A Study on Multi-Criteria Decision Making for Route Selection in Multimodal Logistics and Transportation Systems

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Keywords: Multimodal transportation, Route selection, Multi-Criteria Decision Making (MCDM), Risk analysis, Optimization problem.

Research Content

Freight transportation is a main supply chain and logistics component to ensure the efficient movement and timely availability of raw materials and finished products. With the changing requirements of global supply chains, multimodal transportation is now a key element of modern transportation systems, especially for long distance transportation and large volume. Multimodal transportation, as defined by the Multimodal Transport Handbook published by UNCTAD, is the transport of products by several modes of transport from one point or port of origin via one or more interface points to a final point or port where one of the carriers organize the entire transport. Multimodal transportation has considered as an important development in making local industry and international trade more efficient and competitive, by its potential to create a smooth flow of goods and better control over the transport chain. The main advantages of the multimodal transportation lead to lower transportation cost, lead time and, consequently, fuel cost. Besides saving up for the market, it also results in a simple service for environmental sustainability.

Multimodal transportation route selection strategy has become an important component in the logistics of transportation to correctly prioritize multimodal transportation routes. Solving the freight route choice problem by simultaneously considering the wide range of constraints, including transport logistics cost, transport time and inherent risks, are considered the most effective approach for generating an optimized freight route choice. Most of previous studies
about multimodal transportation route selection have emphasized on minimum cost and time only. However, risk is one of the important factors in route selection. Risk can associate with accidents which cause more direct cost, time and quality of logistics systems. Additionally, in the case of transportation and logistics process, risks not only imply a direct cost, but also reduce the competitiveness of exports. Therefore, in transportation route selection decision making process, it is important to consider all three objectives, i.e., cost, time, and risk, in the optimization model.

However, considering all these factors make complex route selection problem. To address this important issue, many scholars have been developing mathematical programming models to optimize route selection to improve the logistics and transportation performance. Although there have been many studies conducted on this issue. The previous studies’ aim was to find the optimal route by considering the various factors in combination with certain optimization algorithms, but they were based on the established transportation system and subjectively influenced by field experts when evaluating the importance of weights. Therefore, applying the methods above directly cannot solve the multimodal route selection problem effectively. To mitigate for the shortcoming, this research developed a multi-objective optimization model, considering transportation cost, time, and risks. It utilized the Fuzzy Analytic Hierarchy Process (FAHP) and Zero-one Goal Programming (ZOGP) to solve the optimal route for the multimodal logistics and transportation problem. The practicability of the proposed method is proved by a real case study. The contribution of this study lies in the development of a methodology realizing a pragmatic route selection plan.

Furthermore, the methodology is flexible and applicable to the industrial sector to adopt in all multimodal transportation practices. The concept of this research is to determine the optimal route that optimizes cost, lead time, and risk in multimodal transportation systems by using a five phases framework. The first phase is to define areas of study and identify all the related routes. The second phase is to calculate transportation cost and time of each route. The third phase is to integrate qualitative risk analysis which are assessed by the experts for each criterion. The fourth phase is to prioritize criteria by using FAHP. The final phase is to optimize the route. The results have shown that the approach can provide a guidance in choosing the optimal cost, time and risk for multimodal transportation in coal industry effectively.

**Research Purpose**

Multimodal transport is the combination of two or more modes of transport to move passengers or goods from one source to a destination. The multimodal transport problem has been addressed by many authors proposing different abstractions and algorithms. The previous research study found that the selected multimodal transportation routes have emphasized the selection of a multimodal transportation route for minimum cost and time. However, there appears to be only a few researches dealing with minimum risk. In the case of transportation and logistics process, risks and accident not only imply a direct cost, but also reduce the competitiveness of exports. At the present, there are a lot of researches on transportation risk assessment because an accident may arise unexpectedly at any point along the way and transportation risks have a critical effect on the quality of transportation but there is still no research on the multimodal transportation yet. Moreover, several researchers have studied only risk on road, rail, air or waterway transport but have not studied risk on multimodal transportation in the research. Therefore, the new conceptual framework for quantitative risk assessment (QRA) in multimodal
transportation from the points of view of both logistics service providers (LSPs) and customers is proposed to combine into the model of this research.

Multi-Criteria Decision Making (MCDM) methods are approaches to structure information and decision evaluation in formal problems with multiple, conflicting goals. In the literature, many authors have applied MCDM methods to evaluate and select the transportation routes such as the Analytic Hierarchy Process (AHP). In their study, Kengpol et al. (2016) applies the AHP to determine the weights of the criteria and linguistic terms of assessment grades for route selection between Thailand and Vietnam multimodal freight routes. AHP became a popular tool for solving a multi-criteria decision-making problem. The traditional AHP method provides a structured framework for setting priorities on each level of the hierarchy using pairwise comparisons that are quantified using 1-9 scales and requires only exact judgments. Since the uncertainty of the experts’ opinion is the prominent characteristic of the problems, AHP is difficult to assign an exact numerical value in pairwise comparison as the prioritization process is complex and subjective. Thus, instead of using exact numerical number, the fuzzy set theory was introduced. It was oriented to the rationality of uncertainty order to imprecision or vagueness. A significant contribution of fuzzy set theory is its capability of representing vague data. A fuzzy set is a class of objects with a continuum of grades of membership. The membership of an element to a fuzzy set is a single value between zero and one. Fuzzy set theory has been providing a more widely frame than classic set theory, contributing to capability of reflecting real world. Various works now combine fuzzy concepts with other scientific disciplines as well as modern technologies. Thus, FAHP method is systematically decision-making methodology that apply the concept of fuzzy set theory and AHP.

Zero-one goal programming (ZOGP) is a technique for MCDM when a decision maker requires to satisfy several goals, to reach the optimal solution. The main advantage of this method is that it has the capacity to handle large-scale problems. Its ability to produce infinite alternatives provides a significant advantage over some methods. However, ZOGP has an inability to weight coefficients. Many applications find its usage necessary in combination with other methods, such as FAHP, to properly weight coefficients. This approach allows for proper weighting by eliminating this weakness while still being able to choose from infinite alternatives. For examples, Kim Emetry (2000) and Badri et al. (2001) also used ZOGP for a project selection problem. The previous research studies indicate that the integrated FAHP-ZOGP is appropriate and widely used for prioritizing transportation routes. Moreover, the combined FAHP and ZOGP methods can deal with qualitative and quantitative data. Thus, it is more practical and easier for ranking decisions compared to a large number of alternatives. Therefore, the value of this research compared with other international research are that FAHP-ZOGP model has competitive performance compared with other techniques for determining multimodal transportation routes. To avoid a large number of pairwise comparisons in FAHP method, the proposed model requires the experts to only provide pairwise comparisons on decision criteria. Therefore, the model has no synthesis of pairwise comparison matrices and requires only simple calculation.

Furthermore, the novelty point of this research is a valid risk analysis. The proposed risk analysis model is the combination of quantitative risk analysis, FAHP and DEA to prioritize and optimize the multimodal transportation routes. The FAHP technique is used to determine the weights of the risk criteria. The DEA method is employed to determine the values of the linguistic terms such as Very High, High, Medium, Low and Very Low to assess transportation risks under each criterion. Finally, the Simple Additive Weighting (SAW) method is applied to aggregate the risks under different criteria into an overall risk score. The literature review
revealed that the integrated FAHP-DEA is very simple, applicable to many decision alternatives and particularly effective for complex MCDM problems. DEA is the method for evaluating the efficiency of homogeneous units with multiple inputs and multiple outputs. This method is a linear programming method that can be used for measuring the relative efficiencies of decision-making units. There have been several ideas of combining the FAHP and DEA because the FAHP can only compare a very limited number of decision alternatives and it is also not easy when there are many alternatives to be ranked. Then, the local risk scores are aggregated into an overall risk score for each decision alternative by using SAW method. The SAW is a weighted linear combination or scoring method which is a simple method and most often used as a multi attribute decision technique. The result will be shown routes and nodes quantitative risk score of multimodal transportation by using a combined routes and nodes quantitative risk model. Risk analysis helps managers focus on the most relevant risk in multimodal freight transportation. This proposed technique presents a new valid and reliable approach for prioritizing risks.

**Research Accomplishment**


Doctoral Dissertation

A Study on Hybrid Models for Behavior and Root-Cause Analysis with Application to Freight Transportation

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Abstract

Part 1: Research Content

Currently, data from multiple sensors and the Internet of Things (IoT) provide essential mobility information for both governments and industries. They use this information to support smart city planning, medical care, and transportation domains. Recently, the transportation domain has played an essential role in the era of digital eCommerce, especially in transport logistics. The rapid growth of logistics demand also reflects the cost and profit of the logistics industry.

Historical statistics show that in 2019, the logistics industry had only 56% fleet utilization in the United States and 54% in Europe. The lack of efficiency in vehicle route optimization caused difficulties in transportation planning and management and created a direct impact on operational costs. To solve this issue, logistics agencies use the data obtained from the IoT to support their operations, for instance, transportation scheduling, planning, and resource allocation. Their goal is to obtain a suitable policy that can minimize agency operational costs and reveal the potential of route optimization.

The policy described in this study is used for managing the vehicle route optimization process. Therefore, numerous methodologies have been introduced to extract rich information from these data. Furthermore, anomaly detection and root-cause analysis are performed to understand the transport operation characteristics. However, these data come from multiple sources. Therefore, conventional methods cannot handle these data directly because of different data formats, and the data are also dependent on spatial-temporal contexts and behavior attributes.

The issues mentioned earlier motivated the author to in-depth study and developed a new methodology of anomaly detection and root-cause analysis for addressing those issues. After that, the anomaly detection models are employed to analyzing the transportation environment.

To demonstrate the practicality of the proposed methodology, the experimental results are validated with real data and compared against state-of-the-art models. Once the model for detecting anomalies in transportation is developed, the model was also applied to the other application domains to demonstrate the model’s generality. The results show an accuracy of up to 0.83 (0.88 of the area under the RoC curve) with less processing time than that required by other existing methods. The model is also general and can be employed in other application domains with minor modifications. Finally, real case studies are presented to demonstrate the practical significance of anomaly detection and root-cause analysis in assisting vehicle route optimization tasks performed by reinforcement learning (RL).

The real case studies’ results implied that the interconnection between RL, behavior analysis, and reward processing of the proposed model increased the ability of the agent to perform vehicle route optimizations in a similar way as humans for routine daily scheduling. Furthermore, when uncertain changes (e.g., the sudden change of customer demand, road-network traffic condition, and fleet resources) occurred in the environment, the agent also outperformed
the humans when making rescheduling decisions. Thus, this proposed methodology improved
the vehicle route optimization solution up to 57.91% of profit improvement when compared
against the optimal baselines.

Part 2: Research Purpose

This study proposes a novel methodology for performing anomaly detection (e.g., temporal
and static anomalies) and root-cause analysis for transportation logistics (e.g., explanation of
anomaly in transportation logistics). Later on, the anomaly detection models contributed to
analyzing the transportation environment and RL agent’s behavior in optimizing daily vehicle
routing for the logistics agency. This phenomenon is presented in the case studies. The author
assumes that the RL agent has the same role as humans. Suppose that the optimal vehicle
route is obtained by the RL agent, it denotes that when a human follows this recommended
route pattern provided the optimal decision.

The methodology consists of five models. They are used in two different stages: (1) the
detection stage and (2) root-cause analysis stage. In the first stage, anomaly detection using
Long Short-Term Memory (LSTM)-based and unsupervised hybrid anomaly detection models
is proposed. These two models are designed to detect a point, contextual, and collective
anomalies. In the second stage, forward and inverse problem analysis models are proposed.
They are also compared with the machine learning-based model to derive the root cause of
the detected anomaly. These outcomes will increase the reliability and interpretability of the
anomaly detection result. The obtained outcomes also increase anomaly detection rates and
significantly reduce the bias of labeling the data.

The data from multiple sensors are preprocessed and transformed into structured data, and
the features are extracted using feature engineering to perform this experiment. A different set
of anomaly detection methods is then used to distinguish between regular operation patterns
and disturbances. Its outcome is further used as an input to analyze the root cause of distur-
bances. Finally, root-cause analysis is performed. Thus, these steps are employed to analyze
environmental changes. The analyzed information is then used to adjust the RL agent’s be-
havior when it optimized vehicle routes. The vehicle route optimization solution is therefore
adapted to environmental changes by doing so.

Part 3: Research Accomplishment

The accomplishment of this study is presented in aspects of theoretically and practically of
behavior and root-cause analysis with application to freight transportation. This accomplish-
ment is being demonstrated by the publications in both international journals and international
conference proceedings as follows:

International Journals

1. Thananut Phiboonbanakit, Van-Nam Huynh, Teerayut Horanont, and Thepchai Surn

nithi, “Unsupervised hybrid anomaly detection model for logistics fleet management sys-

2. Thananut Phiboonbanakit, Teerayut Horanont, Van-Nam Huynh, and Thepchai Su
nnithi, “A Hybrid Reinforcement Learning-based Model for the Vehicle Routing Problem

### International Conference Proceedings


**Keywords**: Anomaly detection, Deep learning, Logistics, Root-cause analysis, Transportation.
Modelling the effects of ICT design on the employee’s cognitive understanding of HRM and KM - Based on survey research of Saudi Aramco HRM/KM platform case-

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Abstract

Research Content:

**Keywords:** Inter-Functional, Overlapping, Database, Cognitive understanding, Knowledge management practices, Information communication technology, Human resources practices.

This case study examines a new management phenomenon of what we call Human Resource Knowledge Management (HRKM), i.e., emergence of a new management function through the merger of existing Human Resource Management (HRM) and Knowledge Management (KM) through the usage of common Information and Communication Technologies (ICTs).

The literature review shows that between Human Resource Management (HRM) and Knowledge Management (KM) cognitive understanding issue arises in the Inter-Functional through the usage of common Information and Communication Technologies when accessing databases. However, there is still lack in the literature with regard to a theoretical model of overlap understanding causing Inter-Functional between these two related but different domains. Therefore, we built a theoretical model of the overlapped understanding by investigating Human Resource Management (HRM) technologies and Knowledge Management (KM) technologies at the case company of Saudi ARAMCO. The second objective of this research is to provide practical suggestions for Human Resource Management (HRM) professionals and KM professionals at petroleum companies worldwide.

To attain the above objectives, the study uses a thematic analysis and structural equation modeling SPSS Amos questionnaire analysis of Saudi ARAMCO to analyze the Inter-Functional in the sense of cognitive understanding between HRM and KM activities. Often it is differentiated between HRM and KM activities in theoretical terms. However, exploratory questionnaire is the best option. The reason is that it can give a detailed understanding of the experiences and influencing elements in the cognitive confusion between HRM activities and KM activities. The first postulation was that learning in the context of an organization would have a positive influence on the cognitive understanding of ICT usage. Our analyses showed an inverse effect of organizational learning on the cognitive understanding ability of the employee ($\beta = -0.17$, $p > 0.05$). This effect was not significant. Additionally, the results found from the analysis supported the postulation that a positive cultural environment would positively influence the cognitive understanding of ICT usage. The results following this analysis, however, did not show any significant effect of a positive business cultural environment on how employees perceived the usefulness of ICT ($\beta = -0.34$, $p > 0.05$). Moreover, the chapter hypothesized that cognitive understanding of ICT usage would have a positive impact on the understanding of the overlap between HRM and KM activities. In this regard, the findings from the analyses support our postulation, albeit in a partial sense since the influence was not statistically significant ($\beta = 0.10$, $p > 0.05$).
An inverse relationship was observed between ease of use and the ICT tools usage and perceived control, a finding that was not in support of the postulation that perceived (EU) would positively influence the utilization of ICT tools and their control ($\beta=-.50$, p>.05). The influence was also not statistically significant. On the other hand, as postulated, a positive perception of the usefulness of the IT tool positively and significantly influences ICT tools usage and perceived control. The result suggested that the weight of ease of use in the prediction of ICT tools and perceived control ($\beta=1.31$, p<.05). Similarly, and in line with our postulation, positive ICT tools usage and perceived control significantly positively influence the affective technological experience ($\beta=1.03$, p<.05). Furthermore, the findings did not backup the postulation that positive perception by employees of the ease of use of either HRM and KM strategy significantly impacts the usage of the ICT tool and the following perceived control (IPC) ($\beta=-.50$, p>.05).

Improvements in employee trust and reductions in their perceived risk of using HRKM databases were postulated as a significant factor positively influencing the overlapped understanding between KM and HRM (OC). This postulation is supported by the findings in which trust, and perceived risk significantly impact employee understanding of the overlapped understanding between HRM and KM ($\beta=.49$, p<.05). Similarly, trust and perceived risk of the ICT tool significantly positively impacted affective technology experience ($\beta=.84$, p<.05). The developed model showed an inverse relationship between technology experience and understanding of the overlap. In this way, the model supported our hypothesis of positive technology experience impacting KM and HRM overlap understanding, even though the findings were non-significant ($\beta=-.40$, p>.05). Even though the model showed a positive effect of the improved conception of ICT tools usage on employee understanding of the overlap between KM and HRM, the effect was not significant ($\beta=.35$, p>.05). Cognitive understanding of ICT usage and perceived control of the tool also positively impacted KM and HRM overlap understanding, though not significantly, and thus supported the postulation made herein ($\beta=.09$, p>.05).

**Research Purpose:**

KM and HRM are using the function both and overlapping it unconsciously which was not intended to, so this causes the overloading and cause user cognitive confusion phenomena. In Figure 1, the designer designed the function with sub-goal (A) and Not sub-goal (B), but the user uses A and B regardless, (not intended design). The overloading and overlapping looks similar, however, in the overloading the user is not conscious. Therefore, based on the data from the case study we can see they designed it for KM (ShareK’s platform), and they are still using it both and overlapping it unconsciously. Also, because it was not meant for this amount of activities and load it causes user cognitive confusion too.
In Figure 2: (A) Current Overlapped Configuration, you will notice that based on the evidence we found that KM (ShareK’s platform) database’s views are overloaded, simultaneously, the database itself are being used by the HRM practitioners too, therefore, ICT designers should separate databases or build database views on top of the database to improve cognitive understanding (see Figure: (B), Improved and Separate Configuration).
For the theoretical implications, this study suggested a Model of cognitive understanding overlap between these two related but different domains. In our model the usage of database and the social phenomenon promotes the cognitive understanding overlap confusion of KM and HRM. In other words, the two social phenomena are inter-promoting with each other.

As for the practical implications suggestions of the partially overlapped causing overloading in the database between two related, but different concepts: HRM technologies/practices and KM technologies/practices, and to avoid overloading we suggest that it is better to separate database, database views and tables, they can improve it by using our proposed model, because they are using KM platform for HRM and overlapping it unconsciously so this cause user cognitive confusion. Based on that we propose next step of the system development and change of the employee understanding model.

Finally, we have addressed the understandability problem thoroughly; highlight the commonalities and variabilities between the two related but different domains, restructuring the domains & improve their shared understanding, reduce, or eliminate conceptual and terminological confusion. We believe that we contributed to uncover some hidden features in representing any or enabling smoother database usage and utilization.

Research Accomplishment:

**International Journal:**

**International Conference:**
Abstract

Part 1. Research Content

Knowledge has become a strategic resource for economic development in a knowledge-based economy. The globalization, networking, and informational society have further accelerated the arrival of the era of open cooperative innovation. University and enterprises have gradually become the main R&D subjects in the national innovation system and play a crucial role in economic development. However, the imbalance of regional university-industry (U-I) collaborations in China restricts this type of effect. How to shorten the “distance” between university and enterprises enhancing the efficiency knowledge flow from university to enterprises for innovation? A proximity approach gives us a new view to understanding U-I linkages. Therefore, this research aims to explore the spatial trend, different influencing factors from proximity perspective on knowledge flow from university to enterprises and proposes two types of strategies through entrepreneurship education and region-industry linkage to foster the U-I knowledge flow drawing on the national innovation system, the new knowledge production mode, and triple helix theory. The thesis are organized as following:

Chapter 1, the research background, meanings, questions and research framework were introduced.

Chapter 2, the literature on U-I collaboration, knowledge flow and proximity were reviewed.

Chapter 3 and chapter 4, to find the rule of spatial trend from university to enterprises, we should understand how the knowledge flow. Therefore, this research construct a framework of knowledge flow on U-I collaboration and explore the flow mechanism on two stages of knowledge outflow and inflow from proximity perspective. Then, the trend of inter-region U-I knowledge flow with 7,994 co-invent patents by university-industry over the period 2013 to 2018 in China were illustrated.

Chapter 5 and chapter 6, this research will discuss what types of proximity impact on regional and enterprise innovation performance through U-I knowledge flow. We used 484 pairs of patents to test the proximity effects and regional heterogeneity on the regional innovation performance firstly. We further verify the catch-up moderating role of regional internal and external absorptive capacity. Then, in chapter 6, we focus on proximity effects on enterprise innovation performance and examine whether the knowledge embeddedness and the enterprise’s absorptive capacity affect these relationships.

Finally, in chapter 7, we emerge two types of strategies: one is from entrepreneurship education as a means for fostering U-I knowledge flow and the other is region-industry linkages development pathway. These expand in-depth analysis of the impact of proximity, innovation performance, and regional resource endowments on U-I knowledge flow.

We got the results from the following three aspects:

As for "spatial trend ", the gaps between regions are obvious, showing a spatial pattern of "strong in eastern and weak in the other areas" in China. There is ladder shape of imbalances development on U-I collaborations in prosperous and lagging regions.

For "influential factors"of flow form universities to enterprises, (1) The far geographic distance is not a hamper for improving regional and enterprises innovation performance. The economic development level has no significantly different effects on such role. (2) Technological proximity plays a negative role in increasing inter-region U-I innovative performance, eastern region has the most noticeable results. However, it can foster the enterprises innovation performance. (3) The better relationship and social trust of subjects can get more innovation performance in eastern and
western, but the central area negatively affects. Simultaneously, social proximity also can improve enterprises innovation performance. (4) The U-I collaboration for innovation performance-enhancing advantages are not equal for all regions but are moderating by specific regional absorptive capacity dimensions. The areas with a higher level of internal human capital can get more catch-up effects, the knowledge embeddedness helps enterprises shape innovation performance.

For fostering U-I collaboration "strategies", entrepreneurship education integrated with professional education contribute to U-I knowledge flow through fostering students’ creative thinking and problem-solving capability. The universities and enterprises located in lagging regions should increase entrepreneurship education, as a means for U-I knowledge flow. And then the regions cultivate the innovation atmosphere to absorb talents fostering cross-regional cooperation for catching up. Region-industry linkages promote the clustering growth, then push the U-I collaboration development. The conclusion section highlights the most relevant findings of this paper and formulates a set of recommendations. These findings can provide theoretical guidance for innovation by real-world university–industry collaborations.

Part 2. Research purpose

Research novelty. Prior research gradually shifted from linear analysis focusing on U-I collaborative models, mechanisms, and talent training to network spatial analysis. As an external mechanism unconsciously produced by human economic activities, knowledge flow has spatial, scale, and interactivity. Research on proximity is an essential branch of U-I collaborations spatial studies and has provided a solid foundation for innovation study, organizational cooperation, and regional development. Scholars proposed the "distance" of the relationship is a prerequisite for interaction between subjects and knowledge spillover. This field mainly includes three directions: First, extending geographical proximity to multidimensional proximity, such as cognitive, technological, social, and institutional proximity, etc.; Second is introducing proximity factors to the measurement model of U-I knowledge spillover effects; The third is the impacts of diversity proximity mechanism on U-I collaborative performance in different countries.

Most works discussed the relationships of proximity on U-I collaboration from individual or organizational levels. Based on the triple helix theory, the existing research on the relationship between enterprises, universities and the government from the perspective of proximity is rare, and lacking analysis on the factors from the "learning area" context. The regional resource endowments of learning area would be objects factors that affect the knowledge flow from university to enterprises. A number of previous studies took the European Union, the US, and Italy etc., as samples, ignoring regional heterogeneity may lead to estimation errors.

These studied showed a gap in integrating proximity on U-I's spatial interaction processes from an inter-regional and heterogeneity context. Some empirical studies have also verified the influences of some organizational factors on proximity, like firm size, organizational absorptive capacity. And they fail to incorporate the knowledge carriers' role of inflow region's absorptive capacity into the research framework, ignoring the availability of regional endowments to capture local proximity. Therefore, the aims of this thesis is to improve the knowledge flow from university to enterprises, especially in lagging areas.

Research originality. As China's regional development is extremely uneven, economic development different level between regions are not conducive to the innovation and development of the entire country. Therefore, based on regional heterogeneity, this thesis inclined to pay attention to the development of lagging areas, taking cross-regional U-I collaboration as the starting point to explore the impact of spatial proximity effects on the knowledge flow from universities to enterprises. At the same time, it is the first time that this research attempts to consider the impact of regional resource endowment on the performance of knowledge flow between industry and university. In addition to the government, enterprises and universities mentioned in the triple helix theory, this kind of regional endogenous resources has been discussed for university-industry collaboration. The influence of the research model for the interaction among
university, enterprises and regions has been constructed, and it is of great significance for promoting regional innovation and development.

**Academic contributions.** This research contributes to the existing spatial proximity research by cross-level perspective with embedding two stage absorptive capacity into these process to cross regional and organizational boundary. Firstly, we constructed a "subject-region" interactive spillover way and introduce regional heterogeneity and regional absorptive capacity into the analysis framework, focusing on the U-I collaboration from non-local universities to local regions that significantly impact lagging regional U-I collaborative innovation performance. Following this analysis, focusing on the organizational boundary, the research tests the mediating role of knowledge embeddedness and moderating role of enterprises absorptive capacity. The findings rich triple helix theory from the subjects side which considers the integrated resource endowments in the triple helix research framework and fosters the knowledge flow activities between university and enterprises.

At the same time, the research contributes to "catch-up theory" from the U-I collaboration perspective. Considering two main "later-mover advantage" and "absorptive capacity" hypothesis of catch-up theory, we added "technology gap" as a new proxy variable to test the regional external absorptive capability. The results help us to understand the status of the non-linear role between different subjects in the process of knowledge flow from non-local university to local enterprises.

**Practice contributions.** This thesis’s major contribution is to finding the effects of diversity proximity on U-I collaboration from cross-level perspective. For regions, this research helps each provincial government, primarily undeveloped areas enhance the introduction, absorption, and effective use of external knowledge based on their actual conditions and influences enterprises’ behavior. For enterprises, this research helps enterprises identify the characteristics of various proximity and explore the effective way to absorb the knowledge flow from university.

The second contribution is to explore the dynamic knowledge flow of U-I collaboration from the two dimensions of time and spatial. U-I collaboration is a dynamic process that includes both the characteristics of spatial flow and time flow. Therefore, this study uses two dimensions of time and spatial to study the knowledge flow of U-I collaboration by social network analysis.

Third, discussing the two types of strategies entrepreneurship education and region-industry linkages to fostering U-I collaboration. Previous researches on knowledge flow strategies of U-I collaboration focused on the flow channels, flow mechanisms, etc., while there are few findings considering the education especially entrepreneurship education contribution to U-I collaboration. At the same time, since we have verified the role of regional resource endowment in the U-I knowledge flow, it is also important to link industry with regional endowment factors to discuss the knowledge flow strategy for enhancing U-I innovation capability.

**Research possibilities.** The author is a teacher in Dalian Polytechnic University. She has taught many courses such as management, marketing, entrepreneurship management, etc., and has a strong theoretical foundation. While engaged in teaching work, she also has undertaken some social service functions, providing consulting and training for enterprises, and has a certain degree of understanding of university-industry collaboration. In the early stage, she has been paying attention to regional and industrial innovation and development, and has hosted many provincial vertical projects, therefore, the author also has a strong practical foundation. All these lay a good foundation for the successful completion of this thesis and also help the successful completion of this research.
Part 3: Research Accomplishment

List of published journal papers

[j1] Shu, Yu, Takaya, Yuizono, A proximity approach to understanding university-industry collaborations for innovations in non-local context: Exploring the catch-up role of regional absorptive capacity, Sustainability, 13/6, 3539, 2021. (with peer review)

[j2] Shu, Yu, Shuangshuang, Zhang, Takaya, Yuizono, Exploring the influences of innovation climate and resource endowments through two types of University–Industry collaborative activities on regional sustainable development, Sustainability, 13/14, 7559, 2021. (with peer review)

[j3] Shu, Yu, Takaya, Yuizono, Opening the ‘black box’ of cooperative learning in face-to-face versus computer-supported learning in the time of COVID-19, Education sciences, 11/3, 120, 2021. (with peer review)


List of international conference papers


[c2] Shu, Yu, Takaya Yuizono, Ma, liangliang, Analysis of aging population on consumption structure: Creativity in effective industry supply, proceeding of 13 KICSS international conference, 141-146, 2018/11/16, Pattaya, Thailand. <Oral Presentation> (with peer review)

Keywords: Knowledge flow; University-Industry (U-I) collaboration; spatial trend; proximity; innovation performance
Abstract

Research content

Research and development (R&D) is an important activity of the organization to gain a competitive advantage as it leads to the production of new and innovative products and services for customers. In the globally connected world, innovation becomes more and more dependent on the collaboration among people from different backgrounds who exchange and combine their own knowledge and expertise to create innovative outcomes. Literature has long shown that diversity of knowledge increases the creativity and innovation of teams and corporations. Multinational corporations (MNCs) expand their R&D function abroad and take advantage of global knowledge resources. However, there are challenges to overcome ranging from organizational level such as international R&D strategies, global R&D team cooperation to individual level issues such as R&D manager assignment, researcher relocation, and expatriate adjustment. During the early days of R&D internationalization around the 1980s, prior studies in R&D internationalization focused on the organizational level, how firms organize their international R&D operations. Therefore, issues such as international R&D strategies and global R&D team cooperation were better developed and well established. As the business environment has always been changing and the world has become more connected, although the organization management needs to adapt to the changing environment, it is also necessary to pay attention to the individual level issues to enhance the global R&D operations.

Facilitating research collaboration between teams located in different countries and have members of diverse backgrounds is a challenging task for managers. Organizations operate global R&D projects all over the world to gain access to diverse knowledge resources. Global R&D projects involve both internal and external stakeholders who are from different countries and having diverse backgrounds. Although global R&D project members can interact with each other using technology support tools, the effectiveness of interaction is limited by the communication channels such as email, phone, etc. Cultural differences which are the different values, beliefs, behaviors, languages, and practices play an important role in global R&D project collaboration. Organizations employ managers, who we call “R&D bridge managers (BMs)”, to facilitate research collaboration in global R&D
projects. They are facilitators in charge of bridging research activities between teams in the home country of the company and foreign R&D teams. There is a limited number of studies of BMs who help the organizations to put in place a smooth operation of global R&D projects.

Individual managers require particular competencies to perform their tasks effectively. The concept of competency has been used to improve the task performance of individuals. A number of prior studies focused on leadership competencies and defined competency to include skills, knowledge, abilities, and characteristics that lead to superior results. Competency development frameworks were identified for different professions such as project managers and medical workers. In the case of global R&D projects, the research found that manager’s sophisticated people skills and leadership to deal with the human aspect influence performance of dispersed R&D teams. Extant studies have shown that the leadership competencies of managers are an important factor for successful cross-cultural collaboration. The competency concept is used in this dissertation to improve the global R&D project facilitation. The competencies of managers who facilitate research collaboration between headquarters and foreign R&D laboratories in global R&D projects have not been identified.

**Research purpose**

This dissertation aims to identify crucial competencies of BMs for the facilitation of global R&D projects of MNCs in the information technology industry and to investigate the relationship between difficulties of facilitating global R&D projects and competencies of BMs. Particularly, this dissertation attempts to address the major research question: *How are the difficulties and competencies of managers in global R&D projects related?* This dissertation employed multi methodology, including semi-structured interviews and questionnaire surveys as data collection methods. Thematic coding was used to analyze interview data of BMs to identify difficulties in facilitating global R&D projects. A list of competencies was derived from existing literature on leadership competency to develop measurement items of the questionnaire survey. Relevance ratio and qualitative comparative analysis were conducted to explore the relationships between difficulties and competencies. Findings reveal four difficulties that the BMs face when they facilitate global R&D projects, including quality control, research approach guidance, requirement clarification, and team communication. In addition, the results show important competencies of BMs for solving difficulties in global R&D projects, including knowledge management skills, perception, resilience, decision-making skills, ability to understand worldwide business, ability to learn foreign culture, and communication skills. To the best of our knowledge, there are no competencies specifically identify for BMs concerning difficulties they faced, especially in the context of global R&D projects. It is plausible to conclude that there are crucial competencies for BMs to overcome particular difficulties in global R&D projects. BMs may develop and possess those competencies hence they could improve global R&D project facilitation. In addition,
organizations may utilize crucial competencies of BMs in their human resource management practices, including new manager recruitment, manager assignment, and manager’s training program development.

**Keywords:** Global R&D project, R&D bridge manager, Project difficulty, Manager competency, Global team collaboration

**Research accomplishment**

*International journal*

Nawarerk Chalarak, Yasuo Sasaki, Naoshi Uchihira, “Difficulties of Global R&D Projects: A Bridge Manager’s Perspective.” International Journal of Innovation and Technology Management, Status: Accepted, Number of pages: 18 pages (with peer review)

*International conference proceeding*


*International conference*


Nawarerk Chalarak, Naoshi Uchihira, Yasuo Sasaki, Srigowtham Arunagiri, “Difficulties of Global R&D Projects and Role of Bridge Managers.” ISPIM Innovation Summit 2017, Melbourne, Australia, 10 - 13 December 2017. (with peer review)

*Other publications*


Srigowtham Arunagiri, Nawarerk Chalarak, Naoshi Uchihira, Yasuo Sasaki, Mary Mathew, “Global Knowledge Transfer Framework: A University-Industry Collaboration Perspective.” The International Society for Professional Innovation Management (ISPIM), Kuala Lumpur, Malaysia, 4 - 7 December 2016. (with peer review)
Title: Emotional Design from Research to Education Based on the Case Study of Hill censers

Intended degree: Knowledge Science

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Abstract:

Part 1: Research Content

Emotional design has been used to ensure that the intended users are offered a positive emotional experience. Emotions could deeply influence the overall user experience, understanding the users’ feelings and emotions is vital in the design process. Recently, achieving positive users’ emotional experience has been recognized as a crucial advantage in product design. This research explores the design of products based on the users’ positive emotional requirements and how it can stimulate students to generate novel emotional design ideas in design education. To achieve these aims, multistage evaluation design case study was utilized in this research. In case study I, 23 selected historical samples (hill censers) were evaluated based on content analysis, semantic network and methodological triangulation methods. In case study II, 18 selected contemporary samples were evaluated based on an explanatory sequential design to learn how to design products that reflect the professional knowledge of the designers as well as according to the users’ emotional requirements. In case study III, an online course was conducted to stimulate the students in order to come up with innovational emotional design ideas. Thematic analysis and high-frequency vocabulary analysis approaches were employed to study the positive influence of the students’ designs.

Through the case studies conducted in this research the findings were used to propose the theory about emotional design. Case study I discovered the important relation ‘emotional experience and design style’. Case study II proposed the emotional design theory from the user, design trend and emotional experience aspects. The theory explains the designers’ tacit and explicit knowledge in
providing positive emotional experience. This three-sided design theory (user, design trend and emotional experience) could help provide positive emotional experiences in product design. Two findings were obtained from case study III. The first finding is that the second-person perspective enables the students to acquire better design ideas quickly. The other finding was the vital themes offering positive emotional experiences to the users; ‘design method’, ‘emotional experience’ and ‘culture connotation’.

Finally, an emotional design framework was built in this research to help the students get innovational design ideas when designing products according to users’ positive emotional requirements. This framework is general enough to be utilized to design different kinds of products. Furthermore, an emotional design appraisal model was built to evaluate the products from knowledge, skills and value perspectives.

**Part 2: Research Purpose**

The ever-changing and ephemeral nature of emotions has led many to believe that it is impossible to trigger emotional responses through design consistently. However, the researchers have already continued to examine the relationship between design and emotions over the last four decades. Some tools (Geneva Emotion Wheel, Feeltrace), methods, frameworks or emotional appraisal scales (PrEmo) have been using to test the emotional influence on the users or customers. Whereas there are no related emotional design models to help the students to do emotional design work based on users’ positive emotional requirements. Emotional design is so far mostly restricted to research and industry, only a few trials researched teaching for design students. Most of the professionals using emotional design slowly acquired the required skills by experience without direct education. Teaching emotional design to students has been overlooked due to its difficulty. This research conducted an online course to teach emotional design, to help the students generalize innovative emotional design ideas quickly. In this research emotional design framework and emotional design appraisal model were built to facilitate emotional design work of the students and researchers in the future.

**Part 3: Research accomplishment**
1. Conference proceedings


2. Conference proceedings


3. Conference proceedings


4. Journal paper


5. Journal paper


6. Journal paper

Yu, Q., Nagai, Y., & Luo, Y. (2020) Co-Creation with Ceramic Practitioner for Improving the

7. Book


8. Book


9. Book

A Learning Environment to Promote Awareness of Experiential Learning Process with Reflective Writing Support

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Abstract

Research Contents

This research uses reflective writing based on the EL model as a framework to learn EL concepts and promote reflective thinking. In this study, the participants were 70 students (hereafter “learners”) from a private university in Thailand who were enrolled in an object-orientated programming course in a distance learning setup. We conducted the research with this sample because of the nature of the course, which needs meta-cognitive skills. In the course, they were taught how to analyze problems, represent the solution using different strategies, and verify the solution. Next, the learners needed to convert the problem solution into a program using a particular programming language, then evaluate their program for syntactical and logical errors to ensure that the output satisfied the problem. This required the learners to go through repeated attempts of trial and error, which continued until they successfully solved the programming problems. These activities taught them the thinking process needed to transfer acquired problem-solving skills to new contexts. The study period lasted for 10 weeks, and at the end of each week, all learners needed to complete reflective writings about their distance-learning experience in the course.

Promoting reflective thinking has become increasingly important for helping learners build strategies for applying new information to dynamic situations in their day-to-day activities. Reflective writing based on Kolb's experiential learning cycle could be one method for promoting reflective thinking that allows learners to consider their experiences and transform them into transferable knowledge that they can then apply in new contexts. However, learners cannot sufficiently practice reflective writing and thus cannot learn from their experiences. In order to address this issue, our primary goal is to promote thinking through writing support. This research proposes a learning environment design to help learners learn experiential learning concepts by reflective writing to promote reflective
thinking. This research designed a dual usage of the support function to both promote learning and make the learning observable. This research showed how the learning support function enhances experiential learning, while the desired learning process can be captured, which helps the facilitators give proper support in experiential learning. This research found that the learning environment design can help the learner learn experiential learning well. As a result, the learning environment design, the dual role of implicit thinking process support, and an observation of the thinking process can be applied to a meta-level thinking support framework for other problem domains.

This research demonstrates that learning through a learning environment helps learners acquire EL concepts by supporting reflective writing to promote reflective thinking. The learners can observe their own learning processes. The sentence opener functions help the learners understand their own thinking process and capture the implicit thinking process. Therefore, this work contributes to supporting thinking by writing support as follows:

1. Propose a learning environment to promote awareness of EL processes by reflective writing support.
2. Propose a design framework of dual roles that can support implicit thinking behaviors, which can acquire two goals: thinking support and thinking observation.
3. Proposes learning support functions to enable learners to recognize their learning process
4. Proposes monitoring support functions to assist the teacher in interpreting the implicit thinking processes of the learners.

**Research Purpose**

This study aims to design a learning environment to promote reflective thinking and improve the EL process. To overcome the difficulties in learning the EL concepts, we designed learning support functions of reflective writing to promote reflective thinking through EL concepts. At the same time, capturing the EL process can help the teacher identify the learning status to provide better support to the learners who need support. This study shows that the support functions help learners acquire thinking abilities and observe the process that they learned for applying EL to promote reflective thinking.

This work proposed a learning environment to promote the awareness of the EL process by promoting reflective thinking through reflective writing. Experiential learning and reflective thinking are difficult to learn due to the complication and implicitness of the learning process.
We investigated the role of reflective writing to promote reflective thinking by applying EL skills in a learning environment. By providing the sentence openers and reflective writing environment, the system can support reflective writing and good clues or information of learners’ thinking by sentence openers. The learners can observe what kind of sentence openers are available for hints on how to think and how the learner uses the sentence that can show how they think. The design of dual usage of the sentence opener function provides a hint on how to think and make the thinking process observable.

An analysis of case studies showed that the learner develops their EL skills step-by-step. We proposed a method to sense the learner’s meta-level thinking processes. The LBP visualization platform can show how they think, which cannot be explicitly observed without the environment. We can see that the self-regulated learner develops deep thinking.
The results show that our proposed design to show the dual roles of learning support and learning observation is well designed.

The intended learning behavioral patterns were prepared in advance and captured as we desired, and future research will provide a more detailed analysis of the unintended LBPs. Moreover, to fully support the educational value of this learning environment, further investigation on the open learner models (OLMs) can be good to provide a representation of the learner as a necessary means of learning support. An OLM aims to provide learners with learning process information that enables them to view information about themselves for helping them to promote learner reflection or monitor their learning.

Furthermore, the idea of writing to promote thinking and monitoring the learning process can be generalized to a meta-level thinking support framework that can be applied in other problem domains, such as internship activity, active classroom, distance learning, and new employee training. As a result, society can become a knowledge society that applies reflective thinking. The main point of a learning environment is to promote EL processes’ awareness by supporting reflective writing. However, the short period of a 10-weeks course was used to test our idea. The acquisition of metacognitive skills by learners cannot be accomplished within a short term, they must be acquired through everyday activities. Further research investigates this learning model's longer period effect to investigate how the learners become autonomous.

Research Accomplishment

[1] Chanakarn KINGKAEW, Thanaruk THEERAMUNKONG, Thepchai SUPNITHI, Pornsiri CHATPREECHA, Kai MORITA, Koji TANAKA & Mitsuru IKEDA (2021), A learning environment to promote awareness of experiential learning processes with reflective writing support, in IEEE Access. (To be published online, peer review)


Keywords: Experiential learning, knowledge science, learning behavioral pattern, learning environment design, metacognition, reflection, reflective thinking, reflective writing, Self-regulated Learning
Outlier Detection and Class Imbalance Based on Mass Estimation Integrated with Evidential Reasoning

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September 2021
Abstract

Part 1: Research Content

This doctoral thesis has five chapters. Chapter 1 introduces the outlier detection and class imbalance challenges, the main research questions, significant contributions, and the directions for future works. Chapter 2 presents the research background consisting of the mass-based dissimilarity measurement and Dempster-Shafer theory (DST) of evidence. That is all the required knowledge to understand the rest of the thesis. The next two chapters are the main body of this dissertation. Chapter 3 proposes a novel approach for detecting local outliers. Chapter 4 presents two mass-based algorithms for classifying the imbalanced datasets. Finally, chapter 5 is a conclusion that lists the main achievements. Then we provide an outlook, what the future work looks like, and the impact of this thesis be.

Particularly, in chapter 2, we firstly review the mass-based measurement. That is an alternative method to measure the dissimilarity between two instances. Distance-based functions such as Euclidean distance or Manhattan distance are popular in KDD and data science for measuring how data samples are related to each other. However, these distance-based measures have some weaknesses. Then, we reply to the distance-based functions by the mass-based measures to assess the relationship among instances. Then, we remind the main concepts of Dempster-Shafer's theory of evidence (DST). That is used to assign the basic probability by each neighbor of the query instance then combine these pieces of evidence for making a decision. Next, the evaluation metrics are reviewed as a significant step for developing any machine learning model, which figures out the best model after training. The F1 score, Brier score, and AUC values are our main evaluation metrics for studying the imbalanced datasets. Finally, we used the Wilcoxon signed ranks test as a non-parametric statistical analysis to validate the experimental results.

In chapter 3, we formulate the outlier detection problem firstly. Then, the related works have been reviewed and the shortcomings of the distance- or density-based outlier models have been figured out. To address these weaknesses of the previous outlier detector, we introduced a new mass-based approach for local outlier detection, the so-called MLOS model. Then, the experiments are conducted on both synthetic datasets and benchmark datasets. The experimental results show that our proposed local outlier model works well on a wide range of application domains, numbers of features, and numbers of instances. The proposed approach can also be modified for novelty detection when determining whether a new observation is an outlier.

In chapter 4, we describe the imbalance classification problem within its application domains. Then we propose two related models for solving the class imbalance issue. The first model is called Sk-LMN, in which the similarity between two instances is computed based on the mass
estimation. Then, the simple weighted sum framework aggregates the information from the $k$-neighbor to make a decision. The second model is the extended version of the previous one, the so-called EMass. In this model, Dempster-Shafer's theory of evidence is utilized instead of using the weighted sum. Each neighbor of the query instance is considered as a piece of evidence. Then the Dempster’s rule of combination is used to pool the evidence. The experiments are conducted on 60 benchmark datasets with 12 tested competitive models. The results show that our two proposed models outperform the existing competitive models on several evaluation metrics such as F1 score, PR-AUC, and ROC-AUC values.

**Part 2: Research Purpose**

The primary aim of this dissertation was to exploit a new alternative approach for local outlier detection tasks by fundamentally changing the way to measure the outlier degree of each data point. To achieve this goal, we developed a mass-based approach to measure the dissimilarity between data points. Then, we introduced a new outlier scoring method by employing mass-based dissimilarity and probability modeling to detect the local outliers in a given dataset. The experimental study tested on artificial datasets and real application datasets show that our proposed MLOS approach is competitive with the state-of-the-art approaches.

In the same manner, to exploit the mass-based measurement for learning from the imbalanced datasets, we introduce the other two new methods for the class imbalance task. The first model is a simple application of weighted sum. The second model is an integration of the mass estimation and the Dempster-Shafer theory of evidence. These proposed models were assessed by using significant evaluation metrics such as F1 score, Brier score, ROC-AUC, and PR-AUC score testing on a wide range of benchmark datasets. In addition, all experimental results were validated using the non-parametric statistical Wilcoxon signed ranks test.

This dissertation was the first study, regarding to the best of our knowledge, to investigate the local outlier detection problem using mass-based dissimilarity measurement; the key finding was that the proposed MLOS approach presents an alternative way to score the outlierness of each data point in a given dataset. Secondly, the simulation results showed that our proposed new models for the class imbalance task outperformed the other 11 competitive methods. The experiments were conducted on a wide varying application domains, a varied imbalance ratio, and the number of instances.

In summary, this thesis has contributed three new approaches to KDD and data science. The first model called MLOS approach for the local outlier detection task, and the other two models are called Sk-LMN and EMass for the class imbalance task. We knowledge that there are limitations in this research. Then, we raise several future directions for the next plan.
Part 3: Research Accomplishment

The accomplishment of this work is presented from perspectives of theoretically and practically for the outlier detection and class imbalance problems. This accomplishment is being demonstrated by the publications in both international journals and international conferences as follows:

**International Journals**


**International Conferences**


**Keywords:** Imbalanced data, outlier detection, outlier modeling, massbased dissimilarity, weighted sum, Dempster-Shafer theory.