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ISSN 1812-5638

INFORMATION TECHNOLOGY JOURNAL

ANSInet
Asian Network for Scientific Information
308 Lasani Town, Sargodha Road, Faisalabad - Pakistan

Information Technology Journal 12 (7): 1318-1325, 2013
ISSN 1812-5638 / DOI: 10.3923/itj.2013.1318.1325

Coupling of Information Industry and Building Industry Based on Choquet Integral

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Abstract: With the increasing complexity interaction, the relationship between information industry and building industry shows the nonlinear coupling characterizations. In this study, the industry comprehensive evaluation value is calculated by using the Choquet integral and the coupling and coordination between information industry and construction industry is analyzed. Their coupling and coordination degrees can be used to study the development path and industrial strategy of the present building industry. Based on the coupling of information industry and construction industry, the model of their coupling degree and coordination degree is established. Meantime, a numerical example for information industry and building industry is given by using the given model. Empirical results show that the proposed model is an effective way to improve forecasting accuracy.

Key words: Information industry, building Industry, Choquet integral, coupling degree, coordination degree

INTRODUCTION

With the rapid development of network information technology and the fast dissemination and sharing of information resources on a global scale, information has become the most active and the most important resource of the world's economic and social development. Various countries have been accelerating the integration of information industries and traditional industries. Construction is traditional basic industries of the national economy and the information industry (especially the software services industry) belongs to the country's strategic emerging industries. The application of information technology to promote the upgrade of traditional construction industry structure has become an important part of the industrial economics research (Tehran and Bayad, 1997).

Due to the integration of the world economy and the policy environment of the large-scale country's industrial structure adjustment, the interaction between the information industry and the construction industry has become increasingly complex and exhibits a nonlinear and coupling characteristics, its coupling coordination degree studies related to the development path of construction industry at this stage and industry strategic decisions. Therefore, there is an urgent need to delve into the coupling mechanism between the information industry and the construction industry and to reveal the inherent technical path of information technology in the construction industry (Xiong and Li, 2010a, b).

According to data analysis, current research is a qualitative description of the information technology in the building industry, stressed the importance of the information technology in the building industry, but the lack of a quantitative study of the problem. Therefore, in this study, we use the industries coupling theory and Choquet integral method to build the coupled coordinated development model of the information industry and the construction industry, calculating the degree of coupling and coordination to reflect the degree of information technology in the building industry. The ultimate goal is to build a collaborative developing and virtuous-circle coupled model of information industry and construction industry, as a new exploration of the rapid development of China's construction industry (Li *et al*., 2008). Therefore, we urgently need to further explore the coupling mechanism between information industry and the construction industry, revealing the inner technology path of the construction informationization.

The current related data is qualitative description on construction informationization, emphasizing the importance of construction informatization and lack of quantitative research. Therefore, the authors apply industrial coupling theory and Choquet integral to build coupling coordinated development model of information industry and building industry and research the trends of construction informationization by the method combining qualitative and quantitative. The industrial coupling

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degree reflects the degree of construction informationization. We attempt to establish a coupling model on the coordinated development and virtuous circle between information industry and construction industry. This coupling model makes as a new exploration to rapidly develop China's construction industry (Isard and Schooler, 1959).

COUPLING RELATIONSHIP OF INFORMATION INDUSTRY AND CONSTRUCTION INDUSTRY

Coupling refers to a phenomenon that the movement of two or more systems affects each other so as to unite together through various interactions and a dynamic interaction relationship under a benign interaction between the various subsystems of interdependence, mutual coordination and promote. This phenomenon, which respective coupling subsystem produces interactions and influences each other in different systems, called the coupling relationship.

There is a natural coupling relationship between information industry and the construction industry. In the process of economic operation, there exists the close coupling relation in information industry and the construction industry. Development of the construction industry is the basis for the development of information industry (these concepts, such as intelligent building and green ecological building, need the support of information technology). The changes of demand, such as information equipments, software products and information services needed by the building industry, became the fundamental motion power of the development of the information industry. Because of information technology possessing the characteristics such as permeability, driven, doubled, network and system, the application of information technology will promote the construction industry to reform its management content, processes and ways and then will promote to restructure the original organization to adapt to the management of the information society. The business reconstruction and management changes will directly contribute to promote the reform of management organization and optimization and upgrading of industrial structure in the construction. Information industry can promote the overall management of the construction to keep pace with the times and accelerate the reform of management organization and optimization and upgrading of industrial structure in the construction.

COUPLING COORDINATED DEVELOPMENT MODEL OF INFORMATION INDUSTRY AND BUILDING INDUSTRY

Design on coupling coordinated development evaluation index system of information industry and building industry: The coupling relationship between information industry and construction industry is the complex system engineering. There are more elements of reflecting the relationship and the relationship is complex among these elements of the two systems. Each subsystem is also under the state network. Establishment of index system is the key element of the coupling evaluation system. Currently, there are no uniform indices at home. This study ascertains corresponding index option according to the characteristics of each system combining information industry with the construction industry.

According to the relevant literature material, combining with the coupling characteristics of information industry and construction industry, we respectively choose the indices closely affecting the coupling degree of information industry and construction industry. The indices of construction industry include the scale of construction, the human resource of construction (mostly containing personnel engaging in information technology in the construction industry), expenditure of information resources of construction and development vigor of construction and so on four aspects; the indices of information industry include the scale of information industry, the human resource of information industry, investment of science and technology in the construction industry (specifically referring to the investment of research and development engaging in construction software in information industry) and development vigor of information industry and so on four aspects (Hao and Yu, 2008). The coupling coordinated development evaluation index system of information industry and building industry is shown in Fig. 1.

Coupling coordinated evaluation model of information industry and building industry: Coordination refers to a benign relationship between two (or more) systems or system elements. It is a harmony, proper and benign loop relationship between systems or internal elements in systems. The coordination degree of the system elements (or subsystems) in the development process, is a mutual and harmonious measure, dynamically revealing a systematic trend from disorderly to order. According to the connotation of harmonious development and coupling coordinated development evaluation index system of information industry and construction industry, we use

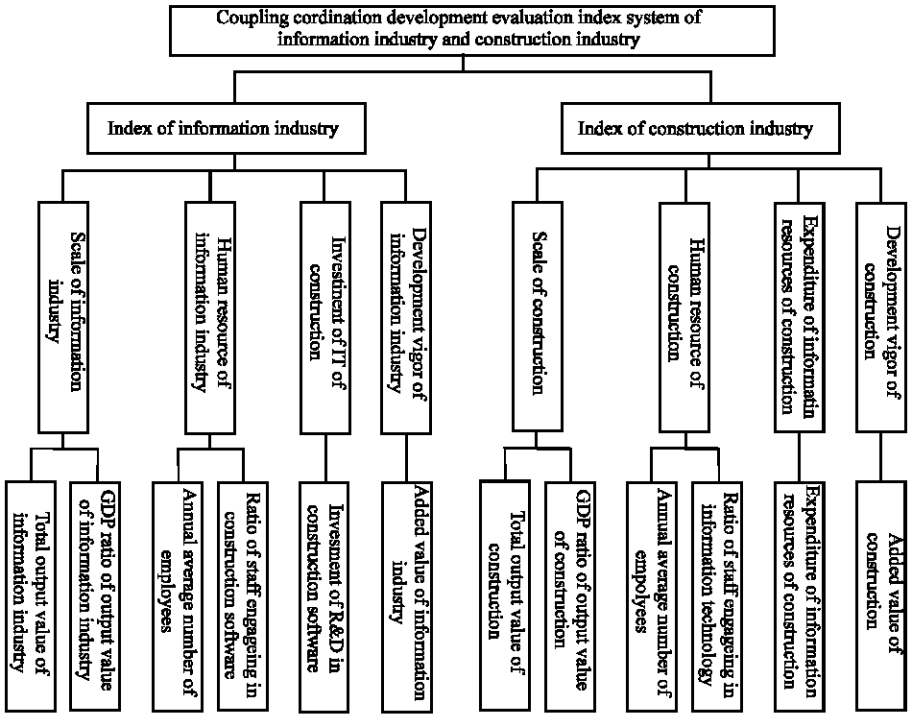

Fig. 1: Evaluation index system of information industry and building industry

evaluation model of coupling degree and coordination degree to study the coupling coordinated development degree of information industry and construction industry for quantitative research (Qiao and Fang, 2005).

The coupling coordinated development model of information industry and construction industry consists of efficacy function, coupling degree function and coordination degree function. The various indicators in the evaluation index system are order parameters of information industry and construction industry system (Cheng and Tao, 2012).

Efficacy function: Fuzzy integral is defined in many ways, it is a nonlinear function based on the connotation of fuzzy measure. We commonly use Sugeno integral (Sugeno, 1974) and Choquet integral (Choquet, 1954). Choquet integral comprehensive evaluation method can take the importance of each evaluation index into account and it can also emphasize the interrelated, mutual constraints on the evaluation results. Therefore, we mainly use the basic principles of Choquet integral to comprehensively evaluate information industry and construction industry (Wu, 2008).

Definition 1 (Sugeno, 1974): Let $X = \{x_1, x_2, ..., x_n\}$ be a limited nonempty set and let P (X) be the power set of X. If μ: P (X)→[0,1] Is the set function of P(X), then, μ is called a fuzzy measure, where:

- $\mu(\Phi) = 0$, $\mu(X) = 1$
- $\forall A,B \in P(X)$, if $A \subseteq B$, then, $\mu(A) \leq (B)$

Definition 1 shows that the fuzzy measure uses monotonicity to replace the addictive of traditional measure. It is a kind of promotion for traditional measure.

Definition 2 (Choquet, 1954): Let $X = \{x_1, x_2, ..., x_n\}$ be a limited nonempty set, μ denotes a fuzzy measure on X and let f: $X \in [0,+\infty]$ be a negative real value function, then the Choquet integral of fuzzy measure μ related to f shown as follows:

$$CI_{\mu}(f) = (C)\int f d\mu$$

In particular, if $X = \{x_1, x_2,..., x_n\}$, then the Choquet integral can be expressed by:

$$CI_{\mu}(f) = (C)\int f d\mu = \sum_{i=1}^{n} (f(x_i) - f(x_{i-1}))\mu(A_i)$$

where, $A_i = \{x_i, x_{i+1},..., x_n\}$. If it can not meet $0 \leq f(x_1) \leq f(x_2) \leq ... \leq f(x_n \leq 1)$ in calculation, we have to rearrange the elements in limited non-empty set. After arrangement, elements $\{x^*_1, x^*_2,..., x^*_n\}$ should meet $0 \leq f(x^*_1) \leq f(x^*_2) \leq ... \leq f(x^*_n \leq 1)$. When we use the Choquet integral to solve comprehensive evaluation value of information industry

and construction industry, let f (x_i) be the order parameter on the ith index in the evaluation index system of information industry and construction industry and let μ (A_i) be the important degree (weight) of each interactive index, the Choquet integral can be represented as comprehensive evaluation of industrial value when considering the interaction between the indices.

Coupling degree function: Let C be a coupling degree of information industry and construction industry, we use the concepts and coefficient model of capacitive coupling in the Physics for reference, the coupling degree model of several interactive systems can be expressed by:

$$C_n = \{(u_1.u_2...u_m)/[\prod(u_i + u_j)]\}^{1/n}$$

Assuming that only a single information industry and a single construction industry are in the coupling system, then the coupling function of information industry and construction industry can be defined as follows:

$$C = \{(X.Y)/[(X + Y)(X + Y)]\}^{1/2}$$

In the formula above, X, Y, respectively denote the comprehensive evaluation value of information industry and construction industry when using Choquet integral. We can see that the value of the coupling degree C is between 0 and 1 and will never reach the ideal value 1. When C tends to 1, the coupling degree tends to maximum, the relationship tends to be benign resonance coupling between systems or internal elements of the system and system will tend to the new orderly structure. When C tends to 0, the coupling degree tends to minimum, the relationship is at unrelated stage between systems or internal elements of the system and the system will tend to the disorderly structure.

Coordination degree function: It is effective to use coupling degree to reflect the coupling strength of information industry and construction industry, but it is difficult to reflect the coordination effect of information industry and construction industry, especially we want to compare more industries. The upper and lower limit values calculating coupling degrees are generally derived from reference annual values and development planning values of each area. The judgment is possible to cause the misleading result merely relying on the coupling degrees, because information industry and construction industry of each area have the staggered, dynamic and Disorders characteristics.

Therefore, based on the coupling degree of information industry and construction industry, we introduce the concept of coordination degree of information industry and construction industry to analyze and judge the coordination degree of information industry and construction industry. The coordination degree of information industry and construction industry can reflect the strength degree of the "efficacy" and "synergistic" utilities between variables when the two industries have interaction process. The "efficacy" and "synergistic" utilities enable the system from disorder state to orderly and effective development.

The coordination model can be shown as follows:

$$D = (C \times T)^{\frac{1}{2}}$$
$$T = aX + bY$$

where, D is coupling coordination degree. T is comprehensive coordination index of information industry and construction industry system, which reflects overall synergistic effects or efficacy α and b are undetermined coefficients, moreover α+b = 1, which, respectively represent efficacy coefficients of information industry and construction industry (we take 0.5 for convenient calculation). In practice, we had better ensur $T \in (0,1)$, so we can ensure $D \in (0,1)$ in order to use it.

Judging standard for coupling coordinated development of information industry and construction industry: Information industry can promote the management of construction industry to keep pace with the times and speed up the management system reform and industrial structure optimization and upgrading of construction industry. The situation shows that the construction industry in more developed areas have a greater impact on the development of information industry. In order to reflect the coupling coordinated relationship of information industry and construction industry, we accessed to a large number of relevant documents and we put forward the judging standard and basic types, shown in Table 1.

Although, the above coordinated model of information industry and construction industry is simple, it can really reflect the dynamic situation of coordinated development of information industry and construction industry. It can also measure the coordinated development degree of information industry and construction industry very well. The optimal coordination degree can reflect whether the coordinated development systems are in the best combination state or not. Through, the above model we can calculate the

Table 1: Evaluation of coupling degree of information industry and construction industry

Coupling degree	Level classification	Evaluation
0,0.4	Embryonic stage	The relationship of information industry and construction industry is not close
0.4,0.5	Starting stage	The information industry gradually influences construction industry
0.5,0.8	Stable stage	The information industry promotes the development of construction industry
0.8,1	Mature stage	The information industry and construction industry are mutual promotion and common development

Table 2: Classification system and judging standard of coordination degree of information industry and construction industry

			Basic type		
Category	Coordination degree	Subclass	X-Y>0.1	0≤|X-Y|≤0.1	Y-Z>0.1
Coordination class	0.8,1.0	Best coordinated development class	Best coordinated development class and construction industry lag type	Best coordinated development class and type of synchronization	Best coordinated development class and information industry lag type
	0.7,0.8	Good coordinated development class	Good coordinated development class and construction industry lag type	Good coordinated development class and type of synchronization	Good coordinated development class and information industry lag type
	0.6,0.7	Medium coordinated development class	Medium coordinated development class and construction industry lag type	Medium coordinated development class and type of synchronization	Medium coordinated development class and information industry lag type
Barely coordination class	0.5,0.6	Barely coordinated development class	Barely coordinated development class and construction industry lag type	Barely coordinated development class and type of synchronization	Barely coordinated development class and information industry lag type
Disorders recession class	0.4,0.5	Disorders recession class	Disorders recession class and construction industry lag type	Disorders recession class and type of synchronization	Disorders recession class and information industry lag type
	0.3,0.4	Medium disorders recession class	Medium disorders recession class and construction industry lag type	Medium disorders recession class and type of synchronization	Medium disorders recession class and information industry lag type
	0,0.3	Serious disorders recession class	Serious disorders recession class and construction industry lag type	Serious disorders recession class and type of synchronization	Serious disorders recession class and information industry lag type

coordinated degree which can quantitatively describe the interaction and development of information industry and construction industry with a strong operability. In order to determine the coordination level of the development of information industry and construction industry, we have to divide coordinated degree of information industry and construction industry to several levels (Wei *et al*., 2007). According to the value of coordination degree D, we can set the coordination grade, shown in Table 2.

EMPIRICAL ANALYSIS ON THE COUPLING RELATIONSHIP OF INFORMATION INDUSTRY AND CONSTRUCTION INDUSTRY IN CERTAIN CITY OF CHINA

This study collects the related index data from "the Statistical Yearbook in certain cities of China" in 2008-2010 and the official website of the statistics department, shown in Table 3 and 4.

We use entropy and the 0-1 standardization method to calculate relative weight of each index as shown in Table 5 and 6. From calculation results, we can see that the weight difference is not big between the six indices of information industry and the six indices of the construction industry. It indicates that each index has similar contribution to the evolution of system coupling.

According to efficacy function, we use information industry of 2005 to calculate the comprehensive evaluation value of Choquet integral (Table 6). The calculation process is shown as follows:

First of all, we should sort the standardized value of information industry:

$$f(x_6) = 0.0965,\ f(x_1)\ 0.1115,\ f(x_5) = 0.1148,\ f(x_4) = 0.1230,$$
$$f(x_3) = 0.1481,\ f(x_2) = 0.1688$$

Secondly, we should build fuzzy measure according to the above calculation:

$$\mu(\{X\}) = 1, \qquad \mu(\{x_1, x_2, x_3, x_4, x_5\}) = 0.95,$$
$$\mu(\{x_2, x_3, x_4, x_5\}) = 0.85, \qquad \mu(\{x_2, x_3, x_4,\}) = 0.7$$
$$\mu(\{x_2, x_3\}) = 0.5, \qquad \mu(\{x_2\}) = 0.2$$

Finally, we should calculate the comprehensive evaluation value of Choquet integral:

$$CI_\mu(f) = 0.0965*1 + (0.1115 - 0.0965)*0.95 + (0.1148 - 0.1115)$$
$$*0.85 + (0.123 - 0.1148)*0.7 + (0.1481 - 0.123)$$
$$*0.5 + (0.1688 - 0.1481)*0.2 = 0.136$$

In the same way, we also can calculate the industrial the same way, we also can calculate the industrial comprehensive evaluation value of information industry and construction industry of other years. Based on the

Table 3: Information industry indices

	Year					
Index	2005	2006	2007	2008	2009	2010
Total output value of information industry X1 (one hundred million)	249.11	293.7	350.68	413.8	441.53	485.24
GDP ratio of output value of information industry X2 (%)	0.0927	0.0923	0.0935	0.0940	0.0910	0.0856
Aunual average number of employees X3 (ten thousand people)	1.2	1.3	1.4	1.3	1.4	1.5
Ratio of staff engaging in construction software X4 (%)	3.0	3.2	4.0	4.4	4.8	5.0
Investment of R and D in constmction software X5 (%)	2.1	2.4	2.9	3.4	3.6	3.9
Added value of information industry X6 (one hundred million)	47.43	56.79	68.53	97.82	104.37	116.53

Table 4: Construction industry indices

	Year					
Index	2005	2006	2007	2008	2009	2010
Total output value of construction industry Y1 (one hundred million)	348.47	405.41	467.98	560.09	686.47	813.71
GDP Ratio of output value of construction Y2 (%)	0.1297	0.1274	0.1248	0.1272	0.1414	0.1436
Aunual average number of employees Y3 (ten thousand people)	21.8	16	16.8	14.4	15	16.1
Ratio of staff engaging in information technology Y4 (%)	4.4	4.9	5.9	5.6	5.8	6.7
Expenditure of information resources in construction Y5 (%)	2.3	2.6	2.7	2.7	3.1	4.00
Added value of construction industry Y6 (one hundred million)	132.96	149.68	168.24	193.45	245.71	304.43

Table 5: Relative weight of information industry indices

	Index					
Year	X1	X2	X3	X4	X5	X6
2005	0.1115	0.1688	0.1481	0.123	0.1148	0.0965
2006	0.1315	0.168	0.1605	0.1311	0.1311	0.1156
2007	0.157	0.1703	0.1728	0.1639	0.1585	0.1394
2008	0.1852	0.1712	0.1605	0.1803	0.1858	0.199
2009	0.1976	0.1657	0.1728	0.1967	0.1967	0.2124
2010	0.2172	0.156	0.1852	0.2049	0.2131	0.2371
Weight	0.1625	0.1904	0.161	0.1636	0.163	0.1595

Table 6: Standardized data and relative weight of construction industry indices

	Index					
Year	Y1	Y2	Y3	Y4	Y5	Y6
2005	0.1062	0.1633	0.2178	0.1321	0.1322	0.1113
2006	0.1235	0.1604	0.1598	0.1471	0.1494	0.1253
2007	0.1426	0.1571	0.1678	0.1772	0.1552	0.1408
2008	0.1706	0.1602	0.1439	0.1682	0.1552	0.1620
2009	0.2092	0.1781	0.1499	0.1742	0.1782	0.2057
2010	0.2479	0.1808	0.1608	0.2012	0.2299	0.2549
Weight	0.1704	0.1661	0.1561	0.1811	0.1601	0.1663

Table 7: Coordination degree and judging of coupling coordinated development of information industry and constmction industry

	Year					
Index	2005	2006	2007	2008	2009	2010
Comprehensive index value of information industry (X)	0.136	0.3066	0.4648	0.6846	0.7959	0.8099
Comprehensive index value of construction industry (Y)	0.1489	0.3485	0.5104	0.5637	0.6881	0.7253
Coupling degree (C)	0.4995	0.499	0.4995	0.4977	0.4987	0.4992
Coordination degree (D)	0.2667	0.3518	0.4809	0.5573	0.6083	0.6191
Type	Serious disorders	Medium disorders	Disorders	Barely coordination	Medium coordination	Medium coordination

industrial comprehensive evaluation value we can calculate the comprehensive index value of information industry and construction industry in the year 2005-2010 and coupling degree and coordination degree. Then we can judge the type of coupling coordinated development of information industry and construction industry. The result is shown in Table 7.

From Table 7, the relationship between the comprehensive index values, the coupling degree and coordination degree of information industry and that of construction industry is as shown in Fig. 2.

According to the above calculations and Fig. 1 and 2 analysis. We can see that information industry and construction industry have a rising trend. Among them

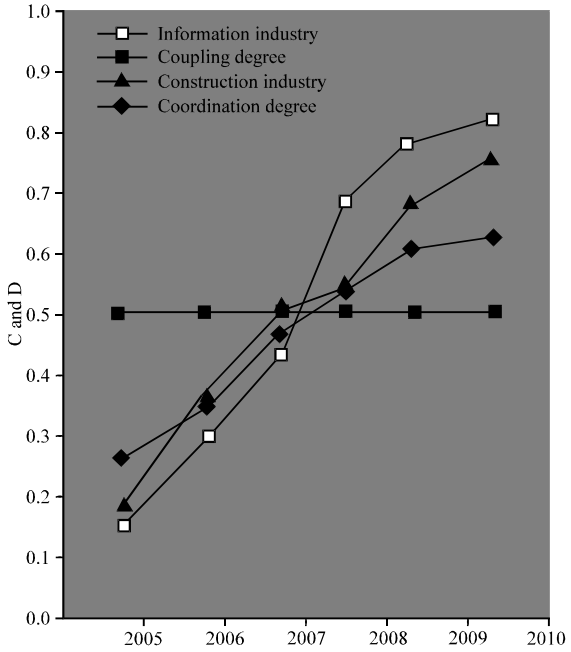

Fig. 2: Coupling degree curve and coordination degree curve of information industry and building industry

information industry has shown a strong upward trend, every year it has a big progress. But construction industry is showing slight twists. Due to financial crisis in 2008, the growth rate in the construction industry has slowed down. From 2005-2010, six years, information industry and construction industry are developing very quickly. This could explain that information industry and construction industry in this city has a good coupling relationship.

From coupling model of information industry and construction industry, we can see that all the coupling degree values fall in the interval (0.4,0.8) and the coupling change range is not big and increased slightly. These data have been close to 0.5 and very stable. It shows that information industry is gradually affecting construction industry in this city. According to the coupling law of information industry and construction industry, the city should promote the development of information industry based on the development of construction industry and information needs. It also should play comparative advantages of the city in order to promote both construction industry and information industry and form benign mutual promotion and development model.

According to the analysis of coordination degree index, the indices are more stable than the method of entropy and the method of Shapley. In general, the value of coordination degree is more and more high. From the point of subdivision analysis, the coupling coordinated development of information industry and construction industry in this city of 2005-2010 can be divided into three stages: type of Disorders, type of barely coordinated development, type of medium coordinated development. In summary, the relationship between the information industry and construction industry is now in the starting stage, the development between the two systems is more coordinated, which is in accord with the present status of the city's industry.

CONCLUSION

We came to the conclusion that there is a coupling relationship between information industry and construction industry applying the industrial coupling theory and system science theory to analyze the information industry and construction industry. Meanwhile, according to the output of the mathematical model, we came to the following conclusions:

- The coupling degree of information industry and construction industry reflects the synergistic level between variables in the interaction of the two kinds of industries, so that the system development is from disorder to order and effective. Meanwhile, the choice of coupling degree index has played a crucial role in establishing the model. This study follows the scientific, logical and applicable principle and also refers to the related index used to calculate the development of information industry and construction industry by the country and refers to the coupling degree particularity in establishment of index system
- The coupling degree can effectively reflect the coupling level of information industry and construction industry, but it is difficult to reflect the synergistic effect. Therefore, on the basis of research on the coupling degree of information industry and construction industry, this study introduces the coupling coordination degree to judge its interaction coupling coordination level. Observing the change trend in the coupling coordination development of information industry and building industry among the cities, analyzing the interlaced, dynamic and unbalance characteristics on the development of information industry and construction industry in each area, which is used to guide the technical path of industrial structure optimization and upgrading

REFERENCES

Cheng, H. and D.T. Tao, 2012. Research on the coupling of information industry and building industry. Res. J. Applied Sci. Eng. Technol., 4: 1748-1753.

Choquet, G., 1954. Theory of capacities. Annales de l'Institut Fourier, 5: 131-295.

Hao, S.B. and B. Yu, 2008. Research on coupling degree model and application of the enterprise's technology capacity and technology management capacity. Forecasting, 27: 12-15.

Isard, W. and E.W. Schooler, 1959. Industrial complex analysis, agglomeration economies and regional development. J. Regional Sci., 1: 19-33.

Li, Q.X., Y. Su and Y.L. Pei, 2008. Research on coupling coordination degree model between up stream and downstream enterprises. Proceedings of the International Conference on Information Management, Innovation Management and Industrial Engineering, Volume 2, December 19-21, 2008, Taipei City, Taiwan, pp: 172-175.

Qiao, B. and C.L. Fang, 2005. The dynamic coupling model and its application of urbanization and eco-environment in Hexi Corridor. J. Geog. Sci., 15: 491-499.

Sugeno, M., 1974. Theory of fuzzy integral and its application. Ph.D. Thesis, Tokyo Institute of Technology. Japan.

Tehran, M. and M. Bayad, 1997. Competitive strategies and performance in the european union high-tech industries: An empirical study. Proceedings of the Annual Meeting of the Decision Sciences Institute, November 1997, San Diego, CA., pp: 434-436.

Wei, X., Y. Wang, N. Li and Q.W. Zhu, 2007. Grey- relation analysis of traffic system and urbanization in Jilin Province of China. Chin. Geog., Sci., 17: 216-221.

Wu, J.Y., 2008. Study on Supplier Evaluation and Selection Based on Fuzzy Integral. Harbin University of Science and Technology, China, pp: 18-21.

Xiong, Y.Q. and S.C. Li, 2010a. Research on coupling development of strategic emerging industry and traditional industry. Res. Finan. Econ., 323: 38-44.

Xiong, Y.Q. and S.C. Li, 2010b. Research on the process and mechanism of coupling development of strategic emerging industry and traditional industry. Sci. Sci. Manag., 31: 84-87.