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Intellectual capital-based innovation planning: empirical studies using wiNK model

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Abstract

Purpose – Innovation is essential for business growth that cannot be created by financial investment alone but with intellectual capital (IC). IC management is critical for the organization, yet many firms do not have proper strategies. The purpose of this paper is to present an effective planning model that enables organizations to raise their innovation capability through strategic IC management.
Design/methodology/approach – Two R&D groups in an information and communication technology organization are examined with an IC-based complex system model (wiNK model). The model includes a descriptive part that determines the current IC state of the group and a prescriptive part that identifies the IC strategies for optimal innovation performance.
Findings – This paper demonstrated that the wiNK model is an easy-to-use prescriptive tool using IC to optimize innovation performance.
Research limitations/implications – The IC state of an organization is dynamic and changing. Regular IC examinations are necessary to track its changes.
Practical implications – This IC-based model can be applied individually without benchmarking with other organizations. The IC location map can be documented as an organization DNA profile for the organization. The tracking of the continuous and dynamic changes is beneficial to the organization and its stakeholders. It can be served as both planning and evaluation tools.
Originality/value – This study offers a systemic approach to the interdisciplinary study of organizational behavior and innovation with a pioneering use of an IC framework. It contributes to the field of innovation management with a new attempt of its kind to integrate management research and mathematical simulation model.

Keywords Innovation, Intellectual capital, Complexity theory
Paper type Research paper

1. Introduction

Innovation has been identified as the driving force for value creation (Schumpeter, 1976) and future survival of an organization (Terziovski, 2007). Peter Drucker (1985, p. 25) defined Innovation as "the specific instrument of entrepreneurship […] the act that endows resources with a new capacity to create wealth." There is a growing awareness that competitive advantage and sustainability is directly linked to the learning and innovation capabilities of organizations. As distinguished from invention, innovation is systemic. Developing systemic innovation capability is the key element of growth in enterprises. Firms and organizations compete on the underlying capabilities that make the products and services sustainable. Innovation can be brought about in an organization and be embedded in the business process, management philosophy and culture of the organization, as an asset that an organization can cultivate and manage.

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Innovations cannot be created by financial investment alone but leverage on intangible assets (Lev, 2001), also known as the intellectual capital (IC). IC has long been recognized as a source of innovation. A systemic view of the fundamental impacting factors interacting together in a complex, dynamic world is essential but lacking. Studies on the relationship between IC stocks and flows are scarce (Al-Laham *et al.*, 2011; Andreous and Bontis, 2007; Vargas and Lloria, 2014). Stocks of IC refers to the intangibles that are listed and recorded in a company, and the flow relates to the sharing and diffusion of knowledge and know-how among the stakeholders. Investigation of the link between IC and innovation capability lead to the firm performance is a challenge demands more empirical research (Wu and Sivalogathasan, 2013). Research in analyzing the relationship between the IC in a complex manner is absent. Therefore, it is necessary to identify the critical factors and their interacting relationship in order to provide a comprehensive understanding of the overall contribution to innovation.

Calabrese *et al.* (2013) pointed out that IC management is a fundamental factor for organizational competitive advantage, yet many firms fail to balance IC investments. Balancing does not mean even distribution of financial or resources allocation in various aspects of IC. It requires knowledge of the current IC status of the organization, and intelligence to strategize an IC development plan so that the combination of IC characteristics of the organization will benefit innovation performance and hence company competitiveness. IC is a complex representation of the organizational DNA (Neilson and Fernandes, 2008; Govindarajan and Trimble, 2005). The combination and interaction of different genes (described as elements in human capital (HC), structural capital (SC), and relational capital (RC)) form a unique characteristic for each organization. Such nature of the firm can be called intellectual capital complexity (ICC) (Dumay and Cuganesan, 2011; Fan and Lee, 2012). Since each firm has different characters, the best way to achieve innovation performance leveraging their ICC can be very different. Methods that work for a company may not benefit most to another one. Best practices and benchmarking that commonly used in management field assume orderly condition and static climate.

Innovation, however, happens at the "edge of chaos" in the domain of complexity. The firm and its environment change dynamically. Calabrese *et al.* (2013) proposed a benchmarking method that compares a target company with the average of the IC configuration of best practices belonging to the same industry. We applaud their effort in promoting IC management planning which is addressed as the third stage of IC research (Guthrie *et al.*, 2012; Mouritsen, 2006; Cuganesan and Dumay, 2009). However, as Dumay (2012, p. 4) pointed out that "managers should attempt to better understand the possible causal relationships between their people, processes and stakeholders (HC, SC, and RC) rather than adopting someone else's mousetrap." It is crucial to understand the unique characteristics of the target company to plan a strategy that fit. The dynamic and complex nature of IC and innovation should be taken into consideration.

In this paper, the wiNK model is applied to two R&D groups in an information and communication technology (ICT) organization for the IC investigation as well as innovation planning. Section 2 describes the complexity of IC and prior research in this area. In Section 3, a brief description of the IC planning method and wiNK model are presented. It is shown that even within same organization different groups exhibit different ICC characteristics; hence require different strategy planning for IC development for innovation. The empirical studies of two groups of an R&D organization and the findings are reported in Section 4. Finally, the management implication, limitation and future development of the model are discussed in Section 5.

2. The complexity of IC and the wiNK model

Existing studies of IC lay a foundation for understanding what can be done to help an organization to generate higher innovation capability with IC. However, only recently attempts have been made to integrate IC elements and study their interdependencies. For example, Bratianu (2013) presented a dynamic IC model with integrators based on interdependence and synergy. One need to ask the question: with the organization's current IC on hand, what can be done? On which dimension of IC shall the organization focus for improvement to gain maximum return? Not only an organization may not be able to build up all dimensions of IC, but also not necessarily be beneficial to do so, as some of the requirements may be contradictory. This brings in the consideration of complex systems.

2.1 Complexity science and organization studies

Complexity science is particularly helpful in the advancement of organization studies and management science. The mechanical metaphors used in the last century have helped the organization in the areas of manufacturing, quality control, production and inventory planning, organization efficiency, and process management. However, it is not sufficient to describe and plan for a dynamic and evolving entity, and unable to explain the co-evolving relationship between entities and why the sum could be more than the total of its parts. The critical factors for contemporary organizations and industries such as innovation, competitive advantages, and sustainability require more than mechanical rules and formulas. Complexity science is a necessary tool to understand the contradictions and conflicts in managing an organization.

Allen *et al.* (2011) define complexity science as the systematic study of complex systems. A complex system is a whole that is made up of a large number of interacting or interrelating parts. As individual parts response to certain governing rules or forces, distinct qualitative properties emerge at the system level. This phenomenon and upward non-linear causality cannot be predicted from knowledge of the individual parts and rules. When the upper-level change occurs, it, in turn, has downward effects onto the individual parts. Applying complexity science in organization and management studies is a powerful way to bring values out of individual agents playing different roles. It will truly reflect the beliefs, values, cognitive, and qualitative aspects of the organization. Studies (Frenken *et al.*, 1999) indicated that in complex systems with high interdependency, the probability of successful innovation is inversely related to the number of parts that are changed simultaneously. The interdependency of parts within a complex system also relates to the reversibility of technological development. Therefore, a complex system view of technological development calls for a local, sequential and irreversible search.

2.2 IC complexity and wiNK model

Complexity theory has been used to study organizations and evolutionary economics in the recent years. Levinthal (1997) and Frenken (2000, 2006) are among the few who dedicated to building up the NK model (Kauffman, 1995) to be applied in organization studies. Applying NK model complexity behavior to an organization, it signifies that innovation performance will require an appropriate level of interdependency among the components to enable innovation. To strategize a roadmap for the search of higher innovation performance, the components, and their interdependency must be identified first. With an evolutionary biology analogy, we can describe that IC genes construct

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unique characters of an organization. By distinguishing the crucial IC genes and their interdependencies, and using complexity science and NK model, the path to higher innovation capability can be searched and mapped out.

The term "ICC" was first employed by Gupta and Roos (2001) referring to the number of interdependent resources linked to core ICs. Their proposition is that the higher the complexity, the higher the transformation inertia. High inertia will inhibit the trading of IC and thus make imitation difficult. Cuganesan (2005) highlighted the difficulty of measuring and managing IC due to the complex inter-relationship between IC resources and the creating value. The realization of ICC (Chatzkel, 2003; Dumay and Cuganesan, 2011) makes the valuation of IC with traditional causation and measurement inadequate. A growing need to study the complexity of IC was raised (Cuganesan, 2005; Mouritsen, 2006; Bueno *et al.*, 2006). However, the complexity of IC was not measured until Dumay and Cuganesan (2011). They used the Cognitive Edge Sense Maker Suite (Snowden, 2000) to conduct a case study in an Australian financial services organization. Through the collection of narratives, indexing, and sense making, the users can gain multiple perspectives on complex issues and assist decision-making.

Dumay and Garanina (2013, p. 12) argue that the "dynamic theory of IC introduces that the roles and effects of different elements of IC are very complex and therefore difficult to predict and forecast." Edvinsson (2013) reflects that we should go beyond IC reporting to become a systematic cross-disciplinary study as IC systems science. Bontis (1998) has shown the inter-relationship among HC, SC, and RC. However, these three categories are rather a high level and are difficult to be put into operation. The complexity of IC components warrants a deeper and more thorough investigation.

Fan and Lee (2012) proposed the wiNK model, an extended NK model that offers a systemic and flexible tool for innovation planning using IC components. The NK model is a stochastic combinatorial optimization model with two parameters, N and K. The study of innovation using the NK model requires the identification of N components of the system, and the K interaction or epistasis among them. The value of K forms a tunable rugged fitness landscape that allows a path-searching for optimization and strategy planning. The wiNK model further enhances the NK model with weighted contribution influence of different IC components and the informed relationship among the components as well as the current IC status. Due to computational complexity increases as N (number of elements) increases, we use six components for this model. Two elements of each capital are selected, expanding IC to the next level of three pairs:

(1) HC: knowledge workers (KW) (Amabile, 1988; Shalley and Gilson, 2004) and transformative leaders (TL) (Avolio and Bass, 1995; Bass and Avolio, 2000; Elkins and Keller, 2003);

(2) SC: innovation supportive culture (OC) (Chandler *et al.*, 2000; Ahmed, 1998; Martins and Terblanche, 2003) and infrastructure of systems and processes (SP) (Tushman and O'Reilly, 2002); and

(3) RC (Nahapiet and Ghoshal, 1998; Burt, 1995; Tsai and Ghoshal, 1998): internal social network (ISN) and external social network (ESN).

The selection of the pairs bears some Chinese philosophy of contrary forces or complementary opposites that are interconnected and interdependent in a dynamic system. The discovery of the ICC is a useful index to describe the characteristics of an organization, which can be modified and evolved for a better future.

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3. A two-stage IC planning tool for innovation

The proposed two-stage IC planning tool includes a descriptive study of the present status with statistical and regression analysis and a prescriptive study with the use of simulation and the wiNK model.

3.1 Describing the present status

Understanding the current condition is crucial because, by definition, a complex system is very sensitive to the initial state. IC elements and their status need to be identified. Researchers have studied the influential factors of innovation performance with many different perspectives and directions. These studies usually adopt regression model with linear unidirectional causality. There are two major weaknesses in this type of research. First, as many have pointed out that, an organization is a complex system, the assumptions of linearity and unidirectional cannot hold true. However, there have not been sufficient quantitative studies using a complex model in the area of IC and innovation research. Second, the modeling ignores the unique behavior of different organizations, industry sectors, and innovation systems; and the research outcome cannot benefit all organizations in the same fashion (Hart, 1995). A systemic view of critical impacting factors interacting together in a complex, dynamic world is essential.

To study the correlation between the IC components, non-linear regression analysis, and structural equation modeling are leveraged. The main purpose of this method is to confirm the relationship between IC components and innovation performance and to identify the correlation (interdependency) among the variables. The output will confirm the main factors for innovation, and produce a correlation matrix that provides the degree of interdependency between each pair of variables. Partial least square (PLS) offers least restrictive multivariate extensions of multiple regression models. The benefits of PLS include the estimation of multicollinearity among the variables, the path estimation of non-linearity of the relation and the relaxed requirement of the data sample size.

3.2 Prescribing the IC planning for innovation

Once the status and correlation of IC components are determined, the weighting factors and information of the inter-relationship are then applied to the wiNK model. The innovation performance is determined as:

$$\Phi(x) = \left[\sum \omega_i \varphi_i(x)\right] / N$$

The descriptive information addresses three concerns of using NK model in management and organizational strategy planning. The three concerns are the binary state of a component (A), number of the inter-relationship between components (K), and the weighting and impact of all components (W) on the performance (Fan and Lee, 2012). The relationship between two components is measured with seven levels instead of the binary state. The correlation matrix of n variables $x_1, \ldots, x_{\mathrm{n}}$ is an $n \times n$ matrix where the entry on position i, j is k_{ij} representing the correlation coefficient between variable i and j. The correlation matrix from the descriptive phase is used for the interaction matrix K of the NK model. The weighting factors of the components described as vector $W = [\omega_1, \omega_2, \ldots, \omega_n]$ has $\omega_i = \beta_i$ from the coefficient array β with $[\beta_1, \beta_2, \ldots, \beta_n]$.

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4. Implementation of IC planning using wiNK in ICT organizations

An empirical study of the proposed IC planning tool using wiNK with a Canadian telecom company was reported by Fan and Lee (2012). The planning tool was applied to two groups of an R&D institution (HKRADI) in Hong Kong to have a deeper look into the impact of IC complexity on innovation planning. The objective was to examine if and how much difference at the group level within one organization, and therefore different IC strategies are required. These two groups operated under the same administration headquarter, but their R&D teams were allowed to select their innovation, collaboration, and networking strategies. It was of interest to study the differences between groups within the same environment, policies, and political constraints. The results of the descriptive studies of Group A (HKRADI-A) and Group B (HKRADI-B) are presented in the next two sections, and their comparison discussed in the sections followed.

4.1 The procedures

HKRADI was founded in 2000 by the Hong Kong government with a mission to enhance the city's competitiveness through innovation and technology. The organization recruited world-renowned technology and business leaders in the ICT industry to build teams and pilot different initiatives. Experienced staffs and bright new graduates were employed from local, mainland China and overseas. The majority of the professional staff had master or PhD. degrees. The organization had over 550 research and development staff. Over the decade, it had gone through changes with different leadership, business models, and governing policy rules. The organization had five groups. Some were established since the inception. The latest addition was in 2009. These R&D groups were under the same administrative management. Headquarter leaderships served all groups with same processes and guidelines.

HKRADI-A and HKRADI-B were selected in the comparative study because of their close establishment dates. The two groups had experienced similar changes in corporate strategy, management process, and headquarter leadership. The investigation the unique IC and its complexity of the two groups can, therefore, operate in a controlled manner.

Under the ICT industry pillar, the two research groups have different research focusses. HKRADI-A's main focus was multimedia and networking technologies for consumer and enterprise electronics. HKRADI-B was in the area of advanced photonic packaging. Web-based surveys were conducted with the two groups separately. Survey items are listed in Table AI. Management agreed on conducting the studies, and subsequently, a questionnaire was sent to all staff. Data were then analyzed with regression analysis (SPSS 18) and PLS (warpPLS 1.0). The resulting data, namely, the weighting factors and the correlation matrix were then used in the wiNK model for prescriptive analysis. Reliability and validity of constructs were tested and reported in Table I. Test results indicate internal consistency and reliability. Descriptive results are presented in Section 4.2, and prescriptive results are presented in Section 4.3.

4.2 Descriptive results

4.2.1 HKRADI-A. For HKRADI-A, 48 out of 120 survey responses were received. There was 24 percent managerial and 76 percent non-managerial staff. On a Likert seven scale, all item means lied within 3.17-5.29. KW1 (5.29) and KW2 (5.19) received the two highest scores. INP5 (3.17) and INP1 (3.46) received the two lowest scores. Internal consistency and reliability were tested positive. Cronbach's α values varied from 0.82 to 0.97.

	KW	TL	OC	SP	ISN	ESN	INP
Cronbach α coefficients							
HKRADI-A	0.855	0.966	0.905	0.817	0.919	0.922	0.916
HKRADI-B	0.949	0.941	0.843	0.861	0.935	0.902	0.920
Compositive reliability coefficients							
HKRADI-A	0.932	0.978	0.934	0.892	0.943	0.945	0.938
HKRADI-B	0.967	0.962	0.895	0.916	0.953	0.932	0.940
Average variances extracted (AVE)							
HKRADI-A	0.873	0.936	0.780	0.735	0.805	0.811	0.752
HKRADI-B	0.908	0.894	0.681	0.785	0.836	0.773	0.759

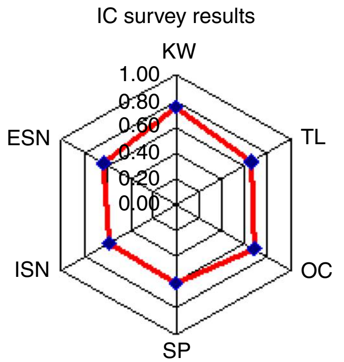
Notes: KW, knowledge workers; TL, transformative leaders; OC, innovation supportive culture; SP, systems and processes; ISN, internal social network; ESN, external social network; INP, innovation performance

Table I. Validity and reliability test results

Figure 1 depicts the IC status of HKRADI-A. Among the six dimensions, intrinsic motivation of KW had the highest mean value, trailed by OC, and intellectual stimulation of TL. They were followed by ESN and SP. ISN rated the lowest.

The innovation model indicated that HKRADI-A collaborated with external partners along with in-house R&D. The group was not aggressive in licensing out innovated technologies.

The effects of the six IC components on innovation performance were tested with SEM modeling. A first model tested the direct causal relationship among the six IC constructs with innovation performance. They together contributed 64.6 percent variance explanation on INP. ESN demonstrated a strong contribution of 60.7 percent. SP came second with 27.5 percent. The contributions of the other four were not significant. Correlations among the IC components were also observed (Table II). There was no multicollinearity but had substantial bidirectional correlations.



Notes: KW, knowledge workers; TL, transformative leaders; OC, innovation supportive culture; SP, systems and processes; ISN, internal social network; ESN, external social network

Figure 1. Current IC status of HKRADI-A

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	INP	KW	TL	OC	SP	ISN	ESN
Correlation matrix							
INP	(0.867)	0.239	0.621	0.465	0.625	0.623	0.759
KW	0.239	(0.935)	0.317	0.503	0.265	0.317	0.376
TL	0.621	0.317	(0.968)	0.740	0.671	0.712	0.732
OC	0.465	0.503	0.740	(0.883)	0.554	0.541	0.536
SP	0.625	0.265	0.671	0.554	(0.857)	0.709	0.614
ISN	0.623	0.317	0.712	0.541	0.709	(0.897)	0.703
ESN	0.759	0.376	0.732	0.536	0.614	0.703	(0.900)
Path coefficients of Model 1							
R^2	0.65	0.002	0.005	−0.001	241**	0.047	0.589***

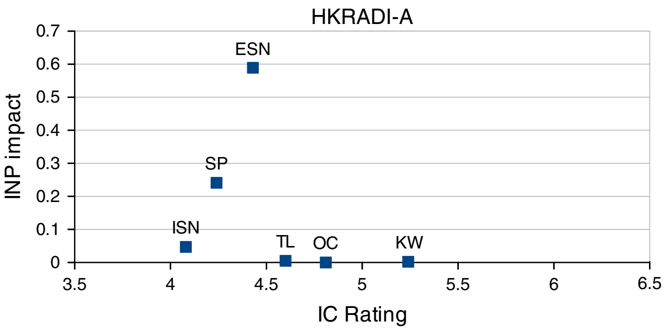
Notes: Square roots of average variances extracted AVE's shown on diagonal in parentheses. KW, knowledge workers; TL, transformative leaders; OC, innovation supportive culture; SP, systems and processes; ISN, internal social network; ESN, external social network; INP, innovation performance

Table II. Result of HKRADI-A

A second model tested the mediating effects of OC and SP as SC and ISN and ESN as RC on KW and TL as HC. The result confirmed that ESN and SP were key contributors to INP. TL had played a vital role that affects both structural and RC. KW had affected OC and to some degree ESN.

The survey results indicated that the organization had high intrinsic motivations, innovative culture, and transformational leadership. ISN was rated the lowest among the six. Figure 2 showed that although KW, TL, and OC were highly rated, they did not contribute to the innovation performance as high as the other three (SP, ISN, ESN). The survey respondents considered that there were a good innovative environment and great leaders. They were also confident in their capability to innovate. However, these good qualities were not attributed to the performance result. On the other hand, ESN and SP were highly related to the success of innovation. It is essential for management to examine the organization processes and networking strategies to eliminate hindrances.

4.2.2 HKRADI-B. For HKRADI-B, 46 out of 130 survey responses were received. There was 24 percent managerial and 76 percent non-managerial staff. On a Likert seven



Notes: KW, knowledge workers; TL, transformative leaders; OC, innovation supportive culture; SP, systems and processes; ISN, internal social network; ESN, external social network; IC rating, intellectual capital rating; INP, innovation performance

Figure 2. HKRADI-A IC impact to innovation

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scale, all item means lied within 3.52 to 5.71. All items in KW3 (5.71), KW1 (5.63) and KW2 (5.51) and OC3 (5.69) received the four highest scores. INP5 (4.10) and INP1 (4.17) received the two lowest scores. The next three lowest items are all ISN items. Internal consistency and reliability were tested. Cronbach's α values ranged from 0.84 to 0.95.

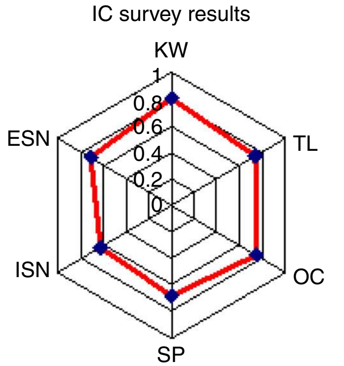
Figure 3 depicts the IC status of HKRADI-B. Among the six dimensions, intrinsic motivation of KW ranked first, followed by OC and intellectual stimulation of TL. ESN and SP trailed with average ratings. ISN rated the lowest. The ratings were all higher than HKRADI-A with the same ranking order.

The innovation model indicated that the organization adopted collaboration and open innovation with external parties along with in-house R&D and innovation. The organization was relatively aggressive in licensing out innovated technologies.

The effects of the six IC components on innovation performance were tested with SEM modeling. A first model tested the direct causal relationship among the six IC constructs with Innovation Performance. They together contributed 69.7 percent variance explanation on INP. All model fit indices were good. SP demonstrated a strong contribution of 45.4 percent path coefficient. ISN and ESN followed with 28.8 and 18.1 percent, respectively. Correlations (Table III) among the variables were free from multicollinearity.

A second model tested the mediating effects of OC and SP as SC, and ISN and ESN as RC on KW and TL as HC. The result confirmed that SP was the major contributors to INP. Furthermore, it was observed that TL had played a critical role affecting OC and SP.

The survey results indicated that the organization had KW with high intrinsic motivations, good innovative culture, and transformational leadership. Figure 4 depicts that although the three IC factors had been perceived to be strong, they had not contributed to the innovation performance as much as the other three IC (SP, ISN, ESN). They accredited the performance success mostly to organization SP. ISN was rated the lowest among the six but with high impact to innovation. If the management designed



Notes: KW, knowledge workers;
TL, transformative leaders;
OC, innovation supportive culture;
SP, systems and processes;
ISN, internal social network;
ESN, external social network

Figure 3.
Current IC status of the HKRADI-B

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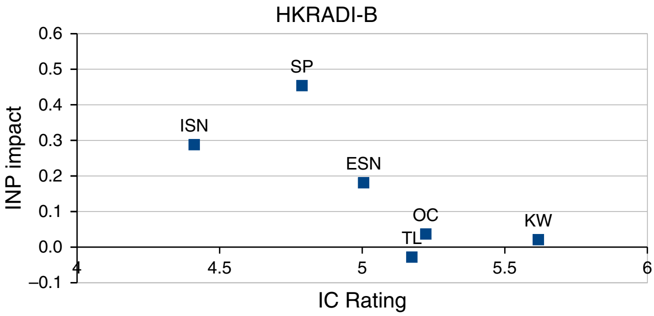
Table III.
Result of HKRADI-B

	INP	KW	TL	OC	SP	ISN	ESN
Correlation matrix							
INP	(0.871)	0.218	0.472	0.211	0.756	0.710	0.753
KW	0.218	(0.953)	0.593	0.424	0.387	0.178	0.435
TL	0.472	0.593	(0.946)	0.533	0.590	0.416	0.606
OC	0.211	0.424	0.533	(0.825)	0.242	0.151	0.236
SP	0.756	0.387	0.590	0.242	(0.886)	0.587	0.707
ISN	0.710	0.178	0.416	0.151	0.587	(0.914)	0.797
ESN	0.753	0.435	0.606	0.236	0.707	0.797	(0.879)
Path coefficients of Model 2							
R^2	0.697	0.021	−0.028	0.037	0.454**	0.288	0.181

Notes: Square roots of average variances extracted AVE's shown on diagonal in parentheses. KW, knowledge workers; TL, transformative leaders; OC, innovation supportive culture; SP, systems and processes; ISN, internal social network; ESN, external social network; INP, innovation performance



Notes: KW, knowledge workers; TL, transformative leaders; OC, innovation supportive culture; SP, systems and processes; ISN, internal social network; ESN, external social network; IC rating, intellectual capital rating; INP, innovation performance

Figure 4.
HKRADI-B IC impact to innovation

a plan to bring out the other good attributes to complement the internal network and processes, it would likely benefit the innovation performance.

4.3 The prescriptive wiNK model

While the two groups were under the headquarter administration, they were free to have their own business and innovation strategies. The headquarter provided the supporting infrastructure and administration. The external economics and political situations were the same. The government policies toward the two groups were similar. However, the two groups might exhibit very different characteristics in their respective ICC.

The purpose of comparing the two groups was not to distinguish which one is better but to identify possible paths for each of them to be able to reach higher ground. There may be common IC attributes that both can be benefited, that the overall organization can implement. There can also be different IC attributes that one can gain a great advantage. Organization should also enable an environment that allows cultivation of individual groups. The wiNK model is not to be used for determination of the single best path, as there is no such path exists in reality that can be applied to all situations at

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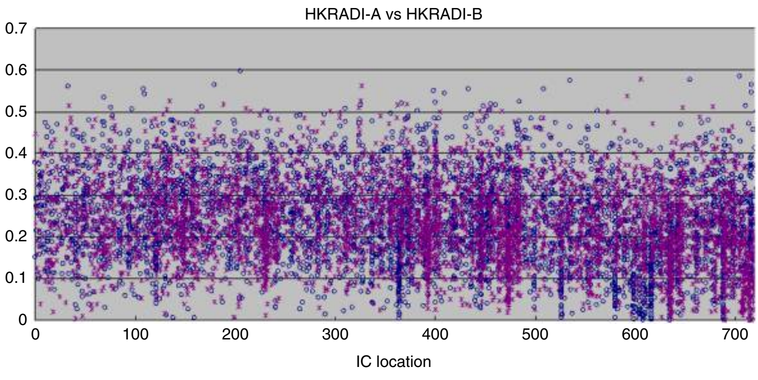
all times. Organizations are undergoing constant changes. The best case study of business school may not apply to another organization, not even the same organization at different times. The model should be used to detect the trend and tendency instead of determining a fixed route. Each simulation run may produce different landscape and end at a different optimum location. The key is to identify the cluster of locations that yield the highest differences in the maximum likelihood. If the majority of the path searches find that similar IC characteristics have produced better innovation performance, it can be determined that cultivating those IC attributes is beneficial for the organization.

Each group had 10,000 simulation runs applied with the input parameters. The initial location and value, as well as the final location and value of each run, were logged. The gain of the run was calculated as the difference between final and initial values. Figure 5 compares the distribution of final locations of the two groups. The dense areas highlight the local optimums that a large number of runs ended at those locations. The spread of the area vertically demonstrate the gains by landing in those locations. The higher the vertical position of the dense area signifies the better performance of the optimums.

It was observed that HKRADI-A had more end locations with the higher performance gain. HKRADI-B clusters were located closer to the lower region of the graph. However, it was also noticed that HKRADI-A outcomes spread wider than HKRADI-B. HKRADI-B also had clusters that were more obvious. It can be interpreted that HKRADI-B can have more confidence in strategizing its IC resources for innovation results than HKRADI-A.

4.4 Discussion

Figures 6 and 7 depict the cumulative gain over the simulation runs. The *x*-axis is the IC location point representing the six-digit-string IC elements (e.g. 111111) defining the IC combination in the order of (KW, TL, OC, SP, ISN, and ESN) using a ternary numeral system. *y*-Axis represents the cumulative innovation performance gain. HKRADI-A has 391 (112111) as the highest point cumulatively. Other best locations include 364 (111111), 373 (111211), 391 (112111), 445 (121111) and 472 (122111). HKRADI-B has the highest point cumulatively at 482 (122212). Other best locations are 230 (022112), 479 (122202), 607 (211111), 644 (212212). Figure 8 compares the two groups. HKRADI-A has five



Notes: *x*-axis – IC location point represent combination of the six IC elements; *y*-axis – innovation performance simulation results

Figure 5. Comparison of HKRADI-A and HKRADI-B wiNK results

locations over 20, whereas HKRADI-B has only one location above 20, but is the highest among all.

HKRADI-A starts at the initial location 607 (211111) and its best location with current IC complexity is at 391 (112111). It means that the group should increase the OC while decrease KW. By examining all best locations of HKRADI-A, all KW values are 1 instead of the current value of 2. It is possible that the excessive intrinsic motivation or self-confidence of the KW has a detrimental effect on the innovation performance.

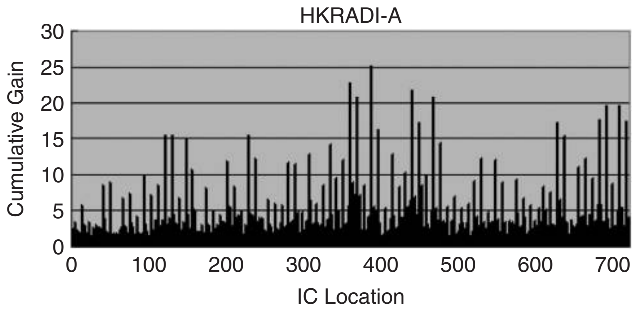


Figure 6.
HKRADI-A cumulative gain

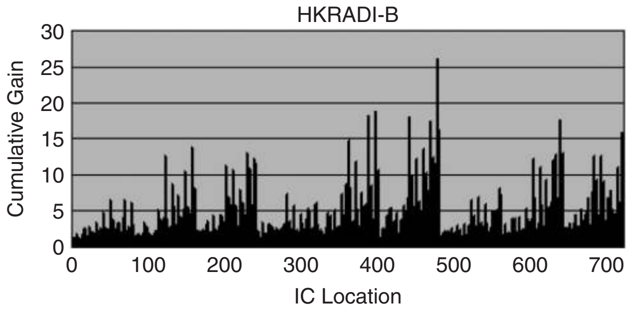


Figure 7.
HKRADI-B cumulative gain

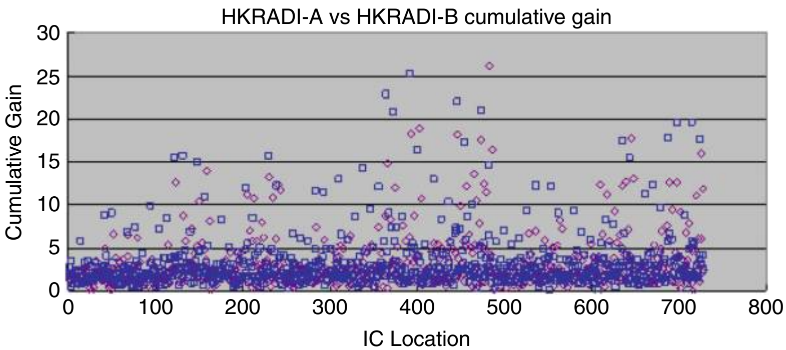


Figure 8.
HKRADI-A vs HKRADI-B cumulative gain

Notes: *x*-axis – IC location point represent combination of the six IC elements; *y*-axis – cumulative innovation performance gain

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One can also increase the transformational leadership rating by encouraging leaders to look at more alternatives and different perspectives. The combination may reflect a current problem of confident KW feeling suppressed by the leader. The path choices apparently indicated that the group should focus on handling the HC issues while maintaining structural and RCs at the current level.

HKRADI-B starts at the initial location 716 (222112) and its best location with current IC complexity is at 482 (122212). HKRADI-B has a different IC complexity from HKRADI-A and its innovation strategy apparently should be different. The intrinsic motivation of KW, similar to HKRADI-A, is to be lowered. The SP should be increased. It possibly implies a current situation of insufficient intellectual property and technology development processes. The lack of documentation may hinder the ability to share knowledge among KW. Although the KW are motivated, innovation performance is inhibited without proper processes. This result confirms the importance of SP for HKRADI-B, as indicated in the PLS analysis, despite the equal weighting factors of all components used in the simulation model.

5. Conclusion

5.1 Brief summary of the paper's findings

This comparative study between HKRADI-A and HKRADI-B has demonstrated that using the wiNK model with knowledge about the current IC complexity as the initial location can offer a path search for higher innovation performance. From the simulation studies, it is also discovered that an increase in certain elements of IC may not yield a similar effect in different cases. An idiom says right, "One man's meat is another man's poison." Considering the complex context of every case, traditional case studies and empirical studies have limitations to address unique organization situations.

5.2 Limitations of the research and findings

The simulation model certainly still bears some limitations. It needs human rationalization to ensure that the alternatives are sensible and operable. The theoretical alternative in a combinatorial perspective may not be feasible in reality. Therefore, the state space and the constraints need to be defined. The decisions of what can be done to change the IC require human intelligence and judgment. Two other factors should be considered: time and degree of granularity. The strategy plan should continuously be reviewed over the period, to monitor the change of the ICC and hence the effect on innovation performance. An annual review using the IC survey can offer a good benchmark for planning. Second, the model currently uses three levels of measurements on each IC components (low, medium, high). More levels can offer a more defined relative effort for the strategy planning. However, the computational power would be much higher, and the memory required storing the results of simulations would be a lot more demanding.

5.3 Implications for practitioners and researchers

ICC should be examined and leveraged as a useful indicator for an organization to define strategies to fit its unique characteristics. The inter-relationship among KW, TL, OC, SP, ISN, and ESN can affect each other in a unique way. These IC measurements are like genes in an organization. One can understand the organization better and know how to support it with the genetic information.

The knowledge about the organizational complexity brings value not only in knowing the present situation of the organization but offers a view to the future. The wiNK model supports the study by simulating the possible innovation landscape specifically according to the characteristics of the organization. The plots of optima illustrate the likelihood of high innovation performance locations and thus the possible strategies to reach the peak. It also informs the strategic planner if the organization is trapped in a local optimum. It provides suggestions if the organization can leap forth with a bold jump of radical changes. A practical and constructive view to what action the organization can take can be reached by knowing the constraints and the complex inter-relationship.

5.4 Possible areas for future research

Research studies can be expanded in various dimensions. ICT industry is the focus of current study. ICC can be very different in financial, retailing, or health care industries. Studies between different cultural groups or geographical dispersion can bring new understandings to their impacts on the innovation performance.

The model can be used beyond the field of innovation and IC. The use of the correlation matrix is a robust and simple way to study existing problems or researches. Chronicle studies of an organization with the tool can validate the model and concept, and to add the time series element to the research.

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Appendix

KW1	I am confident in my ability to provide knowledge that others in my organization consider valuable
KW2	I have the expertise required to provide valuable knowledge for my organization
KW3	I have confidence in my ability to solve problems creatively
TL1	Our leaders seek differing perspectives when solving problems
TL2	Our leaders suggest new ways of looking at how we do our jobs
TL3	Our leaders get our staff to look at problems from many different angles
OC1	Our organization is a very dynamic entrepreneurial place. People is willing to stick their necks out and take risks
OC2	We are committed to innovation and development, and emphasis on being on the cutting edge
OC3	We believe unique and new products and services are keys for success.
	OC4-OC7: if I participated in the following activity, I would be: disapproved; mildly disapproved; neither approved nor disapproved; mildly approved; and approved
OC4	Improved product quality
OC5	Developed a new product idea
OC6	Improved team efficiency
OC7	Tried new ways of doing things
SP1	Well-defined intellectual property management processes are in place and followed
SP2	Our organization has well-defined new product/technology development processes and documentation systems
SP3	Information and Communication Technologies (ICT) infrastructure is in place to store new ideas, discussions, presentations and documents
ISN1	Our staffs build network relationship across different teams and departments in order to exchange idea and information
ISN2	Our staff members and management communicate freely and frequently
ISN3	Our staffs collaborate across different teams and departments in order to get information about customers' need
ISN4	Our staff can get help and support from across the organization when solving problems
ESN1	Our organization builds network relationship with our customers, suppliers and partners in order to exchange idea and information
ESN2	Our organization communicate freely and frequently with our customers, suppliers and partners
ESN3	Our organization actively participates in industrial conferences to network with our customers, suppliers and partners
ESN4	Our organization often host seminars to inform our customers, suppliers and partners about our newest developments, products and services
INP1	We have more patent filed and granted than others in the same industry
INP2	We offer new products/services on regular bases
INP3	Our innovative products/services are well recognized by peers (e.g. Industry awards, etc.)
INP4	Our technology level is highly rated as forefront in the market
INP5	Our innovation project development to launch time is shorter than others are in the same industry

Table AI. Survey items

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