSIS are used to deal with the uncertainties inherent in the opinions expressed by domain experts. One of the weaknesses arising with the traditional fuzzy TOPSIS is when two or more alternatives are at the same distances from both reference points, and thus it is difficult to identify the better choice. The problem can become especially acute when linguistically assessing numerous alternatives, as in our case. To overcome this, alternatives can be differentiated by further taking into consideration the number of times they are superior and inferior with regard to their individual criteria. For example, when one alternative outperforms the others in a criterion over a pre-defined threshold value, then this raises its winning count. Such a threshold value, termed the attitude factor, reflects the attitudes of decision makers with respect to the degree of strictness in assessing what superiority or inferiority mean, with a higher value representing a stricter attitude. By using this parameter, decision makers can make more consistent evaluations.

Furthermore, we also investigate the aggregation strategy that exists in most MCDM problems, and propose a new such strategy on the basis of the separation ratio, which measures the differences in the opinions of decision makers. A quantitative assessment of the proposed strategy is also carried out, so that its impact on the ranking results can be analyzed objectively. After operational performance evaluation, the telecom rooms are clustered into various categories, by profiling the characteristics of each category, the senior staff advise on the appropriate operational modes of power planning. The proposed model thus enables planners and managers to develop more appropriate power resource plans for telecom rooms.

The rest of the paper is organized as follows. In Section 2, we review the related studies. The power planning model, P^2M, for CHT's telecom rooms is described in detail in Section 3. Section 4 demonstrates how the model works, including the three phases of operational performance management, aggregation and clustering. Discussions and conclusions are then presented in Sections 5 and 6, respectively.

2. Literature review

2.1. Repertory grid

Repertory grids (RG) have been widely used as a tool for capturing and recording the unique structures of interviews, and thus as a way of acquiring knowledge [4]. A complete RG includes elements, constructs, and a linking mechanism. Elements are objects related to a specific topic, and between 15 and 25 of these is an appropriate number for generating a "universe of meaning" regarding a specific domain [5]. In general, there are two basic ways that elements can be selected, as they are either supplied or elicited [5]. The former is when the elements are provided by the researchers, whereas the latter is when the research participants are asked to provide them. A triad method is often used to gather constructs to differentiate between elements. Some authors refer to RG as a methodological tool rather than a research method, while others as an interviewing technique [6,7]. Over the years, RG has been applied to acquire and understand knowledge in many different domains, such as marketing research [8,9], project management [10–13], policy setting [14], and exploring customer attitudes [15].

In 1969, Kelly extended the dichotomous linking mechanism used in RG into crisp ratings (usually 1–5 or 1–7). However, the acquisition capability of this classic form of RG was limited, because the use of crisp numbers could not represent the vagueness inherent in human judgments. In order to do so, many researchers have extended RG into fuzzy environments [4,16–21], and the resulting fuzzy repertory table (FRT) technique has been applied to machine learning [4], negotiating agents [22], and decision support [17]. However, FRT [17] only considers single rather than group decision-maker scenarios. In this study, we extend FRT to the scenario of a group of decision-makers, and use it to elicit the constructs from a set of representative elements.

2.2. MCDM

MCDM is a set of methods which allow the aggregation and consideration of numerous (often conflicting) criteria in order to choose, rank, sort or describe a set of alternatives to aid a decision process [23,24]. Although there are many different MCDM approaches to systematically evaluate criteria and rank alternatives, TOPSIS is one of the most widely used of these [3,25]. Its advantages include computational simplicity, simultaneous consideration of the best and worst alternatives, and the ability to yield an indisputable preference order [26–28]. TOPSIS differs from other MCDM methods by explicitly considering benefit and cost criteria along with the positive ideal solution (PIS) and negative ideal solution (NIS), such that the decision results lead to greater performance for the benefit criteria and lesser performance for the cost ones.

Due to the vagueness of human expression, TOPSIS has been extended into fuzzy environments for which there are group decision-making scenarios [25,29–44]. The TOPSIS approach has also been applied to a wide range of domains, such as supplier selection [36,45], plant location selection [46], personnel selection [47], and case-based application [48,49], and is often combined with other methods, for example, VIKOR [50], AHP [51–55], fuzzy ANP [56], and fuzzy goal programming [57–59]. In addition, it has been used to examine and compare with other MCDM methods, such as DEA (Data Envelopment Analysis) [60] and utility-based approaches [61]. The ideal-solution concept of TOPSIS has also been integrated in the decision procedures of other MCDM methods [62–64]. However, very few studies use MCDM to consider the issue of telecom rooms.

While many researchers have extended TOPSIS into group scenarios [25,27,32,37,45,65–69], they presented no specific procedures to process group decision-making problems, and each used a different way to deal with the issue of aggregation, as well as the selection of alternatives and the problem of reaching a consensus [62,64,67,70]. In general, there are two approaches for aggregating values, including the weights of the evaluation criteria and the rating of alternatives: first and last aggregations [27]. In