A multi-criteria assessment of alternative sustainable solid waste management of flexible packaging

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Abstract

Purpose – The purpose of this paper is to examine the issues affecting end of life (EOL) management of flexible packaging. It focuses on Sustainable Solid Waste Management by using multi-criteria decision making, analytic network process (ANP), and Strengths, Weaknesses, Opportunities, and Threats (SWOT).
Design/methodology/approach – Data were collected from 33 expert stakeholders, though a series of interviews and questionnaires. The subject seven aspects were applied from integrated sustainable waste management with 19 sub-criteria identified. Criteria were prioritized by using ANP and SWOT to the internal and external environments of organizations directly responsible for waste management.
Findings – The five most important factors in the management of flexible packaging waste include: techniques for waste management, material and design, management support, legislation and rule, and environmental care and environmental health, respectively. Solutions addressing flexible packaging waste were identified, including reuse and recycle, waste to energy, biopolymers, new innovative materials and material recovery.
Research limitations/implications – Data were derived from the national authorities and large companies. The findings may not represent local authorities and small-scale manufacturers. Future research should be conducted, in order to investigate and focus around small manufacturing enterprises.
Practical implications – The findings provide a strategic framework for policy makers and industrial manufacturers. The benefits of this will enable them to address flexible packaging waste, by using qualitative and quantitative criteria.
Originality/value – This is the first paper developing a multi-criteria assessment model to specifically manage EOL flexible packaging, a possible pioneering piece of research in this field.

Keywords SWOT, Analytic network process, Multi-criteria decision-making, Flexible packaging, Sustainable waste management

Paper type Research paper

1. Introduction

Recently, rigid packaging has been replaced by flexible packaging due to its light weight, cost-effectiveness and flexibility (Reclay StewardEdge, 2013; Manalili *et al.*, 2014). For instance, a plastic film protects certain products and is easily formed into various shapes (Rohmer and Mérat, 2014). This has led to advanced development and production techniques (El-Haggar, 2010).

As for packaging materials, flexible packaging is not only environmentally friendly but also likely to reduce pollution, material costs, energy use and logistics costs compared with rigid packaging (Coles *et al.*, 2003; Flexible Packaging Association (FPA), 2008; Ramos *et al.*, 2015; Tartakowski, 2010). Therefore, flexible packaging has been accepted as an effective form of packaging material (Marsh and Bugusu, 2007).

However, the end of life (EOL) stage of these materials, particularly multilayer flexible packaging, is likely to pose inherent problems in the future. These materials are found to be extremely difficult, in terms of their degradation and separation properties. It is recommended that the packaging industry should not aim solely to improve the production process of their packaging. Equal if not higher focus should be attributed to produce

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packaging which is able to reduce negative impacts to the environment (Büsser and Jungbluth, 2009).

Currently, there is a demand for a more responsible action to be taken, which will reduce the impact of plastic-packaging materials on the environment. This would become possible, by developing innovative technologies, which are both economically viable and environmentally friendly. Therefore, it is vital that the evolving manufacturing technologies and innovations align with the capacities and strategies of both national and local authorities who are responsible for waste management.

Several forms of recent research have been limited to experimental techniques used in innovated materials (e.g., Davis and Song, 2006; Al-Salem *et al.*, 2009; Kulkarni *et al.*, 2011) and waste management technologies (e.g., Arvanitoyannis, 2008; Themelis and Arsova, 2010; Entec Consulting Ltd., 2012).

However, it remains challenging to apply EOL flexible packaging, because it is necessary to take into account factors such as cost and investment, environmental impact, and waste management systems (Ayalon *et al.*, 2009; RTI International, 2012; Reclay Steward Edge, 2013).

So far, there have been no solutions developed which could sustainably manage this kind of waste (Vidal *et al.*, 2007). Hence, this current study aims to investigate the criteria of "after use" waste management, based on an expert stakeholder's point of view. This study not only exclusively focuses on after-use management, but also examines the upstream and downstream factors for an appropriate solution.

In order to determine the weights of the criteria and sub-criteria, the analytic network process (ANP) method was applied. Afterward, the policy makers are prioritized by using weights from ANP process to identify the strengths, weaknesses, opportunities, and threats for SWOT analysis. This then defines the strategies and obtains insights surrounding management solutions.

To better demonstrate the performance of the proposed method, the main research questions of this study were as follows:

RQ1. What is prioritization of waste management for flexible packaging, from the stakeholder point of view on technical, environmental, financial/economic, sociocultural, institutional and policy/legal/political aspects?

RQ2. What is the score of each alternative in the "EOL" solutions of waste management for flexible packaging?

RQ3. How can those criteria contribute to provide a useful, reliable, valid and efficient guideline in order to help stakeholders optimize the use of EOL flexible packaging?

The rest of the paper is organized as follows. Section 2 reviews some of the relevant studies and outlines the theories and key concepts used to explain flexible packaging and Integrated Sustainable Solid Waste Management (ISSWM) along with ANP and SWOT analysis techniques in studying strategic decisions. The methodology review comes in Section 3. Finally, the results are outlined in Section 4 and the discussion comes under Section 5, followed by the conclusion in Section 6.

2. Literature review

2.1 Flexible packaging

Flexible packaging is a sustainable light-weight packaging material that could potentially reduce fuel consumption and greenhouse gas emissions during transportation (Flexible Packaging Association (FPA), 2009; Wooster, 2012). It has been widely used in global and regional markets (Spinner, 2012). In Thailand, the use of flexible packaging amounted to 14,963.6m units in 2009 (Euromonitor International, 2011) and is forecasted to increase to 25.7bn units in 2021 (Long, 2018).

Thailand has an increasing need for flexible packaging and continued growth in the future (Arvanitoyannis, 2008). Indeed, these materials are relatively useful in production and are convenient to use. It is unlikely to limit the use of such materials; nevertheless, to dispose them remains challenging.

Multilayer flexible packaging holds several positive attributes such as longevity, reduced transportation costs, and strong product protection. However, its waste management is found to be problematic, as multilayer laminate packaging cannot be reused. Despite the likelihood of possible recycling, the process is complicated due to the complexities and the combination of materials used in the manufacturing process. Most multilayer flexible packaging is essentially used for the production of electrical appliances, fabrics, food produce, and snack foods, which results in large amounts of solid waste, as these materials do not decompose easily.

2.2 Integrated sustainable solid waste management (ISSWM)

ISSWM is a concept encompassing waste generation, collection, and disposal, with the key aspects such as technical, environmental, financial/economic, sociocultural, institutional, and policy/legal/political considerations (Muller and Hoffman, 2001).

Its activities serve to reduce harm to the environment. However, the concept of sustainable waste management has many different interpretations (McDougall and White, 2001; Woolridge *et al.*, 2005) and remains controversial due to the differences in localities (Contreras *et al.*, 2009).

To illustrate (Maxwell and Sheate, 2006) argued that the sole environmental concerns such as reduction of raw materials, or elimination of hazardous waste, may not affirm sustainable development. Therefore, the concept of ISSWM should be expanded to take account of the participation of all stakeholders (OECD, 2002) and in particular between localities. This is to recognize that the efforts of the local officials on the ground are mainly pushed through governmental policies and regulations from industries (Verghese *et al.*, 2012). The packaging industry responds to social and environmental pressures, by making its products more sustainable (Jedlicka, 2009).

Recently, most countries have tried to develop technologies and innovations to discover likely solutions, which could help to deal with waste from flexible packaging films (Entec Consulting Ltd., 2012), though despite the current limited availability of solutions (where progress appears to be slow in the development field) due to a number of reasons. One of which is the current financial limitations with regard to investment in the technologies needed, resulting in the inability to gauge the impact of such a solution, and how it would benefit the environment.

Furthermore (Fiksel *et al.*, 2012) different sites or communities need an approach which is appropriate in their own context; thus, different strategies would result in different sustainability assessment indicators. This is the case of Thailand, where the problems of waste management are addressed by immediate reaction. Neither long-term planning nor cooperative planning from all stakeholders is currently in place (Kaosol, 2009). Furthermore, the main failures in this model or system result from the lack of a comprehensive policy framework, and of the analytical tool to improve sustainability (Klundert and Anschutz, 2001).

It may be argued that the management of flexible packaging waste organizations have not yet sought clarification to sustainable development, and that there remains a need to find solutions to EOL criteria for flexible packaging.

2.3 Analytic network process (ANP)

The ANP was introduced by Thomas Saaty of Yale University. It was developed from the analytical hierarchy process (AHP). AHP is limited since decision-making does not always

have layers of hierarchy. Elements of the decision-making process in each layer of the hierarchy may or may not be associated with other elements in higher or lower layers of the hierarchy. ANP can arrange relationships among the criteria for decision-making, their effects on each other, and between criteria and alternatives, by using a ratio scale and a supermatrix approach (Saaty, 2013).

The results of ANP are more concordant with the reality of decision-making (Yi *et al.*, 2005). ANP can be applied in many ways, for example, in multi-criteria decision making (MCDM). Khan and Faisal (2008) used ANP as an ANP model for municipal solid waste disposal solutions. (Khoshnava *et al.*, 2018) utilized criteria ratings of green building materials (GBM) in terms of sustainability to propose a prototype of an analytical method to support decision-making based on MCDM. It is therefore useful for decision makers to develop a project by considering the use of GBM and the three pillars of sustainability.

This paper applied ANP to prioritize the aspects, criteria, factors, and solutions in decision-making for flexible packaging waste management.

2.4 SWOT analysis

SWOT is a basic strategic management tool used in an organization's decision-making to define a strategic plan. It can provide information about an organization's current status (Srivastava *et al.*, 2005), enabling it to correctly set its goals. It is necessary to analyze the effects of several factors by assessing the internal and external environment to specifically develop the solution. These data build on the awareness of the strengths and weaknesses of the internal environment, the opportunities and threats from the external environment, and their potential impacts. SWOT analysis is widely implemented since it is easy to understand, convenient and simple to use in support of the majority of decision-making situations.

SWOT analysis is an essential tool for making a range of strategic decisions (Chang and Huang, 2006). For example, SWOT can be used to make a decision based on many situations, prioritizing incidents, and identify a desirable change management, as well as to analyze and solve problems.

Pariatamby and Victor (2013) used SWOT analysis to elucidate the policy trends of e-waste management in Asia. In another case, SWOT analysis was used to analyze and select suitable criteria and factors for strategy development (Aich and Ghosh, 2016).

For more effective decision-making, AHP and ANP prioritizes each factor or compares the solutions of each factor. (Wickramasinghe and Takano, 2010) combined a SWOT matrix and AHP to analytically determine the priority factors and made them commensurable. Yüksel and Dağdeviren (2007) combined a quantitative MCDA method, specifically ANP and SWOT analysis, to determine possible dependencies among factors of a textile firm.

The current research study applied ANP to prioritize the factors of flexible packaging waste management by weighting the factors. SWOT analysis was used to develop a position matrix and to define possible strategies for solutions (Table I).

3. Methodology

This paper emphasizes the points of view of the expert stakeholders in assessing each criterion and factor to obtain the most appropriate solutions for flexible packaging waste management. Nevertheless, there may be other solutions for managing waste that can be identified through MCDM. These alternatives are offered to decision makers in their quest for a best solution.

The current study identified important factors based on the concept of ISSWM, or the end-of-life considerations. Seven attributes were considered. On the basis of literature review and interviews, nineteen sub-criteria affecting flexible packaging

Table I. The multi-criteria for waste management of flexible packaging

	Technical		Environmental		Financial/economic		Strategies			
	Material and design	Technical for waste management	Environment care and environment health	Lifecycle assessment thinking	Cost-benefit effectiveness	Budget	Incentive payments	Marketing competencies	Technology competencies	Management support
Author (s) Year	MD	TWM	ECEH	LCAT	CBE	BG	IP	MC	TC	MS
Arvanitoyannis, I. (2008)	X	X	X					X	X	
Al-Salem *et al.* (2009)		X								
Verghese and Carre (2012)	X	X	X	X	X	X				X
Mahajan and Vakharia (2016)		X	X		X	X			X	X
Mwanza and Mbohwa (2017)		X	X		X	X	X	X		
Mwanza *et al.* (2018)		X			X	X	X	X	X	X
Yıldız-Geyhan *et al.* (2019)			X	X					X	
From Interviews	X	X	X	X	X	X	X	X	X	X

	Socio-culture			Institutional			Policy/legal/political		
	Collaboration	ECSR Concept	Regional behavior different	Education and information	Research and development	Adjustment government structure and methods	Policy and planning	Legislation and rule	Political instability
Author (s) year	COL	ECSR	RBD	ED	RD	AGSM	PP	LR	PI
Arvanitoyannis, I. (2008)			X				X		
Al-Salem *et al.* (2009)	X							X	
Verghese and Carre (2012)	X		X	X	X		X	X	X
Mahajan and Vakharia (2016)	X			X	X	X	X		
Mwanza and Mbohwa (2017)							X	X	X
Mwanza *et al.* (2018)							X	X	
Yıldız-Geyhan *et al.* (2019)					X	X	X	X	
From Interviews	X	X	X	X		X	X	X	X

waste management, and five solutions were identified considering management expectations/descriptions.

ANP was used to identify appropriate weights and priority levels as shown in Table VI. The results were then analyzed by using SWOT analysis to formulate strategies as shown in Table VII. Also, Table VIII highlights the yielding significance of "EOL" factors.

3.1 Stakeholder expert group

There were three expert stakeholder groups: a government body, a nonprofit organization and the private sector and a selection of customers. The government sector was responsible for policies and planning, creating laws and legislations. It also promoted waste management activities. The nonprofit organizations could support the efforts of the private sector and the government, by ensuring the effectiveness of relevant programs.

The packaging material that ultimately becomes waste is produced and developed by the private sector. Other private sector stakeholders were in waste management. The customer stakeholders were the companies who use flexible packaging in manufacturing, such as food and beverage, personal care and home care products. They generate the most waste (Euromonitor International, 2011). This current study highlights three types of companies, i.e., a food producer, beverage producer, and a beauty and personal care product producer.

A total of 33 experts participated in the interviews and questionnaires, in order to evaluate the relative importance of each identified criterion. There were 3 groups, each of which comprised 11 experts. The first group included two subjects responsible for policy and planning, two for public waste management, three for packaging organizations, three academic experts and two for nonprofit organizations, respectively. The second group included the private sectors, comprising two subjects involved in plastic raw material packaging, three working in flexible packaging manufacturing and four involved in waste management businesses. The last group involved the manufacturer of consumer-packaged products. Four subjects worked for food product companies, three for beverage companies, and four for the manufacture of personal care and home care products. Furthermore, there were five policy makers from the waste management sector who evaluated the respondents' SWOT analysis.

Experts were selected based on the following criteria: they have worked in the identified sectors for at least ten years, were willing to participate and have extensive experience with EOL issues of flexible packaging.

4. Results

4.1 Selection criteria

The development of the ANP model was based on the principles of SSWM in which there are seven aspects, including technical, environmental, financial/economic, sociocultural, institutional and policy/legal/political considerations. Additional sub-criteria were specified.

This was achieved by reviewing technical literature as well as interviewing expert stakeholders, policy makers, academics, packaging manufacturers, waste management businesses and product producers. These discussions greatly assisted the development of a network for evaluation, and the selection of important criteria for flexible packaging waste management (Table II).

4.2 Analytic network model

ANP was applied to prioritize the aspects and criteria of flexible packaging waste management.

Step ANP 1: ANP model construction. The structure of the relevant factors and appropriate criteria for decision-making was determined based on SSWM aspects. After

SSWM aspects	Criteria/sub-criteria		Expectations/descriptions for management
Technical	Material and design (MD)	MD1	Optimization design is the main concept to be considered when designing flexible packaging, e.g. reducing usage of packaging materials, appropriate packaging size
		MD2	Design of flexible packaging for the changing behavior of the customer in proper disposal
		MD2	Using biodegradable packaging material
	Technical for waste management (TWM)	TWM1	Recycling. There should be designs or different types of creative products made of recycled materials
		TWM2	Efficiency waste to energy, e.g., incinerators and refuse derived fuel (RDF), effective inventory, systems for waste management, sufficient volumes of waste and waste management system
		TWM3	There should be appropriate waste management for flexible packaging before disposal, e.g., separation of these types of packaging from general or organic wastes and cleaning flexible packaging waste before disposal
Environmental	Environment care and Environment health (ECEH)	ECEH1	Cleaner Production and Cleaner Technology (clean and environmentally friendly production process should be applied)
		ECEH2	Considering the impacts of degradable packaging material after use
		ECEH3	Air pollution control in flexible packaging waste – incineration such as Dioxins/Furans
	Lifecycle assessment thinking (LCAT)	LCAT1	Life cycle assessment analyses, e.g., global warming, greenhouse gas emissions and the risks of carcinogenic compounds
		LCAT2	Life Cycle Inventory Database for flexible packaging in Thailand
Financial/ Economic	Cost-benefit effectiveness (CBE)	CBE1	Considering the life cycle costs, including operations and maintenance, e.g., material and design cost, waste management cost, research and development (R&D), costs, legislation and regulation costs
	Budget (BG)	BG1	The government should support green production through research and investment funds
Strategies	Incentive payments (IP)	IP1	Setting incentives for flexible packaging waste and selecting better operation
	Marketing competencies (MC)	MC1	Setting proper positioning of green products
	Technology competencies (TC)	TC1	Experts and in-house technology should be developed
		TC2	New technology to make better flexible packaging
	Management Support (MS)	MS1	Entrepreneurs should promote activities or campaigns showing responsibility for proper waste management of flexible packaging, e.g., extended producer responsibility (EPR) principles. Large companies should take the leading role to encourage smaller business to follow suit, recall packaging waste for elimination
		MS2	Solving urgent problems for recycling businesses in respect of labor, technology, regulations, location, and tax structure
		MS3	Using bioplastic materials in the future

(*continued*)

Table II.
Sustainable waste management (SWM) aspects, criteria, and summary of expectations of stakeholders for management in end-of-life flexible packaging

SSWM aspects	Criteria/sub-criteria		Expectations/descriptions for management
Socio-culture	Collaboration (COL)	COL1	Entrepreneurs in recycling businesses are to involve setting policies with the government
		COL2	Promoting stakeholders networks to build relationships, share supply chain information
		COL3	Producers must collaborate with waste management firms to foster mutual understanding on the value of each other's business
		COL4	All stakeholders, from both the public and private sectors should collaborate and commit to reducing flexible packaging waste
	ECSR concept (ECSR)	ECSR1	Corporate Social *and* Environmental Responsibility: CSER
	Regional behavior different (RBD)	RBD1	Differences in the areas and communities should be taken into consideration for waste management
		RBD2	Promoting the use of biodegradable packaging in tourist area. Violators should be fined
Institutional	Education and information (EI)	EI1	The awareness and education of proper flexible packaging waste management should be raised, e.g., approaches to returning packaging for proper disposal, separation of these types of packaging from general or organic wastes and cleaning flexible packaging waste before disposing
		EI2	Establishment of a school-based pilot management program for flexible packaging waste
	Research and development (RD)	RD1	More support for research in bioplastics for flexible packaging should be provided to enhance commercial potential
		RD2	Research and development technology for waste management should be supported so that factories can transform waste into useful products
		RD3	Conducting research to study cost-effectiveness of each waste management system
		RD4	Studying the role models and the best practices from developed countries that are appropriate to Thailand
	Adjustment Government structure and methods (AGSM)	AGSM1	Government structure and methods should be appropriately adjusted to remove overlapping functions and make the system faster and more flexible
Policy/legal/ political	Policy and planning (PP)	PP1	Identification markings on flexible packaging should appear to indicate the different materials used and how to properly dispose of them
		PP2	Setting goals to reduce the amount of packaging waste and increase waste utilization
		PP3	The private sector should promote waste management
	Legislation and rule (LR)	LR1	The regulations providing for waste disposal taxes on products should be improved, e.g., a packaging waste disposal tax symbol on each product
		LR2	Waste Management should be legislated on a clear classification of packaging waste and their disposal processes
	Political instability (PI)	PI1	Set packaging waste management as a national agenda item and incorporate it into the National Economic and Social Development Plan for continuous management

Table II.

analysis, the experts chose those factors affecting decision-making. Finally, subcriteria and potential EOL solutions were gathered.

The relationship of each factor was reassessed by the experts to create a diagram of network relationships consisting of the main factors and subfactors, with arrows showing the relationships and influence of each factor as demonstrated in Figure 1.

Step ANP 2: pairwise comparison. A pairwise comparison examined matrices to find the significance of a vector. Matrices were utilized as tools to assess the priority of each pair by comparing their elements between matrices and within the same matrix.

In addition, a relationship among matrices was made and replaced with a numerical score depicting a significance level ranging from 1 to 9 (Saaty, 2005). Numerical scores of 1–9 provide an appropriate categorization and basis of comparison of human decisions. The priority scores were ordered from the least to the most important as 1/9, 1/8, 1/7 …, 1, …, 7, 8, 9, respectively (1 refers to equal importance).

Group discussions produced the aspects and criteria for pairwise comparisons and avoided individual bias. The relative weights of the aspects and criteria were calculated. The weights of pairwise comparisons, grounded on SSWM principles, are displayed in Tables III–V. The CI, referring to the consistency index and CR, referring to concurrency reasonable obtained, were acceptable since both values were less than 0.1.

Step ANP 3: supermatrix formation and transformation. Priority was calculated by using a supermatrix. This step was done to discover the priority of the whole solution. The matrix of the total obtained weights was multiplied by every relevant matrix to find a weighted supermatrix. The total weighted supermatrix value of each column must be 1. Alternatively, if the value was not 1, a normalization was conducted to determine the

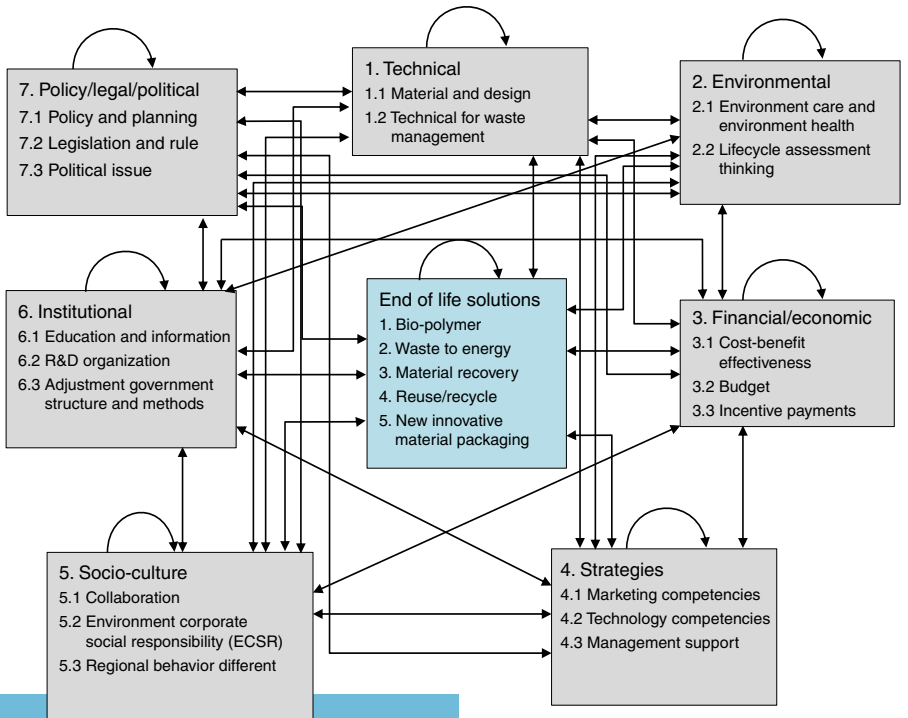

Figure 1.
Diagram of a network relationship

Table III.
An example of a pairwise comparison matrix based on EOL solutions

	EOL solution	Technical	Environmental	Financial/economic	Strategies	Socio-culture	Institutional	Policy/legal/political	Priority vector
EOL solution	1.000	1.500	1.000	1.000	1.000	1.000	2.000	1.000	0.2003
Technical	0.667	1.000	1.000	1.000	2.000	2.000	3.000	2.000	0.2469
Environmental	1.000	1.000	1.000	1.000	1.000	1.000	2.000	1.000	0.1904
Financial/economic	1.000	1.000	1.000	1.000	1.000	1.000	3.000	0.500	0.1837
Strategies	1.000	0.500	1.000	1.000	1.000	2.000	2.000	0.500	0.1746
Socio-culture	1.000	0.500	1.000	1.000	0.500	1.000	1.500	1.000	0.1545
Institutional	0.500	0.333	0.500	0.333	0.500	0.667	1.000	0.500	0.0892
Policy/legal/political	1.000	0.500	1.000	2.000	2.000	1.000	2.000	1.000	0.2076
	C.I. = 0.0434		C.R. 0.0308						

limiting supermatrix by squaring the weighted supermatrix until the values of each column were equal, referred to as the steady state. The final fixed weight could then be identified.

Step ANP 4: final priorities. This step illustrates the priority scores of each option and factor as shown in Table VI. The highest score represents the best option and it is concordant with various other factors. The priority weight is used for SWOT analysis to define the management strategy.

	Waste to energy	Material recovery	Reuse/recycle	New innovative	Priority vector
Waste to energy	1.000	4.000	1.000	2.000	0.2003
Material recovery	0.250	1.000	0.333	1.000	0.2469
Reuse/recycle	1.000	3.003	1.000	2.000	0.1904
New innovative	0.500	1.000	0.500	1.000	0.1837
	C.I. = 0.0186	C.R. 0.0207			

Table IV. An example of a pairwise comparison matrix based on EOL solutions and biopolymer production

	Marketing competencies	Technology competencies	Management support	Priority vector
Marketing competencies	1.000	1.000	0.50	0.7937
Technology competencies	1.000	1.000	1.00	1.0000
Management support	2	1	1.000	1.2599
	C.I. = 0.0268	C.R. 0.0463		

Table V. An example of a pairwise comparison matrix of the strategy of waste-to-energy considerations

Solution/aspects	Solutions/criteria			Weight	Normalized
End of life solution	S1: biopolymer material			0.0476	0.1874
	S2: waste to energy (WtE)			0.0534	0.2102
	S3: material recovery			0.0471	0.1854
	S4: reuse/recycle			0.0599	0.2355
	S5: new innovative material packaging			0.0461	0.1815
1. Technical	1.1	MD	Material and design	0.0520	0.4746
	1.2	TWM	Technology for waste management	0.0576	0.5254
2. Environmental	2.1	ECEH	Environmental care and health	0.0410	0.5056
	2.2	LCAT	Lifecycle assessment thinking	0.0401	0.4944
3. Financial/economic	3.1	CBE	Cost-benefit effectiveness	0.0353	0.3299
	3.2	BG	Budget	0.0357	0.3294
	3.3	IP	Incentive payments	0.0367	0.3408
4. Strategies	4.1	MC	Marketing competencies	0.0374	0.3089
	4.2	TC	Technology competencies	0.0369	0.3052
	4.3	MS	Management support	0.0467	0.3859
5. Socioculture	5.1	COL	Collaboration	0.0383	0.3532
	5.2	ECSR	ECSR	0.0352	0.3252
	5.3	RBD	Regional behavior differences	0.0348	0.3216
6. Institutional	6.1	ED	Education and information	0.0312	0.3091
	6.2	RD	Research and development	0.0350	0.3469
	6.3	AGSM	Adjustment government structure and process	0.0347	0.3440
7. Policy/legal/political	7.1	PP	Policy and planning	0.0383	0.3265
	7.2	LR	Legislation and regulations	0.0416	0.3545
	7.3	PI	Political instability	0.0374	0.3190

Table VI. Results of prioritization of all factors using ANP analysis

According to Table VI, the column weight describes that aspects 1–7 stakeholders realized the importance of the criteria in the ascending order of seven levels, i.e., technology for waste management, material and design, management support, legislation and regulations, environmental care and health, lifecycle assessment thinking, and collaboration, respectively.

The column Normalized illustrates the results showing the level of importance in each criterion. Similarly, in the EOL solution, the first five rows show the alternative solutions and the following rows show the percentage of each criterion – affecting a decision to select alternative solutions. The following are the account of the seven aspects:

(1) As for the technical aspect, stakeholders realized the importance of criteria in the ascending order, i.e., technology for waste management and material and design, respectively.

(2) As for the environmental aspect, stakeholders realized the importance of criteria in the ascending order, i.e., environmental care and health and lifecycle assessment thinking, respectively.

(3) As for financial/economic aspects, stakeholders realized the importance of criteria in the ascending order, i.e., incentive payments, cost-benefit effectiveness, and budget, respectively.

(4) As for strategy aspects, stakeholders realized the importance of criteria in the ascending order, i.e., management support, marketing competencies, and technology competencies, respectively.

(5) As for the socio-culture aspect, stakeholders realized the importance of criteria in the ascending order, i.e., collaboration, ECSR, and regional behavior differences, respectively.

(6) As for the institutional aspect, stakeholders realized the importance of criteria in the ascending order, i.e., research and development, adjustment government structure and process, and education and information, respectively.

(7) As for the policy/legal/political aspect, stakeholders realized the importance of criteria in the ascending order, i.e., legislation and regulations, policy and planning, and political instability, respectively.

4.3 SWOT analysis of the strategy waste management for flexible packaging

After conducting ANP analysis to gain the priority weights of each factor and option, SWOT analysis was applied to the scenario. It examined the strengths and weaknesses of the internal environment, and the opportunities and threats of the external environment. This analysis was useful for the decision makers to realize current changes. In this stage, the data were collected from experts, especially policy makers, by using informal discussions with academics and experts working in the field of waste management. The situations and solutions for waste management were evaluated, while the criteria were utilized to specify the SWOT. The priority weights of previous incidents and potential changes in the future were given. This was highly beneficial in defining the strategy and the operation, concordant with the real context and suitable management. The steps of SWOT analysis are summarized below.

Step SWOT 1: identify the strengths, weaknesses, opportunities, and threats. When the priority weights were gained from the ANP process, the subfactors of each criterion were utilized to identify the strengths, weaknesses, opportunities, and threats for SWOT analysis. In addition, the weights obtained from the ANP process were adjusted to make the total criteria values of SWOT equal to 1.00. Regarding the five solutions, the weight

values acquired from the ANP weight and the SWOT-adjusted weight are presented in Tables VII and VIII:

$$\pi_{i=1}^{n}\left(\text{frames/second}_i\right)^{(w_i)}.$$

Please note: "Above is the formula for determining a weighted geometric mean, where n is the number of individual tests in a viewset, and w is the weight of each individual test, expressed as a number between 0.0 and 1.0. (A test with a weight of '10.0 percent' is a w of 0.10. Note the sum of the weights of the individual tests must equal 1.00.) (A test which has a weight of '10.0 percent' is a w of 0.10. Note the sum of the weights of the individual tests must equal 1.00) (Licea-Kane, 2014)."

From this table, the policy makers set up SWOT factors and the strengths, weaknesses, opportunities and threats and also used ANP weight reference then adjusted weight to be stable. The results were helpful to consider the strategies appropriate to the situations.

Step SWOT 2: prioritization. The second step of SWOT analysis was prioritizing each factor and solution from the weights of the previous step. Each factor was rated on a scale of 1 to 3. Then these weights were multiplied by the scores to yield the results representing real situations.

Please note: the rating for critical SWOT factors is scored from 1 to 3, 3 refers to major strengths, 1 refers to minor strengths and 2 refers to an intermediate condition. For the weaknesses, 3 refers to major weaknesses and 1 refers to minor weaknesses. The rating for opportunities and threats was different from that of strengths and weaknesses. Probabilities of incidents were considered, which led to opportunities or threats affecting the organization. 1 refers to a low probability and 2 refers to an intermediate probability.

For Table VIII, the policy makers can develop critical SWOT factors and provide ratings on how to manage EOL solutions for waste management of flexible packaging for example: if they

SWOT	Priority of factors	SWOT subfactors	ANP weight	Weight adjustment
Strength	0.384	S1: high demand for material and design	0.475	0.156
		S2: full support of technological competencies	0.305	0.101
		S3: provide management support	0.386	0.127
		S4: active research and development	0.347	0.114
Weakness	0.502	W1: high investment technology for waste management	0.525	0.173
		W2: awareness of cost-benefit issues	0.330	0.109
		W3: large budget for waste management	0.329	0.108
		W4: no incentive payments	0.341	0.112
				1.0000
Opportunity	0.434	O1: new marketing competencies	0.309	0.081
		O2: promoting collaboration	0.353	0.093
		O3: enhance education and information sharing	0.309	0.081
		O4: national policy and planning in place	0.327	0.086
		O5: legislation and regulation based	0.354	0.093
Threat	0.476	T1: awareness of environmental care and health	0.344	0.090
		T2: lifecycle assessment thinking concept	0.494	0.130
		T3: considers ECSR concept	0.325	0.085
		T4: differentiation in regional behavior	0.322	0.084
		T5: political instability	0.327	0.086
		T6: inflexibility of government structure and processes	0.344	0.090
				1.0000

Table VII. Overall priority of SWOT subfactors and weight adjustment

Table VIII. Advanced SWOT yielding significant factors affecting end of life solutions for waste management of flexible packaging

SWOT factors	Weight	Biopolymer Rating	Biopolymer Weighted score	Waste to energy (WtE) Rating	Waste to energy (WtE) Weighted score	Material recovery Rating	Material recovery Weighted score	Reuse/recycle Rating	Reuse/recycle Weighted score	New innovative material Rating	New innovative material Weighted score
Critical SWOT factors											
Strength	0.384		1.110		1.165		1.009		1.279		1.055
S1: High demand for material and design	0.156	2	0.312	3	0.468	2	0.312	3	0.468	1	0.156
S2: Full support of Technological competencies	0.101	2	0.202	1	0.101	1	0.101	2	0.202	3	0.303
S3: Provide management support	0.127	2	0.254	2	0.254	2	0.254	3	0.381	2	0.254
S4: Active research and development	0.114	3	0.342	3	0.342	3	0.342	2	0.228	3	0.342
Weakness	0.616		0.828		1.221		1.109		0.892		0.719
W1: High investment technology for waste management	0.173	1	0.173	2	0.346	2	0.346	2	0.346	1	0.173
W2: Awareness of cost-benefit issues	0.109	3	0.327	3	0.327	3	0.327	2	0.218	2	0.218
W3: Large budget for waste management	0.108	2	0.216	3	0.324	3	0.324	2	0.216	2	0.216
W4: No incentive payments	0.112	1	0.112	2	0.224	1	0.112	1	0.112	1	0.112
Opportunity	0.525		0.775		0.780		0.515		1.128		0.792
O1 New marketing competencies	0.309	3	0.243	2	0.162	2	0.162	3	0.243	1	0.081
O2 Promoting collaboration	0.353	2	0.186	2	0.186	1	0.093	3	0.279	2	0.186
O3 Education and information sharing	0.309	1	0.081	1	0.081	1	0.081	2	0.162	1	0.081
O5 (Policy and planning: PP)	0.327	2	0.172	3	0.258	1	0.086	3	0.258	3	0.258
O6 (Legislation and regulations: LR)	0.354	1	0.093	1	0.093	1	0.093	2	0.186	2	0.186
Threat	0.475		0.949		1.045		0.739		0.869		0.695
T1 Environment care and health: ECEH	0.344	1	0.090	2	0.180	2	0.180	2	0.180	1	0.090
T2 Lifecycle assessment thinking: LCAT	0.494	2	0.260	2	0.260	1	0.130	2	0.260	2	0.260
T3 (ECSR concept: ECSR)	0.325	1	0.085	1	0.085	1	0.085	1	0.085	1	0.085
T4 Regional behavior differentiation: RBD	0.322	3	0.252	2	0.168	2	0.168	2	0.168	1	0.084
T5 Political instability: PI	0.327	2	0.172	2	0.172	1	0.086	1	0.086	1	0.086
T6: Inflexibility of government structure and processes	0.090	1	0.090	2	0.180	1	0.090	1	0.090	1	0.090

use bio-polymer solution, the active research and development has is the highest strength, while the weakness on the awareness of cost-benefit issues becomes the most weakness of these factors. Regarding opportunity, the new marketing competencies is the most important factor. In threat SWOT factor, regional behavior differentiation: RBD is the most important factor.

Please note: By using Table VIII, a decision based on the results could be taken from analyzing in the following: depending on the 5 weighted headed solutions (bio-polymer, waste to energy (WtE), material recover, reuse/recycle and new innovative material). The performance properties (highlighted in gray) can be measured in each of the SWOT categories. I.E overall weight (first column) has been derived from Table VII. However, the individual ratings were calculated by internal discussions which were carried out by the five policy makers from the waste management sector, who evaluated the respondents' SWOT analysis.

Step SWOT 3: the TOWS matrix model. This step implemented the results to formulate strategies. There were various solutions applicable to fully determine an aggressive strategy. In contrast, there might be some threats and weaknesses that need to be mitigated and turned into opportunities to create more aggressive strategies. Strategies for flexible packaging waste management were proposed following the TOWS Matrix Model as shown in Table IX.

According to Table IX, this step was used to analyze the relationship between strengths and opportunities, strengths and threats, weaknesses and opportunities, and weaknesses

	Internal factors	
External factors	Strengths (S)	Weaknesses (W)
	S1: high demand for material and design	W1: high investment in tech for waste management
	S2: full support of technological competencies	W2: awareness of cost-benefit issues
	S3: provide management support	W3: large budget for waste management
	S4: active research and development	W4: no incentive payments
Opportunities (O)	SO strategy	WO strategy
O1: new marketing competencies	S1 S2 S3 O1 O2	W1 W2 W3 W4 O2 O3 O4 O5
O2: promoting collaboration	SO1: develop technology and research to support the recycle market and future growth	WO1: set price rates for trading flexible packaging waste
O3: enhance education and information sharing	SO2: increase the amount of waste management to effectively support a growing recycled market	WO2: expand investment in packaging waste utilization by promoting public-private partnerships (PPP) to decrease investment required
O4: national policy and planning in place	SO3: high-efficiency sorting of flexible packaging waste	
O5: legislation and regulation based	SO4: improve requirements and define regulations on use and disposal of flexible packaging waste	
Threat (T)	ST Strategy	WT Strategy
T1: awareness of environmental care and environmental health	S2 S4 T4 T5 T6	W1 W2 W3 W4 T2 T5
T2: lifecycle assessment thinking concept	ST1: support consideration on life cycle assessment (LCA) to calculate consumed energy and effectively manage resources	WT1: build understanding of flexible packaging to change consumer behavior regarding waste disposal
T3: consider ECSR Concept	ST2: encourage use of solutions and technology for waste management suitable for different areas	WT2: shift from CSR to ECSR
T4: differentiation in regional behavior	ST3: offer privately managed waste	WT3: create specific signs/symbols for appropriate disposal of flexible packaging waste
T5: political instability		WT4: promote printing sign/symbol on packaging which pays for an environment tax or a waste management tax
T6: inflexibility of government structure and processes		

Table IX.
A TOWS matrix for strategy formulation to manage flexible packaging waste

Source: The TOWS matrix for strategy formulation was adapted from Weihrich and Koontz (1993, p. 175)

and threats. The results were helpful to consider the strategies appropriate to the situations as follows:

(1) Aggressive strategy (SO strategy) was obtained from the data on environment evaluation in terms of strengths and opportunities.

(2) Diversification strategy (ST strategy) was obtained from the data on environment evaluation in terms of strengths and opportunities. Even though the organizations had several strengths, they might encounter certain uncontrollable limitations from the external environment. However, the existing strengths of organizations could be used to cope with such limitations from outside.

(3) Turnaround-oriented strategy (WO strategy) was acquired from the data on environment evaluation in terms of weaknesses and opportunities. The organizations had opportunities to generate new ideas or new methods to improve their weaknesses.

(4) Defensive strategy (WT strategy) was retrieved from the data on environment evaluation in terms of weaknesses and threats. The organizations might face uncontrollable weaknesses and threats from the external environment. Hence, the results could help reduce the expected obstacles and threats. They were also beneficial to define the defensive strategy to prevent possible impacts.

5. Discussion and implication

The first step applied the ANP technique to specify the priority weight. It was found that the technical aspects were the primary concern of the expert stakeholders. These included subfactors such as technical issues for waste management, materials and design.

Their second point of view dealt with strategies, especially management support. The expert stakeholders emphasized policy/legal/political aspects, including subfactors such as legislation and regulations. The environmental aspect consisted of environment care and health, with lifecycle assessment as a subfactor.

The remaining points of view and criteria had similar values but were lower in value than the above aspects, depending on the strategies and operations. For instance, the technical aspects of the waste management subfactor were associated with the management support subfactor. Therefore, the waste disposal technique should be selected for effective management because there were no purchasers for flexible packaging and hence no pricing and no volume.

Thus, this type of waste was not appropriately managed and it was necessary to define a specific, multilayer system for flexible packaging waste management. It should start by separating the waste, followed by setting a standardized process for waste management that avoids any impact on society and the environment. Such a process consisted of waste collection, transportation to a collection station, intermediate treatment, and disposal. Responsible and competent persons should be assigned at each step. Returning the flexible packaging for disposal was another option. This option requires incentives to promote public mindfulness and help people to voluntarily reduce, reuse, and recycle. The authorities in the local administration should promulgate a municipal law to maintain cleanliness and sanitation.

Moreover, a collective consciousness should be built to make people aware of waste management as a national problem. The legislation and regulation subfactor is related to environmental care and health, as well as the lifecycle assessment subfactor.

In Thailand, the amount of multilayer flexible packaging waste has been increasing every year due to a lack of recycling (Chinda *et al.*, 2012; Pollution Control Department (PCD), 2016). Flexible packaging waste was not suitably disposed of and that led to a greater workload for the government agency. Illegal burning of waste also led to air pollution, causing protests by

the neighboring communities because it was a source of illness. The number of sanitary landfills was reduced, making it more difficult to manage waste effectively.

An effective waste management processes should start with the correct packaging material selection to suit the environment, regulations, and standards (Ngoc and Schnitzer, 2009). Restrictions may be required regarding multilayer flexible packaging materials so that they cause minimal environmental impact and avoid residues. The suitability of packaging should be evaluated and compared with products used using Life Cycle Assessment (LCA).

This analysis will consider the materials from production to the disposal phase. Verghese and Carre (2012) indicated that LCA for recycled packaging should involve Closed-Loop Recycling for virgin material reprocessing to avoid negative impacts. Hence, if virgin material production has greater negative impacts than reprocessing, then recycling generates a net benefit.

Conversely, priority weight might not be sufficient for generating proper solutions. Therefore, SWOT analysis was conducted. It was useful to assess organizations or projects in real situations (Heath and Wall, 1992). In the current study, SWOT analysis was applied to evaluate solutions for flexible packaging waste management with regard to both the internal and external environment. The results were used to examine the influences on actual operations, strengths of using flexible packaging waste management, solutions for flexible packaging waste reduction, and weaknesses and threats should be addressed.

SWOT analysis provided four management strategies through the TOWS Matrix. The first strategy was an aggressive strategy (SO strategy) associated with promoting opportunities. Flexible packaging is disposable and there is no separation or recycling process and its use is growing. This is also regarded as one of its strengths as a source of material for waste recycling (Hopewell *et al.*, 2009; Themelis *et al.*, 2011).

Moreover, Amerplast Company developed flexible packaging made from recycled plastic. The company cooperated with Ekokem to supply recycled plastic granules produced from consumer waste (Plastemart.com, 2016). We consider the SWOT analysis position matrix for the various solutions in Table VIII. It was found that the reuse/recycle method was the primary option, followed by new innovative material packaging, biopolymer production, and WtE processes. If these solutions were fully supported, they would provide many opportunities to utilize flexible packaging waste (Tchobanoglous and Kreith, 2002; Ngoc and Schnitzer, 2009) with input from strategic partners (Badir *et al.*, 2005). It can also encourage public-private partnerships to add more value to the waste recycling process. For example, policies toward legislation and waste separation for recycling could be promulgated.

Recently, the government combined the national agenda concerning sustainable waste management with the National Economic and Social Development Plan, in order to reduce the amount of plastic waste. Other possible solutions, such as new innovative packaging material, biopolymer production and WtE conversion would still be required for further development. This could suit each local area and facilitate budgets.

The WO strategy stemmed from the weaknesses (high costs and investment requirements) of flexible packaging waste management. This was because of its complex composition and structure. Other types of waste are reusable at a price. Thus, it was convenient to consider the cost of waste management and recycling.

Policy makers need to create incentives to motivate use of this process (Tietenberg, 2003, p. 570). In Table VIII, it can be seen that the solution of WtE should be primarily used to remove weaknesses and create opportunities, followed by solutions for material recovery, reuse/recycle, biopolymer production and new innovative packaging materials. Hence, the public sector should play a more important role in building, understanding and supporting all relevant sections to apply them in this matter. Currently, the Siam Cement Group (SCG) and TPI Polene use composite waste as raw material for electricity generation, which is then sold.

There is still a lack of knowledge and understanding of the needs and benefits of multilayer flexible packaging. Strategies should motivate all parties to use waste such as by

investment in promotions to the public sector and communities, legislation, formulation of regulations and standard enforcement.

Collaboration between the public and private sectors should be promoted to manage waste. For example, research and technological development can be presented in educational institutions to build positive attitudes about waste management. Such participatory management would benefit all parties, eliminate weaknesses and generate more opportunities in the future.

The next approach was a diversification strategy (ST strategy) employed to utilize an organization's strengths to mitigate uncontrollable external threats. Further, it was helpful in creating and promoting opportunities to develop technology and marketing channels for recycling. Some organizations provide technical and research support to reuse waste as a renewable source. Both the public and private sectors supported certain projects.

Nevertheless, there were several problems regarding transportation, as well as the suitability of technology and machines. Current technologies were developed by foreign companies and were not appropriate for use with the contaminated waste found in Thailand. This type of packaging was acceptable for the production of hydrocarbon feedstock or fuel made from unseparated plastic waste. In addition, there were several legal limitations such as the waste being an asset of the local administration and that it should comply with the joint venture law (Chinda *et al.*, 2012). That would lead to higher costs and longer consideration periods for projects under the joint venture law.

The efficiency of the administration and the approach to investment should be improved. Obstacles to success should be taken into consideration, while unstable politics might disrupt development by various agencies and impede operations. This may lead to duplication of work and low performance of some projects. However, these problems can be reduced by integrating operations.

Nevertheless, some solutions might be appropriate to certain areas. For instance, waste near industrial areas or tourist attractions may have restrictions regarding waste disposal. Unseparated waste might be recycled to generate power or used as fuel in some areas. The selected solution should be based on LCA to evaluate the environmental impact at every stage. This will be beneficial in increasing confidence and improving operational efficiency.

The defensive strategy (WT strategy) stemmed from the weaknesses of flexible packaging waste management, i.e., the high budget and investment required. Nevertheless, there was no pricing for this type of waste and it did not suit commercial procedures. Unstable politics also caused an intermittent promotion of waste management policy and this put pressure on WtE biopolymer production and reuse/recycle activities.

There were some threats from solutions such as material recovery and innovative packaging materials. The impacts of external threats were mitigated because the solutions in the organizations still needed further development in the future. The strategies were implemented to encourage the use of flexible packaging waste and to reinforce the strengths of all agencies without waiting for government policy to be developed. This was helpful in driving a reuse project for flexible packaging waste.

It can be concluded that even though today's solutions are not the best, they are good alternatives that are applicable to decision-making "upstream." Most of the present technology for the flexible packaging industry seems to focus on "thinner properties." This can increase the production rates and decrease the use of raw materials, while offering better packaging properties.

The use of biopolymers is also a practical and sustainable concept, but the cost is higher than for other materials and it has not yet been successfully developed. For this reason, biopolymer use is rarely found in Thailand. Cross-functional communication can enhance a team's ability to develop a new product or packaging material (Darawong, 2015).

In addition, continuous support for research and technological advancement can "make anything possible" with the participation of all of the necessary agencies (e.g. plastic

manufacturers, plastic consumer policy makers and waste producers). When considering downstream activities, it is essential to explore the utilization of waste packaging.

Collaboration among the producers who are (upstream of the process) being the packaging users who are (midstream of the process) and the agencies responsible for waste management (downstream of the process) should be promoted. Along with effective operations, they include proper packaging selections, packaging waste collection, clear regulations and standards, and solution implementation that are appropriate to the system. This will be helpful in achieving the goal of waste management and more effectively reducing the amount of waste generated.

6. Conclusion

This research aimed to provide appropriate solutions for waste management of flexible packaging considering the expert stakeholders' points of view where physically possible. Significant factors, criteria, and concordant solutions were identified to suit the current conditions, based on 7 aspects of SSWM, 19 subfactors and 5 solutions.

The ANP technique was used to evaluate the significance of each criterion to prioritize the relevant factors, followed by a SWOT analysis which was applied to define strategies and obtain insights regarding management solutions.

Inevitably, there are certain limitations within this research, since the proposed solutions represent a small cross section of the industry. However, there may be further constraints in some areas or provinces, such as tourist destinations or places where there is insufficient area for waste management. Therefore, the future studies on flexible packaging should aim to develop a management process, and encourage expert participation in specific areas. This would certainly enhance the efficiency and appropriateness of waste management for the future.

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