Measure the Performance of Reducing Digital Divide – the BSC and AHP Approach

Hsing-I Wang
Dept. of Information Management
Overseas Chinese University, Taichung, Taiwan,
Email: hsing@ocu.edu.tw

Chien-Chih Yu
Dept. of Management Information Systems
National ChengChi University, Taipei, Taiwan
Email: ccyu@nccu.edu.tw

***Abstract*—Digital divides are the byproducts of the development of information technologies and digitalization. What concern most of the governments and the international organizations are the disturbance of the advancement of national competitiveness as well as the improvement of human lives caused by the presence of digital divides.**

Countries world wide have proposed numerous of strategies to reduce digital divides. However, the absence of the follow-up of the performance of the strategies forms another issue in reducing digital divides. Previous researches built digital divide balance scorecard to realize the objectives as well as to improve the performance of the strategies. This research adopts the analytical hierarchy process to prioritize the performance indicators which have been determined in the digital divide balance scorecard. The architecture proposed by the research would be applied to examine the merits of the strategies.

***Index Terms*—digital divide, performance measurement, analytical hierarchy process, balance scorecard**

I. INTRODUCTION

Digital divides (DD) are the byproducts of the fast development of information technologies and digitalization. The existence of DD not only implies the vanishment of opportunities, it also discloses the existence of poverty, the lack of fundamental literacy, as well as some serious social problems [1]. Countries world wide have put a lot of efforts and proposed numerous of strategies to reduce digital divides. Have the phenomenon disappeared? Take Taiwan for an instance, "Ref. [2]" reported that digital divides could be found between metropolitan and rural area, and between different levels of educations in Taiwan. Evidences indicate that, after all the attempts, reducing digital divides remain the most important issue and concern in information epoch.

We believe that reducing digital divides is indeed a hardship task, the point is that if the governments have taken appropriate actions and effective strategies. And more important, is whether the performances have been reasonably evaluated. "Ref. [3]" tried to adopt the balance scorecard approach to measure the performances of reducing digital divide. In their researches, the gaps between performances and strategies were located [4], a strategy map was designed [5], and the framework of digital divide balance scorecard (DD-BSC) was developed [6]. However, the indicators have not been validated, neither have the implication of the measurements been demonstrated. This research proposes the analytical hierarchy process (AHP) method to fill up the absences.

This paper is organized as follows: section 2 briefly introduces the DD-BSC framework proposed by [6] and reviews the strategies of reducing digital divides that have been initiated, proposed as well as implemented by governments world wide. Section 3 introduces the AHP method. Section 4 states the research method and the results of the research. Section 5 discusses the findings of this research and the final section gives conclusions of the paper.

II. THE REVIEW OF STRATEGIES OF REDUCING DIGITAL DIVIDES AND DD-BSC FRAMEWORK

Previous digital divides researches can be classified into four categories. The first category observes the phenomenon of digital divide of a single country or compares the degree of digital divide between countries. The second category focuses mainly on the penetration of information technologies. The researches of the first two categories conclude that the opportunities of accessing or using of information technologies explain the major portion of the existence of digital divides. The third category applies different theories to explain the

Manuscript received June 15, 2010; revised August 15, 2010; accepted October 10, 2010.

doi:10.4304/jcp.6.3.389-396

existence and the causes of digital divides. “Ref. [7]” proposed that digital divides were impossible to be entirely eliminated if they were explained with Diffusion of Innovations, Increasing Knowledge Gap, and Adaptive Structuration Theory. Finally, the fourth category explores digital divides with various research models. Research findings of [8], for example, proved that economic, social, ethno-linguistic and infrastructure were the major constructs that cause digital divides.

“Ref. [3]” integrated previous researches and proposed that the phenomenon of digital divides should be examined from four dimensions including ICT, equal opportunities, information society and national competitiveness respectively. “Ref. [6]” further presented the DD-BSC framework (as shown in figure 1) so that the strategies for reducing digital divides were further classified into four balanced scorecard perspectives including beneficiaries, governmental functions and processes, nation-wide learning and growth as well as public finance.

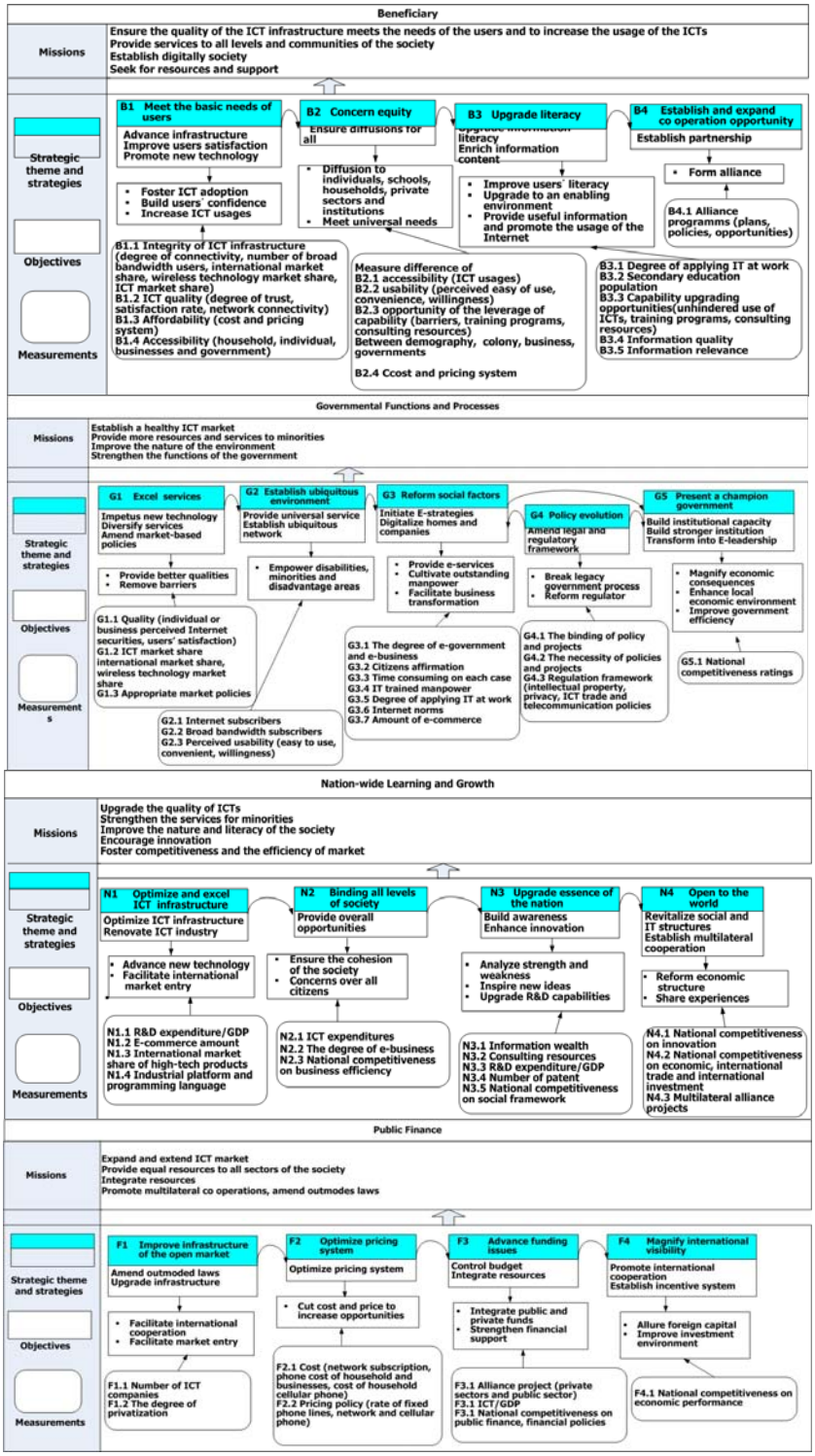

Fig. 1: DD-BSC framework [6]

In the DD-BSC framework, each perspective has its missions. The strategies that are necessary to fulfill the missions are defined along with the strategic objectives. Notice that the measurements are not only specified in the framework, the relationships between the measurements and the strategies are also established. The approach that [6] adopted would help the governments to correctly and efficiently locate the less productive strategies, and furthermore, to take proper actions to recover the drawbacks in time.

III. THE AHP

In the literatures, AHP has been applied to numerous decision making problems. The AHP, developed by [9], is based on a pair-wise comparison of the criteria. The criteria could be prioritized and ranked based on the preferences given by the involved parties. By applying AHP, the interacted effects could be eliminated efficiently. The steps of AHP analysis are firstly, building the hierarchical architecture of the criteria, constructing the pair wised matrix, computing the eigenvalues and eigenvector, and finally validating the consistence of the AHP tree. Figure 2 shows the basic architecture of an AHP tree.

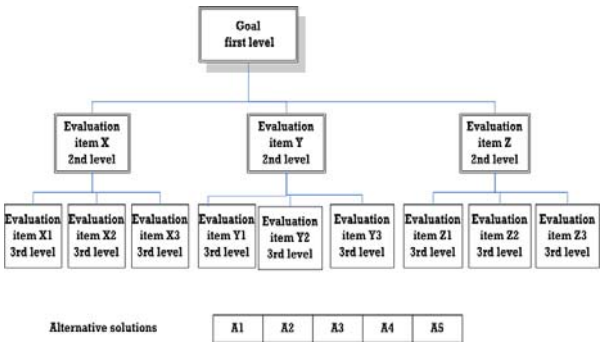

Fig. 2: The AHP structure

The purposes of consistence check are to determine the rationality of the involved parties and to examine the consistence of the entire structure of AHP tree. The consistence is determined by consistency ratio (C.R.), which is the quotient of consistence index (C.I.) and random index (R.I).

$$CR. = \frac{CI}{RI}$$

"Ref. [10]" suggested that RI is closely related to the number of levels of the AHP tree and the number of criteria at each level is less than 7 [11]. The mappings of RI and the number of levels in an AHP tree are given in table 1. "Ref. [11]" also suggested that C.R. should be less than 0.1 to guarantee the consistence of an AHP tree.

The AHP tree is then transformed into a pair wised matrix and the respondent will prioritize each pair with respect to the relative importance of the two criteria. The options for the responses are presented on the AHP scale from 1 to 9. The odd numbers represent equal important, weak important, essential important, very strong important and absolute important, and the even numbers represent the mid values between two odd numbers [12, 13].

Table 1: RI value for different number of levels

No. of levels	1、2	3	4	5	6	7
RI.	0.00	0.58	0.90	1.12	1.24	1.32
No. of levels		8	9	10	11	12
RI.		1.41	1.45	1.49	1.51	1.48

Resource：[10]

IV. RESEARCH METHOD AND RESULTS

This research adopts the four DD dimensions and the BSC perspective proposed by [6]. The criteria and indicators used in the DD-BSC framework are applied to construct the AHP tree of this research. Figure 3 shows the AHP tree of this research.

A questionnaire was designed in which the criteria of each level were compared in pair. Fourteen experts who are familiar with the subject of digital divide were invited. They include three scholars from universities; two from the digital divide group of the Research Development and Evaluation Commission of Taiwan; four specialists from industries, and four governmental officials. The respondents were required to complete the questionnaires according to their experiences or expertise on the issue of digital divides. Thirteen questionnaires were collected; the response rate was 92%. Expert Choice 2000 was applied to analyze the data. In the validation of the consistence of the answers, one questionnaire showed high CR value 0.54, which meant the comparisons between indicators were inconsistent and the answers were ignored. The remaining 12 responses were analyzed. Table 2 shows the results of the main construct of the AHP tree. Table 2 indicates that the CR value is less than 0.1 and meets the requirement of consistence of AHP.

Table 2: Results of the main level

criteria	weight	rank
ICT diffusion	0.335	1
Equal opportunities	0.283	2
Information society	0.208	3
National competitiveness	0.173	4
CI=0.01, n=4, RI=0.9, CR=0.01		

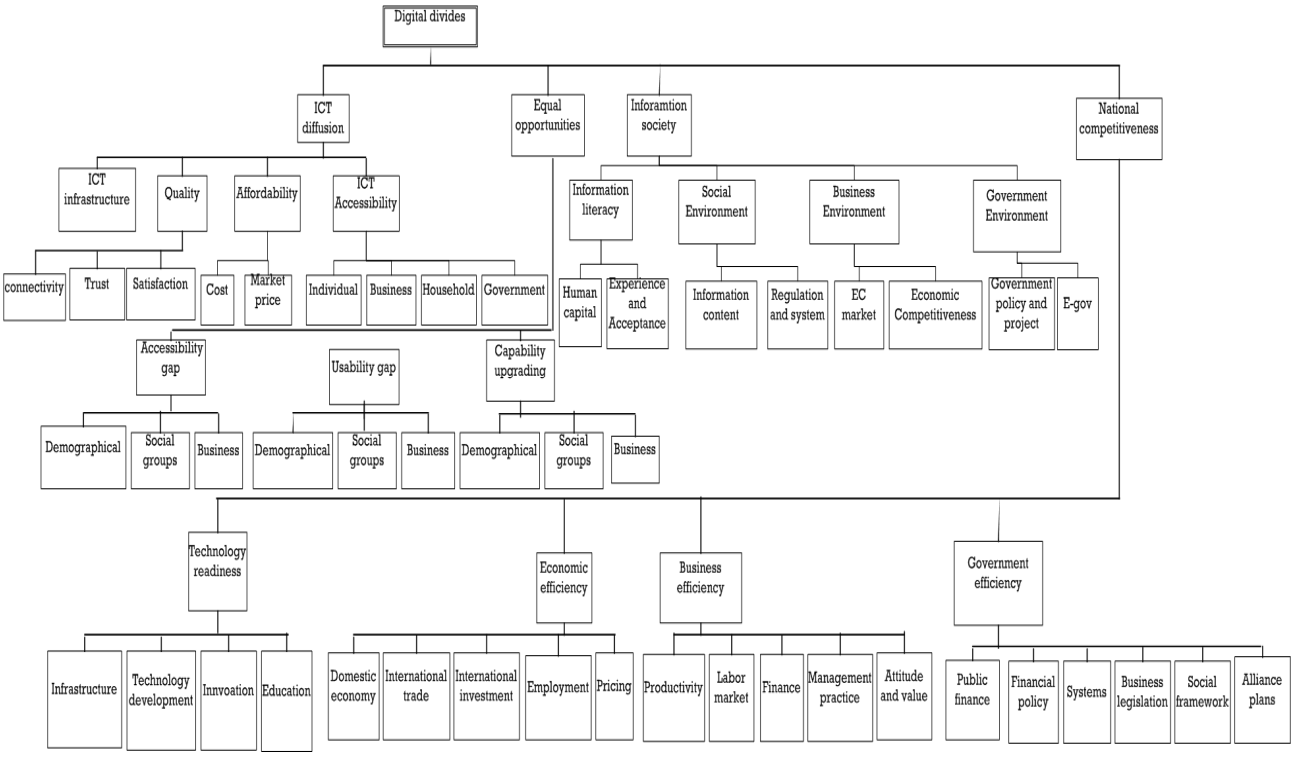

Fig. 3: The AHP tree of this research

To validate the consistence of the entire AHP architecture of this research, this research further calculates the consistent index hierarchy (CIH), random index hierarch (RIH) and consistent ratio hierarchy (CRH) as follows.

CIH = 0.01 * 1 + 0.01 * 0.335 + 0.00* 0.283+ 0.02 * 0.208+ 0.00 * 0.173
= 0.01751

RIH = 0.9 * 1 + 0.9 * 0.335 + 0.58 * 0.283+ 0.9 * 0.208+ 0.09 * 0.173 = 1.70854

CRH = CIH / RIH = 0.010

Again, the CRH value is acceptable and assures the consistence of the design of this research.

Tables 3 give the weights of the criteria in each level of the AHP tree.

V. THE USE OF THE AHP RESULTS

To demonstrate how to apply the results of this research to the real cases, this research applies the weights of the ICT individual accessibility indicators to Taiwan. Table 4 collects the real data of 2008 and 2009 of Taiwan [14, 15, 16]. By multiplying each data with the weights, the score of indicator "individual accessibility" of 2008 is 81.83 while in 2009, the score is 82.88. The score of ICT accessibility is 27.98 in 2008 and 28.34 in 2009. For a country, if the scores are lower than the expected values, the government would have an easier way to locate the less efficient strategies and make appropriate actions. We further notice that table 4 shows that "individual accessibility" is the most important indicator (with the highest weight) on the "ICT accessibility" level, which means the government needs to take the gap between individuals more seriously in order to gain higher scores.

The second example examines the performance of national competitiveness in Taiwan. According to the national competitiveness report of 2007 [17], the ranks of each category of Taiwan are listed in table 5. Based on the results of this research, the score of national competitiveness of Taiwan in 2007 would be 60.55 (71.1*0.159+58.4*0.251+69.3*0.287+48.5*0.303). The contribution of national competitiveness to reduce digital divide is 10.48 (60.55*0.173). When compare with the score of 2006 (table 6), we notice that the changes are not surprisingly. The government would then have to review the achievements of the strategies more cautiously.

VI. CONCLUSIONS

This research applies the AHP method to the DD-BSC framework that [6] proposed. In this paper, the weight of each criterion in the AHP tree is calculated and examples of demonstrating how the indicators are applied to the real cases to determine the performance of the strategies for reducing digital divides are given. The contributions of this research are summarized as follows:

1. The importance of each indicator of the performance of strategies for reducing digital divides is determined.
2. The AHP method is adopted to calculate the weights of the indicators. Since the AHP considers the relative importance of the criteria evaluated by

specialist in the domain, the bias as well as the interactive effects of criteria would be minimized.

3. In the real situation, the scores gained from the AHP architecture of this research would be compared with the expecting value that governments have set. The comparisons would help the governments firstly, to locate the gap between the outcomes and objectives, secondly, to review the effectiveness of strategies, and finally, to make appropriate actions to mend the gaps.

Nevertheless, the questionnaires were distributed in Taiwan; the importance of the indicators may be different if the AHP structure is evaluated in other countries. Fortunately, the design of this research is flexible and can be applied to all countries even if the weights are different or the importance of an indicator is changed.

Moreover, during the research, we notice that a large number of indicators have been neglected and were not included in the investigations of digital divides or related issues in Taiwan. As a result, the performance of strategies for reducing digital divides would be difficult to be observed. The same situation may exist in many other countries. This research, however, provides the reference for governments to follow.

Further works of this research would look for international cooperation to construct a more general measurement for countries to evaluate the situation of digital divides and to examine the performance of digital divide strategies.

Table 3**:** Results of AHP analysis

Level 0	**Level 1**	**CR**	**Level 2**	**CR**
ICT diffusion (0.335) CI=0.00 n=5 RI=1.12 CR=0.00	ICT infrastructure(0.184)	0.008		
	Quality(0.121)	0.008	Connectivity(0.441)	0.011
			Trusty(0.314)	0
			Users satisfaction (0.275)	0
	Affordability(0.446)	0	Cost (0.588)	0.022
			Market pricing (0.412)	0
	ICT accessibility (0.249)	0.008	Individual accessibility (0.338)	0.011
			Business accessibility (0.189)	0.02
			Household accessibility (0.265)	0.03
			Government accessibility (0.208)	0
Equal Opportunities (0.283) CI=0.00 n=3 RI=0.58 CR=0.00	Accessibility gap (0.183)	0.02	Demographical (0.188)	0.01
			Social groups (0.188)	0.01
			Business (0.188)	0
	Usability gap (0.304)	0.03	Demographical (0.188)	0
			Social groups (0.188)	0
			Business (0.188)	0
	Capability upgrading (0.513)	0	Demographical (0.188)	0
			Social groups (0.188)	0
			Business (0.188)	0
Information society (0.208) CI=0.01 n=4 RI=0.9 CR=0.01	Information literacy (0.395)	0	Human capital (0.463)	0.05
			Experience and Acceptance (0.537)	0.03
	Social Environment (0.200)	0	Information content (0.574)	0
			Regulation and system (0.426)	0.02
	Business Environment (0.186)	0	EC market (0.463)	0.05
			Economic Competitiveness (0.537)	0.05
	Government Environment (0.219)	0	Government policy and project (0.708)	0.05
			E-government (0.292)	0.09

Level 0	Level 1	CR	Level 2	CR
National competitiveness (0.173) CI=0.00 n=5 RI=1.120 CR=0.00	Technology readiness (0.159)	0	Infrastructure(0.241)	NA
			Technology development(0.132)	
			Innovation (0.206)	
			Education (0.421)	
	Economic efficiency (0.251)	0.01	Domestic economy (0.266)	
			International trade (0.146)	
			International investment (0.153)	
			Employment (0.257)	
			Pricing (0.178)	
	Business efficiency (0.287)	0.01	Productivity(0.22)	NA
			Labor market (0.165)	
			Finance (0.141)	
			Management practice (0.197)	
			Attitude and value (0.278)	
	Government efficiency (0.303)	0.001	Public finance (0.098)	NA
			Financial policy (0.177)	
			Systems (0.267)	
			Business legislation (0.137)	
			Social framework (0.228)	
			Alliance plans (0.094)	

*the second level of national competitiveness are the indicators, no CR values are applied.

Table 4: The application of weights in ICT accessibility (the case of Taiwan)

Level 1	Level 2	Indicators	Weight (A)	2008data (B)	A*B	2009data (C)	A*C
ICT accessibility (0.257)	Individual accessibility (0.342)	Number of households with fixed telephone lines	0.113	0.98	0.1107	0.98	0.1107
		Population of mobile phones	0.149	1.05	0.1565	1.11	0.1654
		Population of network	0.448	0.68	0.3046	0.69	0.3091
		Owns personal computers	0.290	0.85	0.2465	0.84	0.2436

*: data source [15, 16]

Table 5: The application of weights in National Competitiveness (the case of Taiwan)

Level 1	Indicators	weight	order	2007rank	1-index*	Weighted value	Score
Technology readiness (0.159)	Infrastructure	0.251	2	22	0.6	0.151	71.1
	Technology development	0.133	4	6	0.89	0.118	
	Innovation	0.191	3	10	0.82	0.156	
	Education	0.425	1	18	0.67	0.286	
Economic	Domestic economy	0.266	1	23	0.58	0.155	58.4

Level 1	Indicators	weight	order	2007rank	1-index*	Weighted value	Score
efficiency (0.251)	International trade	0.147	5	16	0.71	0.104	
	International investment	0.148	4	42	0.24	0.035	
	Employment	0.259	2	22	0.6	0.155	
	Price	0.18	3	14	0.75	0.134	
Business efficiency (0.287)	Labor	0.216	2	11	0.8	0.173	69.3
	Labor market	0.158	4	11	0.8	0.126	
	Finance	0.136	5	14	0.75	0.101	
	Management	0.201	3	24	0.56	0.113	
	Attitude value	0.289	1	21	0.62	0.179	
Government efficiency (0.303)	Public finance	0.094	6	21	0.62	0.058	48.5
	Financial policy	0.167	3	3	0.95	0.158	
	Regulation system	0.257	1	29	0.47	0.121	
	Business legislation	0.136	4	28	0.49	0.067	
	Societal framework	0.246	2	37	0.33	0.081	
	Alliance	0.099	5	NA	NA	NA	

*：index = 2007 rank / 55 (total countries investigated)

Table 6: Comparisons of National Competitiveness of Taiwan and other countries 2006-2007

category / year / country	Overall rank		Technology readiness		Economic efficiency		Business efficiency		Government efficiency		overall		Contribution to DD	
	2006	2007	2006	2007	2006	2007	2006	2007	2006	2007	2006	2007	2006	2007
Taiwan	18	13	74.4	71.10	49.6	58.4	77.8	69.3	44.1	48.5	59.96	60.55	10.37	10.48
Denmark	5	6	82.7	88.5	51.8	61.7	87.2	86.4	74.7	74	73.81	76.8	12.77	13.29
Finland	17	15	90.4	77.9	43.3	45.1	76.1	64.7	74.9	62.0	70.39	61.06	12.18	10.56
Japan	24	22	74.2	71.6	64.7	60.3	54.3	49.7	44.2	36.8	56.99	51.93	9.86	8.98
Korea	29	31	53.7	65.9	44.7	40.6	31.0	31.0	26.8	34.2	36.79	39.94	6.36	6.91
Norway	13	11	81.2	80.5	58.2	61.4	69.4	71.7	67.5	62.8	67.89	67.83	11.74	11.73
Singapore	2	2	84.9	86.0	86.7	80.7	80.6	83.9	77.2	79.1	81.76	82.00	14.14	14.19
Sweden	9	9	84.0	81.7	54.0	59.6	75.1	77.7	54.7	63.8	65.02	69.56	11.25	12.03
United States	1	1	91.0	88.5	88.1	85.8	80.0	75.7	65.5	58.4	79.4	75.00	13.74	12.98
China	15	17	43.7	50.6	87.2	90.9	53.5	56.1	55.3	57.9	60.94	64.5	10.54	11.16
India	27	29	27.8	23.9	80.1	69.8	67.7	67.9	37.8	35.6	55.59	51.6	9.62	8.93

Data source: [17, 18]

REFERENCES

[1] Bridges.org, R.: 'Spanning_the_Digital_Divide - Understanding and Tackling the Issues,' 2000. 1http://www.bridges.org/spanning/pdf/spanning_the_digital_divide.pdf.

[2] Yu, C. C and Wang, H.I.: 'Digital Divide in Taiwan: Evidences, Comparisons, and Strategies', Electronic Government, an International Journal, 2004, 1(2), 179-197.

[3] Yu, C. C. and Wang, H.I.: 'Measuring the Performance of Digital Divide Strategies: The Balanced Scorecard Approach', EGOV 2005, R.

Traunmuller (Eds.), Lecture Notes in Computer Science, 2005, 3591(0), 151-162.

[4] Yu, C. C. and Wang, H.I.: 'Towards Refining Digital Divide Strategies via Strategy Gap Analysis – the Method and Case Study', Journal of International Management Studies, 2008, 3(2), 28-36.

[5] Yu, C. C. and Wang, H.I.: 'Developing Strategy Maps for the Formulation of Digital Divides Strategies', Proceedings of the 7th International Conference on Electronic Business, Taipei, Taiwan, 2007.

[6] Yu, C. C. and Wang, H.I.: 'Strategy Mapping in the Process of Formulating Digital Divide Strategies,' Electronic Government, An International Journal, 2009, 6(2), 143–161.

[7] Manson, S. M. and Hacker, K. L.: 'Applying Communication Theory to Digital Divide Research', IT & Society, 2003, 1(5): 40-55.

[8] Bagchi, K.: 'Factors Contributing to Global Digital Divide: Some Empirical Results', Journal of Global Information Technology Management, 2005, 8(3): 47-65.

[9] Saaty, T. L.: 'A Analytic Hierarchy Process', New York, McGraw Hill, 1980.

[10] Saaty, T. L.: 'Decision Making for Leaders - The Analytic Hierarchy Process for Decisions in A Complex World', Resource Allocation, Pittsburgh, RWS Publications, 1988.

[11] Saaty, T. L.: 'Multi Criteria Decision Making: The Analytic Hierarchy Process - Planning, Priority Setting', Resource Allocation, Pittsburgh, RWS Publications, 1990.

[12] Deng, J.Y. and Tseng, K H.: 'AHP Theory and Its Applications - 1', Journal of Chinese Statistics, 1989, 27(6): 13707-13724.

[13] Deng, J.Y. and Tseng, K H.: 'AHP Theory and Its Applications - 2', Journal of Chinese Statistics, 1989, 27(7):13767-13786.

[14] Directorate – General of Budget, Accounting, and Statistics, Executive Yuan, Taiwan. http://www.dgbas.gov.tw.

[15] RDEC, '2008 Digital Divide Report', Research, Development and Evaluation Commission, Executive Yuan, Taiwan. http://www.rdec.gov.tw/public/Attachment/92313455871.pdf.

[16] RDEC, '2009 Digital Divide Report', Research, Development and Evaluation Commission, Executive Yuan, Taiwan. http://www.rdec.gov.tw/public/Attachment/91215951771.pdf.

[17] IMD: 'The World Competitiveness Yearbook,' 2007 International Institute for Management Development, Lausanne.

[18] IMD: 'The World Competitiveness Yearbook,' 2006 International Institute for Management Development, Lausanne.