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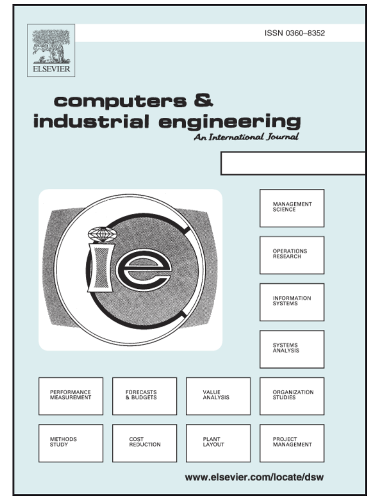

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A framework for knowledge management of university–industry collaboration and an illustration

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ABSTRACT

Knowledge is a core competency for maintaining competitive advantages of organizations. While universities conduct research and create knowledge, few studies have been conducted to address the applications of knowledge management (KM) to higher education in light of the increasing requirement for universities to play additional roles in the modern society. This study aims to develop a KM framework for university–industry collaboration (UIC) with a plan-do-check-act (PDCA) improvement circle. An empirical study was conducted in Taiwan for improving employee productivity, optimizing resource use, motivating employees, and realizing continuous improvement. The results have shown practical viability of the proposed KM models to improve the performance of UIC as well as strengthen the efficiency and operational excellence for the university serving various social responsibilities. Indeed, the case study university, National Tsing Hua University, becomes the first national university being awarded for the National Quality Award in Taiwan. This study concludes with the contributions and discussions of future research directions.

Keywords: Knowledge management; higher education; university–industry collaboration; operational excellence

1. Introduction

Knowledge is a national core competency in the era of the modern economy (Chen, Chien, and Lin, 2013). Knowledge management (KM) is important in the organization for maintaining competitive advantages (Sallis and Jone, 2013). Most studies (Hou et al., 2004; Hou et al., 2005; Hou and Tsai, 2008) explored industrial KM and proposed frameworks or models of related technologies (e.g., information technology, computer–integrated manufacturing) to manage or expedite the accumulation and application of domain knowledge which ends up with business performance improving. However, few studies have been done to address KM for higher education (Rowley, 2000; Piccoli et al., 2000; Eleni, 2003; Chou Yeh, 2005; Fullwood et al., 2013). On the other hand, due to declining birthrates, internationalization, marketization, and fiscal tightening by the government, higher education faces critical challenges for maintaining the same quality of education as well as meeting more demands for social responsibilities. In addition, in a transitional economic environment such as Taiwan, universities should grow with the industry and focus more attention to university–industry collaboration (UIC) activities for resolving operational problem in the industries existing at this stage (Hu, Hung, Lo, and Tseng, 2016; Chen et al., 2013).

To fill the gap and address the needs to enhance university–industry collaboration, this study aims to develop a comprehensive framework for knowledge management to empower university–industry collaboration via acquiring various domain knowledge efficiently and accurately. In particular, a UNISON Decision Analysis Framework was employed to develop a six-stage KM framework with a plan-do-check-act (PDCA) improvement mechanism for increasing the UIC KM performance and ensuring the competitiveness of universities. An empirical study was conducted at National Tsing Hua University (NTHU) that is an elite university in Taiwan. With its huge amount of knowledge creation, accumulation and diffusion, NTHU can fulfill its mission of higher education, in the past. Indeed, the progress of technology and science developing is so rapid, especially, with the rocket growing of artificial intelligent technology, the impact of both academic and industrial is decided. Taiwan industries including small and medium enterprise (SMEs) are in a transition and fast changing economic environment, short of research and technology development resources. The support of UIC from research organization, like NTHU, to enact with such challenge is very important to the industry. NTHU achieved optimal performance by implementing UIC KM and a continuous improvement mechanism. Moreover, NTHU mentored and supported SMEs and assisted in industrial upgrade to fulfill university social responsibility (USR). Indeed, National Tsing Hua University becomes the first national university being awarded for the National Quality Award. These results have shown practical viability of the proposed approach. Before further discussion, a list of acronyms is provided as follows to enhance readability.

GEP	Gene Expression Programming
IP	Intellectual Property
KM	Knowledge Management
NAI	National Academy of Inventors
NTHU	National Tsing Hua University
PDCA	Plan-Do-Check-Act
R&D	Research and Development

SMEs Small and Medium Enterprises

SWOT Strengths, Weaknesses, Opportunities, Threats

UIC University–Industry Collaboration

USPTO US Patent and Trademark Office

The remainder of this paper is organized as follows. Section 2 reviews the fundamentals of this study. Section 3 introduces the proposed mechanisms of KM in higher education. Section 4 details the conducted empirical study in Taiwan for validation. Section 5 concludes this study by summarizing the contributions and discussing future research directions.

2. Literature review

2.1 Knowledge management

KM is as crucial as its emergence (Oztemel and Arslankaya, 2012). There is an increased interest in knowledge as an important organizational resource (Alavi and Leidner, 2001). KM also requires the application and innovation of knowledge to increase the values of human. In the future, effective management of "knowledge" will be a primary concern (Chen, et al., 2002). KM is an important process of creating valuable resources from intangible assets (Hsu et al., 2006). Lee and Kim (2001) proposed a comprehensive framework for KM and defined the concept of organizational knowledge, KM processes, knowledge workers, and information technology as four elements of KM. Yao et al., (2003) proposed a guide to share commercial knowledge of collaborative products. Hou et al., (2004) proposed a two-phase model for the authority of technical documents and the determination of certification sequences. They also developed a prototype system for the integration of knowledge files as the core aspect of technical document management and exchange to provide effective solutions for a computer-integrated manufacturing environment (Fig. 1). Trappey and Trappey (2004) proposed the concept of a unified content platform to integrate the distribution and reuse of information and knowledge. Hou et al., (2005) proposed an intelligent KM model with a self-service capability to support knowledge construction and management for reducing the workload of knowledge engineers or domain experts. Hou and Tsai (2008) proposed a model for enterprise e-training and KM systems to enhance the reuse of domain knowledge. King (2009) proposed a process cycle model of KM to provide a useful method for organizing KM processes. Yang et al., (2013) proposed a knowledge component extraction model to provide a method for knowledge receivers to acquire domain knowledge efficiently and accurately. Many studies (e.g., Chien, Chen, & Lin, 2002; Asadi et al., 2012; Hsu and Chien, 2007; Chien, Chen, and Peng, 2010; Narenji et al., 2013; Kaboli, Selvar, and Rahim, 2016; Mostafa et al., 2016; Rafieerad et al., 2016; Kaboli et al., 2017; Kaboli, Selvaraj, and Rahim, 2017; Rafieerad et al., 2017; Hong et al., 2018; Huynh and Chien, 2018; Sebtahmadi et al., 2018; Zhao, Chien, and Gen, 2018) have used relevant methods employing domain knowledge such as the backtracking search algorithm, artificial cooperative search algorithm, gene expression programming (GEP), rain-fall optimization algorithm, electronic supply chain, two-phase decoding genetic algorithm, particle swarm optimization and GEP-based model, for different applications to propose algorithmic intelligent solutions and develop better KM-based solutions than before. Furthermore, business processes and worklists (Xie, Chien, and Tang, 2013, 2016) have been employed for improving KM.

(Fig. 1)

The critical aspects of KM are the systematic collection, storage, sharing, diffusion, and reuse of tangible and intangible information or knowledge (King, 2009). Moreover, this information is developed into an organization's unique intangible assets and used as the basis of organizational knowledge transfer, work improvement, and technological innovation (Chou Yeh, 2005). KM can also involve a set of practices to improve the use and sharing of information in decision making (Petrides and Nodine, 2003). KM requires factors such as trust, organizational culture, and rewards to increase knowledge sharing (Tan, 2016). Moreover, KM relies on the contributions of co-worker and decentralization of knowledge holders. Without such a culture, KM programs may fail (Davenport and Prusak, 1997). KM stimulates the specific recognition of the organization and its members, thus allowing the effective use of and innovation in knowledge. Universities are the optimal institutions for knowledge creation, dissemination, and management (Rowley, 2000). However, they are subsidized by resources from the government, which weakens the motivation to pursue competitive advantage and the ability to respond to social changes (Massaro et al., 2015). In the future, due to declining birthrates, internationalization, marketization, and fiscal tightening by the government, higher education will encounter a huge challenge. Thus, it is essential to implement the integration, sharing, control, reuse, and evaluation of knowledge. Shaping a university's image and brand toward excellency and improving its operation efficiency are the key to successful and sustainable development in the future international competitive environment.

2.2 KM for higher education

The application of KM in education is relatively late and limited (Rowley, 2000; Piccoli et al., 2000; Eleni, 2003; Chou Yeh, 2005; Fullwood et al., 2013). As scholars have suggested that university KM can promote the concrete realization and effectiveness of the primary tasks of university (such as teaching, research, and service) and improve its performance. The concept of university KM is gradually receiving attention (Leitner, 2004). Developing KM and sharing knowledge to achieve organizational goals add considerable value to higher education (Laal, 2011). Nilsook and Sriwongkol (2009) proposed that there are three goals for realizing a higher education KM: (1) development of tasks for better quality and effectiveness, (2) development of human resources, and (3) development of knowledge bases for knowledge development and increase of knowledge or wisdom investment. Basu and Sengupta (2007) revealed four useful success factors for KM in organizational learning of higher education. Ramachandran, Chong, and Wong (2013) proposed a series of key strategic enablers to overcome the gap between utilization and importance so that higher education can become a true knowledge-based enterprise. Rivera and Rivera (2016) proposed six factors that promote knowledge creation, storage, transfer, and application processes. Naser, Shobaki, and Amuna (2016) proposed the most important four factors that affect the performance excellence of higher education KM. Table 1 summarizes the key factors of higher education KM proposed by the above four journal scholars. Higher education KM can be described as the creation and control of valuable knowledge (Sedziuviene, and Vveinhardt 2009). Universities need to consciously and explicitly manage the processes related to the creation of knowledge assets and recognize the value of their intellectual capital for their continued role in the society and the global higher education market (Rowley, 2000).

(Table 1)

2.3 UIC KM in higher education

Transferring university knowledge to the industry has become an important topic for KM and competitiveness (Gertner et al., 2011; Anatan, 2013; Bodas Freitas et al., 2013). Universities have been recognized as knowledge transfer organizations (Geuna and Muscio, 2009; Bodas

Freitas et al., 2013) and a major source of innovation (Mansfield, 1991; Cohen et al., 2002; Mueller, 2006). The transfer of knowledge between universities and industries involves research cooperation, intellectual property (IP) rights (mainly patents), start-ups, spin-offs and technology transfer (Perkmann et al., 2013; Anatan, 2013). Abbasnejad et al., (2011) proposed that key factors that affect knowledge transfer between universities and the industry are culture, absorptive capacity, research and development (R&D) intensity, structure, strategy, size, and trust. The performance drivers of university technology transfer include human resources, institutional or cultural resources, financial resources, and commercial resources. The first two factors are the most important resources for improving university technology transfer (Hsu et al., 2015). The cooperation between a university and the industry is a powerful tool for promoting universities to develop their unproven technology commercialization. However, this cooperation will not provide positive results if there are no university technical management personnel performing proper patent management (Watanabe, 2009). Indeed, people expect universities to develop human capital for highly competitive and knowledge-based societies (Sallis and Jones, 2013) and cause universities form into learning organizations through KM (Bollinger and Smith, 2001). Knowledge transfer activities from the university to the company that are driven by external environmental pressures, especially innovation capabilities in R&D portfolio management, improve organizational performance (both the university and industry) and alliance performance to maintain competitiveness and survival (Chien, 2002; Anatan, 2015). Hu et al. (2016) proposed knowledge transfer activities as a vital approach for latecomer countries to promote industrial transition and transformation.

3. Research framework

Based on the UNISON Decision Analysis Framework (Chien, 2014), we proposed a KM framework consists of six stages: (1) identifying and defining problems, (2) defining the niche for decision quality improvement, (3) architecture the impact relationships among uncertain events, (4) objective narrative to identify and describe expected outcomes, (5) subjective measures and value assessments, and (6) making decision through trade-offs by using decision analysis, as shown in Fig. 2. Indeed, the UNISON Decision Analysis Framework has been validated in various decision problems such as evaluating alternative strategies for the final testing of integrated circuits under risk (Chien et al., 2007), outsourcing vendor selection and order allocation for a semiconductor assembly (Wu and Chien, 2008), determination of the inspection frequency for the wafer bumping process (Chien et al., 2008), modeling and reduction of overlay errors for wafer fabrication (Chien and Hsu, 2011), constructing a workforce planning decision model for semiconductor manufacturing (Lin, Chien, and Yu, 2015), enhancing the overall space effectiveness for fab space productivity (Chien, Hu, and Hu, 2016a), and extraction of user experience for data-driven innovations (Chien et al., 2014; Chien, Kerh, Lin, & Yu,, 2016b; Lin, Chien, & Kerh,, 2016).

(Fig. 2)

3.1 Structuring problem

The proposed framework begins with structuring and defining the problem. To understand and define the current problems, decision analysts have to ask a number of investigative questions. Decision analysts should prepare a checklist of the decision elements, such as customers, competitors, available resources, the industry, execution costs, plan scope, decision makers, decision stakeholders, goals, attributes, uncertain events, strategies, consequences, alternatives, and expected results. Table 2 presents a checklist of the decision elements that decomposes a large and complex decision problem into small and basic elements to systematically review and analyze decision elements. There are three evaluation criteria for KM of university UIC: including university UIC annual total income, average income of each employee for UIC, and number of patents approved.

(Table 2)

3.2 Strategy formulation and objective

By integrating existing entities and virtual resources in the electronic network of a campus, the software and hardware facilities of KM can be improved, and future demand can be determined in advance to realize the needs of long-term planning. In the campus, we use existing infrastructure to compensate for the lack of resource and to facilitate knowledge workers. In a software environment, we integrated R&D resources (e.g., a patent application flowchart) to conduct academic research and UIC. Knowledge sharing and transfer enables continuous accumulation of R&D portfolios (Chien, 2002; Chien and Huynh, 2018), thereby realizing the benefits of the overall quality improvement of UIC in higher education.

3.3 Alternative generation and objective hierarchy

The influence diagrams of UIC KM, as displayed in Fig. 3, influences the relationship by creating an efficient and convenient environment, increasing UIC to foster willingness to cooperate, strengthening the acquisition of talented people, and hiring highly talented people to improve the quality of KM for realizing an excellent quality university UIC KM model. By exploiting environmental and geographical factors, striving for cooperation opportunities between the industry and universities, grasping research and application opportunities, and establishing an optimal cooperation environment to attract experts to join UIC. These practices will create new values of UIC through KM, accelerate technological innovation, and strengthen the R&D of a forward-looking industrial technology so that both universities and companies can smoothly plan IP rights for products and technologies.

(Fig. 3)

3.4 Expected outcomes

In the objective part of the narrative, UIC KM platform mechanisms were established. The mechanisms included four stages–knowledge gathering, knowledge enhancement, knowledge reuse, and knowledge sharing and transfer. Indeed, Shen (2018) analyzed organizational KM platform and proposed mechanisms such as “knowledge sorting,” “knowledge provision,” and “knowledge reading and reuse” to enhance the benefits for KM system users for the organization. The purpose of establishing mechanisms is to summarize the procedures, content and objectives of the relevant phases for exploring the significance and contribution of UIC KM, as presented in Table 3. Due to the gradual achievement of goals in each phase, the assessment indicators differ. In face of rapid technological advancement, universities with optimal UIC performance should be reviewed, heard, answered, and shared the performance and needs regularly to achieve the ultimate goal of full participation, evaluate the key performance indicators, and compare the universities with other universities. These processes will be useful for benchmarking. Universities with optimal UIC performance gain exemplary experience. Thus, continuous improvement and sustainable development can be successfully achieved by such universities.

(Table 3)

3.5 Value assessment

Based on the assessment of value and judgments, the risk attitude and preference structure of the decision maker can be accessed. With the establishment of a KM platform and the concrete construction of organizational learning, more energy will be collected. Through the development of patent rights, technology transfer, and the implementation of innovation and entrepreneurship, a vibrant atmosphere of UIC on campus will be established.

3.6 Creation of the management mechanism

Based on the revised UNISON Decision Analysis Framework, the decision maker can select the optimal KM platform. In addition, PDCA cycle is proposed for continuous improvement for KM quality, including the sequence of planning, implementing the plan, checking the implementation, and processing the results. KM is established using a platform where knowledge is gathered, enhanced, reused, shared, and transferred to improve efficiency. Fig. 4 displays the PDCA cycle in KM for improving the quality of decisions.

(Fig. 4)

The proposed approach integrates KM decision analysis framework, the auxiliary management mechanism, and the PDCA cycle can thus improve the productivity of UIC and optimize the use of resources, thereby ensuring the effectiveness of KM and organizational learning, and stimulating the workflow of university employees. Methods become more efficient, which in turn improve organizational performance and increase employee productivity and creativity.

4. Empirical study

NTHU is one of the leading research universities in Taiwan. NTHU has sufficient research potential and geographical advantage due to its proximity to the Hsinchu Science Park (known as Silicon Valley of Taiwan), Industrial Technology Research Institute and other universities. In particular, due to the development of many strategic high-tech industrial clusters, NTHU has become a proactive industry manager of these clusters. Annual R&D funding (from public and private sectors) continues to increase, from total NT$600 million (US$20 million) in 1990 to NT$2,158 million (US$72 million) as presented in Fig. 5. In 2012 and 2013, NTHU was ranked as the 15th patentee of the US Patent and Trademark Office (USPTO) among the global top 100 universities. NTHU was also ranked among the best in the world from 2012 to 2017 and was awarded the National Technology Transfer Center Merit Award for five consecutive years from 2007 to 2011. NTHU's number of patents in US accounted first for four consecutive years in Taiwan universities from 2014 to 2017 (Hu et al., 2016; NTHU; National Academy of Inventors [NAI]). Since 1998, NTHU has created various incentives to manage knowledge dissemination practices (Hu et al., 2016). Over the years, NTHU has created and diffused of knowledge to improve the efficiency of resolving challenges associated with higher education and has obtained optimal results (e.g., R&D portfolio management, funding increased from the industry, patent data were extracted from the USPTO, and many start-ups had graduated from its incubator) in UIC.

(Fig. 5)

4.1. Problem definition

NTHU has actively promoted the value of knowledge. Through KM, a learning-centered environment was created, and a series of supporting measures were used to improve knowledge transfer efficiency and enhance UIC performance. As a result, R&D funding from the industry has continued to increase over the years, as presented in Fig. 6. The funding increased from NT$107 million (US$3.56 million) in 2011 to NT$254 million (US$8.46 million) in 2017. However, NTHU still encounters influence of low birthrate, internationalization, globalization, marketization and the decrease in higher education resources. NTHU should actively strengthen the effectiveness of UIC resources to enhance the effectiveness of operational activity management. Moreover, it is crucial to develop a systematic KM framework for improving the performance of UIC management by continuously improving the management cycle to lay a more solid foundation for sustainable development. Table 4 presents the results of the strength, weakness, opportunity, and threat (SWOT) analysis of UIC in NTHU. Through SWOT analysis, it is easy for NTHU to know its strengths (e.g., historical reputation, top staffs and students), and opportunities (e.g., the establishment of the Artificial Intelligence for Intelligent Manufacturing Systems Research Center) of UIC. Thus, more attention should be focused on the weaknesses (e.g., uncompetitive teachers' salaries) and threats (e.g., the inflexible use of funds). NTHU must optimally use the advantages, grasp the opportunities, compensate for the disadvantages, and resolve the threats to achieve the goals of both UIC and the university.

(Fig. 6)

(Table 4)

This section is aimed to analyze the vision, advantages and opportunities in UIC of NTHU, formulate relevant strategies and action plans, invest resources to strengthen the advantages and compete for opportunities as the best strategy. And also, cooperate with the internal and external environment closely, make full use of superior resources, expand development opportunities, as well as remedy the weaknesses and resistance from external threats. Based on this SWOT analysis, NTHU can understand the strengths or weakness of UIC and gradually develop and adopt a follow-up strategy.

4.2. Strategy formulation

To achieve the goal of enhancing UIC performance through KM, planning and research were conducted on the basis of the university's development vision, medium–long-range planning, and UIC strategy of NTHU. By implementing the strategy, an action plan was formulated and gradually implemented to actively establish the university–industry alliance; develop the innovation; creativity and entrepreneurial mechanism; assist teachers in research energy growth; promote the application of UIC results; improve the strength of cross-disciplinary research; and "strengthen the academic career growth of teachers based on the strategic concept. In 2011, the Operations Center for Industry Collaboration was established to promote UIC of NTHU. In 2018, it was renamed the International Operations Center for Industry Collaboration to integrate and plan UIC-related activities and increase cooperation with global industries. Next, a Global Research & Industry Alliance Center was established. The center not only focuses on advanced technology fields, but also builds industry–university–institute platforms for linking Taiwan with the global market to expand the benefits derived from the university's scientific research achievements, and fulfill the USR.

4.3. Alternatives generation

NTHU, through its SWOT analysis, assesses and understands the university's positioning based on its vision and develops UIC-related planning strategies, for example, technology transfer process development and R&D meetings to resolve crucial R&D problems and promote research standards. Various measures are then passed to the various review mechanisms of the internal and external loops, such as the University Development Advisory Committee, for confirmation and revision to begin the implementation and problem-solving processes.

To encourage teachers to engage in UIC and reward outstanding industry contributions, NTHU has been presenting the Outstanding UIC Award since 2006. In 2011, it began granting the UIC Merit Award. The awards are based on the amount of technology transfer and the implementation of the UIC program as a benchmark for rewarding teachers with outstanding performance in UIC. NTHU also intends to organize related training courses. Education and training give rise to knowledge sharing, different experience opportunities for the university, and different ideas. This greatly benefits the development of UIC for a university. In 2013, NTHU launched the Learning Network Platform, which employs the business–learning cooperation model of Massive Open Online Courses to establish an online course service. By using the online -learning platform technology and technology licensing mechanisms, professional knowledge is transferred to the public and industry. Analysis is conducted via the cloud database and learning experience to determine the most effective methods for achieving the combined effects of teaching expertise and experience sharing.

Due to environmental changes and strengthening competitiveness, globalization and technology have considerably changed the knowledge transfer method. NTHU has actively promoted the value of knowledge. Through KM, NTHU has constructed a learning-centered environment and actively responded through a series of supporting measures to increase the efficiency of knowledge transfer and improve the performance of UIC.

4.4. Expected outcomes

The International Operations Center for Industry Collaboration of NTHU is responsible for the overall management of UIC achievements, patent applications, maintenance, income distribution, technology transfer, promotion, and other management-related problems. The center formulated measures from R&D results management to motivate the staff to research, write, invent, innovate, start-up, and commercialize UIC results, and provide management services related to UIC results. The center also studies and formulates measures for the protection of IP rights and sets up a group to protect IP rights in order to coordinate IP protection. The effective development and use of knowledge transfer, innovation, and entrepreneurship by integrating industrial and academic resources, IP rights, and patented technology will enhance the global competitiveness of the university. The NTHU patent application flowchart is displayed in Fig. 7. This flowchart will help university researchers apply for patents through a clear application process and improve UIC performance for individuals or a university.

(Fig. 7)

4.5. Value assessment

NTHU invites domestic and foreign scholars and experts to serve on its Development Advisory Committee. The committee provides advice on the development of university affairs, the direction of UIC, and regularly addresses problems associated with university development. Based on the university's vision in its Development Plan and R&D Conference, NTHU continues to report results and future prospects to its Development Advisory Committee through the rolling mechanism and the PDCA improvement cycle. NTHU also conducts strategic and resource allocation and review consultations. Through the creation and diffusion of knowledge, NTHU has made remarkable achievements in UIC. The KM cycle of UIC in NTHU is presented in Fig. 8 and is formed by the creation and collection of knowledge (e.g., patents and publications), organization and storage of knowledge (e.g., newsletter and web pages), sharing and dissemination of knowledge (e.g., video sharing), and knowledge value-added services and innovation (e.g., user feedback). The number of invention patents was ranked in the top 25 in the global academic world of the NAI from 2012 to 2017, especially, be ranked as the 15th from 2012 to 2013. NTHU was ranked first among all of the universities in Taiwan for four consecutive years (from 2014 to 2017), as listed in Table 5. The annual technology transfer funding increased from NT$40 million (US$1.33 million) in 2011 to NT$132 million (US$4.4 million) in 2016 is shown in Fig. 9. This reveals that NTHU's top patent content and performance of technology transfer. The Center of Innovative Incubator in NTHU was established in 1998 and combines university resources and professional for with mentoring and supporting SMEs to achieve business success opportunities, assisting the SMEs in the commercialization of new technologies, and creating UIC opportunities. NTHU has helped benchmark companies, such as Taiwan Semiconductor Manufacturing Corporation, MediaTek, HIWIN, LITE-ON Technology, and Unimicron, to set up joint research centers in the campus, assist in industrial R&D, and fulfill USR. As of 2018, a total of 180 companies had graduated from the incubator, from which 97 companies were founded by faculty, students, and alumni. After graduation, 11 firms have moved to the adjoining Hsinchu Science Park, and 8 companies have already publicly revealed with the staging of initial public offerings.

(Fig. 8 & 9)

(Table 5)

4.6. Creation of the management mechanism

This study follows the PDCA cycle to propose a KM mechanism for UIC. These steps can be used to execute and track the UIC strategy established through KM. As presented in Fig. 10, in the initial phase of the plan, the KM framework is established; annual goals of UIC are set; and the requirements of KM are evaluated using a bottom-up approach, which is proposed and implemented by the chief executive officer of the center. The next step is to collect, enhance, reuse, share, and transfer platform data or information to internal and external organizations through KM. Then, the performance is tracked and monitored and platform utilization is evaluated. Whether or not performance and utilization meet the targets, loops are built and mechanisms are continuously improved to promote more efficient workflows. Thus, university efficiency and UIC performance are improved.

(Fig. 10)

5. Conclusion

Knowledge has become core competence of the organization in knowledge economy. Due to declining birthrates, internationalization, marketization, and fiscal tightening by the government, higher education of a transitional economic environment such as Taiwan is facing increasing challenges. Universities have enhanced various industrial collaborations to bring in external resources and fulfill social responsibilities. This study developed an effective approach that integrates the UNISON Decision Analysis Framework for KM to enhance UIC for higher education with PDCA-based mechanisms. An empirical study was conducted for validation and the results have shown the proposed approach can improve employee productivity, optimize resource reuse, motivate employees, increase the number of patents, and increase R&D funding from the industry. Indeed, NTHU integrates research, teaching, and human resources and uses information technology to effectively collect, organize, store, disseminate, share and diffuse knowledge to achieve knowledge innovation and promote operational excellence. Furthermore, the proposed framework can help the university to continuously improve by using UIC KM (e.g., total annual R&D funding from the industry increased, the number of patents extracted from the USPTO increased, and many start-ups had graduated from its incubator). Indeed, the case study university, National Tsing Hua University, becomes the first national university being awarded for the National Quality Award in Taiwan.

The paradigms of higher educations are shifting, while the increasing adoption of MOOCs (massive open online courses) and Free Online Courses, crowdsourcing, social media and social networking, cloud sourcing and open source codes, big data and artificial intelligence have empowered an unprecedented level of intelligence generation and knowledge sharing. Future research can be done to employ the proposed framework for universities in different contexts to maintain the competitiveness of higher education, enhance the performance and productivity of UIC, or fulfill university social responsibilities. By comparing results in different higher education organizations (e.g., public and private, local and international, and research and technology), the key success factors can be derived for adopting KM and operational excellence for universities to address increasing needs in future societies.

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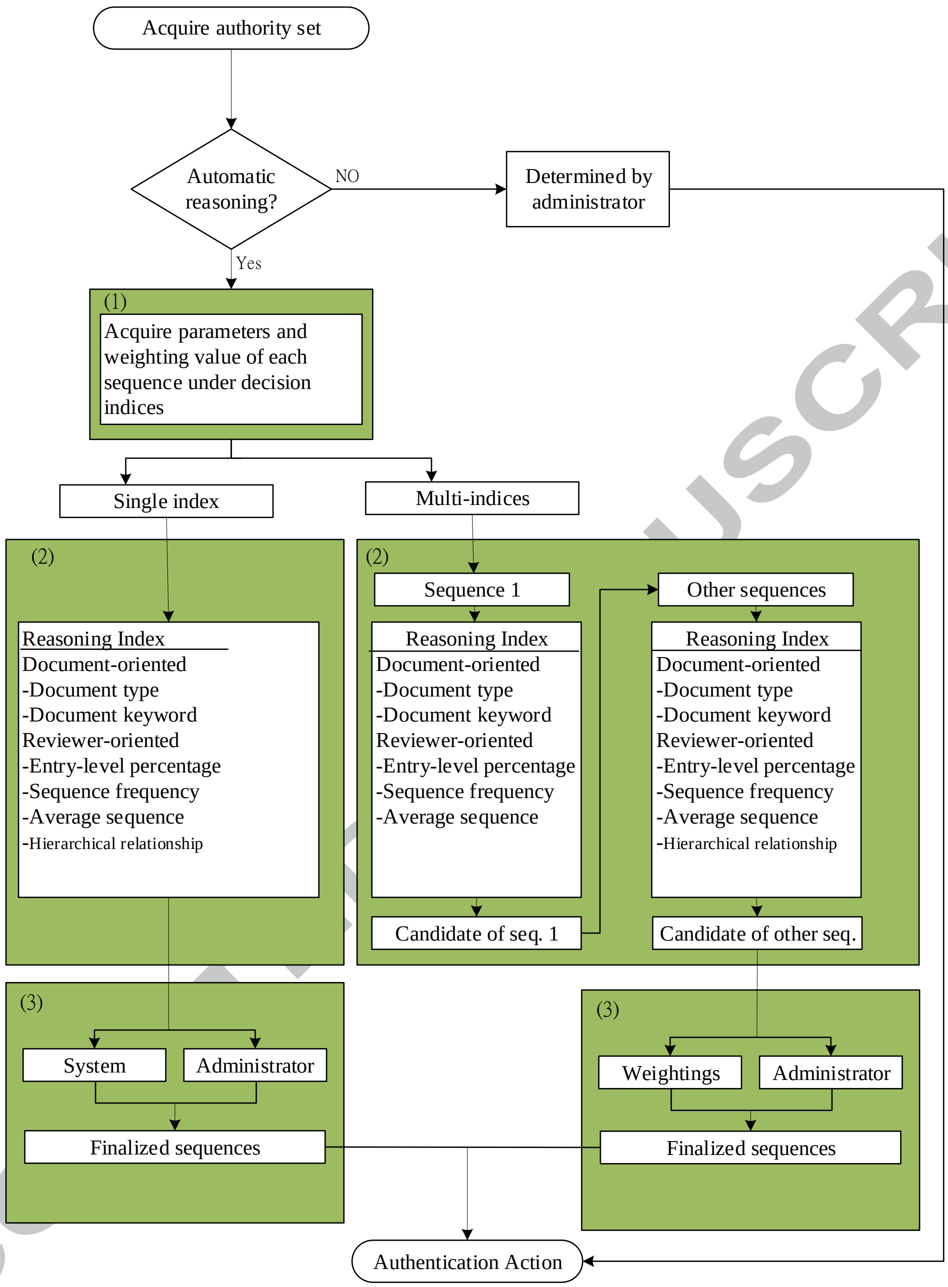


Fig. 1. Flowchart of heuristic authentication reasoning model (Source: Hou et al., 2004).

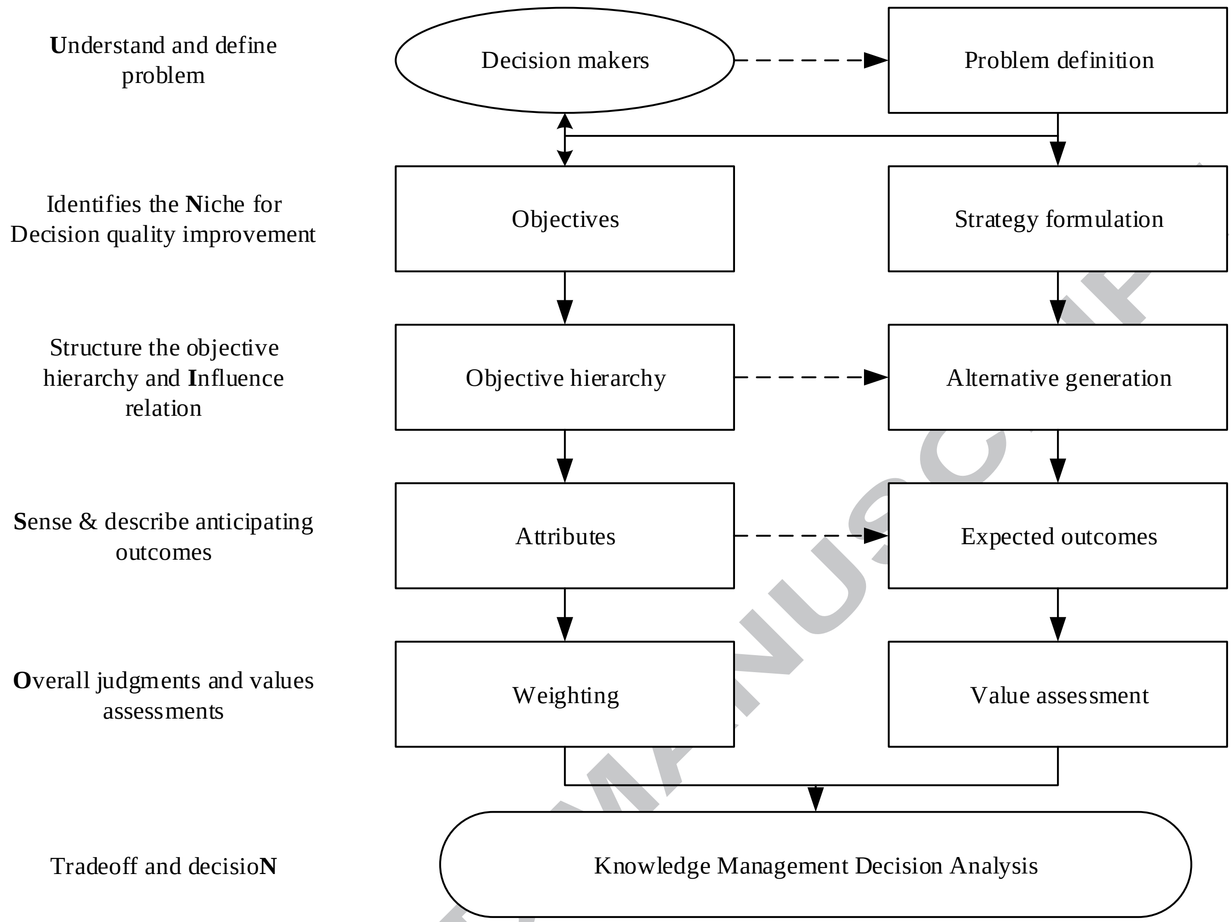


Fig.2. UNISON framework for KM (source: modified from Chien, 2014).

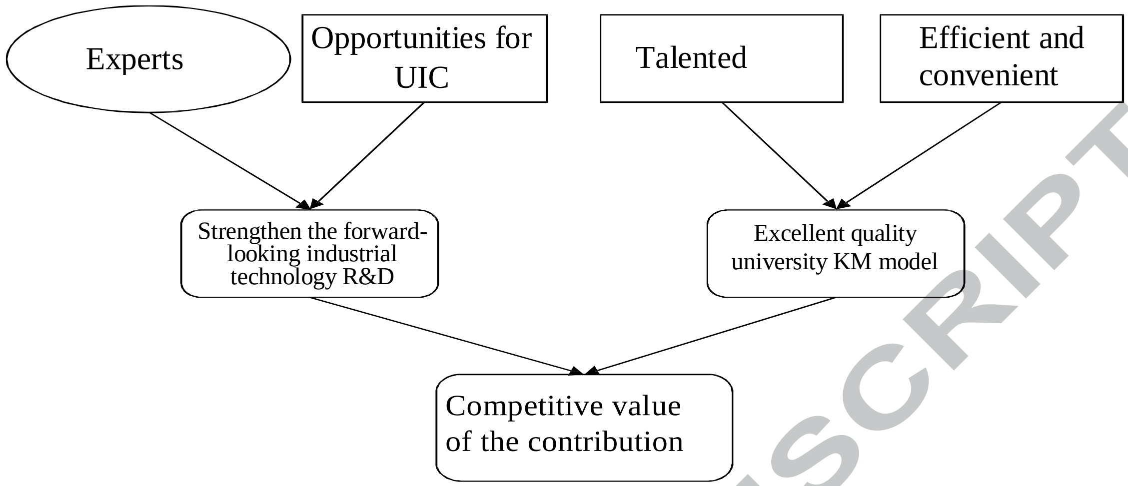
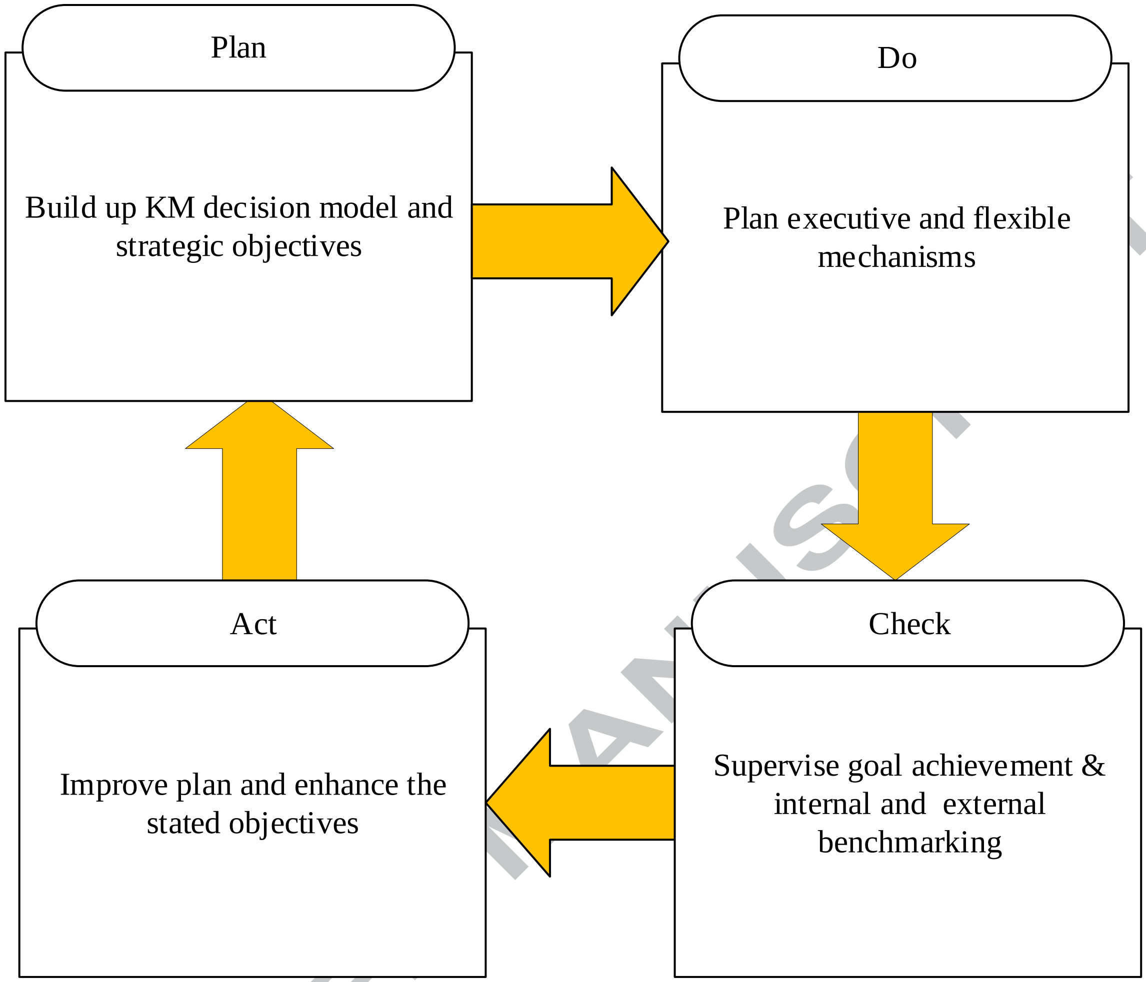


Fig. 3. Influence diagrams for KM of UIC



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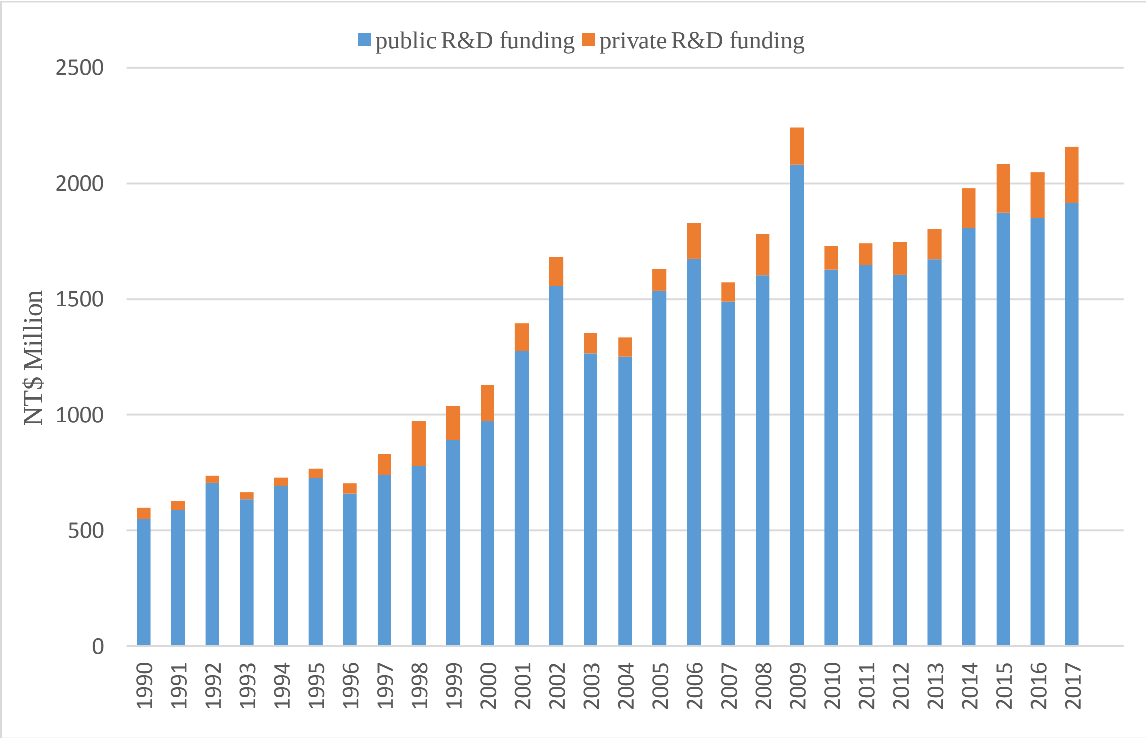

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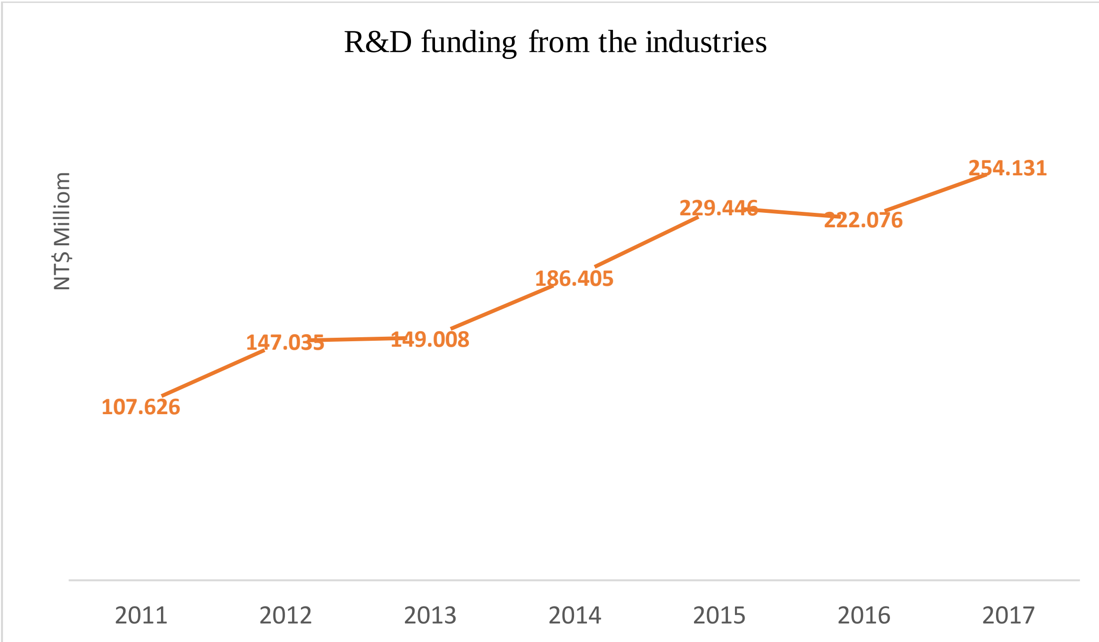

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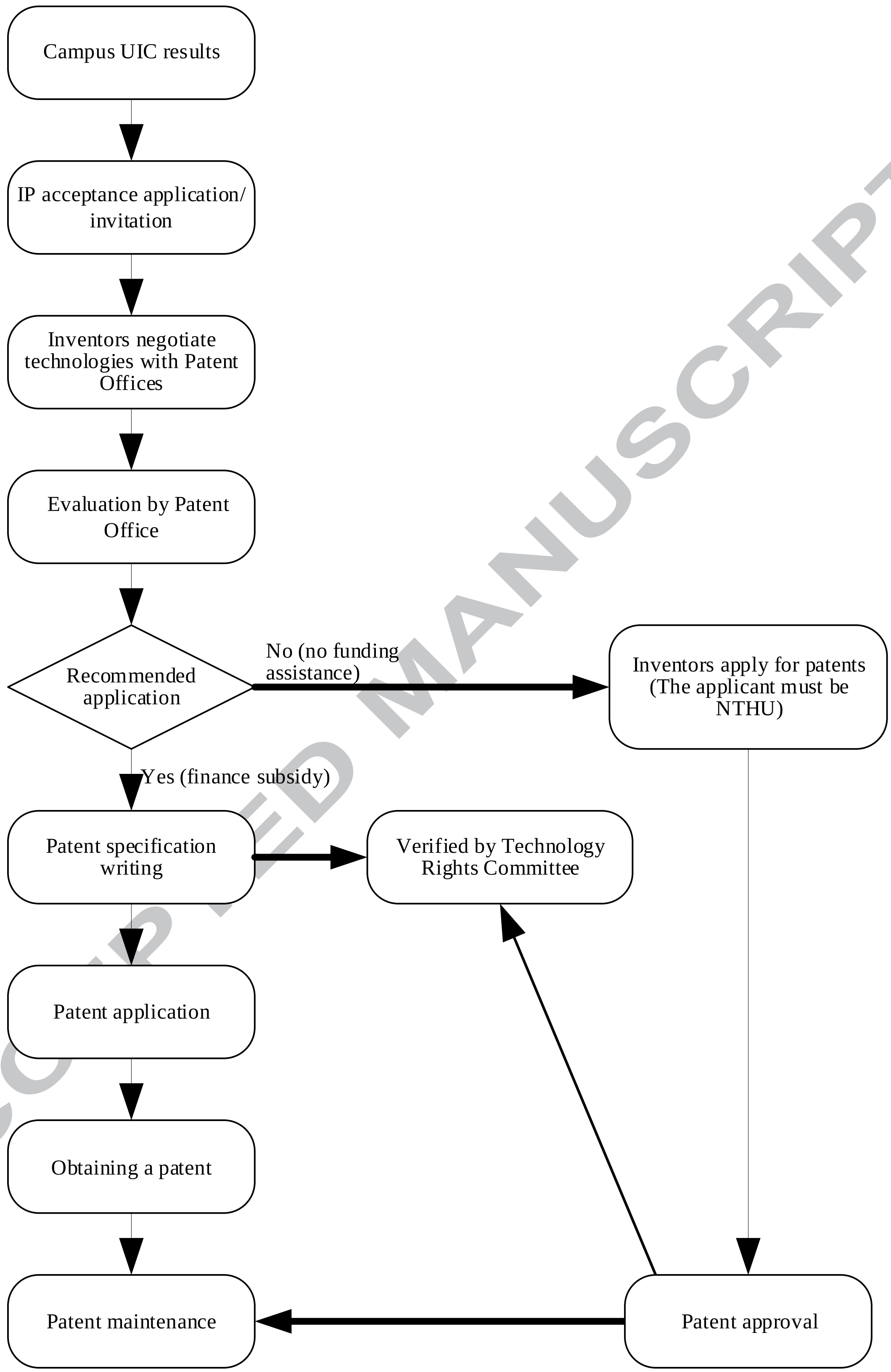
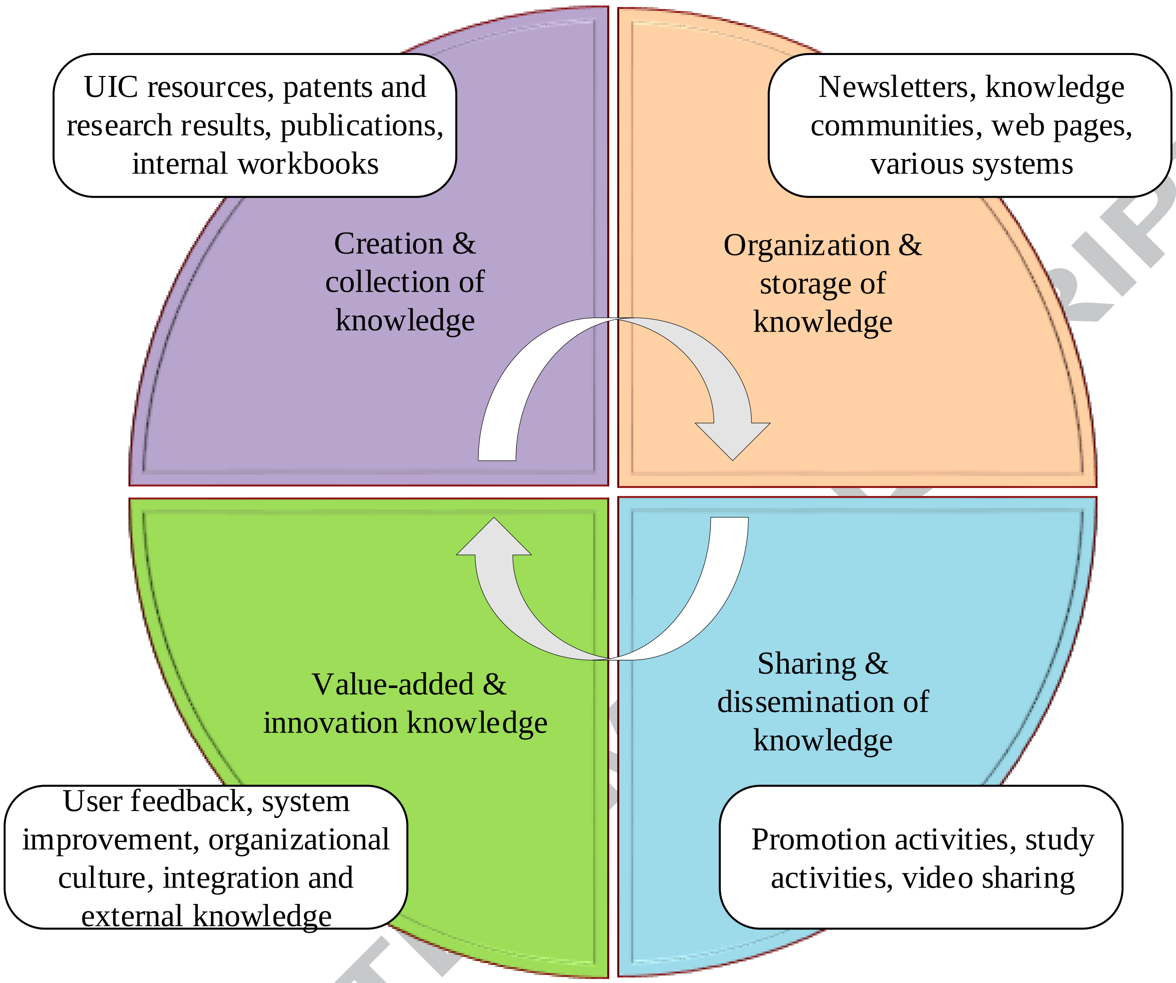


Fig. 7. Patent application flow chart in NTHU



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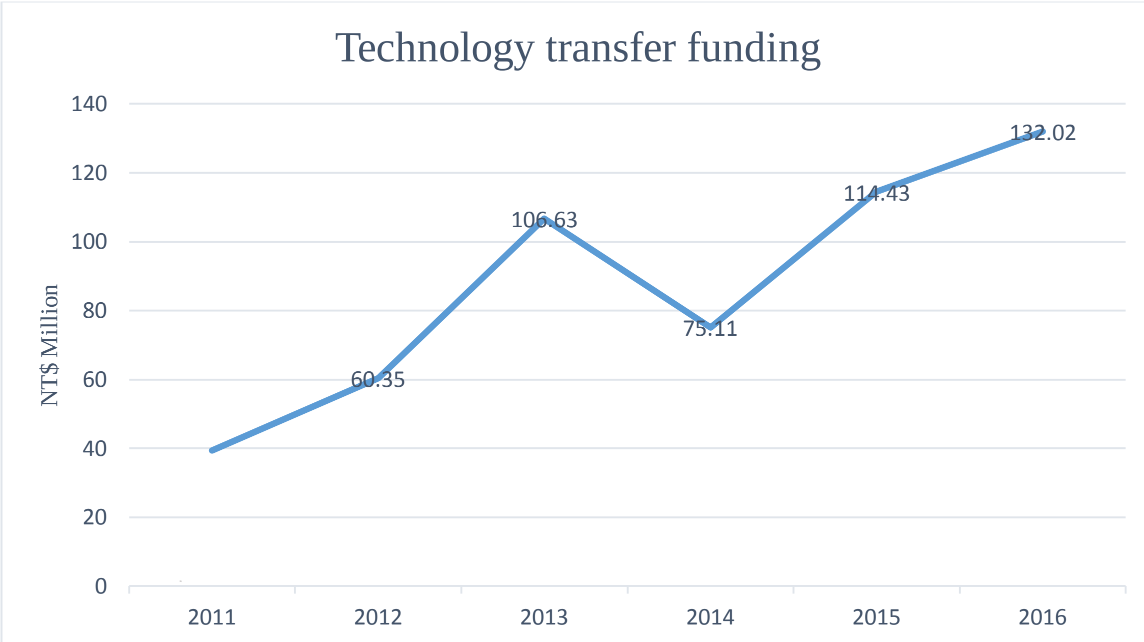

Fig. 9. Technology transfer funding in NTHU during 2011 to 2016 (source: NTHU)

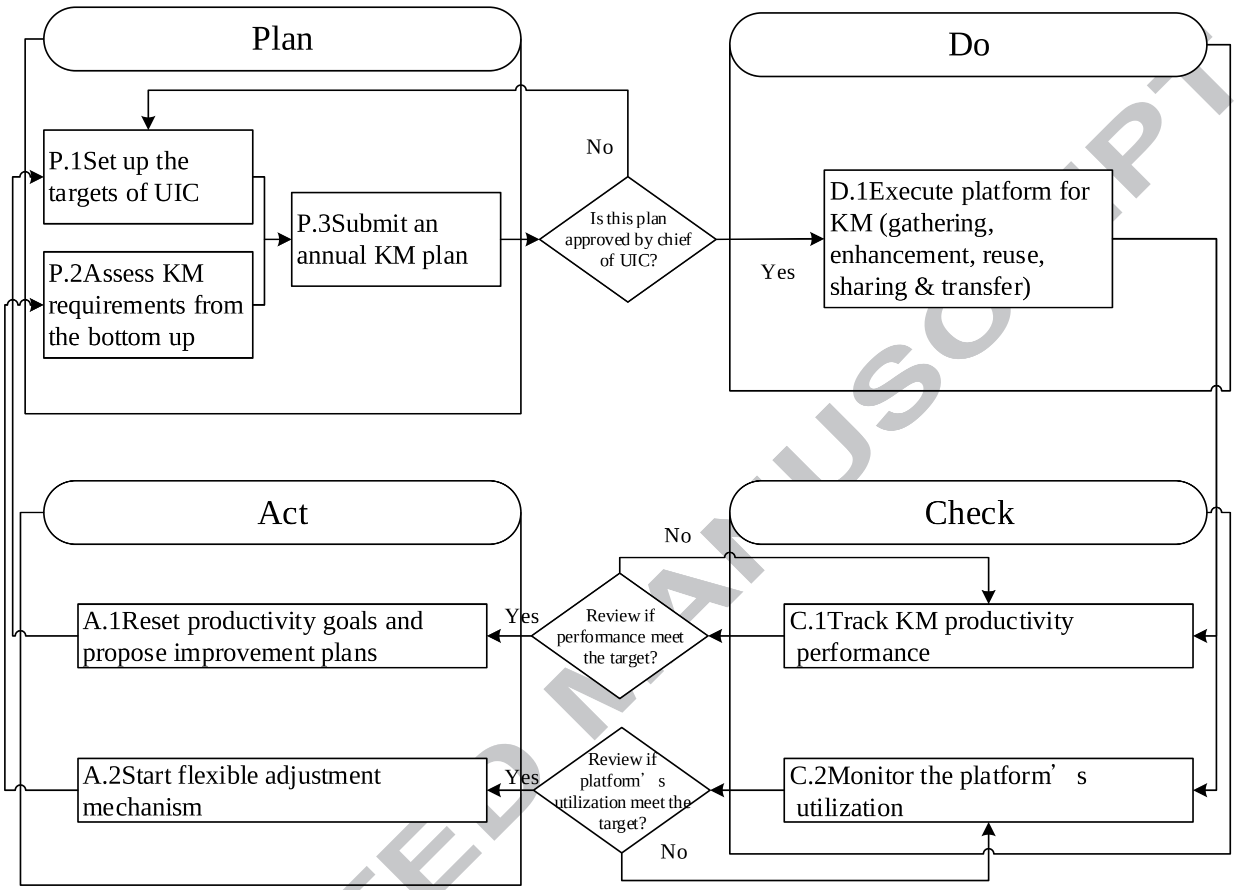

Fig. 10. PDCA continuous improvement for KM of UIC.

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Table 1. Key factors of knowledge management in higher education

Basu and Sengupta (2007)	**Ramachandran, Chong, and Wong (2013)**	**Rivera and Rivera (2016)**	**Abu Naser, Al Shobaki, and Abu Amuna (2016)**
integrated technical infrastructure	strategy and leadership	leadership	processes
organizational culture	organizational culture	culture	KM leadership
motivation and commitment of users	performance measurement	structure	people
senior management support	information technology	human resources	KM outcomes
		information technologies	
		measurement	

Table 2. Decision elements checklist for knowledge management of UIC

Category	Decision element	Decision element description
Context	External and internal customers	KM of UIC-related units
	Organizational needs	Higher education productivity and knowledge workers continue to improve work efficiency
Constraints	Cost of decision making	Analysis of KM expense budget
	Timing of decision making	Non-economic slowdown or forced increase in demand
Decision makers	Decision makers	President, vice president of R&D and chief of UIC
	Stakeholders	Professors, students, and partners
	Impact	CEO of industry
	Evaluation criteria	UIC total annual income, average income of each employee for UIC, and number of patents approved
Domain	Objectives	Improved productivity of staff
	Uncertain event	UIC willingness, patent passing
	Consequences	Increase in number of UIC and total annual income
	Related implementation strategies	Productivity and competitiveness

Table 3. Relevant mechanisms of knowledge management in UIC

Stage	Mechanisms	Mechanism content	Mechanism goal
Knowledge gathering	Knowledge files classification	1.Include multiple sources of knowledge files in platform management 2.Quickly establish knowledge documents and classify their data	1.Reduce the time to find things 2.Make the platform easy to use 3.Activate and use knowledge of platform
Knowledge enhancement	Knowledge files review process function	1.Review the correctness of the content of knowledge files provided by users 2.Assist reviewers in reviewing user uploaded knowledge files 3.Use this function to modify, recommend and read files	1.Encourage user to provide files to the platform 2.Make the control of the files quality of UIC easy 3.Manage and improve the quality of knowledge files
	Knowledge files format integration function	1.Platform support of commonly used files 2.Users can use Viewer to browse files	1.Easy to provide knowledge files to the platform 2.Managers can easily manage uploaded files 3.Platform knowledge of UIC is becoming more abundant
	Knowledge files version management	1.Platform can save old versions of knowledge files --The platform of UIC provides users with the ability to view, track and restore knowledge files in the future	1.Know other users' revisions and ideas 2.Encourage users to provide meaningful and valuable files to the platform
	Q&A center function	1.Find other users to help solve problems 2.Collect and sort out frequently asked questions and corresponding solutions	1.Improve user productivity 2.Help the flow of platform knowledge 3.Extensively use platform knowledge
Knowledge reuse	Chinese search engine function	1.Assist users to quickly collect old knowledge files they wish to browse 2.The function of combines word processing feature and synonym/speech recognition.	1.Improve knowledge file search accuracy 2.Reduce search time 3.Encourage browsing and using platform knowledge files
	Expertise community function	1. Assist users in consulting internal professionals 2. Preserve knowledge or experience of UIC provided by professionals	1.Users can learn the required knowledge 2.Encourage active reading and use of expert articles
	Personalized page function	1. Users can adjust the presentation of the fields according to their preferences and habits 2. Users can include external links in their personal pages	1.Reduce search time 2.Improve search efficiency 3.Increase the chance that platform files will be viewed and used
Knowledge sharing & transfer	Knowledge diffusion	1.Establish knowledge sharing and feedback 2.Withstand external environmental pressures to drive innovation 3.Find relative technology and the right partners	1.Increase knowledge of UIC diffusion opportunities and create greater value 2.Improve organizational performance and innovation 3.Increase the opportunities of UIC

Source: Modified from Shen (2018).

Table 4. SWOT Analysis of NTHU UIC

Strengths	Weaknesses
1.NTHU has a good academic tradition, top staff and students. 2.There are a number of subsidies and incentives to encourage teachers to carry out high-quality academic research and UIC. 3.The academic research atmosphere is prosperous, the research results are fruitful, the quality of the papers is excellent, and the teacher's per capita performance value is good. 4.The neighboring national laboratories have the advantage of cooperating with the regional industries to help with cutting-edge research. 5.The operations center for industry collaboration integrates and plans UIC-related affairs.	1.In recent years, students' willingness to attend doctoral classes has been low, which will lessen human resources for future R&D. 2.The desire of UIC, research, innovation and entrepreneurship needs to be strengthened. 3.International cooperation is not popular enough and needs to be strengthened. 4.Teachers' salaries and other conditions are not competitive with those in other countries. It is not easy for foreign outstanding scholars to come. 5.Technology transfer, patent application and layout planning need to be strengthened. 6.Taiwan's economic plight causes investment insufficiency and affects the UIC expenditures of the industrial sector.
Opportunities	**Threats**
1.With the establishment of the AIMS Research Center of the Ministry of Science and Technology, companies will enhance the UIC energy and cultivate AI talents for intelligent manufacturing. 2.Through the implementation of a number of UIC programs, combined with theory and practice, the level of academic research is promoted and innovation applications are improved. 3.In conjunction with research institutes such as the ITRI and the National Guardianship Institute, the cooperation area of industry, education, and research is shaped. 4.Southeast Asian countries are close to Taiwan, academic research is booming, and opportunities for further academic research cooperation with these countries can be developed to expand the international perspective of academic research. 5.After the completion of Innovation & Incubation Hall, the UIC energy, incubator space and quality are all improved. Combined with NTHU's cutting-edge	1.The use of funds must comply with government ordinances, and some of them are less flexible. For example, investment in start-up companies is not flexible enough. 2.It is not easy to develop professional intellectual resource and train personnel. 3.The operation models of Tsinghua Laboratories and Innovation & Incubation Hall must be properly planned and implemented. 4.The trend of promoting the industrialization results or the creation of new businesses needs to be strengthened. 5.Emerging countries are actively investing resources to enhance the level of university research. The universities are facing increasing and fierce competition. 6.The resources of the public sector to invest in universities are increasingly tightening, which may

Strengths	Weaknesses
technology and R&D energy this provides a base for new production and learning strategies and new business models.	affect subsequent academic research.

Table 5. US Patents in NTHU (Source: NTHU)

year	2012	2013	2014	2015	2016	2017
Global Ranking (amount)	15(79)	15(91)	11(114)	15(101)	25(80)	23(87)
Taiwan Ranking	2	2	1	1	1	1

Highlights

A framework for knowledge management is developed for university-industry collaboration. >PDCA improvement mechanism is integrated. >A case study was validated in a research university in Taiwan. >The results have validated the proposed approach in real settings.

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