CHEMICAL ENGINEERING TRANSACTIONS

VOL. 70, 2018

A publication of
AIDIC
The Italian Association
of Chemical Engineering
Online at www.aidic.it/cet

Guest Editors: Timothy G. Walmsley, Petar S. Varbanov, Rongxin Su, Jiří J. Klemeš

ISBN 978-88-95608-67-9; **ISSN** 2283-9216

DOI: 10.3303/CET1870222

Integrating Stakeholder’s Role in Mitigating Risks for Future Cleaner Production

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Risk assessment and management has gained high interest in recently year, both in research field and business arena. It is mainly due to the advancement of information technology, amelioration of big data for artificial intelligence which made precaution more plausible and viable. With global movement to shift to cleaner production system, it also spurs up the development and adoption of various risk assessment and analysis tools that cater cleaner production project’s profile. As cleaner production system and infrastructures often engaged with high upfront cost, effective risk management and mitigations is deemed necessary to secure the high investment cost. Different methods have been proposed and developed in the past to diagnose and analyse potential risk events to recommend mitigation strategies. However, there is considerably less works incorporating the role of stakeholders in managing and mitigating risks. Every stakeholder plays different and yet crucial roles in the development of an industry, and each with their own strengths and weaknesses. It is imperative for the stakeholders to understand and uptake its strength in mitigating risk to avoid a waste of resources and efforts to act beyond their capability or power of influences. In this work, fuzzy analytical network process (FANP), and Decision Making Trial and Evaluation Laboratory (DEMATEL) are adopted to develop a hybrid model to evaluate risk mitigation strategies based on the role of industry stakeholders. The outer-dependency of the role of stakeholders and risk mitigation strategies are derived by pairwise comparison questionnaires of FANP with linguistic scale. On the other hands, the interdependency (i.e. dependency power, influence power) of the role of stakeholders and risk mitigation strategies are evaluated with DEMATEL. The outputs from FANP and DEMATEL are then combined with the composition of supermatrix to select the most effective mitigation strategy. This method provides a systematic way to incorporate the role of different stakeholders in enhancing the overall effectiveness of mitigation strategies.

1. Introduction

Climate change and energy security issue have been the world major concerns over the past decades. In relation with that, a series of long-term and short-term goals have introduced to combat these global sustainability issues together. Paris Agreement is by far one of the most influential target, for the world to keep the global temperature below 2 °C. Cleaner production is often cited as one of the best strategies to maintain the energy demand while significantly reduce the emission and long-term impact to the environment (Mizsey and Racz, 2010). UNEP (1990) defined cleaner production as the continuous application of an integrated environmental strategy to processes, products and services to increase efficiency and reduce risks to humans and the environment. It can be achieved by substitution of conventional technology and process with cleaner development mechanism or technology, optimising the process and supply chain for cost reduction, efficient use of energy resources and incorporate environmental factors in its overall production chain. As cleaner production project often associated with high upfront cost and longer project life, risk management is recognized

Please cite this article as: Ngan S.L., How B.S., Promentilla M.A.B., Yatim P., Lam H.L., 2018, Integrating stakeholder’s role in mitigating risks for future cleaner production , Chemical Engineering Transactions, 70, 1327-1332 DOI:10.3303/CET1870222

as one of the most important element in decision making related to the project (Dehdasht t al., 2017). Malaysia, the major producer and exporter of palm oil product worldwide consists a significant amount of oil palm biomass residues from oil palm plantation and palm oil mill that can be best utilized as a form of cleaner production. Biomass industry that brought together multidisciplinary area to convert biomass waste into value-added product and energy associates with a wide range of risks and stakeholders, and thus, add complication on the selection of the best risk mitigation strategy. There are a vast number of researches focus on the application of oil palm biomass (Lam et al., 2015), integration and optimization of biomass supply chain (How et al., 2015), development and improvement of process and technology associated with palm oil mill and biorefinery (Foong et al., 2018) etc. However, there are very less studies focus on risk management of Malaysia oil palm biomass industry, particularly on integrate the role of the stakeholders in the prioritization of risks. Thus, in this work, Fuzzy Analytic Network Process (FANP) and Decision Making Trial and Evaluation Laboratory (DEMATEL) are combined to develop a hybrid model that incorporate the strength and weaknesses of stakeholders to access the risks associated with the biomass industry.

DEMATEL method has long established back in 1970s by the Geneva Research Centre of the Battelle Memorial Institution to analyse the casual and effect relationship of complex problem or system (Gabus and Fontela, 1972). It is well recognized as a powerful tool in analysing interdependency to identify causal and effect factors out of a group of variables (Si et al., 2018). It also enables visualisation of the relationship through the representation of matrices and digraph. On the other hand, FANP is a combination of fuzzy set theory with Analytics Network Process developed by Saaty in late 1980s. ANP is the generalization of Analytics Hierarchical Process (AHP) that overcome the limit of top-to-bottom problem structure (Saaty and Takizawa, 1986). The integration of fuzzy set theory in ANP allows the level of dominance relationship and confidence level of human judgements to be expressed more precise and accurately. The core operation of ANP, supermatrix approach allow the all the possible relationship (i.e. direct dependence, feedback dependence, inner dependence) of elements in the model to be included to derive final priority weightage. The proposed methodology combines the strengths of two multiple criteria decision analysis tools to analyse a complex problem in a more systematic and transparent way.

2. Methodology

The procedure of methodology for the hybrid model is illustrated in following Figure 1:

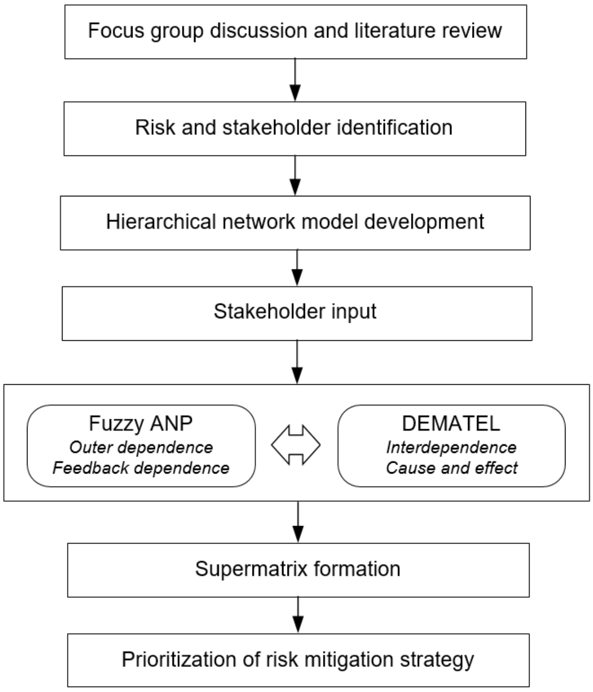
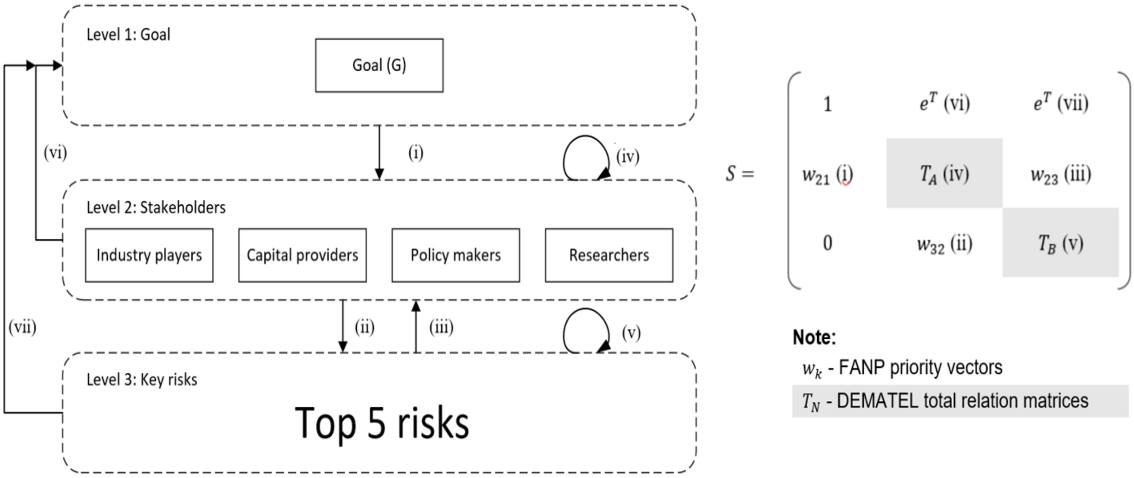


Figure 1: Methodology flow chart

Step 1: Literature review is performed to identify the risks related to biomass industry. Based on Yatim et al. (2017), biomass industry is closely associates with five key risks, namely technology risk, financing risk, supply chain risk, regulatory risk and environmental and social risk. Focus group discussion is conducted to gather industry stakeholders to verify and validate literature finding and provide extra inputs on the risks associated with the industry. The roles of each stakeholders in the overall development of biomass industry are also discussed.

Step 2: The problem of the study is constructed into a hierarchical network model as illustrated in Figure 2. The model of this study consists of 3 levels, with the top level as the goal, to determine the importance of risks to be mitigated. Level 2 comprises of the main stakeholders of the biomass industry (i.e., industry players, capital providers, policy makers, researchers) and level 3 is the top five risks identified in the previous step. Different arrows are used to represent the relationship of the levels and elements in the model. Downward arrow indicates the direct dependency of the element(s) in lower level cluster with respect to element(s) in the upper level cluster. Upward arrow indicates the feedback dependency of the element(s) in upper level cluster with respect to element(s) in the lower level clusters. Self-loop arrow in the level cluster representing the interdependency of the elements in the cluster itself. Last but not least, feedback control loop, connecting all the elements back to controlling element of the model (Promentilla et al., 2008).

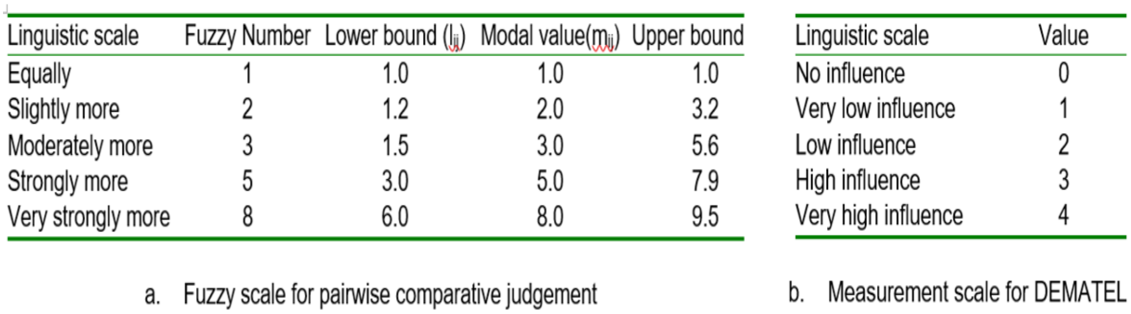


$$S = \begin{pmatrix} 1 & e^T \text{ (vi)} & e^T \text{ (vii)} \\ w_{21} \text{ (i)} & T_A \text{ (iv)} & w_{23} \text{ (iii)} \\ 0 & w_{32} \text{ (ii)} & T_B \text{ (v)} \end{pmatrix}$$

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

Figure 2: Hierarchical network model and its supermatrix representation.

Step 3: Elicit judgements from experts and industry stakeholders on the level of dominance relationship between elements and clusters with questionnaires. The questionnaires are divided into two parts, with the first part of FANP pairwise comparison questions to determine: (a) the importance of stakeholders in mitigating risks, (b) the importance of key risks based on each stakeholder and (c) the degree of effectiveness of stakeholders in mitigate key risks enlisted in level 3; and second part, the DEMATEL questions to evaluate (d) the interdependency of stakeholders and (e) the interdependency of risks. Linguistics term are adopted for the questionnaires and the value associated with the linguistic terms are described in Figure 3.



Linguistic scale	Fuzzy Number	Lower bound (l_{ij})	Modal value(m_{ij})	Upper bound
Equally	1	1.0	1.0	1.0
Slightly more	2	1.2	2.0	3.2
Moderately more	3	1.5	3.0	5.6
Strongly more	5	3.0	5.0	7.9
Very strongly more	8	6.0	8.0	9.5

a. Fuzzy scale for pairwise comparative judgement

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

b. Measurement scale for DEMATEL

Figure 3: Linguistic scale for Fuzzy ANP and DEMATEL

Step 4: After eliciting judgements from experts, the judgements are converted into priority vectors (i.e., outputs of FANP) and total relation matrices (i.e., outputs for DEMATEL) to populate supermatrix. Even though the mathematic operation for both FANP and DEMATEL involves matrices, the calculation steps are different and described as follows:

For FANP questions, fuzzy judgement represented in the form of a vector as <l,m,u>, where l is the lower bound, m is the modal value, and u is the upper bound of the judgment. The judgements are converted to form reciprocal pairwise comparisons matrices (i.e., $\hat{A}$) based on the following formula:

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

Every relationship in the model is represented by a reciprocal matrix, namely local priority matrix. Non-linear programming that calibrated by Promentilla et al. (2015) is adopted in this work to generate the priority vector for each local priority matrix. The priority vectors are derived to maximize the overall degree of satisfaction, λ as described in the following equation:

$$\text{Maximize } \lambda \tag{2a}$$

s.t.:

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

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

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

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

$$\sum_{i=1}^{n} w_i = 1 \tag{2f}$$

$$w_i > 1, \forall i = 1, \dots, n \tag{2g}$$

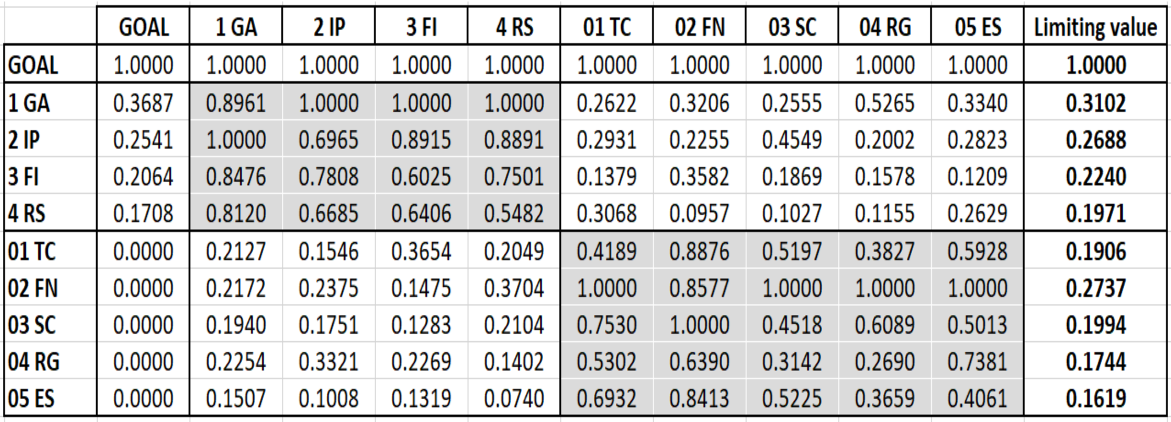
λ that fulfills the above conditions also acts as a measure of consistency. It is suggested that λ value to be in between 0 and 1, where λ closer to 1 signifies better consistency, while λ value equal to 0 means the judgements only satisfy at its boundary (Tan et al., 2014).

The judgements collected through DEMATEL questions are populated into a square matrix, namely direct relation matrix (D). Varying with the reciprocal local priority matrix as populated with FANP method, D indicates the intensity of influence of elements in row i with respect to the elements in column j. The value of the diagonal elements (i.e. i=j) of the matrix is equal to zero, as an element has no influence upon itself. The direct relation matrix is then normalized by divided with the largest row sum to form normalized direct relation matrix (M). Next, convert M to form total-influence matrix, (T) with the following formula:

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

where M is the normalized direct relation matrix and I is an Identity matrix.
The sum of row $(R_i)$and column (C_i) of the T are calculated, where (R_i) represents the influence power of row's element in the system, while (C_i) represents the intensity of column's element being influenced by other elements in the system. The cause and effect relationship of the elements can be visualized by plotting the $(R_i + C_i)$ against $(R_i - C_i)$ in a digraph. The horizontal axis, $(R_i + C_i)$ indicates the prominence of the element in the overall system, while $(R_i - C_i)$ indicates the net effects of the element in the system. The element with positive value for $(r_i - c_i)$ is classified as cause factor, while element with negative value for $(r_j - c_j)$ is categorized as effect factor. The total relation matrix is then normalized by dividing the maximum value of the column prior populated to the supermatrix.

Step 5: Priority vectors (i.e. w_k) derived from FANP and normalized total relation matrix (i.e. T_N) from DEMATEL are then populated into initial supermatrix based on the order as described in Figure 1b. For example, w_{21} is the priority vector representing the importance of different stakeholder (i.e. level 2) in manage and mitigate risks (i.e. the goal, level 1). w_{32} is priority vectors representing the degree of importance of the risks (i.e. level 3) with respect to each stakeholder (i.e. level 2). w_{23} is priority vectors representing the degree of effectiveness of stakeholders in mitigate and manage the risks. T_A is the normalization total relation matrix showing the interdependency relationship amongst different stakeholders while, T_B is the normalization total relation matrix representing the interdependency relationship amongst the risks. e^T is an unit row vector (i.e. [1,…,1]) that acts as an entry for feedback control loop to create a stronger bonding of the multiple level model. The initial supermatrix is illustrated in Figure 4. The supermatrix is then raised to the power until its value converged (i.e. limiting value). This process implies that all the possible interaction and movement of the elements in the model are captured in deriving the final priority weightage.



	GOAL	1 GA	2 IP	3 FI	4 RS	01 TC	02 FN	03 SC	04 RG	05 ES	Limiting value
GOAL	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	**1.0000**
1 GA	0.3687	0.8961	1.0000	1.0000	1.0000	0.2622	0.3206	0.2555	0.5265	0.3340	**0.3102**
2 IP	0.2541	1.0000	0.6965	0.8915	0.8891	0.2931	0.2255	0.4549	0.2002	0.2823	**0.2688**
3 FI	0.2064	0.8476	0.7808	0.6025	0.7501	0.1379	0.3582	0.1869	0.1578	0.1209	**0.2240**
4 RS	0.1708	0.8120	0.6685	0.6406	0.5482	0.3068	0.0957	0.1027	0.1155	0.2629	**0.1971**
01 TC	0.0000	0.2127	0.1546	0.3654	0.2049	0.4189	0.8876	0.5197	0.3827	0.5928	**0.1906**
02 FN	0.0000	0.2172	0.2375	0.1475	0.3704	1.0000	0.8577	1.0000	1.0000	1.0000	**0.2737**
03 SC	0.0000	0.1940	0.1751	0.1283	0.2104	0.7530	1.0000	0.4518	0.6089	0.5013	**0.1994**
04 RG	0.0000	0.2254	0.3321	0.2269	0.1402	0.5302	0.6390	0.3142	0.2690	0.7381	**0.1744**
05 ES	0.0000	0.1507	0.1008	0.1319	0.0740	0.6932	0.8413	0.5225	0.3659	0.4061	**0.1619**

Figure 4: The initial supermatrix populated with priority vectors derived from FANP and total relation matrix generated from DEMATEL with its final limiting value.

3. Result and discussion

The final priority weightages for this work are presented in the limiting value column in Figure 4. Based on the outcome, financing risk (0.2737) is ranked the first as the risk need to be mitigated for palm oil biomass industry, followed by supply chain risk (0.1994), technology risk (0.1906), regulatory risk (0.1744) and environmental and social risk (0.1619). Most of the biomass related projects are engaged with high upfront cost and long payback period due to the complication of its process and less commercialize technology (Luiz et al., 2016). Industry players often suffer with limited capital resources to start-up the business, and to meet the debt obligations during the operation period. Furthermore, the information about the supply, demand, cost related with biomass industry in Malaysia are rather scattered, with lack of centralized data system to consolidate them for further analysis and interpretation (NEPCon, 2016). This increase the difficulties for capital providers to accurately analyse and forecast the industry's financial performance to customize financial services and products that suit the industry's attribute. Supply chain risk arises with interruption of flow of good, information, services to secure continuous operation of a business. The uncertain of consistent long-term biomass supply, fluctuation of price and demand of biomass value-added product, high logistics cost are some example of supply chain risk events that closely associated with oil palm biomass. It is necessary for the industry players to understand the overall flow of the products and relationships of the stages of the production to optimize the process to maximize output at minimum cost. As biomass production is still relatively new as compare to conventional energy industry such as gas and coal, the industry is still highly relying on oversea technology which is very expensive. Local manufactured technologies that are mainly for research and product development purpose still facing scalability issues to convert to industrial scale (Kemp and Volpi 2008). Researchers should work closely with the industry players to bridge the gaps to help the transition of these technologies from laboratory setting to commercial production. Various incentives and supports are offered by worldwide organization and the government to encourage the uptake of cleaner production. In order to enjoy these incentives, industry players are subject to compliance with the relevant rules and regulations. Regulatory risk arises with a change in regulations and policies that directly or indirectly affect the performance of the project, industry and market. Environmental and social risk is the potential threat to the ecological, environment and social well-being caused by the industry. Policy makers play the key role to manage both the regulatory risk and environmental and social risk. It is important for policy makers to encourage the adoption of sustainable practices through enacts rules and regulation for the long-term economic, environmental and social benefits. Regardless of the dominance role of different stakeholders on managing respective risk, the close gaps between the limiting value (i.e., policy makers – 0.3102; capital providers – 0.2688; capital providers – 0.2240; researchers – 0.1971) suggests that all stakeholders are playing significant role in mitigating risks for the biomass industry. Thus, it is necessary for stakeholders to collaborate and work together to create synergy in managing risks associated with the palm oil biomass industry.

4. Conclusions

The proposed model that combines FANP and DEMATEL provides a systematic and transparent way for the stakeholders to prioritize the risk to be mitigated. Even though FANP is This method does not only take in consideration of the importance and dependency of risk with respect to the goal, but also included the strength and weaknesses of each stakeholder in mitigate and manage the risk. Thus, provides a new dimension for the stakeholders to design and execute risk management plan and policy that in accordance to the strengths of the respective stakeholder group. Future work will be focus on applying the proposed model in a case study, to compare the net present value of the project with and without risk mitigation plan.

Acknowledgments

The authors would like to thank Long Term Research Grant Scheme (LRGS Code: LRGS/2013/UKM-UKM/PT/06) from Ministry of Higher Education (MOHE), Malaysia, Universiti Kebangsaan Malaysia (UKM) and University of Nottingham Malaysia Campus for the funding of this research.

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