No. D008

博士論文審査結果報告
Report on Ph.D. / Doctoral Dissertation Defense

2024/2/21

National Graduate Institute for Policy Studies (GRIPS)
政策研究大学院大学
Professor TANAKA Makoto
教授　田中　誠

審査委員会を代表し、以下のとおり博士論文審査に合格したことを報告します。

On behalf of the Doctoral Dissertation Review Committee, I would like to report the pass result of the Doctoral Dissertation Defense as follows.

プログラム名 Program	科学技術イノベーション政策プログラム Science, Technology and Innovation Policy Program	
学位申請者氏名（ID） Ph.D. Candidate (ID)	Ibrahim Elsayed Mahmoud Kshanh (DOC20152)	
Dissertation Title 論文タイトル (タイトル和訳)	Towards a Decarbonized and Sustainable Energy System: Multi-Criteria Decision-Making Applications for Evaluation of Energy Efficiency Projects and Hydrogen Production Technologies 脱炭素化し持続可能なエネルギーシステムに向けて：エネルギー効率化プロジェクトと水素製造技術の評価のための多基準意思決定手法の応用	
学位名 Degree Title	博士（公共政策分析） Ph.D. in Public Policy	
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論文最終版提出日/ Submission Date of the Final Dissertation	2024 年 2 月 1 日/ February 1, 2024, 2024	
審査委員会/ Doctoral Dissertation Review Committee	主査 Main referee	田中　誠 TANAKA Makoto
	審査委員 Referee	根井　寿規 NEI Hisanori
	審査委員 Referee	飯塚　倫子 IIZUKA Michiko
	審査委員 Referee	岩船 由美子 東京大学 IWAFUNE Yumiko University of Tokyo
	審査委員（博士課程委員会） Referee (Doctoral Programs Committee)	PORAPAKKARM Ponpoje

※ タイトルが英文の場合、文部科学省に報告するため、和訳を付してください

Please add a Japanese title that will be reported to MEXT.

1. Summary of Defense and Evaluation

This dissertation examines the role of multi-criteria decision-making (MCDM) approaches, which involve multiple conflicting criteria or objectives, in facilitating the evaluation of energy efficiency projects (EEP) and hydrogen production technologies (HPT). Chapter 3 develops a two-stage MCDM framework that allows organizations and policymakers to evaluate and rank EEP concerning sustainability. The proposed MCDM framework was applied to the evaluation of EEP in a real petrochemical complex in Egypt. The results show the advantages of the combination of Fuzzy Analytic Hierarchy Process (FAHP) and VlseKriterijumska Optimizacija I Kompromisno Resenje (VIKOR) and the combination of FAHP and Technique for Order of Preference by Similarity to Ideal Solution (TOPSIS), which are consistent, robust, and simple to implement. Chapter 4 applies an FAHP approach to the evaluation and prioritization of HPT alternatives in the context of Egypt. The results reveal that the photovoltaic-electrolysis technology, among the five technologies, is evaluated as the most sustainable option for the development of a hydrogen economy in Egypt because of the great potential of photovoltaic energy.

Chapter 3 contributes to the literature in several ways: i.e., this study develops a unified approach of two-stage MCDM approach for a more robust evaluation process of EEP; this study considers the balance over the main sustainability criteria (economic, environmental, socio-political, and technological dimensions); and the case study of Egypt provides practical implications to developing countries regarding the decision-making process of EEP. Chapter 4 contributes to the literature in that the FAHP method is applied to prioritizing HPT in the context of developing countries, which would assist policymakers to develop a hydrogen economy in developing countries.

The referees were generally satisfied with the contribution of the dissertation. They however suggested several areas for improvement. After several revisions to the dissertation,

the main referee was satisfied that the revisions were made appropriately in line with the suggestions by the referees. The doctoral dissertation review committee recommends that GRIPS award the degree of Ph.D. in Public Policy to Mr. Ibrahim Kshanh.

2. Dissertation overview and summary of the presentation.

The transition towards a decarbonized and sustainable energy system is viewed as essential in the global effort to combat climate change, given the greenhouse-gas emission contribution by the energy sector. The aim of this dissertation is to investigate the role of multi-criteria decision-making (MCDM) approaches, which involve multiple conflicting criteria or objectives, in facilitating the evaluation of energy efficiency projects (EEP) and hydrogen production technologies (HPT). EEP enables the reduction of energy consumption mitigating greenhouse-gas emissions, while HPT offers effective solutions for clean and versatile energy carriers with less emissions.

After an introduction in Chapter 1 and an extensive literature review in Chapter 2, Chapter 3 develops an MCDM framework that allows organizations and policymakers to evaluate and rank EEP concerning sustainability. This study employs a new set of evaluation criteria validated by a group of energy efficiency experts. Several MCDM techniques are combined for the two-stage assessment of EEP: i.e., the first stage of FAHP for the determination of evaluation criteria weights, followed by the second stage of four methods (VIKOR; TOPSIS; Weighted Aggregated Sum Product Assessment, WASPAS; and Preference Ranking Organization Method for Enrichment Evaluation, PROMETHEE) for ranking and prioritizing the options based on the actual technical data. FAHP quantifies the weights of decision criteria by a pair-wise comparison of the relative importance for each item, in which linguistic values and experts' judgments are used for the evaluation process. On the other hand, VIKOR, TOPSIS, WASPAS, and PROMETHEE rank alternatives using actual technical data

rather than linguistic values. These four methods use different mathematical techniques. The proposed MCDM framework was applied to the evaluation of EEP in a real petrochemical complex in Egypt. The results of the comparative analysis show the advantages of FAHP-VIKOR and FAHP-TOPSIS, which are consistent, robust, and simple to implement. In the case study of a petrochemical complex, EEP related to operation and maintenance measures, especially steam systems, are ranked highest.

Chapter 3 contributes to the literature in several ways. Most of the previous studies implemented one-stage MCDM technique for EEP evaluation, whereas this study develops a unified approach of two-stage MCDM approach for a more robust evaluation process of EEP. Many studies focused only on environmental and economic criteria, whereas this study considers the balance over the main sustainability criteria inducing economic, environmental, socio-political, and technological dimensions. While most existing research focused on developed countries, the case study of Egypt provides practical implications to developing countries regarding the decision-making process of EEP, taking account of the differences in organizational culture between developed and developing countries.

Chapter 4 applies an FAHP approach to the evaluation and prioritization of HPT alternatives in the context of Egypt. Linguistic values and experts' judgments are used for the evaluation process, given that the actual technical data are limited due to the ongoing development of HPT and the small number of projects that have been implemented on a commercial scale worldwide. Specifically, the study compares steam methane reforming (SMR), biomass gasification (BG), photovoltaic-electrolysis (PVE), wind-electrolysis (WE), and grid-electrolysis (GE). SMR produces hydrogen by reaction of hydrocarbons with water; biomass gasification converts biomass to hydrogen; and PVE, WE, and GE split water into hydrogen and oxygen by electricity from photovoltaic, wind, and grid, respectively. The results reveal that the PVE technology, among the five technologies, is evaluated as the most

sustainable option for the development of a hydrogen economy in Egypt because of the great potential of photovoltaic energy.

Chapter 4 contributes to the literature in that the FAHP method is applied to prioritizing HPT in the context of developing countries. Only a few such studies have been conducted in this area for developing countries. The proposed approach would assist policymakers to develop a hydrogen economy in developing countries.

The candidate presented the dissertation on December 27, 2023. He then responded to the questions and comments from the referees.

3. Evaluation Notes from the Doctoral Dissertation Review Committee (including changes required to the dissertation by the referees)

The referees were generally satisfied with the contribution of the dissertation. They however suggested several areas for improvement, particularly better exposition of the dissertation. The comments from the referees include:

- Emphasize the importance of the choice of experts and their selection process.
- Implement a bootstrap approach to check robustness of the proposed FAHP model.
- Discuss generalization and other areas for application.
- Check missing abbreviations.
- Mention the conference papers he presented as the footnote of corresponding chapters.

Under the rules of the defense, the confirmation of satisfaction was delegated to the main referee. The candidate addressed all the issues raised. Particularly, he implemented a bootstrap approach to calculate the criteria weights by randomly selecting 10 subject-matter experts from an original set of 15 and repeating this process 300 times. He confirmed the robustness of the proposed FAHP model by assessing the distribution of the criteria weights obtained by the

bootstrap. He revised the dissertation to incorporate the additional results. He also revised the dissertation to elaborate on the other points raised by the referees. After several further revisions to the dissertation, the main referee was satisfied that the revisions were made appropriately in line with the suggestions by the referees.

4. Confirmation by the Main Referee that changes have been done to the satisfaction of the referees and final recommendations

After a plagiarism check, the main referee confirmed that the revisions were satisfactory, and the quality of the dissertation was improved. On February 1, 2024, the final version of the dissertation was submitted to GRIPS.

The doctoral dissertation review committee recommends that GRIPS award the degree of Ph.D. in Public Policy to Mr. Ibrahim Kshanh.