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Accessing Risk for Malaysian Palm Oil Biomass Industry with FANP-DEMATEL Mmodel

SUE LIN NGAN, HON LOONG LAM, PUAN YATIM & AH CHOY ER

Abstract The urge for climate change mitigation has created a strong resonance in industrial world on the utilization of renewable resources. As the second-world largest palm oil exporter, Malaysia produces abundant amount of oil palm biomass which can be best utilized for "waste-to-wealth". As the country attempts to transition towards green growth, policy frameworks have been established and implemented to promote and support the industry. However, the overall development of the biomass industry remains under-developed. Lack of understanding of risks associated with the industry is often cited as one of the reasons for the industry's slow growth. Therefore, it is imperative that these risk factors are identified and evaluated in a comprehensive manner so that industry players can address these risks and put in place risk management and mitigation mechanisms. In this study, Fuzzy Analytic Network Process (FANP), and Decision Making Trial and Evaluation Laboratory (DEMATEL) are employed to develop a hybrid model to assess risk factors typically found in biomass industry to determine the top risks in order to put in place effective risk mitigation mechanisms to spur up the growth of the industry in Malaysia.

Keywords: • Oil palm biomass • Risk • Risk mitigation • FANP •. DEMATEL •

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1 Introduction

Malaysia, as the second world largest exporter of the oil and fat after neighbouring country, Indonesia produce about 20 million tonnes of crude palm oil per annum (MPOB, 2018). The palm oil biomass, such as oil palm trunk, oil palm frond, empty fruit bunches (EFB), palm oil mill effluent (POME), palm kernel shell (PKS), palm pressed fibre (PPF) and decanter cake are expected to reach 100 million dry tonnes by 2020 (AIM, 2013). At current stage, most of the palm oil biomass are still engaging with low utilization value process in downstream activities. For instances, oil palm frond and trunk are mostly left in the field or pre-process (i.e., mulched) and returned to the field as fertilizer. EFB, PKS generated in the palm oil mill and biorefinery are transformed into pellets for power generation. It is estimated by fully capitalise the palm biomass for high value-added downstream activities could contribute additional 30 billion to the country's gross national income (GNI). Recognizing its potential, the government has stepped up its efforts to promote sustainable utilization of oil palm biomass. Biomass Industry Strategic Action Plan is introduced in 2012 as a joint effort of Malaysia with European Union to help small and medium enterprises (SMEs) in Malaysia to exploit biomass resources for high-value utilization (MIGHT, 2013). National Biomass Strategy 2020 that introduce a series of strategy to exploit biomass for commercial opportunities. Furthermore, fiscal incentives such as tax rebate and tax exemptions are also offered to the new entrant to the industry. Financing scheme is also introduced in 2010 to provides financing aid for the user and producer of green technology project, inclusive biomass industry, wherein the government will provide 60 % of guarantee and subsidy 2 % of the total interest rate imposed on the total financing amount. Despite various actions and initiatives have been taken, the growth of the biomass industry in Malaysia is still relatively slow. Literature, anecdotal evidence and businesses have identified that one of the factors contribute to the slow diffusion of the industry is due to the high-risk profile of the industry. Biomass industry is a multidiscipline industry and thus associated with wide range of expertise and stakeholders. Yatim et al. (2017) identify that the industry does not only associated with financial, operation, technology risk as any other industry, it also exposes to five main risk categories, namely technology, financing, supply chain, regulatory, and environmental and social. Risk is generally defined as the product of probability of occurrences of risk event multiple with its impact or consequences. As biomass industry is a relatively new industry, there is still the lack of historical data to aid the estimation of the probability and impacts. Moreover, risk is exerting in both tangible and intangible as well as can be quantitative and qualitative event. Thus, in this work, Fuzzy Analytic Network Process (FANP) and Decision Making Trial and Evaluation Laboratory (DEMATEL) are adopted to develop a hybrid model to assess and prioritize risks to design the most effective solution.

2 Methodology

2.1 Background

Fuzzy Analytics Network Process (ANP) is a combination of fuzzy set theory and Analytics Network Process. Analytic Network Process is the generic form of Analytic Hierarchy Process (AHP) that developed by Saaty in the late 1980s (Saaty and Takizawa, 1986) ANP overcomes the constraint of AHP on unidirectional (i.e., top-to-bottom) problem structure to include feedback dependence and inner dependence in deriving the final composite priority through supermatrix approach. However, there have been increasing argument on the crisp value of the Saaty's traditional 9-point fundamental scale in elicit judgement on pairwise comparison questions. It is claimed that human judgement can be vague and ambiguity in time and not feasible to be fully represented with single crisp value (Promentilla et al., 2008). Thus, fuzzy membership function has often integrating with ANP on better representation of judgement with inclusion of the confidence level of domain in giving judgement. Fuzzy membership function is represented by a vector <l, m, u> wherein l is the lower bound of the judgement, m is the modal value and u is the upper level. The range of upper bound and lower bound (i.e., u-l) indicates the confidence interval of the domain in giving judgement, wherein huge gap signifies the domain is less certain about the judgements given and vice versa. Fuzzy set theory was first introduced by Zadeh (1965) to overcome the constraints of high uncertainty due to incomplete or insufficient information (Zadeh, 1965). Its application is wide extended to multiple field and industry ever since including in multiple criteria decision-making area to include uncertainties in the judgement given by domain. FANP is a powerful for multiple criteria decision making as it offer high flexibility in problem structuring. It enables a clear indication of dominance relationship between clusters, as well as inner relationship of elements in each cluster in fulfilling the overall goal.

On the other hand, Decision Making Trial and Evaluation Laboratory (DEMATEL) is first introduced by the Geneva Research Centre in 1972 (Gabus and Fontela, 1972). The main function of DEMATEL is to analyse the relationship of multiple elements in a complex system to determine the causal and dependency relationship based on expert knowledges. Its ability to analyse and visualize the relationship in matrices or digraph have attracted high attention in recent year in investigating and intertwined complex problems in various field, inclusive but not limited to business arena, research field etc. By recognizing and categorizing the variables into cause and effect factors, it enhances the decision making for optimal selection of the strategy to tackle the issues. The proposed model that integrating FANP and DEMATEL does not offers solution that solely based on the degree of dominance relation of the variables, but also synchronized with the causal and effect relationship in prioritizing risk. The outcome provides a comprehensive picture for the industry players to design the mitigation strategy that is most effective in managing the risk associated with the biomass industry. Meanwhile, policy makers can also utilize the information to put in place supports and mechanisms to reduce the risk barriers more effectively and efficiently to spur up the overall growth of the industry.

2.2 Model formulation

The proposed methodology consists of five main steps with the detailed explanation as follows:

Step 1: Literature review are performed to identify the risks associated biomass industry. Focus group discussion that consists of 8 to 15 participants is conducted to validate the findings from literature review and get extra inputs that are more relevant to Malaysia context. The focus group participants comprised of a good mixed of biomass industry stakeholders, including industry players, researchers, capital providers and policy makers to encourage discussion on the opportunity and challenges faced by different stakeholders in the biomass industry.

Step 2: The information gathered from stakeholders is then structured into a hierarchical model as shown in Figure 1. The hierarchical model consists of 3 levels, with the top level as the goal, to prioritize the risks for debottlenecking, followed by level 2, risk categories and level 3, risk events. The details for the identified risk events are described in Table 1. Arrows are used to represent the relationship of elements and level clusters associated in the model. Downward arrows (i) and (ii) show the direct dependency of the element(s) in the lower level with respect to the element(s) in upper level. Self-looping arrow (iii) indicates the inner dependency of the element with itself and other element(s) within the same level cluster. Self-looping arrow (iv) indicates the interdependency of element(s) with the other element(s) within the same level cluster. Feedback control loop arrows (v) and (vi) connecting all the element(s) back to the controlling element of the model, which is the goal. The purpose of feedback control loop is to ensure that the whole model is strongly connected to avoid judgements that are non-relevance to the purpose of study (Promentilla et al., 2008).

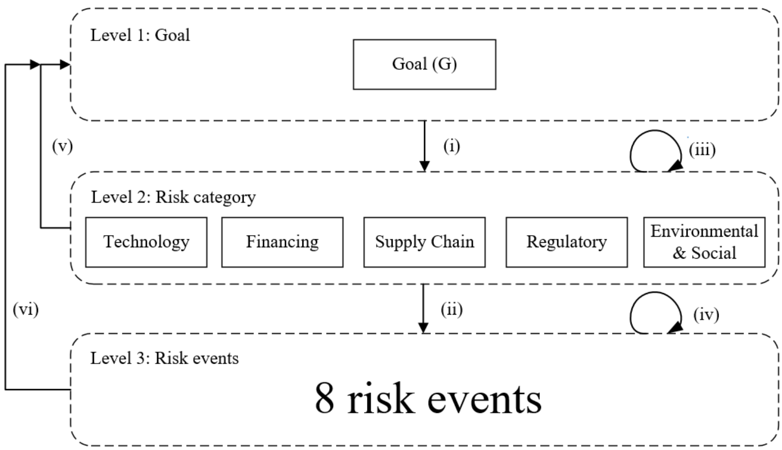

Figure 4: Diagraph of the hierarchical network model

Table 1: The description of the risk events in level 3

Code	Description
R1	Long pay back periods
R2	High upfront capital
R3	Inconsistent feedstock supply
R4	Lack of information to assess the performance of biomass project
R5	High logistics cost
R6	Lack of resources and capability to scale up to industrial level
R7	Lack of technical and safety standards for biomass plant
R8	Unclear regulations and policies related to biomass industry

Step 3: Elicit judgement from experts on the degree of the dominance relationship and intensity of influence power and being influenced through pairwise comparison questionnaires. The questionnaire is divided into two parts. The first section comprises of inputs for FANP to assess: (a) direct dependence of level 2 with respect to level 1; (b) direct dependence of level 3 element(s) with respect level 2 element(s); (c) inner dependence of element(s) in level 2. The second section consists of questions for DEMATEL to determine (d) the interdependence of the element(s) in level 3 and to identify (e) causal and effect factor on the element(s) in level 3. Linguistics scale is adopted in this work to compare the relative dominance relationship of elements and clusters. The description of the linguistics scale with its correspond value for FANP and DEMATEL methods are presented in Table 2 and 3.

Table 2: Fuzzy scale for FANP pairwise comparative judgement

Linguistic scale	Lower bound (l_{ij})	Modal value (m_{ij})	Upper bound (u_{ij})
Equally	1.0	1.0	1.0
Slightly more	1.2	2.0	3.2
Moderately more	1.5	3.0	5.6
Strongly more	3.0	5.0	7.9
Very strongly more	6.0	8.0	9.5

Table 3: Measurement scale for DEMATEL

Linguistic scale	Value
No influence	0
Very low influence	1
Low influence	2
High influence	3
Very high influence	4

Step 4: Derive the priority vectors and matrix to populate the initial supermatrix. The mathematic operation for both FANP and DEMATEL are associated with matrix, with procedures as described in the following. The fuzzy judgements from the first section (i.e. inputs for FANP) of pairwise comparison questionnaire are populated to form reciprocal matrix (i.e., $\hat{A}$) as the following:

$$\hat{A} = \begin{bmatrix} \langle 1,1,1 \rangle & \hat{a}_{12} & \cdots & \hat{a}_{1n} \\ \hat{a}_{21} & \langle 1,1,1 \rangle & \cdots & \hat{a}_{2n} \\ \vdots & \vdots & \ddots & \vdots \\ \hat{a}_{n1} & \hat{a}_{n1} & \cdots & \langle 1,1,1 \rangle \end{bmatrix} \text{where } \hat{a}_{ij} = \langle l_{ij}, m_{ij}, u_{ij} \rangle \quad (1)$$

$$; \hat{a}_{ji} = \langle \frac{1}{u_{ij}}, \frac{1}{m_{ij}}, \frac{1}{l_{ij}} \rangle$$

Geometric mean method is used to aggregate the judgements of multiple experts on the same pairwise comparison judgement prior forming the reciprocal matrix (Orbecido et al., 2016). Every relationship as indicated with arrow (i), (ii) and (iii) consists of its own matrices. The priority vector representing the final priority of the said relationship is derived with the non-linear programming (NLP) calibrated by Promentilla et al. (2015) as follows:

$$\text{Maximize } \lambda \quad (2a)$$

s.t.:

$$(m_{ij} - l_{ij})\lambda w_j - w_i + l_{ij} w_j \leq 0, \forall i = 1, \ldots, n-1; j = i+1, \ldots, n \quad (2b)$$

$$(u_{ij} - m_{ij})\lambda w_j - w_i + u_{ij} w_j \leq 0, \forall i = 1, \ldots, n-1; j = i+1, \ldots, n \quad (2c)$$

$$(m_{ij} - l_{ij})\lambda w_i - w_j + l_{ji} w_i \leq 0, \forall j = j, \ldots, n-1; i = j+1, \ldots, n \quad (2d)$$

$$(u_{ji} - m_{ji})\lambda w_i - w_j + u_{ji} w_i \leq 0, \forall j = 1, \ldots, n-1; j = j+1, \ldots, n \quad (2e)$$

$$\sum_{i=1}^{n} w_i = 1 \quad (2f)$$

$$w_i > 1, \forall i = 1, \ldots, n \quad (2g)$$

where in λ is the overall degree of satisfaction of the judgements and a measure of consistency. λ value is suggested to be within 0.0 and 1.0, which 1.0 indicates that the judgements achieve perfect consistency while 0.0 indicates that the judgements only satisfy at its boundary. In the event that λ appeared to be negative-value, it is suggested for the respective experts to revisit his/her judgements as some of the judgements are conflicting with each other.

The judgements for DEMATEL questions are populated to form direct relation matrix (D). Varying with the FANP matrices which is reciprocal, D is a square matrix that indicates the intensity of the influence power of the row element i with respect to column elements j. The diagonal value for D (i.e., when i=j) is equal to zero, as it is assumed that an element has no influence upon itself (Si et al., 2018). D is then normalized by divided with the largest value of its row to form direct relation matrix (M). All the possible interacting of the elements in M is then captured to derive total relation matrix as illustrated by following equation:

$$T = M + M^2 + M^3 + \cdots + M^n \approx M(I - M)^{-1}, \quad \text{when } n \to \infty \tag{3}$$

where M is the normalized direct relation matrix and I is an identity matrix.

Next, calculate the sum of row (R_i) and column (C_i) of the T, where R_i indicates the overall influence power of row's element, while (C_i) indicates the intensity of column's element being influenced by other elements. The sum of row and column (i.e., $R_i + C_i$) shows the degree of prominence of the element i in the overall cluster. Meanwhile, (R_i - C_i) indicates the net effects of the element i in the system. Element with a positive value for (r_i - c_i) is classified as cause factor while element with a negative value for (r_i - c_i) is categorized as effect factor. The overall prominence level and cause and effect relationship can be illustrated by plotting a digraph with ($R_i + C_i$) against (R_i - C_i). The total relation matrix is normalized by the largest value of its column prior populated to the supermatrix.

Step 5: The priority vectors derived from FANP method and total relation matrix derived from DEMATEL method (i.e., shaded in grey in Figure 2) are act as entry into the initial supermatrix with the order as illustrated in Figure 2. The supermatrix is multiple by itself until the values are converged. The final priority weightage for the model is presented in the last column of the matrix in Figure 2 (i.e., highlighted in yellow).

$$S = \begin{pmatrix} 1 & e^T\,(v) & e^T\,(vi) \\ w_{21}\,(i) & w_{22}\,(iii) & 0 \\ 0 & w_{32}\,(ii) & T\,(iv) \end{pmatrix}$$

Note:
w_k - FANP priority vectors
T - DEMATEL total relation matrices

	Goal	TC	FN	SP	RG	ES	R1	R2	R3	R4	R5	R6	R7	R8	final value
Goal	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.0000
TC	0.22	1.00	0.50	0.37	0.29	0.27	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.2396
FN	0.32	0.41	1.00	0.34	0.19	0.25	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.2994
SP	0.17	0.29	0.28	1.00	0.29	0.28	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.1849
RG	0.14	0.14	0.12	0.14	1.00	0.19	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.1335
ES	0.15	0.16	0.10	0.15	0.23	1.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.1425
R1	0.00	0.03	0.19	0.03	0.12	0.05	0.56	0.70	0.56	0.50	0.53	0.60	0.17	0.20	0.0930
R2	0.00	0.14	0.23	0.08	0.17	0.03	1.00	0.65	0.83	0.45	0.77	0.79	0.16	0.22	0.1157
R3	0.00	0.07	0.17	0.30	0.09	0.16	0.80	0.47	0.57	0.66	0.98	0.39	0.25	0.45	0.1105
R4	0.00	0.14	0.14	0.12	0.11	0.19	0.97	0.79	0.66	0.55	0.58	0.89	0.94	0.78	0.1555
R5	0.00	0.08	0.09	0.19	0.05	0.12	0.85	0.48	1.00	0.38	0.53	0.35	0.13	0.19	0.0913
R6	0.00	0.27	0.03	0.05	0.13	0.07	0.97	1.00	0.96	0.66	1.00	0.68	0.26	0.50	0.1442
R7	0.00	0.18	0.08	0.12	0.17	0.20	0.51	0.45	0.82	0.88	0.60	0.68	0.41	1.00	0.1391
R8	0.00	0.09	0.07	0.11	0.16	0.18	0.57	0.64	0.68	1.00	0.49	1.00	1.00	0.43	0.1507

Figure 2: The initial supermatrix with the final priority weightages

3 Result and Recommendations

Based on the final priority weightage, financing risk (29.94 %) appeared to be the most prominent risk category in hindering the overall development of the biomass industry, followed by the technology risk (23.96 %), supply chain risk (18.49 %), environmental and social risk (14.25 %) and regulatory risk (13.35 %). Biomass project often associated with high upfront cost, which set a high barrier to enter the industry. It is challenging for the industry players to receive financing or investment from capital providers to start-up the project, particularly for small and medium enterprises (SMEs) that are lack with liquidity and assets to serve as guarantee on the total financing amount. At current stage, the technology associated with high-value added conversion is still extremely expensive and yet to achieve cost reduction with production at economic-of-scale. Lack of the commercialize viable technology and uncertain of long-term performance of the technology intensify the technology risk.

Taking into the causal and effect of risk events in deriving the final priority weightage for the 8 risk events, “R4 Lack of information to assess the performance of biomass project” (15.55 %) ranked the first to be debottlenecked the commercialization of biomass value added products in Malaysia, followed with “R8 Unclear regulations and policies related to biomass industry” (15.07 %) and “R6 Lack of resources and capability to scale up to industrial level” (14.42 %). It is suggested for the government to initiate a centralized data system that congregate all the information related to biomass industry, inclusive but not limited to the price of the supply and demand, technology and process available, supports and incentives offered to the industry stakeholders and rules and regulation associated with the industry. Furthermore, clear, consistent and adequate regulatory framework with supporting policies are also necessary to provide essential information for the industry players to understand the industry as a whole and take advantage on the supports and incentives offered by government to manage the respective risks.

4 Conclusion and Future works

The paper proposed a novel methodology for the assessment and prioritization of the risk associated with Malaysia biomass industry. The hybrid model that integrating FANP and DEMATEL provides a systematic and transparent way to identify, analyse and evaluate the correlation between elements and clusters and pinpoint the causal and effect factors in the model. The results provide a reference for the industry stakeholders to design risk management plan that directly tackle prominence and causal risk, to achieve the maximum output with minimum input. Future work will be focus on extending the model to produce a comprehensive risk profile for the biomass industry in Malaysia. Extra risk events can be added to current model to provides more dimension on the risks associated with the industry. An extra level of mitigation strategy can also be added to select the most effective strategy. Case study will be developed to validate the effectiveness of the risk mitigation strategy on hedge, transfer and reduce risks associated with the biomass industry in Malaysia.

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