A Systematic Literature Review of Multi-Criteria Analysis Model Methods on Sustainability Weighting for Ethanol Plant

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The sustainability weighting is crucial as it is practically implemented into sustainability evaluation, especially in industrial development. Sustainability is about the interconnection between three aspects of sustainability impact such as economic impact, environmental impact, and social impact. Multi-Criteria Analysis (MCA) model play important roles to measure the weighting for each impact according to the scenario and criteria selected based on scientific rules and robust statistical methods. However, there were insufficient studies on the existing literature sustainability weighting model from MCA method for the ethanol plant. Hence, the present paper demonstrates a systematic literature review of MCA model methods on sustainability weighting for the ethanol plant. There are two steps involved in systematic literature reviews: formulation of the research question and systematic searching strategies consisting of identification, screening, eligibility, quality appraisal, data abstraction and analysis. The review is based on leading databases; Scopus – ScienceDirect, Springer, Taylor and Francis, and one supporting database – Google Scholar. From the review, the preferable MCA weighting model for sustainability evaluation of ethanol plants is 'integrated Analytical Hierarchy Process (AHP)' rather than 'standalone AHP'. The paper offered a significant contribution to the body of knowledge and sustainability evaluation purposes.

Keywords: systematic literature review; ethanol plant; multi-criteria analysis; Analytical Hierarchy Process (AHP); weighting

I. INTRODUCTION

Sustainability has become a trending topic that has attracted many researchers, stakeholders and policy makers as the world needs to be preserved for our future. According to the 2030 agenda for sustainability development, there are 17 sustainability development goals (SDG's) agreed by 193 member states of the United Nations. The SDG represents a leading tool of action for the planet, people and prosperity. It is also integrated and balances the three dimensions of sustainable development, which are economic, environmental and social. SDG is executing globally, and the impacts of industrial process plants are subjected to 9 goals such as, the social impacts produced by industrial plants will affect human health and safety, therefore Goal 3 (good health and well-being) and Goal 11 (sustainable cities and communities) support in reducing impacts to ensure healthy lives at all ages and making their surrounding area safe, resilient and sustainable. Next, are present again for environmental impact, in Goal 6 (clean water and sanitation), Goal 7 (affordable and clean energy), Goal 9 (industry, innovation and infrastructure), Goal 12 (responsible consumption and production), Goal 13 (climate action), Goal 14 (life below water), Goal 15 (life and land) promoted to build inclusive, resilient and sustainable pollution management (United Nations, 2020). Moreover, the goals also protect the ecosystem as well as urge everyone to take action to combat climate change and its impacts. The stricter

policy will increase the concern to industry in making this world less polluted, social friendliness, but at the same time reduce the cost for economic benefit.

The objective of this study is to determine the MCA models for sustainability assessment purposes. The selected industrial plant for this study is the ethanol plant. There are two methods to produce ethanol, by petrochemical process or by fermentation. Roozbehani *et al.* (2012) stated that the ethanol plant is one of the important contributors to country economies as their energy security strategies enable to accomplish the demand for medical purposes such as antibacterial hand sanitiser gels and medicinal solvents due to ethanol's ability to kill organisms by denaturing proteins and dissolving their lipids. The effectiveness against most bacteria, fungi and viruses is also supported by Golin *et al.* (2020). Other than that, synthetic ethanol is commonly used as a clean-burning fuel source, chemical/industrial solvent and vital substance in manufacturing industries. The fuel additive from ethanol production successfully received interest from academics, researchers, and industrial experts (Abedin *et al.,* 2016). Some of the past researchers concluded that the usage of less than 40% of ethanol together with emulsifier or co-solvent should work together in blended fuel to maintain the stability of diesel (Pidol *et al.,* 2012) hence, reducing harmful emission of CO, CO2, SOx, smoke opacity and particulate matter.

The sustainability of the petrochemical process plant is another significant issue due to its sustainability is varied from biorefinery plants in terms of raw material used, which are from petrochemical sources. Some of the ways to minimise the sustainability impacts of the petrochemical plant are by tracking the wastes that come from the operation, incorporate some recycling routes and introducing MCA at the early stage of plant design (Serna *et al.,* 2016). The framework for sustainability assessment is important as to ensure decision-makers can justify their task by providing qualitative and quantitative analysis; hence, the best solution will be chosen systematically. According to Behzad *et al.* (2019) and Singh *et al.* (2012), sustainability is evaluated from indices and rating systems such as the selection of appropriate indicators (environmental, economic, social and technical criteria), normalisation, criteria weighting, aggregation and sensitivity analysis. The consequences of

poorly conducted indices and weighting is it will lead to misinterpreted and misleading results.

MCA has attracted researchers to its potential usefulness for sustainability weighting evaluation. In the recent study by Martinkus *et al.* (2019), MCA methods have been used for decision-making due to their ability to analyse qualitative and quantitative data simultaneously. Some of the purposes of MCA methods are to use criteria value for further assessment, to determine a problem, to define the significance of each criterion, and to evaluate alternatives in scale values. MCA has the characteristics of simplicity and clear judgment of the correlation between criteria and a powerful tool for balancing stakeholder principles and priorities with respect to multiple criteria and provides useful guidance to help the dynamic decision-making process. Over the past 20 years, MCA methods have become a reliable solution for decision analysis, especially in engineering, management, and other fields. H. Wang *et al.* (2017) stated that MCA had been used in many fields of science, such as environmental resource management. However, the most important before evaluation are selection of the model, type of weighting mechanism and treatment/solution of missing value as they can be varied based on appropriate communities of interest.

II.   MATERIALS AND METHOD

A. Formulation of Research Question

PICo has been used as a tool to guide authors in formulating research questions for the review study. There are three main concepts of PICo for social science purpose, which are Population, Interest, and Context based on Samsuddin *et al.* (2020) study. Meanwhile, for clinical purpose, different PICo which involved Population, Intervention, Context and Outcome, have commonly been used to aid researchers and healthcare practitioners to determine potential risks of bias and evidence related to diseases in the literature (Davies, 2011). For this study, the research question was determined by following social science's PICo concepts, namely researcher and industrial (Population), MCA models for sustainability weighting (Interest) and ethanol plant (Context). It will then be formulated to – What are the MCA models for sustainability weighting practiced by researchers and industrial in ethanol plants?

B. Systematic Searching Strategies

The systematic searching strategies have five main processes, which are identification, screening, eligibility, quality appraisal, and data abstraction and analysis.

1. Identification

The identification process involved searching synonym keywords for related terms of the main keywords. For this study, the synonym of main keywords, namely Multi-Criteria Analysis or MCA, ethanol plant, chemical plant, weighting and sustainability, will be searching for more findings on related articles. The identification process was based on Research Question. The process also used some keywords by past researchers or suggested by the main database and online thesaurus.

The full search string can be developed by authors by expanding the existing keywords using Boolean operator, phrase searching and a wild card on the main databases, namely Scopus - Science Direct, Springer and Taylor and Francis. The advantage in using three databases is due to their high number of articles published yet acknowledged for their article's quality, advanced searching functions offered, and multidisciplinary focus, including studies related to sustainability. Google Scholar is chosen as an additional database because, according to Gusenbauer, (2019) about 389 million documents are available in that database and hence, give an advantage for researchers to search the related articles.

Based on this searching process, 2595 articles were found related to the research question. Combination of keywords searching were aid by Boolean operator (AND,OR) and some truncation character ({}, (), " , *). However, truncation or wild card such as asterisk (*) code is not supported for Elsevier searching database during this study. Even though the '*' code play an important role in widen the words searching, for example, "sustainabl*" for sustainable, but it can be resolved by adding the word sustainable or other synonymous words, next, system will give you the same outcome as desired. The other factor that led to three search strings for article searching was the Boolean operator's restriction to eight uses only. The three relationships were:

    i.   MCA - weighting -plant
    ii.   Sustainability - weighting - plant
    iii.   Sustainability - MCA - plant

The other limitation arose in Springer and Taylor & Francis quest process; there were insufficient articles and book chapters if they were narrowed down using the TITLE-ABS-KEY formula. If one of the formulas does not exist in the search strings, manual selection is required based on the title, abstract and keyword. Some of the search strings used for this study:

Table 1. Search strings according to database

Database	Search String
ScienceDirect	(("multi criteria analysis" OR "MCA" OR "multi criteria decision" OR "multi objective") AND ("weighting" OR "sustainable weight" OR "weighting score") AND ("chemical plant" OR "ethanol plant"))
	TITLE (("environment" OR "economic" OR "social" OR "sustainability") AND ("weight" OR "weighting" OR "sustainable weight or score") AND ("chemical plant" OR "ethanol plant"))
	(("environment" OR "economic" OR "social" OR "sustainability") AND ("multi criteria analysis" OR "MCA" 'OR "multi criteria decision") AND ("chemical plant" OR "ethanol plant"))
Springer	TITLE (("multi criteri* analysis" OR "MCA" OR "MCDA" OR "multi criteri* decision*" OR "multi objectiv*") AND ("weighting*" OR "sustainabl* weight*" OR "weighting scor*") OR ("environment*" OR "economic*" OR "social*" OR "sustain*") AND ("chemical plant" OR "ethanol plant"))
Taylor & Francis	TITLE-KEY(("multi criteri* analysis" OR "MCA" OR "MCDA" OR "multi criteri* decision*" OR "multi objectiv*") AND ("weighting*" OR "sustainabl* weight*" OR "weighting scor*") OR ("environment*" OR "economic*" OR "social*" OR "sustain*") AND ("chemical plant" OR "ethanol plant"))
Google Scholar	(("multi criteria* analysis" OR "MCA" OR "MCDA" OR "multi criteria* decision*" OR "multi objective*") AND ("weighting*" OR "sustainable* weight*" OR "weighting scor*") AND ("chemical plant" OR "ethanol plant" OR "oleochemical plant")

2. Screening

A screening process is a process in which requirements for inclusion and exclusion have been distinguished based on the time range (year), language, type of document and

application area. Table 2 shows the details of the screening sorting process for this study.

Table 2. List of inclusion and exclusion in screening process

Criteria	Inclusion	Exclusion
Period range	2012-2019	< 2012
Language	English	Non – English
Document Type	Article journal (empirical data)	Article review, chapters in book, conference proceeding
Application area	Chemical plant or industrial	Non-industrial

The proposed research-based screening method is important since impossible for researchers to review large numbers of articles (Kitchenham & Charters, 2007). The timeline restriction was from 2012 until 2019 due to the study had been done during the year 2020 and the year still not ended yet this study according to Samsuddin *et al.* (2020). Other than that, a lot of research regarding weighting for sustainability evaluation bloom in 2012 onwards.

In addition, conference proceedings, paper analysis and book chapters were excluded through screening process, and only article journals that have analytical evidence and are related to the chemical industry are selected in this research. To prevent confusion during data analysis, English publication is also one of the inclusive requirements rather than other languages.

Through this process, 2242 articles were omitted as they did not meet the inclusion requirements, and due to overlap, 4 articles were deleted by using Systematic Review Accelerator - Deduplicate Module Software. The remaining 349 articles were used for further process, which is eligibility.

3. Eligibility

Eligibility is the process where the authors deduce the number of articles manually as exclusion criteria and at the same time, ensure the remaining articles fulfil all criteria. The abstract and title of the articles were monitored, and 286 articles were excluded due to:

i. Emphasis on the non-chemical industry
ii. Focus on either one impact rather than three sustainability impacts
iii. Focus on non-engineering rather than chemical plant areas
iv. Type of papers- book chapters or review paper

In this phase, only 61 articles were selected.

4. Quality appraisal

The quality of articles will be presented by quality assessment. The remaining articles were ranked according to the ability to answer all the questions below:

1. Has the multi-criteria methods been discussed in detail?
2. How the method measures for weighting proposes?
3. Has the study related to sustainability?
4. If the study was related to sustainability evaluation of chemical plant, what was the common mca method?

There are three articles' levels based on Samsuddin *et al.* (2020) namely high, moderate, and low. The remaining articles will be categorised, and only articles in two classifications, such as high and low, will be reviewed. The quality rank should be focused on MCA methods for sustainability assessment in chemical plants. This process had ranked 29 articles as high, 16 articles as moderate and 16 articles as low. The remaining 45 articles were eligible for review at both high and moderate levels.

5. Data abstraction and analysis

Twenty-two articles including diverse research designs such as qualitative, quantitative and mixed-method approaches were chosen after the inclusion and exclusion procedure. The researcher will read particularly on abstract, results and discussions to ensure any information and data found should be reflected and answer the research question. Next, iterative comparison can be computed and tabulated between abstracted data as per below relationship:

i. What is the type of MCA method used for study?
ii. Is there a weighting score of sustainability stated?
iii. How are the papers are related to chemical plants?
iv. Do papers discuss MCA together with its implementation?
v. Why usage of MCA is related to sustainability?

The descriptive method in the thematic form will reduce the finding and help the researcher to merge with other data analysis techniques (Samsuddin *et al.,* 2020). The flow diagram (Figure 1) demonstrates systematic review as per shown below:
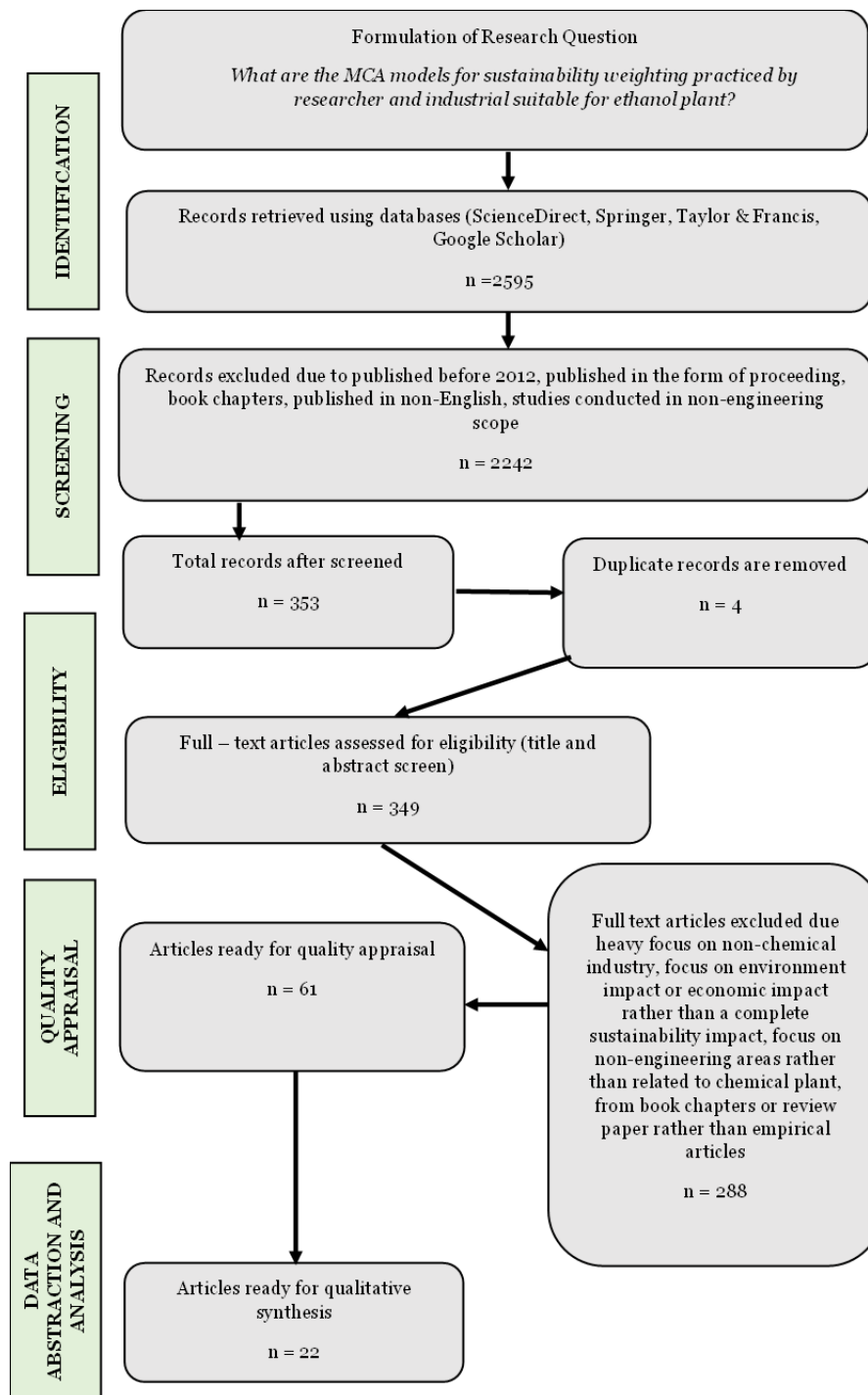
Figure 1. Systematic Literature Review (SLR) flow diagram (adapted from Samsuddin *et al. (*2020))

III.   RESULT AND DISCUSSION

A. Review Findings

Based on   Table 3 shown below, 22 final articles were abstracted and analysed to fulfil the objective as to determine the suitable MCA models for sustainability weighting of ethanol plant. The number of articles for process plants, including chemical plants, industrial plants and other plants are 11, 7 and 4 articles. All relationships based on research questions were addressed in about 12 papers meanwhile, others only listed two of the relationship.

Table 3. Tabulated data findings referring to research questions

STUDIES (REF.)	YEARS	APPLICATION AREA/SCOPE	RELATIONSHIP WITH BELOW:			METHODS IMPLEMENTATION	WEIGHTING SCORE
			WG	SUST	PL		SUST (all)
IKE C *et al.*	2016	CP	x	x		AHP	
BEHZAD *et al.*	2018	CP	x	x	x	AHP, LIKERT	x
RANJAN *et al.*	2014	CP		x	x	DELPHI	
NATALIE *et al.*	2019	CP	x	x	x	AHP	x
HOW BIN SHENG *et al.*	2018	CP	x	x	x	AHP	x
FELICE *et al.*	2013	IP	x	x		AHP	
ANTONIO *et al.*	2012	OP	x	x		AHP	x
FAISAL *et al.*	2014	IP	x	x	x	FUZZY	
JEONG *et al.*	2017	CP	x	x		AHP, FUZZY, DEMATEL	x
KATIA *et al.*	2019	CP	x	x	x	DELPHI	
RUOJUE *et al.*	2019	OP	x	x	x	BWM, AHP	
MATHIYAZHAGAN *et al.*	2017	IP	x	x		AHP, FUZZY, DEMATEL	
MATZEN *et al.*	2015	CP	x	x	x	PUGH	
HS QI *et al.*	2013	CP	x	x	x	FUZZY	
JINGZHENG *et al.*	2014	CP	x	x	x	FUZZY	
YAZDI *et al.*	2018	IP	x	x	x	FUZZY, AHP	x
YAZDI *et al.*	2017	CP	x	x	x	FUZZY, AHP	
ROBERT *et al.*	2018	IP	x	x		SCORE	x
HAO WANG *et al.*	2017	OP	x	x	x	FUZZY, AHP	
LEI WANG *et al.*	2018	IP	x	x		FUZZY, AHP	
ZHAOYANG *et al.*	2019	OP	x	x		AHP	x
FU ZHAO *et al.*	2012	IP	x	x		AHP	

CP = Chemical Plant	SUST = sustainability	AHP = Analytical Hierarchy Process
EP = Ethanol Plant	WG = weighting	DEMATEL = Decision Making Trial and Evaluation Laboratory
OP = Other Plant	PL = plant	TOPSIS = Technique for Order Preferences by Similarity to Ideal Solutions
IP = Industrial Plant		

B. Relationship between MCA and Other Criteria

1. Relationship between MCA and process plant

Out of 22 selected papers, there are three kinds of process plants such as chemical plants, industrial plants and other plants. Due to the lack of petrochemical ethanol plants in MCA study, several papers have been selected that may be relevant to the ethanol plant. In biorefinery plants, most past researchers discuss the system of sustainability with focus on biomass supply chains, site selection, biomass process in biorefinery site and sustainability assessment methodologies (How & Lam, 2018; Jeong & Ramírez-Gómez, 2018a; Jesus *et. al.,* 2019a; Martinkus *et. al.,* 2019a; Parajuli *et al.,* 2015a). Analytical hierarchy process (AHP) has been used by How & Lam (2018) as to determine the priority scale assigned to solve supply chain problem in transportation and technology selected for a case study in Johor, Malaysia. Jeong & Ramírez-Gómez, (2018) and Martinkus *et al.* (2019) also

implement AHP to determine the weighting factor and a pairwise comparison to measure the comparative significance of each sustainability parameters for developing final site selection for biomass process plant. Meanwhile, the DELPHI method presented in the form of web questionnaires has been used by Jesus *et al.* (2019) and Parajuli *et al.* (2015) to two groups: academic experts and industry experts for sustainability purposes in bioethanol plant. Some petrochemical plants use a combination of Fuzzy and AHP in their study to evaluate the risk process for an ethylene plant. It helps stakeholders/decision-makers accept initiatives by incorporating goal programming, AHP and Fuzzy theory. The hybrid approaches were also used to illustrate the prioritisation of hydrogen economy roadmap design plans, adequate budget preparation, and resources allocation to support China's hydrogen economy (Ren *et. al.,* 2015; Yazdi & Kabir, 2017a).

For this review, industrial plants reflect the civil and manufacturing sectors, such as automotive, electronic factories and marine sectors. The purpose of AHP as one of the MCA models is to define the critical factors required to assess the "degree" of environmental sustainability, such as energy-saving, environmental impacts and percent recyclable content (De Felice *et. al.,* 2013a; Zhao *et al.,* 2012). Meanwhile, the combination of AHP-Fuzzy and DEMATEL has been used for risk analysis in offshore process industries to resolve ambiguity in failure data as well as to assess the dependency between incidents. Other than that, it was also used in shipping safety investment decision-making for marine facilities (Mathiyazhagan *et. al.,* 2018; L. Wang *et. al.,* 2018; Yazdi & Kabir, 2017). For other plants category, it represents plants that provide energy supply and source management. In choosing the best approach for energy sustainability evaluation and water management, the studies used the same method – AHP for MCA. However, for energy sustainability, the past researcher added one more method which is Best-Worst-Method (BWM) (Freitas & Magrini, 2013; Lin *et. al.,* 2019a; Yang *et al.,* 2019). However, H. Wang *et al.* (2017) use an integrated approach for groundwater management decision-making, which was a hybrid of AHP-Fuzzy, to reflect the uncertainties that occurred with weights of criteria.

2. Relationship between MCA and sustainability purpose

Decision-making for sustainability requires assessing different criteria considering three common sustainability dimensions, such as economic, environmental and social dimensions. All selected articles address sustainability together with MCA and from the analysis, less than fifty percent of articles include all three elements of sustainability. There are three categories that are discussed under this relationship. First is economic as for example, at the early stage of design, capital budgeting or budgetary control is used to assess the best long-term project strategies for an organisation. It is the mechanism by which an organisation decides whether it is worth undertaking projects such as constructing a new plant or investing in new product development. Meanwhile, in China, some feasibility studies regarding the transition to the hydrogen economy for a more sustainable future grab attention from researchers and

stakeholders (Matzen *et. al.,* 2015a; Ren *et al.,* 2015). Other than that, economic evaluation dealing with various measures in the decision-making process for selection methanol production from renewable or non-renewable resource have also been studied under this category. From all stated studies, 'integrated AHP' has been used rather than 'standalone AHP' for sustainability evaluation, especially in economic impact. In addition, some of the economic tools that used for economic assessment were Cost Benefit Analysis (CBA), Aspen Cost Simulator and LCA (Ehie *et. al.,* 2016a; Matzen *et. al.,* 2015a; Ren *et al.,* 2015).

The second category that gains great concern globally is the environmental impact. To satisfy customers and environmental regulation policies along with improvement of environmental efficiency, the adoption of environmental management practices is necessary in any industry (Matzen *et al.,* 2015a). Environmental impact in chemical industries may potentially expose to the various threat to nature and community. Therefore the factor of impacts should be clearly defined and reduced from getting worst (Parajuli *et al.,* 2015). More recently, instruments such as Environmental Impact Analysis (EIA), Life Cycle Analysis and Excel-based sustainability evaluator have been used along with MCA for environmental impact assessment (Parajuli *et. al.,* 2015; Zhao *et al.,* 2012). Next, MCA enables stakeholders to refine some alternatives under environmental aspects, such as the list of biorefinery locations, list of supplier or supply chain selection, the routes of chemical plants, and restructure of management priority. For example, De Felice *et al.* (2013) implement AHP to describe a relevant classification of electric waste management in terms of performance tracking and to determine the priority or ranking of potential measures to be taken to enhance the sustainability of the integrated system based on their preferences using overall metric weights. To deal with various metrics in the decision-making method for comparisons of alternatives for different purposes in chemical plants, Król *et al.* (2019), Matzen *et al.* (2015) and Parajuli *et al.* (2015) used integrated AHP together with other techniques such as Pugh, Fuzzy and DELPHI method. All types of industries must comply sustainability policy, especially related to environmental risks due to the restrictions for licensing new operations and for public acceptance. Based on studies, environmental risks will

affect the business and the main purpose of profit businesses is to provide a sustainable economic return to its shareholders for the long term even when incorporated to economic, environmental and social demand (Ehie *et. al.,* 2016a; Freitas & Magrini, 2013). The plant's sustainability can be accomplished by reducing environmental pollution at the same time enhancing the viability and social benefits.

The last category is social impact and about ten studies from selected articles classified it into two groups: safety impact and health impact. Nowadays, chemical industries are processing more dangerous substances within densely populated areas and there are increasingly complex risks resulting from the handling, manufacturing and distribution of these hazardous materials (Aqlan & Mustafa Ali, 2014). Safety in process plant should be implemented at early stage of design to prevent misleading of risk assessment. Examples of failure in safety management such as in Iran, fire and explosion disaster accidents occurred at Rage Sefid well in 2017, Bouali Sina petrochemical company in 2016, and Naftshar well in 2010. The accidents attracted government, public, and all industrial sectors' inevitable attention and concern. The investigative reports showed that one of the major problems associated with these incidents is the lack of adequate protection investment plans (Yazdi *et al.,* 2019). Companies must be able to adapt quickly to external and internal risk events and keep their company effective and dynamic to retain their profitability and prevent loss by implementing risk assessment in sustainability management (Aqlan & Mustafa Ali, 2014; L. Wang *et. al.,* 2018; Yazdi *et. al.,* 2019; Yazdi & Kabir, 2017). Aqlan *et al.* (2014) and Qi *et al.* (2015) use Fuzzy logic rules to treat the ambiguity inherent in the safety risks. Conversely, less attention has been given to health impacts based on the selected studies, as safety and risk assessment is the most discussed topic on social impact under sustainability (Jesus *et al.,* 2019).

3. Relationship between MCA and weighting purpose

Sustainability weighting criteria can be divided into three categories, which are subjective weighting, objective weighting and combination weighting (Jeon *et. al.,* 2014; Król *et. al.,* 2019; Mathiyazhagan *et. al.,* 2018; H Wang *et al.,* 2017). Common tools for subjective weighing include consistent matrix analysis, pair-wise comparison, AHP, least-square method, and the Delphi method. The rating/ranking and prioritising of one metric/criteria against another will be obtained through this method. As defined in Król *et al.* (2019), the examples of objective weighting methods are the method for the order of choice by similarity to ideal solution (TOPSIS), methods for entropy evaluation, and the horizontal and vertical method. The entropy method primarily demonstrates to what degree the criterion represents the system's knowledge and the criteria-related uncertainties. For optimisation purposes, the weighting of horizontal and vertical methods will be produced by answering mathematical models. Based on Ehie *et al.* (2016), Jeong & Ramírez-Gómez (2018) and Martinkus *et al.* (2019) studies, comparison among biobased products, fossil-fuel-based products and process routes are necessary for selection and sustainability assessment in a chemical process. Therefore, the pair-wise comparison tends to be useful for stakeholders to entertain preferences on the qualified sustainability indicators.

An integrated approach is proposed based on the combination of two types of weighting as per stated above. AHP and other MCA techniques will be linked together in one research study to represent the uncertainties associated with weights for the assessment and provide more precise measurements of the weights required in the mathematical programming models (Ehie *et. al.,* 2016; Król *et al.,* 2019). In the context of selecting the best distribution network, several researchers also used MCA and theory of multi-attribute value to determine alternatives for choosing a supply chain design and supplier selection based on their expertise (How & Lam, 2018; Król *et. al.,* 2019; Mathiyazhagan *et al.,* 2018). Presently, MCA approaches have been commonly used in both the public and private sectors, such as transport, immigration, education, investment, governance, environment and energy (Lin *et al.,* 2019).

Weights offer a way of assigning relative significance value when knowledge from literature and experts is required to assess their values quantitatively (Król *et. al.,* 2019; Martinkus *et. al.,* 2019; Yazdi & Kabir, 2017). Several articles have included the weighting values associated with sustainability in their research. There are three groups of weighting values that will be discussed under sustainability: economic, environmental, and social. Basically, the

weightage is aggregated from overall ranking (collected from individual criteria) using MCA models and then form into one unitless value for further assessment. Some of the assigned weighting for economic, environmental and social from selected articles are 0.25, 0.5, 0.25 (How & Lam, 2018), 0.3, 0.3, 0.4 (Behzad *et al.,* 2019), 0.33, 0.33, 0.33 (Brunet *et al.,* 2012), 0.3, 0.2, 0.5 (Yazdi & Kabir, 2017) and 0.15, 0.15, 0.6 (Jeong & Ramírez-Gómez, 2018). However, Yang *et al.* (2019) assigned four weighting scores, which are 0.38, 0.11, 0.35, and 0.16 for economic, environmental, social and water resources. The weighting are mostly based on petrochemical and chemical process industry.

C. Discussion

The relationship between MCA and three other topics such as process plant, sustainability and weighting purpose has been reviewed for further discussion. AHP is one of the common techniques that attract researchers, academicians and industrial for the selection of alternatives based on qualitative and quantitative analysis. AHP aims to eradicate bias and reduce the inconsistency of professional decisions in the decision-making process by making pairwise comparisons between the criteria with respect to their impact on the plant and population. However, as the decisions depend on stakeholders' personal decisions, a different set of groups can produce a distinct set of weights for the same sample. This can inevitably lead to the inconsistency of the solutions generated (Król *et. al.,* 2019; H. Wang *et al.,* 2017). Therefore, to curb this issue, an integrated approach is required in selecting an appropriate weight for each sub-index analysis and provide more reliable predictions of the weights required in the mathematical programming models. Fuzzy, DELPHI, TOPSIS, DEMATEL and LIKERT are some of the established techniques that can be combined with current AHP. At the early stage of the ethanol plant design, the weighting by MCA models is used later in sustainability assessment. Therefore, from selected articles, AHP is adopted by most chemical process plants as the core method for weighting purposes and to resolve the inconsistency of ratings, hybrid of Fuzzy-AHP(FAHP), F-AHP DEMATEL and AHP-LIKERT are developed (Behzad *et. al.,* 2019; Jeong & Ramírez-Gómez, 2018b; Król *et. al.,* 2019; Mathiyazhagan *et. al.,* 2018; H Wang *et al.,* 2017). Moreover, LIKERT and DELPHI

technique is getting attention from researchers. These methods require questionnaires that will distribute to two groups' participants such as experts from the chemical industry and academic specialists for realistic estimation. Meanwhile, in Fuzzy, experts' requirement in taking part is equal or less than seven should be enough in answering all research questions for the study. For this study, the goal is to choose the weighting model for ethanol plant sustainability assessment at the early design stage. So, subjective weighting will be chosen rather than objective weighting (TOPSIS) as the optimisation phase has not yet been involved under this development study. By using integrated AHP, it can convert linguistic form to the quantitative index that gathered from expert's opinion and literature into mathematical modelling calculation.

Nowadays, industrial revolution is evolving rapidly in industry. The technologies such as Internet-of-Things (IoT), artificial intelligence (AI) and cloud computing have been introduced to replace many conservative ways, such as the trial-and-error bottom-up approach. High demand from global environment business causes the elimination of traditional approach as it is not effective and efficient in terms of time-consumed and cost (CIJ, 2017). For chemical plant, since the chemical properties of the product are still uncertain, it is possible to look for compliant molecular candidates by exploring them from existing databases or constructing them from a pool of molecular building blocks such as Aspen PLUS or HYSYS (Matzen *et. al.,* 2015b; Yazdi & Kabir, 2017). Moreover, CAMD will assist designers or engineers in designing large quantities of molecules with desired properties, developing plant flowsheets, determine appropriate operating conditions and mimic the actual process plant. From this reverse engineering approach, the reliable sustainability value can be obtained by affiliating it with MCA models. MCA's integrated technique and together with CAMD produce a systematic analysis for sustainability assessment of ethanol plant. Sustainability XML Evaluator in the form of excel format and life cycle analysis (LCA) are tools that are commonly used in sustainability assessment. LCA's advantage is that it provides details on environmental aspects from the cradle to the grave, thus attracting researchers to implement this tool for environmental study (Behzad *et. al.,* 2019; Król *et. al.,* 2019; Martinkus *et al.,* 2019). On the other

hand, Irfan *et al.* (2017). On the other hand, Irfan *et al.* (2017) stated that by using non-LCA tools such as Excel-based sustainability evaluators, measurement of GHG emission from process plant can be solved by using mathematical modelling, which are typically simpler and straightforward. Indeed, it is understandable that LCA application is widely used in biorefinery plants since the flow of concern is very specific, however difficult for a generic approach.

Sustainability consists of three dimensions of economic, environmental, and social. However, from the review, the health aspect is almost overlooked due to a lack of systematic evaluation methodology for social impact at the development phase. For example, workers are exposed to different risks in their working environment. However, it is difficult to define, prioritise risks and establish effective mitigation strategies due to the lack of quantitative mechanisms that take risk ambiguity and mitigation into account (Król *et al.,* 2019). Therefore, to overcome the issue of health index and existing inherent safety system, integrated AHP models together with CAMD and sustainability tools are developed to ensure there is no sign of serious adverse effects on humans that caused by the industrial process. The common steps of MCA consist of indicators selection, weighting, normalisation, and sensitivity analysis. However, the outcome weighting scores among methods are different. For example, AHP and Fuzzy will be assigned a range from 0 to 1. On the contrary, DELPHI, Pugh method and SCORE method indicates integer values that consist negative and positive number. These methods are mostly giving decision-makers a priority ranking by neglecting a group of criteria. Even so, to be used in the sustainability assessment of ethanol plant, the whole number, which is a positive number, is required, therefore AHP and Fuzzy and DEMATEL are preferable compared to other models. The integrated AHP involved interpreted expert opinions and literature finding in the form of value using MATLAB software.

Due to the inability to cope with hundreds of inherent ambiguity and vagueness during the decision-making process, standalone or traditional AHP is less recommended as it does not represent the human language in quantitative value. Therefore, to solve this gap, a reliable way to measure each expert's weight is required. One of the approaches to address the drawback of standalone AHP as discussed in the previous paragraph, is Integrated AHP. However, from the selected articles, if the emphasis is on biorefinery site selection, supplier selection and energy management, the only required MCA is standalone AHP for alternative ranking (How & Lam, 2018; Martinkus *et. al.,* 2019b; Yang *et al.,* 2019). On the other hand, if the purpose of the analysis is to determine the process plant's sustainability, the weighting score from MCA, process simulation and sustainability tools should be involved in the study. These three proven tools are being applied in all selected articles to achieve their aim for sustainability purposes.

IV. CONCLUSION

This study aims to define MCA models for sustainability weighting via systematic literature review to incorporate sustainability assessment of ethanol plant. This study offers significant contributions for knowledge purpose and industrial practice according to communities of interest. From the review, AHP technique results in the highest number of options for several purposes such as the selection of site, supply chain, management judgment, process routes and maintenance. Due to inconsistency of professional opinion in AHP, integrated AHP has been introduced to form quantify value from linguistic term and from this review, the most suitable model of MCA for ethanol sustainability assessment is FAHP.

V. ACKNOWLEDGEMENT

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