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MULTI-CRITERIA ANALYSIS ON THE STRATEGIES TO THE TELECOMMUNICATIONS DEVELOPMENT – A CASE STUDY IN TAIWAN

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Abstract

Telecommunications development is rapid in the world. Telecommunications service markets in Taiwan have been diversified with competitiveness. Even though the 4G, ADSL and Wi-Fi are operated, cable access still could not satisfy the public's increasing broadband access. For enhancing the competitions of services, in 2007, Taiwan's supervisory authority has decided to open wireless broadband access business that is the Worldwide Interoperability for Microwave Access (WiMAX). However, the development of WiMAX in Taiwan had been delayed. The research would find and analyze those impact factors. The study took the methods of Multiple Criteria Decision Making (MCDM) -- a hybrid MADM model combining the Decision Making Trial and Evaluation Laboratory (DEMATEL). The DEMATEL is based on the Analytic Network Process (DANP) with VIKOR. This systematic assessment would obtain the factors' rank, and then analyze those impact factors. The government supervision should be the first one of the most important factors. And then, the factors would be considering for business management and profit. Through the VIKOR, the largest gap from aspired level would be business management. However, the item would be pushed by government supervision level. So, the government supervision level should be the first one to improve.

Keywords: Telecommunications, Multiple Criteria Decision-Making (MCDM), VIKOR, Analytic Network Process (ANP), DEMATEL-Based ANP (DANP), WiMAX

1. Introduction

In Taiwan, telecommunications service markets have been diversified and competitive. It has been operated with the 4G, Wi-Fi and ADSL, but cable access still could not satisfy the public's demand for the broadband access. In 2007, Taiwan's government decided to build the wireless broadband access business, Worldwide Interoperability for Microwave Access (WiMAX), for enhancing services. WiMAX technology was one of the leading cost-effective technologies in the wireless industry, providing opportunities for mobile service providers that lacked third-generation

(3G) licenses or related infrastructure. The developments of WiMAX deserved government and relevant industry review. However, the WiMAX development in Taiwan has been delayed. The Korean government decided to convert WiBro (WiMAX) services into long-term evolutionary time division duplex (LTE-TDD) services (Business Korea, 2013). The issue had been special and important. The WiMAX telecom service in Taiwan also had not achieved the expected results, and the operators were running hard, which involves many aspects and issues. The Taiwan government's telecommunications regulatory authorities had clearly declared industrial development policies and strongly introduced WiMAX. Why was WiMAX not profiting as expected?

This study explores the factors that cause the loss of wireless broadband access services, and uses this as a reference for relevant business promotion strategies. That is, the study expects to use this case to know: What are the key factors if the telecom industry is expected to develop successfully? How should the overall strategy be set? Due to the factors related to each other and feedback, this study would sort and discuss the relevant factors. Further, the research would evaluate and improve the WiMAX market strategy, and try to propose effective strategies. Identifying the key factors for the success of the telecommunications industry, we hope those can be the reference for the development strategy of the telecommunications industry in the future.

2. Telecommunications Development about WiMAX

Korea Telecom, with more than 200,000 users, had taken the WiMAX services first. Sprint then launched commercial WiMAX service in North America in 2008 with positive profit. Brazil, Russia and India were also the major regions of WiMAX (Hsieh and Chao, 2009). WiMAX might link the wired and wireless broadband. WiMAX had three key success factors: the availability of mobile devices and consumer premises equipment, bandwidth speed, interoperability and standardization. A group of WiMAX experts summarize its three powerful applications: IP voice, broadband on demand and wireless service (Viehland and Chawla, 2011).

Both the hurdles and opportunities had been in the diffusion of the WiMAX technology (Olla, 2009). The design of such wireless broadband networks has been similar to that of wired IP platform networks. Lehr and Chapin (2009) have studied whether wired and wireless access networks can be aggregated on a public infrastructure and whether wireless networks can be aggregated over a public wireless infrastructure. However, there is no specific answer. It is only expected that wired broadband access networks will evolve towards a common platform architecture. This is due to the inherent scarcity of the RF spectrum. Khemiri *et al.* (2011) consider how to divide the wireless bandwidth capacity into trunks and divide the adaptive modulation and coding (AMC) scheme into different regions with specific modulation and coding schemes. The main issues being in wireless devices and networks are: quality of service, battery life, capacity and spectrum efficiency, and security (Gupta, 2009). The MMR WiMAX network can increase coverage at lower CAPEX (capital expenditures) and OPEX (operating expenses). Due to the simpler design rather than the more expensive base stations, the deployment of relatively inexpensive relay stations results in lower costs.

Sadowski *et al.* (2009) found that the traditional net present value (NPV) calculations taking into account current European regulatory and legislative frameworks. They indicated that high technology and market uncertainty will delay the implementation of municipal WiMAX networks. Due to licensing fees and base station coverage, there is a profit margin between WiMAX networks operating in unlicensed (5 GHz) and licensed bands (2.5 / 3.5 GHz). Commercial wireless service providers entered the licensed WiMAX band in 2008 and are expected to have an impact on the viability of municipal WiMAX networks. Coster (2009) also pointed out that mobile web applications were very broad in scope of both the industrial and commercial world. Saleh and Fleury (2010) observed that IEEE 802.16e (Mobile WiMAX) uplink behavior was rarely noticed, but emerging interactive media services show that uplink issues should be more valued. This paper presents a possible remedy for selecting a more complex H.264 / AVC Main profile, but having an impact on mobile devices. WiMAX video transmission is still found to be sensitive to the choice of transmission frame size.

Rigas *et al.* (2011) show that WiMAX can provide higher transmission rates and higher quality of service, so it can be used in telemedicine on-site surgery and medical examinations, medical conferences, etc., especially in remote areas. Ganapati and Schoepp (2008) studied the technology alternatives implemented by the city and the governance arrangements for the implementation. In this century, the WiFi, WiMAX and Mesh networks have developed rapidly. Despite the controversy over municipal supply of wireless broadband, they believe that municipalities play a vital role in providing such network infrastructure.

WiMAX has been selected the 4th generation mobile communications network by the Taiwan's Government. There were many domestic carriers having invested heavily in it. However, the WiMAX development in Taiwan had been delayed. The Korean government turned WiBro services into Long Term Evolution Time Division Duplex (LTE-TDD) services in 2013. Taiwan's government had decision to use 4G, not WiMAX. So, this research would serve as a policy experience case study, with WiMAX as a bridge between 3G and 4G.

3. Analysis Methods
3.1 DEMATEL

The DEMATEL, Decision Making Trial and Evaluation Laboratory (DEMATEL), was developed by the Battelle Memorial Institute in Geneva. It can be used to analyze complex and interrelated management issues. It transforms causality into a system-understandable structural model (Tzeng *et al.* 2007; Teng *et al.* 2009). And it builds an influential network relation map (INRM) to solve the relationship problem (Chiu *et al.* 2013). Zhou *et al.* (2011) proposed the critical success factor (CSF) for emergency management and improved it according to the structural relationship. Based on the causality of the causal map, the CSFs for emergency management were calculated. Liu *et al.* (2013) have addressed for selling cruise products, using the DEMATEL process to present optimal improvement models.

The DEMATEL method can be divided into 4 steps: (1) Initializing a direct impact on the relationship matrix (initial direct-relation matrix); (2) normalizing a direct impact on the relationship matrix (normalized direct-influence matrix); (3) calculating the total effect relationship matrix (total influence-relation matrix); and (4) establishing an effect network diagram (network relationship map, NRM). The method would be used to precipitate the critical and connected factors for developing Taiwan's broadband network infrastructure.

The DEMATEL process is as follows:

Step 1: Initializing a direct impact on the relationship matrix (initial direct-relation matrix)

We calculated the initial average matrix by scores. The respondents were asked to indicate the direct effects. Each expert used Likert scales from 0, 1, 2, 3, and 4, which respectively go from "No influence (0)" to "Very high influence (4)". Those scores were converted from their own practical experience through a direct impact on the average relationship matrix approach to integration. After integrating the direct impact on the relationship matrix, it became a non-negative matrix.

Here, r_{ij} represents the i factor influencing the j factor.

$$\mathrm{E} = \frac{1}{H}\sum_{q=1}^{H} r_{ij}^{q} \tag{1}$$

Step 2: Normalizing a direct impact on the relationship matrix (normalized direct-influence matrix)

We added the values by columns and by rows. Among the values, we selected the maximum value of the overall impact. This value would be used as a normalized reference value for the entire initialization relationship matrix (as shown in Equation 3), and then we normalized the matrix using Equation 2. The final values in the matrix N ranged between 0 and 1.

$$\mathrm{N} = \frac{E}{b} \tag{2}$$

$$\mathrm{b} = \max\left[\max_{1\le i\le n}\sum_{j=1}^{n} e_{ij}\ ,\ \max_{1\le j\le n}\sum_{i=1}^{n} e_{ij}\right] \tag{3}$$

Step 3: Calculating the total effect relationship matrix (total influence-relation matrix)

We could set up the normalized direct-influence matrix N several times, $\boldsymbol{T} = \boldsymbol{N} + \boldsymbol{N}^2 + \boldsymbol{N}^3 + \ldots + \boldsymbol{N}^z$, $\boldsymbol{N}^z = [0]$ when $z \to \infty$. Finally, we arrived at the values of the total effect for every evaluated factor. Thus, the whole formula was $\boldsymbol{T} = \boldsymbol{N}(\boldsymbol{I} - \boldsymbol{N})^{-1}$, in which I means the unit matrix.

Step 4: Establishing an effect network diagram (network relationship map, NRM)

We added the impact values by columns and by rows in the total effect relationship matrix, T. Using Equation (4), we found the impact values in which one factor affects the others, while Equation (5) got the impact values from the other factors. Finally, adding the two kinds of values from Equations (4) and (5) that obtained the degree of prominence of factors, while taking the values from Equation (4) and subtracting the values from Equation (5) obtained the degree of causal relation. Thus, we were able to establish a network relationship map for evaluating the whole model (Tzeng *et al.* 2007).

$$\mathrm{r} = [r_i]_{n\times 1} = \left[\sum_{j=1}^{n} t_{ij}\right]_{n\times 1} \tag{4}$$

$$\mathrm{d} = [d_j]'_{1\times n} = \left[\sum_{i=1}^{n} t_{ij}\right]'_{1\times n} \tag{5}$$

3.2 ANP

The ANP, Analysis Network Process, is a general form of the Analytic Hierarchy Process (AHP) for multi-criteria decision analysis. AHP builds decision-making issues into goals, hierarchy of decision criteria and alternatives, and ANP builds it into the network. Both then use a pairwise comparison system to measure the weight of the structural components and finally sort the alternatives in the decision.

3.3 VIKOR

Opricovic (1998) and Opricovic and Tzeng (2002) developed VIKOR. The Serbian name, Vlse Kriterijumska Optimizacija I Kompromisno Resenje, means: multi-standard optimization and compromise solution. The basic concept of VIKOR is to first define the ideal solution for both positive and negative. A positive ideal solution represents the highest value alternative (with a score of 10), while a negative ideal solution represents the lowest value alternative (with a score of 0).

It has been developed as a multi-standard decision-making method for solving discrete decision problems with unmatched and conflicting criteria (Opricovic and Tzeng, 2004). Arrange a set of alternatives and choose the one with the highest score. Then, in order to help the practitioner make the final decision, it is recommended to compromise the issue with conflicting criteria. Here, the compromise solution will be the closest solution, and compromise means reaching an agreement based on mutual concessions.

4. Results

The WiMAX had been taking for the 4th generation mobile communications network by the Taiwan's Government. Its ability for attracting the world's main reason could be summarized in two items at that time period: The first, WiMAX was the Intel Co. leading the R&D for the main communications technology. The second, WiMAX claimed the transfer rate would be 70 Mbps within 70 miles (112.6 km). But shortly, the Australia's Buzz Broadband companies and U.S. Sprint, the two companies pushing WiMAX as the unlimited broadband telecommunications networks, both announced they exited and waited. Those announcements shocked the world.

In Taiwan, there were many domestic carriers having invested heavily in it. The developments of WiMAX recently deserve government and relevant industry review. For the development of Taiwan's WiMAX and to take into account the difficulties encountered due to industry issues, this study used the DEMATEL method. We summarized the opinions and views provided by government officials, telecom carriers, telecom equipment manufacturers, and scholars into key dimensions and criteria that were impacting the development of WiMAX. This study collected via questionnaires experts' advices, issued 22 questionnaires, 18 copies of valid questionnaires. Identify the degree of difference the actual impact value and the expected value, and propose a strategy-driven proposal. That was a multi-criteria decision-making structure: establish a multi-criteria evaluation system for each dimension, evaluate and propose improvement strategies. We would make an analysis for the relationship of impact factors.

The impact factors to promote the WiMAX in Taiwan have been summarized to 4 dimensions and their criteria. As Table 1 shows below, the dimensions were: C1 "market level", C2 "technology level", C3 "business management and profit level" and C4 "government supervision level".

Table 1. The 4 dimensions and their criteria of impact factors

Dimensions	Criteria
market level	Alternative for Service
	The competitiveness of rates in market
	Economies of scale
technology level	Construction rate of Base Stations
	The Situation of International WiMAX Terminal and Base Station Equipment Produced
	The Superiority of Technology Relative to the 3G、LTE(4G)
business management and profit level	Funds of Operating
	Whether Provided Innovation and Application Services Compared The existing Services
government supervision level	Wireless Spectrum Resources Whether Exert Resources Maximum Effectiveness
	Competition Regulations Side

We aim not only to determine what the important factors of promoting the WiMAX in Taiwan are but also to measure the relationships among these dimensions and criteria (Table 2 and Table 3).

Table 2. Total influence-relation matrix - criteria

T	C_{11}	C_{12}	C_{13}	C_{21}	C_{22}	C_{23}	C_{31}	C_{32}	C_{41}	C_{42}
C_{11}	0.76	0.86	0.83	0.86	0.71	0.75	0.73	0.78	0.64	0.52
C_{12}	0.90	0.77	0.877	0.87	0.73	0.80	0.76	0.79	0.64	0.55
C_{13}	0.85	0.863	0.76	0.88	0.75	0.76	0.76	0.80	0.65	0.53
C_{21}	0.93	0.87	0.91	0.80	0.77	0.81	0.80	0.82	0.69	0.57
C_{22}	0.85	0.82	0.84	0.84	0.63	0.76	0.72	0.77	0.63	0.49
C_{23}	0.81	0.81	0.79	0.79	0.72	0.64	0.68	0.73	0.62	0.49
C_{31}	0.83	0.83	0.85	0.84	0.70	0.73	0.64	0.769	0.62	0.50
C_{32}	0.93	0.92	0.91	0.89	0.77	0.83	0.780	0.73	0.66	0.53
C_{41}	0.78	0.75	0.76	0.79	0.64	0.70	0.66	0.69	0.52	0.498
C_{42}	0.63	0.64	0.62	0.63	0.52	0.54	0.52	0.55	0.492	0.35

Table 3. Total influence-relation matrix - dimensions

T	C_1	C_2	C_3	C_4
C_1	0.83	0.79	0.77	0.59
C_2	0.85	0.75	0.75	0.58
C_3	0.88	0.79	0.73	0.58
C_4	0.70	0.64	0.61	0.47

The structure for impact factors would be seen in the Table 4, Table 5 and the Figure 1, and then the systematic assessment could obtain the factors' rank and impact. The influence given (ri - di) and received (ri + di) for each dimension and criterion, as shown in Table 4 and Table 5. It has a positive (ri - di) value which means it will affect other dimensions or criteria more than being affected by others. If (ri - di) is the largest positive value, it will be the most important dimension or criterion. It plays a major role in the evaluation system, and has the greatest effect on all other dimensions or criterion. However, the highest (ri + di) value means that it could dramatically affect and be affected by other dimensions or criterion. Figure 1 shows the impact-relations, (ri + di) and (ri - di), it provides the index of the strength of influences given and received, degree of each dimension and criteria playing in the problem.

Table 4. The interactive impact from the dimensions

T	r_i	d_i	r_i+d_i	r_i-d_i
C_1	2.98	3.25	6.23	-0.27
C_2	2.93	2.97	5.90	-0.04
C_3	2.98	2.86	5.84	0.12
C_4	2.40	2.21	4.62	0.19

Table 5. The interactive impact from the criteria

T	r_i	d_i	r_i+d_i	r_i-d_i
C_{11}	7.43	8.27	15.70	-0.84
C_{12}	7.67	8.12	15.80	-0.45
C_{13}	7.61	8.14	15.75	-0.53
C_{21}	7.97	8.19	16.16	-0.22
C_{22}	7.35	6.93	14.28	0.42
C_{23}	7.07	7.32	14.40	-0.25
C_{31}	7.30	7.06	14.36	0.25
C_{32}	7.95	7.42	15.37	0.53
C_{41}	6.78	6.17	12.95	0.62
C_{42}	5.50	5.02	10.53	0.48

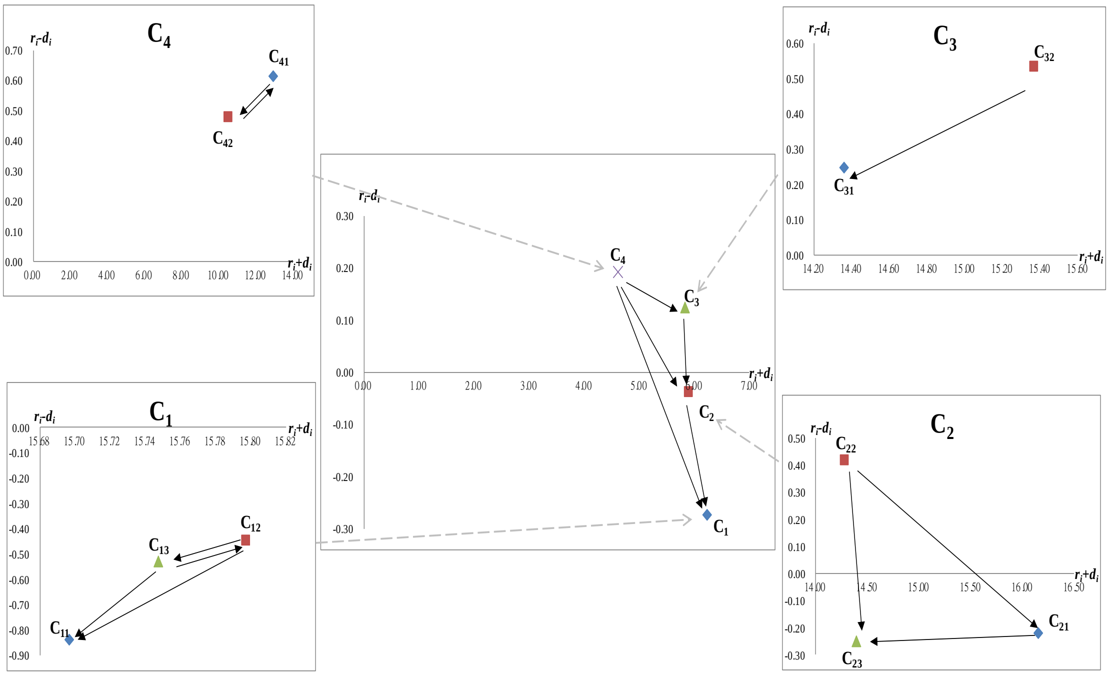

Figure 1. The structure for Impact factors

We take VIKOR technique to leverage for calculating compromise ranking and gap of the alternatives (Table 6 and Table 7). The government supervision should be the first one of the most important factors. And then, the factors would be the considering for business management and profit.

Table 6. The Weights of impact factors –ANP

Criteria	Global Weight	Dimension	Local Weight	Criteria	Local Weight	Ranking
C_{11}	0.0950			C_{11}	0.333	2
C_{12}	0.0952	C_1	0.2851	C_{12}	0.334	1
C_{13}	0.0949			C_{13}	0.333	3
C_{21}	0.0942			C_{21}	0.361	1
C_{22}	0.0805	C_2	0.2613	C_{22}	0.308	3
C_{23}	0.0866			C_{23}	0.331	2
C_{31}	0.1218	C_3	0.2526	C_{31}	0.482	2
C_{32}	0.1308			C_{32}	0.518	1
C_{41}	0.1100	C_4	0.2010	C_{41}	0.547	1
C_{42}	0.0910			C_{42}	0.453	2

We could find in Table 7 that the better performance items are the C1: 1.573 and C4: 1.433. The items to be improved would be the C3 and C2. Through VIKOR, the largest aspired level, 0.1283, would be the C3.

Table 7. The Performance and the Gap from Aspired -Level –VIKOR

Criteria	Local Weight	Global Weight	Performance	VIKOR (Aspired - Level)
C_1	0.285		1.573	0.1278
C_{11}	0.333	0.095	5.636	0.041
C_{12}	0.334	0.095	6.273	0.035
C_{13}	0.333	0.095	4.636	0.051
C_2	0.261		1.346	0.127
C_{21}	0.361	0.094	4.909	0.048
C_{22}	0.308	0.081	4.909	0.041
C_{23}	0.331	0.087	5.636	0.038
C_3	0.253		1.242	0.1283
C_{31}	0.482	0.122	4.636	0.065
C_{32}	0.518	0.131	5.182	0.063
C_4	0.201		1.433	0.089
C_{41}	0.547	0.110	5.636	0.048
C_{42}	0.453	0.091	5.455	0.041
Total			5.594	0.472

5. Conclusion

The performance results from ANP & VIKOR: the better items would be the C4 "government supervision level", and C1 "market level", while the items to be improved would be the C3 "business management level", and C2 "technology level". Through VIKOR, the largest aspired level would be the C3 "business management level". We could improve that item and might attain the best improvement. However, we found that C3 would be pushed by C4 “government supervision level”. So, the “government supervision level” should be improved first.

However, why does “government regulation” affect “operator operations and technology” and ultimately “markets”? The huge capital invested by manufacturers is hard to earn back. Because of policy-driven investment, its responsibility falls to the government’s policy level. The manufacturer believes that the government policy is a panacea, and the regulations can be loosened or lifted. However, the existing regulations are to specify WBA (Wireless Broadband Access Service) transmission technical specification standards (ITU, IEEE, ETSI, etc.) for large data transmission. As a result, voice phones are inconvenient and cannot be interconnected with 2G and 3G players on the market. So government policy is the highest solution. The "technical" part of Taiwan is also affected by Intel's fading out of the WiMAX industry. For example, Australia's Buzz Broadband found that the WiMAX base station's service range was less than two kilometers, and the signal delay time was as high as 1,000 milliseconds, so the company suspended WiMAX service. This can be used as a reference for the world's telecommunications supervision authorities, the telecommunications industry, equipment manufacturers, etc. In the future telecommunications business planning and development priority projects, the technical feasibility, the operational capabilities of the operators and the real needs of the market should be more carefully evaluated.

Though WiMAX has not been used, but 4G still is, the government supervision level should be improved first to make the best decisions about such matters in the future. Through technology and business management, the government supervision will allow related market’s business to make more ideal decisions as well.

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