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The transition towards the circular economy in developing countries - waste management case studies from Vietnam.

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TABLE OF CONTENTS

1. INTRODUCTION

1.1. Problem statement

There is increasing excitement about the possibility of developing more 'circular'- and sustainable - models to deal with climate change and maintaining ecosystem stability and to liberate economic, social and environmental benefits. Visions of what is called a "circular economy" (CE) are based on a systematic approach to resource efficiency, whereby products and materials are not dropped at the end of their life but are recycled, reused, or repaired using circular value chains. The CE also refers to changes in business models that focus on sharing and renting after independent or one-time use, as well as changing consumer preferences, with buyers evaluating "second life" products (i.e., those that are recycled or customized for a new purpose) and allocation of assets to individual ownership.

There has been less exploration and focus on CE discussions in developing countries than those in developed countries (above all in the European Union and China).

The lack of data and analysis on the CE in most developing countries misrepresent important opportunities for accelerating a transition to circular activities and value chains.

Developing countries are all too familiar with the sustainability challenges correlated with urbanization and industrialization-challenges that involve pollution, water scarcity and rising amounts of waste. In the inadequacy of new approaches, these strains will only rise alongside population and economic growth and will be exacerbated by climate change.

Also, developing nations are suffering a growing waste crisis, which has major consequences for environmental and public health outcomes: of the top 20 countries ranked by mass of mismanaged plastic waste in 2015, 12 were low-income (JAMBECK et al., 2015). Middle-class citizens in the developing world are already starting to consume more and reuse less. It is calculated that dumpsites will account for 8–10 per cent of global greenhouse gas emissions by 2025 (MAVROPOULOS and NEWMAN, 2015). A recent *Lancet* paper estimated that 6–16 million people per year are exposed to dangerous concentrations of lead at battery recycling sites (LANDRIGAN et al., 2018). Each year an evaluated 270,000 people die prematurely due to the open burning of waste (KODROS et al., 2016). These numbers demonstrate the necessity of finding new ways to meet development goals while decreasing resource consumption.

Besides, developing countries are the current dominant centres of production and the future centres of consumption in the global economy. An increasing share of the global ‘consuming class’ now lives in emerging and developing countries, with a vast concentration in India and China.

Increasing MSW generation has been becoming an emerging environmental issue for authorities in Viet Nam (LUONG et al., 2013). The growing waste amount causes negative impacts on the environment and human health due to the inadequate disposal of waste (NGOC and SCHNITZER, 2009). Also, 80% of MSW was disposed of in landfills without being recycled, reflecting the material and energy losses of the society (GHINEA et al., 2016).

Hanoi is a centre city of politics, economy, culture, education, training, science and technology of Vietnam. With the number of people 7,520.7 million (GSOVN., 2020), the volume of generated solid waste has increased these years rapidly. Until now, there has been limited progress of 3R goals with only two of nine goals have achieved some progress while the other related goals are still far from the desired targets (THANG, 2017). At present, the municipal solid waste management system in Hanoi is not effective because of the lack of the appropriate financial, technical and human resources, the lack of technical infrastructure for recycling, collection, and transportation (RICHARDSON, 2003). Therefore, establishing a sustainable solid waste management system in the light of CE perspective with a suitable mechanism for the local conditions is critical and urgent.

1.2. Research questions and Hypotheses

To research the transition towards the circular economy in developing countries, this study focuses on an area so-called waste management, which is extremely challenging for not only the emerging nations but also for most of the countries around the globe. With this approach, first, this study analyses the potentials for circular economic transformations in the waste and wastewater management systems to get more effective (material and energy utilisation) and cost-efficient solutions.

Research question 1: How could we minimize wastewater treatment by business model development with low cost and effective, sustainable economic background in fast-growing megacities in Asia?

Hypothesis 1: To answer this question, this study states that the circular transformation could solve the conventional linear wastewater treatment system's problem. Assuming that economic actors and supply chain members integrate their resources into circular systems, then business ecosystems can be continuously redesigned to create dynamic and efficient self-regulating systems. The new business structures and innovative circular models can contribute more to rethinking the economic loop and cascade solutions than just developing exclusive technologies.

Research question 2: Which decision levels of the transition management process should be applied in the perspective of municipal solid waste management at the individual cities and city-regions to interpret in circular business models?

Hypothesis 2: In the context of the developing countries with the municipal solid waste management system in a high population density megapolis, this study supposed that the transformation possibilities should be implemented simultaneously at all three decision levels including governmental, enterprise and personal levels and prevention tools are key factors to make sure the success of this procedure. Besides, this study assumed that the transformation also needs to apply at both the technological and the residential (with personal development) level to develop a sustainable and efficient municipal waste management system.

Research question 3: What methods can be used to determine a good technological solution for waste management if we examine them differently in developed economic ecosystems?

Hypothesis 3: The Analytical Hierarchy Process (AHP) method combines the data to get the rank of alternatives. Finally, sensitivity analysis can be performed to investigate the consequences of a weight change of a criterion. The hierarchical structure of the AHP model allows decision-makers to easily understand the circularity problems in terms of the relevant criteria and sub-criteria.

Research question 4: What is the sustainable solution for the municipal solid waste management system, which is appropriate and should be applied to the megacities in developing countries.

Hypothesis 4: This study assumes the alternative "MBT (Mechanical Biological Treatment) plants for classifying, composting, and Refuse-Derived Fuel (RDF) for waste-to-energy/incineration plants" is a sustainable municipal solid waste management system solution that should be suitable and applied to Hanoi and other major cities in Asia and Africa.

2. MATERIALS AND METHODS

The following section presents the scientific methodologies needed to examine the previously given research questions and hypotheses.

2.1. The ReSOLVE framework and Mapping method are applied to define the main circular and economic transformation points for wastewater treatment.

The formerly used methodologies of wastewater treatment improvement present technological development and new treatment technique researches. The R&D strategy should focus on the business environment and new economic solutions also because the human inquiry and urban population growing ask new solutions with low cost and economically effective methods. This study focuses on a business model implication and a combined method development also. The circular blocks of the current application technology utilize sludge wastewater recovery solutions. Still, they do not provide the possibilities of circular transformation methods to other parts of the treatment chain. This research would like to focus on that, from the applied ReSOLVE framework and mapping method to concept a modified Business Model Canvas structure.

The ReSOLVE framework as a mosaic

One of the main lessons learned from the literature was that not only the circular economy has different interpretations, but also what we can understand underthe so-called "Circular Business Model." (LEWANDOWSKI, 2016) highlights that any business structure that is based on the principles of the circular concept can be considered circular. In his work, he introduces a theoretical framework to facilitate circular business model development. His work is based on the "ReSOLVE" framework (Table 1) that has been defined by (EMF, 2015), who had laid down the pillars for building circular business models based on the ReSOLVE framework (mosaics in English that covers the following key expressions: Regeneration, sharing, optimization, loop, virtualization, and exchange).

Table 1: The ReSOLVE framework

Activity	Description
Regenerate	use renewable energy and materials
	reclaim, retain and regenerate the health of ecosystems
	return recovered biological resources to the biosphere
Share	enhancing product utility by sharing the use, access or ownership
	extending product life through reuse, maintenance (e.g., repair, refurbish) or design for durability
Optimize	optimization of resource use through increasing performance or outsourcingactivities
	remove waste in production and supply chain
Loop	close material loops by remanufacturing, repurposing, recycling or recovering
Virtualize	dematerialize products or services through digital appliances
Exchange	employ new technologies, materials or processes

Source: (EMF, 2015; LEWANDOWSKI, 2016)

(LEWANDOWSKI, 2016) designates this structure as a benchmark for the evaluation/construction of circular business models. Therefore, in this dissertation, the ReSOLVE method is used to deal with the first research question and hypothesis by the placement of circular blocks of business models to help fit the model to CE (circular economic aspects). Water treatment technologies with biological adsorption materials contain many circular technology development points that can be detected by the ReSOLVE method and thus by the development of the Canvas Model. The main goal is to analyze and emphasize circularity options using the ReSOLVE methodology and then apply the results of ReSOLVE to explain the blocks of the Business Model Canvas.

Application of Mapping method to the regenerate part of ReSOLVE

This study presents some connected points of Regenerate blocks to declare the new scientific results of business model development (MÜLLER et al., 2016). The mapping method is a cross-structure system for technological and economic analyses. This method was applied to determine the connection between the Regenerate part of ReSOLVE framework and environmental, ecological, energetical and human segments of new wastewater techniques. The Mapping structure (compare with other methods, e.g., benchmark analyze) gives help to declare the structural points of each segment of any production system. This method could analyze the cross-relations of improved points of the system.

2.2. Systematic transition management approach and benchmarking methodology to determine the decision levels of transition management and select suitable solid waste treatment technologies for Hanoi, Vietnam

2.2.1. The systematic transition management approach for the current system

The transition management and circular transformation methods are applied to solve the Hanoi municipal waste management system's technological problem. The study determines the transformable points of the current management system and gives the possible solution for efficient transformation.

This study accepted the research result of Loorbach (LOORBACH, 2010), which describe four sorts of separated administration exercises in a societal setting according to the conduct of the performing artists involved. This can layout whether a brought together mediation identifying with the disguise of externalities is required, or the backhanded main thrusts of market systems can prompt an increasingly reasonable working of waste management.

This study would like to present a technological improvement with transitional management to get the maximum circularity and totally waste recyclable system as possible. Value 1 means the linear structure without any circular options. Value 5 means the totally circular system. In this case, the author targets the medium version, especially the circular system, because the current technological context of linear conditions cannot answer the question of urban waste management with an emphasis on sustainability and economic efficiency. These results provide a reasonable estimation of the maintainability of each variable (strategic, tactical, operational, and reflexive) and each structure square (value proposition, cost structure, and revenue streams). The following figure (Figure 1) presents the transitional matrix with planned changes of the current municipal waste management system. This transitional matrix demonstrates the complex structure of circular transition management thinking of solid waste management improvement of Hanoi, Vietnam.

Figure 1: The transitional matrix of municipal solid waste management on each level.

Source: (NGUYEN HUU and NGUYEN DUC, 2019)

2.3.2. Benchmarking methodology for choosing improvement directions of technological background

This research also applies the benchmarking methodology to choose the suitable and adaptable technologies for municipal solid waste issue in the conditions of Hanoi, Vietnam. This study applied twelve essential management criteria for five operations and usage technologies.

Analyzing the possible points of system improvement

The current technology options have been evaluated based on KPI values. Each technology solution has a value of between 1 and 5, making it clear which option seems to be the best solution for circularity. Adaptation of each technological solution is definitely necessary at the three decision levels examined (government, enterprise and individual/households levels also). The transition management assessment of the applied waste management methods was carried out with reference to the blocks described in the transition matrix.

2.3. The Analytic hierarchy process (AHP) methodology with Super decision software to choose the best sustainable solid waste management systemfor Hanoi

2.3.1. Research Materials

This research concentrates on analysing the municipal solid waste management system in Hanoi, the capital of Vietnam. As shown in Table 2, from 2018 to 2030, the urban population is expected to increase, and rural communities may continue to decline.

Table 2: Population and waste generation for Hanoi andforecasted data to 2030.

Item	Year 2016	Year 2018	Year 2030	The Direction and Extent of the Change in the Given Years
Urban population (no.)	3,699,500	4,286,272	7,618,293	Increasing (4–7%/year)
Rural population (no.)	3,823,100	3,523,369	2,158,803	Decreasing (4%/year)
Total population (no.)	7,522,600	7,809,641	9,777,095	Annual growth: 1.89%
Urban DSW generation (t/y)	1,687,897	2,046,284	4,773,577	Increasing
Rural DSW Generation (t/y)	1,144,254	1,103,439	887,366	Decreasing
Total DSW generation (t/y)	2,832,151	3,149,723	5,660,943	Annual growth: 4.75%
Urban DSW gen. (kg/cap./day)	1.25	1.31	1.72	Increasing
Rural DSW gen. (kg/cap./day)	0.82	0.86	1.13	Increasing
Total DSW; gen. (kg/cap./day)	1.03	1.10	1.59	Increasing

Source: (VAN DEN BERG, 2018)

Alternative Solutions Compared during the Research Process

Alternative 1: Improving the Current System for Waste Collection and Transportation

This alternative focuses only on optimizing the current selection and transportation system by using transfer stations before transporting to a suitable and environmentally friendly sanitary landfill. From the planning stage to 2030, using this alternative, all people living in residential areas can use this waste selection system (100%). Several transfer stations will be built to improve the performance of the transport strategies. All waste collected will soon be dumped in an appropriate landfill (Figure 2). This alternative does not assume any changes to the present informal recycling system, and the 10% recycling rate has been assumed to be maintained unchanged. The recycling rate (i.e., 10%) is an assumption at a given time and varies with time (VAN DEN BERG, 2018).

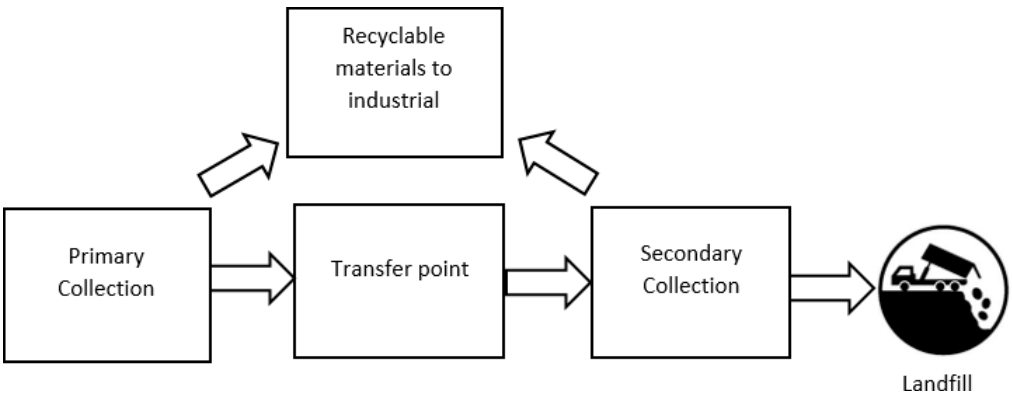

Figure 2: Components in Alternative 1

Source: (HOANG and FOGARASSY, 2020)

Alternative 2: Reducing, Reusing, and Recycling Waste at Source

In this alternative, the recycling rate (collected through the informal sector) is expected to gradually increase from the current 10% to 24% in 2020. In addition, Alternative 2 also includes the additional classifying of recyclable materials in the household, which ranges from 1% in 2018 to 13% in 2030. Regardless of the classification of recyclable materials in the household and during collection and transportation, the system does not include any other processing and/or reduction measures (Figure 3).

In the projected planning period (by 2030), 100% of urban residents will have access to waste collection systems. More transportation stations will be built to improve the efficiency of the waste transportation system (VAN DEN BERG, 2018). All collected waste will be discarded in a suitable sanitary landfill.

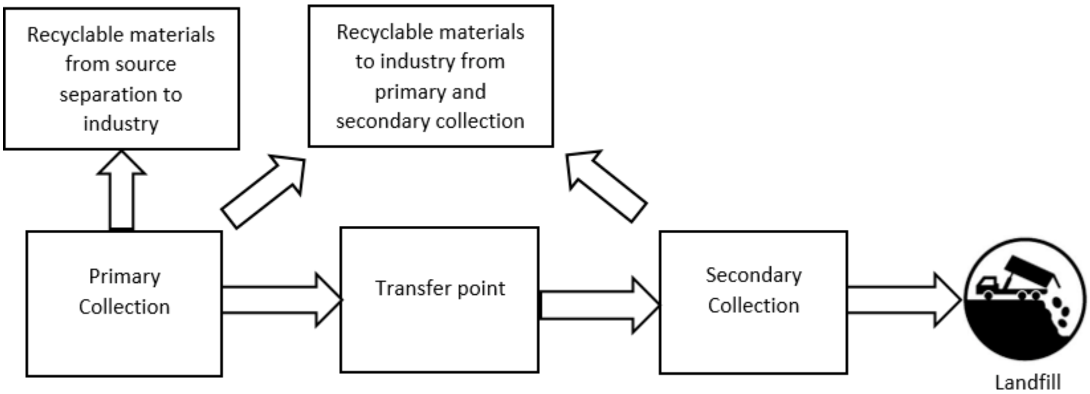

Figure 3: Components in Alternative 2

Source: (HOANG and FOGARASSY, 2020)

Alternative 3: Mechanical–Biological Treatment (MBT) Plants for Classifying, Composting, and Refuse-Derived Fuel (RDF) for the Cement Industry.

Alternative 3 includes MBT plants for sorting, composting, and RDF plants for the cement industry. In this system, the MBT plants incorporate transfer stations that use cost-effective transportation methods for transferring waste to landfills and RDF to the cement industry (Figure 4). During the presumed planning period until 2030, all people who are living in residential areas will be able to use the waste collection system.

The compaction trucks will be applied to carry waste from the pushcarts (and containers in front of high-rise buildings) to many different MBT plants in various places in the service area, thus reducing transportation distances and costs. After being transported to the MBT plants, the waste will be mechanically and manually classified into the following parts: Materials with high-quality recyclable properties for the recycling industry; Organic matter (wet, small and medium particle size) for a compost plant located in the MBT plant; Small non-recyclable particles for landfilling, such as glass, dust, soil, gravel, and RDF made from combustible fractions are provided for the cement industry or incineration facilities at a zero cost.

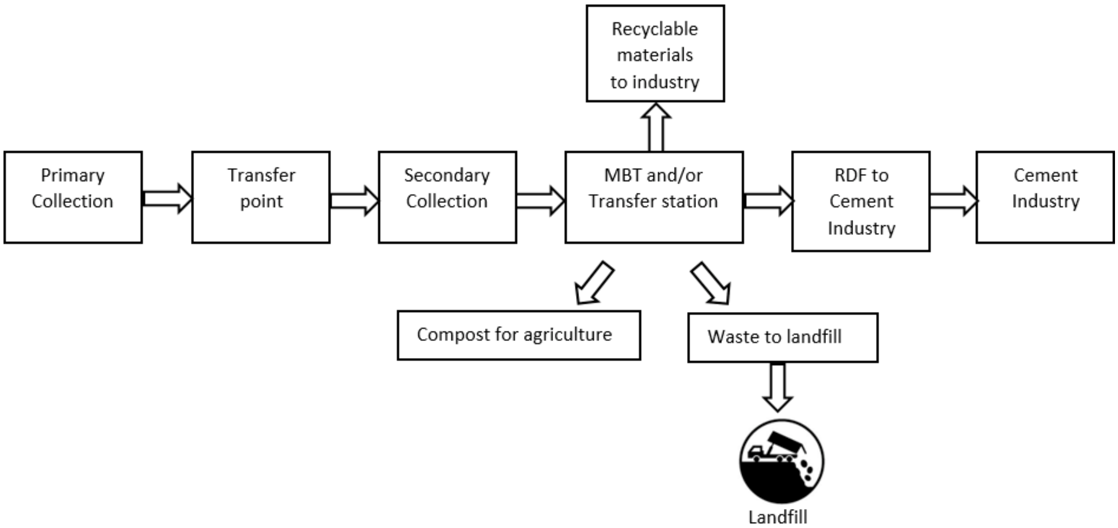

Figure 4: Components in Alternative 3

Source: (HOANG and FOGARASSY, 2020)

Alternative 4: Mechanical–Biological Treatment (MBT) Plants for Sorting, Composting, and Refuse-Derived Fuel (RDF) for Waste-to-Energy/Incineration Plants.

Alternative 4 comprises MBT plants for classifying, composting, and RDF as fuel for waste-to-energy/incineration plants. Further, MBT plants incorporate transfer stations for the costeffective transportation of residual waste to landfills. During the presumed planning period (by 2030), all people who remain in residential areas will have access to the waste collection system. The compaction trucks will be utilized to carry waste from the pushcarts (and containers in front of high-rise buildings) to many different MBT plants in different places in the service area, thus reducing transportation distances and costs (Figure 5).

After being transported to the MBT plant, the waste will be mechanically and manually classified into the following parts: Materials with high-quality recyclable properties for the recycling industry; Organic matter (wet, small and medium particle size) for the compost plant located within the MBT plant; Small non-recyclable particles such as glass, dust, soil, gravel for landfilling and RDF from the remaining combustible materials are assumed to be burned at the on-site waste-to-energy plant.

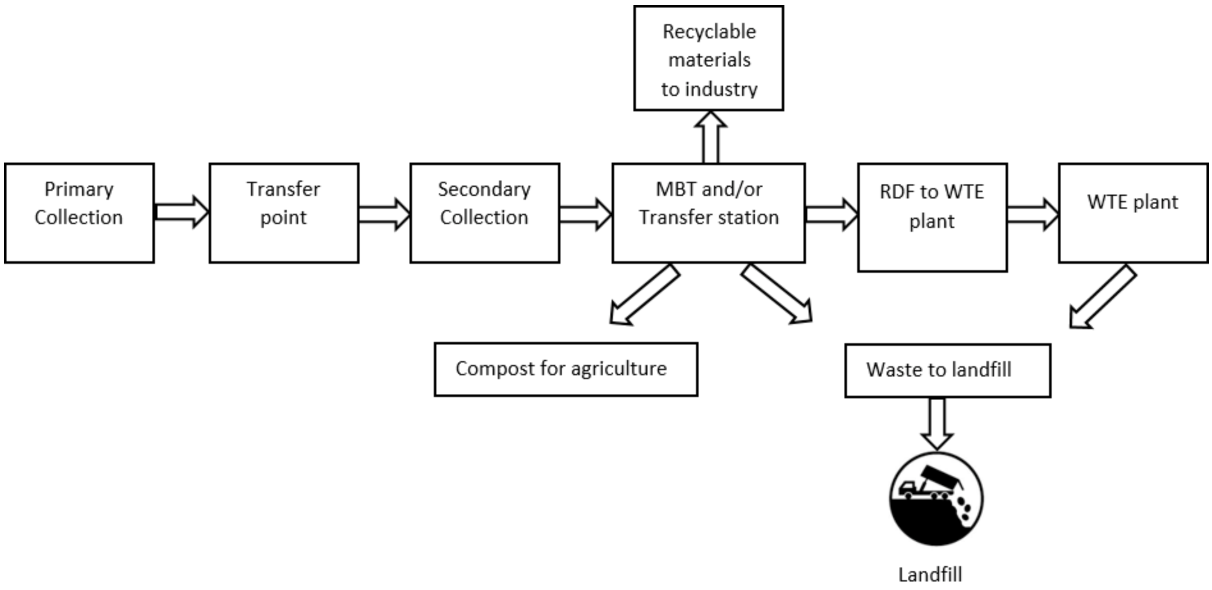

Figure 5: Components in Alternative 4

Source: (HOANG and FOGARASSY, 2020)

3.3.2. Application of the Analytical Hierarchy Process (AHP)

The AHP (analytic hierarchy process) is a multi-criteria decision-making technique, developed by Saaty (SAATY, 1994; SAATY, 2008; SAATY, 2005; SAATY, 2000; SAATY and VARGAS, 2012), in which (BERTOLINI et al., 2006):

- *Analysis* shows that the problem is divided into its constituent elements.
- *Hierarchy* indicates that the hierarchy of listed components is related to the primary goal.
- *Process* suggests that data and judgments are processed to achieve the final result.

AHP is composed of two stages: (i) defining hierarchical trees; (ii) numerical assessing of the trees. The definition of a hierarchical tree starts with identifying the proposed target, then the criteria and sub-criteria are determined by the experience of the experts; Finally, the alternatives known a *priori* represent the leaves of the tree.

The assessment stage is based on a pair-wise comparison. The criteria on the same level of the hierarchy are compared to ascertain the relative weight compared to the *father-level* criteria. This process allows (i) to achieve values that weigh the criteria and (ii) determine the rank of alternatives. Assessment is bottom-up: the decision-making process begins by comparing the options with the criteria of the final level; The evaluation continues according to the criteria of the first level, then it is compared with the goal. The scale to express the intensity of importance for each indicator is as follow (Table 3).

Table 3: Saaty's fundamental scale

Intensity of importance	Definition
1	Equal importance/preference
3	Moderate importance/preference
5	Strong importance/preference
7	Very Strong importance/preference
9	Extreme importance/preference
2, 4, 6, 8	Intermediate values of the judgment

Source: (SAATY, 2000)

The AHP method combines those data to get the rank of alternatives. Finally, sensitivity analysis can be performed to investigate the consequences of a weight change of a criterion. With sensitivity analysis, it is possible to (i) measure the robustness of the solution, and (ii) identify criteria that are more relevant to the final result.

This study collected secondary data from the World Bank report produced in 2018 to evaluate options and action areas to implement Vietnam's national strategy for solid waste management. Based on the given data and scenarios with the support of AHP and Super Decision software, this study will propose the best sustainable solid waste management system in the specific context of Hanoi, Vietnam.

This research conducted an expert-roundtable. During AHP, I followed the Super Decisions Software protocol and sent the results to specialists in Hanoi for confirmation. These results include pairwise comparisons, in which authors must match criteria, subcriteria, and alternatives in pairs to assess their preference. Writing the pairwise comparison matrix for Alternatives A1, A2, ...An. The matrix obtained is shown in Table 4. Alternatives: Improving the current system for waste collection and transportation (A_1); Reducing, reusing, and recycling waste at source (A2); MBT plants for classifying, composting, and refuse-derived fuel (RDF) for cement industry (A3); and MBT plants for classifying, composting, and RDF for waste-to-energy/incineration plants (A4).

Table 4: Analytical hierarchy process (AHP) pairwise comparison matrix

	A_1	A_2	…	A_n
A_1	p_1/p_1	p_1/p_2	...	p_1/p_n
A_2	p_2/p_1	p_2/p_2	...	p_2/p_n
…	...	...	...	...
A_n	p_n/p_1	p_n/p_1	...	p_n/p_n

Source: (BOROS and FOGARASSY, 2019).

In the matrix, $a_{ij} = p_i/p_j$ shows how many times Alternative A_i is better than alternative A_j with respect to each criterion and sub-criterion.

By analyzing and synthesizing the results, the AHP will help to capture both objective and subjective aspects (Figure 6). AHP is also used to lessen distortions in the decision-making procedure and constitutes a helpful way. The first step in solving decision-making tasks will be to structure the judgment task, which includes defining the goal, deciding on the alternatives, and specifying the criteria and sub-criteria.

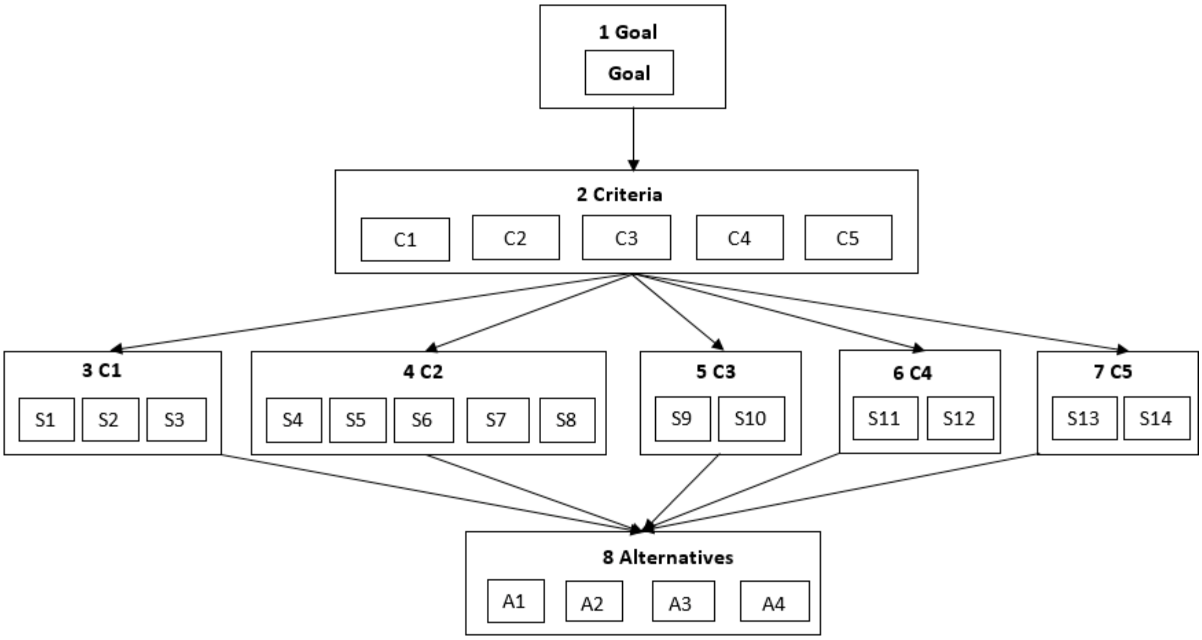

Figure 6: Structure of AHP analysis for sustainable municipal solid waste (MSW) management in Hanoi.

Source: (HOANG and FOGARASSY, 2020)

1. Goal: Choosing the best alternative for sustainable MSW management in Hanoi;
2. Criteria:

a. The waste flow in 2018 and forecasted data to 2030 (C1);

b. The necessary equipment and facilities from 2018 to 2030 (C2);

c. The total investments estimated for municipal solid waste collection and disposal (C3);

d. The annual cost of operation and maintenance for municipal solid waste collection and disposal (C4);

e. The total average costs per capita per year (C5).

3. Sub-criteria:

a. Total of waste collection (t/y) (S1);

b. Recycling t/y (S2);

c. Residual waste for landfill (t/y) (S3);

d. Transfer points in streets (no.) (S4);

e. Pushcarts/containers (no.) (S5);

f. Compaction trucks for collection (no.) (S6);

g. Transfer stations (no.) (S7);

h. New landfills needed (2 million tons capacity each) (S8);

i. Investments estimated for collection (S9);

j. Investments estimated for disposal (S10);

k. Annual operation and maintenance costs for collection (S11);

l. Annual operation and maintenance costs for disposal (S12);

m. Total investments and reinvestments (S13);

n. Total operation and maintenance costs (S14);

Note: Acronyms for each criterion and sub-criteria are in parentheses.

The "Super Decisions Software"is used to resolve the decision taskin this case; the AHP model consisted of the steps listed below.

Creating the Test Matrix to Determine the Weights of the Criteria and Sub-Criteria Based on the Groups of Alternatives (Table 5).

Table 5: Comparative matrix of individual criteria, sub-criteria, and alternatives

Alternatives	**A1**	**A2**	**A3**	**A4**
Criteria	**(p_1...p_5)**	**(p_1...p_5)**	**(p_1...p_5)**	**(p_1...p_5)**
a. C1 (a_1…a_4)	a_1/p_1	a_2/p_1	a_3/p_1	a_4/p_1
b. C2 (b_1…b_4)	b_1/p_2	b_2/p_2	b_3/p_2	b_4/p_2
c. C3 (c_1…c_4)	c_1/p_3	c_2/p_3	c_3/p_3	c_4/p_3
d. C4 (d_1…d_4)	d_1/p_4	d_2/p_4	d_3/p_4	d_4/p_4
e. C5 (e_1…e_4)	e_1/p_5	e_2/p_5	e_3/p_5	e_4/p_5

Source: Based on (BOROS and FOGARASSY, 2019)

The Evaluation Procedure of the Alternative according to the Criteria Given

Saaty′s major scale (SAATY, 2000) was adopted for the comparisons between criteria and the alternatives related to each criterion (in this case: A1, A2, A3, A4) for each leaf criteria (C1…C5) and sub-criteria (S1…S14). Finally, the Super decision software will help to synthesize and give the rank of all alternatives for the final decision.

3. RESULTS AND DISCUSSION

3.1. Results of systematic review of wastwater treatment and waste management in developing countries

3.1.1. Conventional and Business As Usual (BAU) structures of wastewater treatment.

The current economic approaches follow the linear principle, which is primarily a production-output structure. The linear economic system favors high-volume and low-cost production to obtain the raw materials needed at the lowest possible cost. Instead, by studying and applying the fundamental pillars of sustainability - the social, environmental, and economic aspects, a circular system can be developed that is the basis of modern 21st-century economic processes (MICHELINI et al., 2017). These three aspects of sustainability are aligned, so if one of them changes, the other elements will be affected simultaneously (AVEN, 2016). Linear economic models do not want to avoid the negative externalities of production systems and are not well suited to explain consumption's social and economic effects. The new development model closes the linear system and places it in the circular process. This is the next step in the linear-circular transition to a sustainable approach. The circular concept of water recycling focuses on distinguishing between potable and non-potable water treatments. It also underlines its economic and social importance. However, these studies did not address business models that could change intermediate water forms' amount and utilization direction (presented in Figure 7). Therefore, the unfavorable direction of the linear-to-circular conversion may be primarily related to technological changes in process development. Circular water utilization should be promoted in parallel with the development of energy and material cycles.

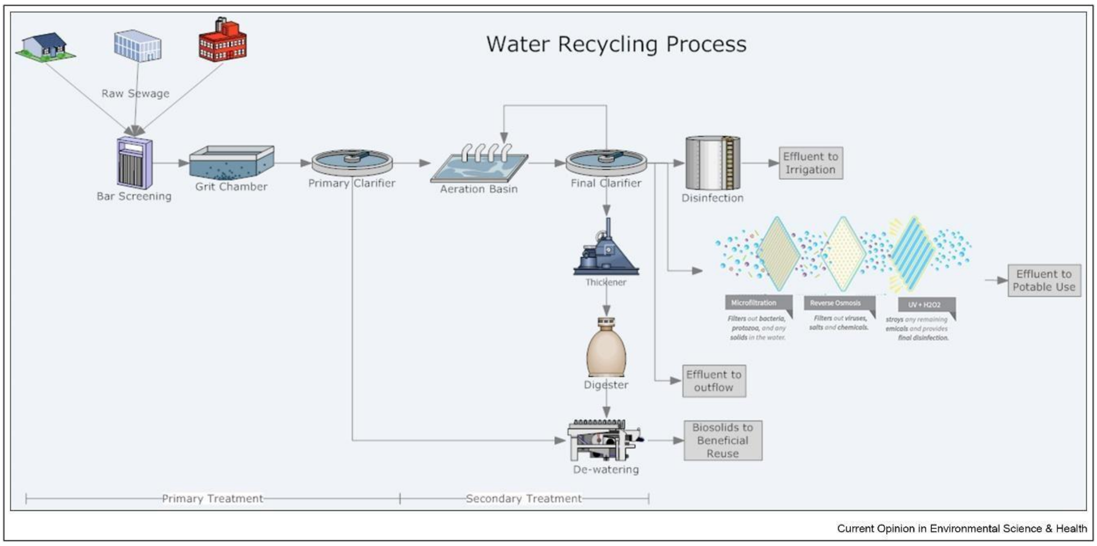

Figure 7: Conventional two-stage biological wastewater treatment and potential options for circular wastewater reuse.

Source: (CZIKKELY et al., 2019)

3.1.2. Transition management objectives and strategic levels for waste management issue

Figure 8 presents the main objective levels of transitional thinking and development. On the upper level (Governmental decision level) placed the overall strategic possibilities, because the law background and direct/indirect forms of organizations could control the whole municipal waste management system. The second (and middle) level based on the small and medium enterprises. These companies could organize the technological parts of waste management. They could collect the municipal waste amount by new technical solutions and prepare waste materials to further application or other utilization. The individual level is the most important. Although the two other upper levels could control the whole system, personal thinking is the basis of the total management process. Transition management should focus on the change of personal thinking and attitude. The households could give more effort to the municipal waste management success because they could collect each type of waste materials separately.

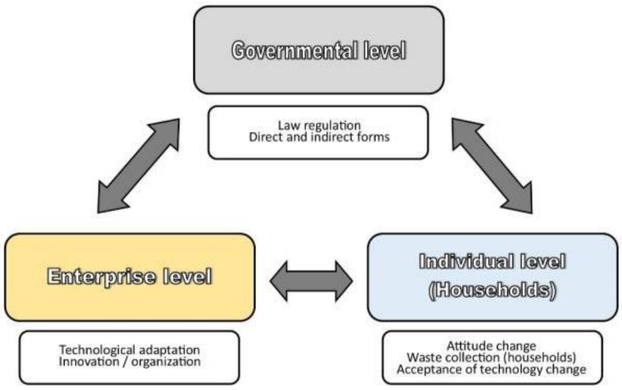

Figure 8: The main levels of transition thinking

Source: (NGUYEN HUU and NGUYEN DUC, 2019)

The following table (Table 6) presents the levels of circularity and sustainability from value 1 to value 5. The KPI – Key Performance Indicators (which is presented by Table 6) define key system performance metrics based on a sustainable Business Model Canvas results, with a five-grade scale.

Table 6: The method for transition structure improvement of the municipal waste management system withKey Performance Indicators – KPI's

Values	Circular level	Properties of economic structure
1	Lowest circularity	Disposal of waste
2	Low circularity	Recovery
3	Medium circularity	Reusing, recycling
4	High circularity	Upcycling, downcycling
5	Highest circularity	Prevention or zero waste (Refuse and reduce)

Source: (NGUYEN HUU and NGUYEN DUC, 2019)

3.1.3. Structural properties of municipal solid waste management in developing countries

Developing countries (in Africa and Asia) often suffer from inadequate waste management systems due to limited financial resources, insufficient awareness, ineffective use of resources, lack of appropriate governance measures, unequal regulations for services, excessive dependence on imported equipment, and sometimes improper application of technology solutions (LOAN, 2016). Poor collection and disposal of urban solid waste leads to the depreciation of environmental esthetics and causes local flooding as well as land, air, and water pollution (HOORNWEG and BHADA-TATA, 2012; THEMELIS et al., 2002). The consequences of these problems lead to human health hazards, which can only be minimized by implementing cost-effective technical and policy measures (SALEEM et al., 2016). Many technologies have been applied to address the serious consequences of ineffective waste management that pose risks to human health and the environment. According to the hierarchy of waste management, landfilling is the most used and widespread method of solid waste (MSW) disposal worldwide (VOBĚRKOVÁ et al., 2017; KODA et al., 2017; JOVANOV et al., 2018; GWOREK et al., 2016; VAVERKOVÁ et al., 2019). Mechanical–biological treatment (MBT) for unsorted organic waste is one of the best and fastest technologies for the decomposition of organic components from a landfilling site (SHARP and SANG-ARUN, 2012). Composting is a process of waste recycling based on the biological degradation of organic material under aerobic conditions, generating stabilized and sanitized compost products (WEI et al., 2017). Of all the recycling methods, composting is recommended due to its environmental and economic benefits (WEI et al., 2017). It has many environmental benefits, such as decreasing greenhouse gas emissions ((USEPA), 2015), minimizing leachate quantities once discarded in landfills (ADHIKARI et al., 2009), and enhancing the quality of soil when used as a soil improvement (WEI et al., 2017). At the same time, if composting is managed and performed improperly, it may cause various environmental issues, including the formation of malodorous or toxic gases (MAULINI-DURAN et al., 2014), dust, and bioaerosols (WÉRY, 2014; SYKES et al., 2011), resulting in occupational health risks or salubrity problems to nearby residents (PEARSON et al., 2015). Besides these traditional technologies, waste-to-energy technologies (WTE-T) are promising technologies, especially for developing countries, to turn waste into a useable form of energy (MOYA et al., 2017). They will play an essential role in sustainable waste management and the relief of environmental matters (BRUNNER and RECHBERGER, 2015; DI MATTEO et al., 2017). These technologies are generally classified as biological treatment technologies (or biochemical processes, such as anaerobic digestion technologies (BAROUTIAN and ANYAOKU, 2018; VAN FAN et al., 2018; TYAGI et al., 2018; HINCHLIFFE et al., 2017;

KUSCH, 2013; KRANERT et al., 2012) or as thermal treatment technologies (or thermochemical processes, such as pyrolysis (MOYA et al., 2017; HINCHLIFFE et al., 2017; BOSMANS et al., 2013), gasification (MOYA et al., 2017; COUTO et al., 2016; THAKARE and NANDI, 2016; MAZZONI and JANAJREH, 2017; RAJASEKHAR et al., 2015; ARENA, 2012), and incineration technologies (MOYA et al., 2017; HINCHLIFFE et al., 2017; DONG et al., 2018; LIU et al., 2015; SEBASTIAN et al., 2019).

MSW management is a complex and multidimensional issue (DI NOLA et al., 2018). MSW management involves many factors, such as political and legal frameworks, institutional settings, application of applicable technologies, operations management, financial management, public participation and awareness, and development of action plans (SHEKDAR, 2009; GUERRERO et al., 2013). The key to successful development is to design a waste management system that suits local needs and traditions, rather than choosing a procedure or technology and transferring it from one country or region to another (ASSOCIATION, 2009).

The selection and application of such technology depend upon different factors including the country's economic condition, priorities, and types of waste generated (MORSELETTO, 2020). It also is one of the critical considerations for the success of a waste management system for a particular town/city. The technologies to be adopted for MSW management and processing predominantly depend upon MSW quantity, quality, and range of variations (GUPTA et al., 2017). However, the efficiency of a particular technology depends on the criteria for which it is designed and planned. A wrong choice of waste processing technology can cause the failure of the entire waste management system leading to lousy economics and environmental cost. There is much research conducted in the technologies applied to process municipal solid waste. However, there is a lack of attention in the study on how to define the criteria for choosing the suitable municipal solid waste technologies in developing countries with the constraints of financial, institutional, technical, and decision-making support system.

In order to manage MSW, the integration of various phases of management (sorting, collection, transport, and final destination) is paramount (PEREIRA and FERNANDINO, 2019). Many techniques, tools, and models have been applied to assess this integration and the quality of MSW management (DE SOUZA MELARÉ et al., 2017).

Many studies have found that in developed and developing countries, even within the European Union, the interpretation of waste-to-energy programs varies. The reason is that the development of recycling systems requires a high level of waste selection, which is very low in developing countries. Therefore, the lack of recycling management is happening in those countries. Meanwhile, developing countries need to extend their regional energy production processes, which can also help by developing waste-to-energy conversion (RADA et al., 2018;

VAN FAN et al., 2020). For emerging countries, the decision-makers prefer to apply the fast-track, cost-effective systems that have a well-understood life cycle and can be successful within five or ten years (ZHOU et al., 2019; NAGY et al., 2018).

3.2. Results of circular economic transformation in the wastewater management system

3.2.1. Results of ReSOLVE framework application

The applicated framework appears in the business model (OSTERWALDER and PIGNEUR, 2010) (known as Business Model Canvas - BMC) for the business development of reviewed wastewater treatment technologies. As far as BMC is concerned, this is a model that allows us to develop water technology (which has been described in the literature review) and lays the foundation for the circular model. BMC is composed of nine blocks that fix the base elements. These blocks are necessary to create, transfer, and set the value. It must be emphasized that circular transformation does not mean that each part of the business model must be replaced with a circular element. There are blocks that are not replaced with circular parts, but they remain unchanged (Table 7). As a result, they can support the operation of the business model and help the circulation of circular elements. Since a real business model cannot be based solely on circular blocks, the use of remaining non-circular elements is absolutely necessary for the optimal functioning of business functions (OGHAZI and MOSTAGHEL, 2018).

Table 7: The ReSOLVE framework method adaptation to biological water treatment technologies in the focus of circular development blocks

Segments of ReSOLVE framework	Additional values to water treatment methods	Circular values*	Part of Business Model Canvas**	Abbreviations in Business Model Canvas
Regenerate (R 1-4)	The adsorption medium can be regenerated, recycled into the system for multiple uses.	+1	X	R1
	It improves the general state of the ecosystem.	+1	X	R2
	Renewable and Alternative energy options.	+1	X	R3
	Social judgment, improving the quality of human life.	0	X	S1
Share (S1)	Market sales of developed technology.	+1	X	R4
Optimize (O 1-4)	Reducing and minimizing waste production from water treatment technology.	+1	X	O1
	Optimizing and increasing resource efficiency.	0	0	O2
	Optimizes the operation of the existing wastewater treatment line.	0	0	O3
	Increasing the useful life of the feedstock used as an adsorption medium.	+1	X	O4
Loop (L1)	Reuse and recycle create an economic loop in the system.	+1	X	L1

Virtualize (V 1-2)	Possibility of using digital control during operation of technology.	0	0	V1
	Application of bioinformatics software, management.	0	0	V2
Exchange (E 1-2)	Introducing new technology.	+1	X	E1
	Use of a new adsorption medium as a primary raw material.	+1	X	E2

Source: (CZIKKELY et al., 2019)

Note:

** +1: Increases the circular nature of the system, contributes to the implementation of the technology circular; 0: neutral from a circular point of view, does not contribute, but does not inhibit circularity; -1: inhibits the circular character, hinders its technological circular transformation.*

*** X is placed in the given location if it has been +1 in the circular evaluation and will be part of the circular development of the Business Model Canvas.*

3.2.2. Results of mapping analyze of Renegerate part

The mapping method was applied to declare the connection of each section in the Regenerate part of ReSOLVE framework. Table 8 presents the new biological treatment technological solutions which could provide environmental friendly methods and drinking water with better chemical and biological quality. The Regenerate part of the ReSOLVE framework could divide into four blocks. Three parts belong to natural and environmental questions and one belongs to human life and social improvement. I present four analysis blocks in Table 8: comparison with linear solutions, the added value of circular transformations, and overall impact on the environment. The mapping analysis shows the analysis and observation of new technical solutions with all relevant problems (belonging to sustainability).

Table 8: Systematic mapping analyzes a regenerate segment of a new business model.

Segments of Regenerate part of ReSOLVE		Comparison with linear conventional methods	On which field could be an added value?	Present a more effective technology	The methodology of reducing resources supply
The adsorption medium can be regenerated, recycled into the system for multiple uses	*Biological segment*	New first raw materials and recycling options because of the material quality	(Natural and environmental value)	The adsorbent could be utilized more times without new first raw materials	Reduce the total amount of natural resource supply
It improves the general state of the ecosystem	*Environmental segment*	The former linear structures could not reduce the number of natural resources	(Ecosystem conservation)	Options of useable material recycling and reusing	Usage of environmentally friendly materials
Renewable and alternative energy options	*Energetically segment*	New energy resource supply (e.g., water or heat energy)	(New energy resources)	The system could solve its own energy supply	Reduce conventional energy consumption
Social judgment, improving the quality of human life	*Human life quality segment*	The new system could provide drinking water with better quality	(Human life quality)	More effective treatment techniques produce drinking water	Sustainable water consumption and water supply

Source: (CZIKKELY et al., 2019)

3.3. Results of choosing municipal waste management options forsustainable transitionsin Hanoi, Vietnam

3.3.1. Systematic approaches to waste management criteria's

Eleven criteria and five technical alternatives (SHARP and SANG-ARUN, 2012) to manage solid waste are presented in Table 9. This table describes an overview of solid waste treatment methods, which has been applied in cities worldwide and presents how each criterion relates to each solid waste disposal plan in general. However, to select suitable criteria for each locality, it is necessary to quantify by the score for the criteria. Table 9. is used as support tools for state management agencies in making appropriate decisions on the selection of solid waste treatment options to identify possible (potential) solid waste treatment options for each city or community.

Table 9: The impact and influence of criteria on methods of SWM operation and utilization

Number of criteria	Part of each segments of transition analyses	Criteria	Composting	Anaerobe digestion	Sanitary landfill	Pyrolysis	Gasification
C1	VP	Solid waste characteristics	4	4	4	3	2
C2	VP	Waste quantity	5	4	3	3	3
C3	RS	Compliance with laws	4	3	4	3	2
C4	RS	Multisector involvement	4	3	3	2	3
C5	RS	Public acceptability	4	3	4	3	3
C6	VP	Possible adverse impacts (environment, society, economy)	5	4	4	4	2
C7	VP	Demand for final products	4	4	3	4	3
C8	CS	Initial investment	4	3	3	4	3
C9	CS	Operating cost	5	3	3	3	3
C10	RS	Time-consuming for the entire process	4	4	3	4	4
C11	CS	Complexity and required amount of raw materials	3	3	3	4	3
C12	CS	Wages in each part of technologies	4	3	4	3	3

Source: (NGUYEN HUU and NGUYEN DUC, 2019)

Notes: Prevention Values of each criteria's: from 1 – linear structure; to 5- fully circularity, based on Table 9. - Values of each circular levels. Abbreviations: VP – Value proposition; RS - Revenue streams; CS – Cost structure.

3.3.2. Results of the transition management approach

To accomplish the most elevated usage of municipal waste management, the centre focuses were controlled by benchmarking of which primary outcomes are appeared at this. Table 10 shows the overview of each circular blocks of transitional management with values of circularity. With these results, I could analyze the systematic improvement directions of the total waste management process. The table shows that improvements are needed in all three respects (value proposition, cost structure and revenue streams) because the current system does not show partly or fully circularity.

Table 1: Results of system analysis to improvement

	Strategic	**Tactical**	**Operational**	**Reflexive**
Value proposition	3.6 (C2)	3.8 (C6)	3.4 (C1)	3.6 (C7)
Cost structure	3.2 (C3)	3.8 (C10)	3.0 (C4)	3.4 (C5)
Revenue streams	3.4 (C8)	3.2 (C11)	3.4 (C9)	3.4 (C12)
Average of each transition level	3.4	3.6	3.2	3.4
Average of each of the evaluated blocks				
Value proposition	3.6			
Cost structure	3.3			
Revenue streams	3.3			

Source: (NGUYEN HUU and NGUYEN DUC, 2019)

Notes: Value 1.0 means the total linear structure, value 5.0 means total circular version. Each column contains the median value of each transition levels. The abbreviations of each block marked from C1 to C12 (according to Table 10 abbreviations)

Table 10 shows the average values of each evaluated blocks also. The highest value is shown by the Value proposition. This means focusing on value creation during transition management, as it is possible to achieve quality change in this area. Technological innovation is not necessary for this, only efficiency has to be increased. Value proposition can be achieved by transforming corporate efficiency with centralized management.

3.3.3. Development strategies – Suggestion of each technological applications

The objective of assessing the appropriateness of solid waste treatment technology is to select the technologies that can be applied in the conditions of Hanoi. This assessment is based on the criteria system, which is used as the tools for the authorities to decide which technology should be adopted appropriately. The selection of criteria will depend on many factors such as natural environment, economy, technology, technology, and society. As shown in Table 11, the total scores of the five technologies assessed are not much different. For commingled waste, the technology's sustainability index shows the sanitary landfill with the collection of biogas (37 points) as the most suitable technology, followed by incinerator with energy collection (36 points), composting (35 points), RDF or SRF (34 points), and anaerobic digestion (32 points), respectively.

Table 2: Assessment of the sustainability of treatment technologies for commingled waste (Scenario 1)

Criteria		**Compost production**	**Anaerobic digestion**	**Sanitary landfill with the collection of biogas**	**Incinerator with energy collection**	**RDF or SRF**
Solid waste characteristics	*Separated solid waste at source*	-	-	-	-	-
	Commingled waste	2	2	5	3	3
Waste quantity		3	1	3	3	1
Compliance with standard/regulation of National Technology of Vietnam		5	5	5	5	5
Time-consuming for entire process		2	3	5	5	3
Complexity and required skills		5	3	4	2	3
Demand for final products		2	2	2	2	2
Initial investment		4	2	3	1	2
Operating cost		2	2	5	1	2
Land requirement: Large scale		2	3	1	4	3
Possible adverse impacts	*Odor*	2	2	1	2	2
	Municipal and industrial wastewater	2	2	1	4	3
	Dust and air pollution	*2*	3	1	2	3
Public acceptability		2	2	1	2	2
Total scores		**35**	**32**	**37**	**36**	**34**

Source: (NGUYEN HUU and NGUYEN DUC, 2019)

Evaluation: Scoring system: 5 = most favorable, 4 = favorable, 3 = Medium, 2= less favorable 1 = unfavorable.

Table 3: Assessment of the sustainability of treatment technologies for separated solid waste (Scenario 2).

Criteria		Compost production	Anaerobic digestion	Sanitary landfill with the collection of biogas	Incinerator with energy collection	RDF or SRF
Solid waste characteristics	*Separated solid waste at source*	5	5	5	5	5
	Commingled waste	-	-	-	-	-
Waste quantity		5	5	5	4	4
Compliance with standard/regulation of National Technology of Vietnam		5	5	5	5	4
Time-consuming for entire process		2	3	1	5	4
Complexity and required skills		5	3	4	2	3
Demand for final products		4	4	1	4	3
Initial investment		5	3	4	2	3
Operating cost		5	3	4	2	3
Land requirement: Large scale		2	3	1	4	3
Possible adverse impacts	*Odor*	2	2	1	2	2
	Municipal and industrial wastewater	2	2	1	4	3
	Dust and air pollution	2	4	1	2	3
Public acceptability		2	3	1	3	3
Total scores		**46**	**45**	**34**	**44**	**43**

Source: (NGUYEN HUU and NGUYEN DUC, 2019)

Scoring system: 5 = most favorable, 4 = favorable, 3 = Medium, 2= less favorable 1 = unfavorable.

Table 12 shows that total scores of all technologies in scenario 2 is higher than scenario 1 because solid waste is separated at the source to form clean, biodegradable organic, recyclable, and the remaining fraction. The assessment of treatment technologies for separated solid waste shows that the composting technology (46 points) is the most applicable, followed by anaerobic digestion (45 points), incinerator with energy collection (44 points), RDF or SRF (43 points), and bioreactor landfill or sanitary landfill (34 points), respectively.

3.3.4. Development goals by a transition of each organizing levels (based on the scenarios)

By assessing the sustainability of solid waste treatment technologies from two scenarios, Scenario 2 have specific advantages such as low operation, high quality of the composting product, more efficient land use, lower environmental impacts and higher production of biogas, energy collection in comparison with the Scenario 1 so that scenario 2 will be selected for integrated solid waste management in Hanoi. These results are consistent with the situation of solid waste and the set targets for the management of solid waste in Hanoi. Also, it is clear that one technology would hardly achieve an efficiency of solid waste management in Hanoi. The need for a combination of multiple technologies yields an integrated solid waste management system leading to zero waste for sustainable resource utilization in Hanoi. Ideally, the composting technology followed anaerobic digestion technologies is found to be the most sustainable for solid waste in the Hanoi. Incineration with energy collection is essential only for non-recycling solid waste (with high calorific value), and residual solid waste will always be needed for landfills. By separating solid waste at sources (application of Scenario 2), the City will be able to:

- Utilize 70 to 80% of the city's solid waste, among which about 60-70% can be used for producing compost and anaerobic digestion for generating energy. Remaining 10-20% can undergo recycling.
- The decrease in pollution caused by odor and leachate from landfills.
- Raise people's awareness of environmental protection.

To achieve zero waste management, the results of the two exampled scenarios show that waste separation at source is an essential factor that prevents waste from entering landfills. Implementing waste separation allows the collection of a great amount of recyclable waste that can be converted into useful materials. Besides, unmixed waste helps waste collectors save time during collection process substantially, and save cost for Hanoi’s waste management. The segregation of the waste is must for sustainable solid waste management, as the waste can be intercepted for recovery of materials and composting, anaerobic digestion, incineration and the minimal amount go to the sanitary landfill.

3.4. Results for selecting the best sustainable solid waste management system for Hanoi

According to the AHP analysis, the protocol provided by the Super Decisions Software was followed. This result included the pair-wise comparisons, in which the participants had to match the criteria and sub-criteria and alternatives in pairs to assess their preferred choice. The details for pair-wise comparison are presented in the Appendix (2) Result charts of Super Decision Software Node comparisons.

Alternative(s) in it:	• A1 • A2 • A3 • A4
Network Type:	Bottom level
Formula:	Not applicable
Clusters/Nodes	• **1 Goal:** *Choosing the best scenario for sustainable MSW management in the situation of Hanoi* ◦ **Goal:** *Choosing the best scenario for sustainable MSW management in the situation of Hanoi* • **2 Criteria:** *Criterias for choosing the best Alternatives* ◦ **C1:** *Waste flow in 2018 and forecasted data to 2030* ◦ **C2:** *Necessary equipment and facilities for handling waste in 2008 and forecasted data to 2030* ◦ **C3:** *Total investments estimated for municipal solid waste collection and disposal* ◦ **C4:** *Annual cost of operation and maintenance for municipal solid waste collection and disposal* ◦ **C5:** *Total average costs per capita per year* • **3 C1:** *Waste flow in 2018 and forecasted data to 2030 with 3 sub-criteria S1 to S3* ◦ **S1:** *Total of waste collection (t/y)* ◦ **S2:** *Recycling (t/y)* ◦ **S3:** *Residual waste for landfill (t/y)* • **4 C2:** *Necessary equipment and facilities for handling waste in 2008 and forecasted data to 2030 with 5 sub-criteria S4 to S8* ◦ **S4:** *Transfer points in streets (No.)* ◦ **S5:** *Pushcarts/containers (No.)* ◦ **S6:** *Compaction trucks for collection (No.)* ◦ **S7:** *Transfer stations (No.)* ◦ **S8:** *New landfills needed (2 mln tons capacity each)* • **5 C3:** *Total investments estimated for solid waste collection and disposal US$) with 2 sub-criteria S9 and S10* ◦ **S9:** *Investments estimated for collection* ◦ **S10:** *Investments estimated for Disposal* • **6 C4:** *Annual operation and maintenance costs for solid waste collection and disposal US$)with 2 sub-criteria S11 and S12* ◦ **S11:** *Annual operation and maintenance costs for collection* ◦ **S12:** *Annual operation and maintenance costs for Disposal* • **7 C5:** *Total average costs per person per year with 2 sub-criteria S13 and S14* ◦ **S13:** *Total investments and reinvestments* ◦ **S14:** *Total operation and maintenance costs* • **8 Alternatives:** *Scenarios for municipal solid waste management system in Hanoi* ◦ **A1:** *Improving the current system for waste collection and transportation* ◦ **A2:** *Reducing, reusing and recycling waste at source* ◦ **A3:** *MBT plants for classifying, composting and refuse-derived fuel (RDF) for cement industry* ◦ **A4:** *MBT plants for classifying, composting and RDF for Waste-to-Energy/incineration plants*

Report for toplevel

This is a report for how alternatives fed up through the system to give us our synthesized values. Return to main menu.

Alternative Rankings

Graphic	Alternatives	Total	Normal	Ideal	Ranking
	A1	0.0760	0.2281	0.6736	2
	A2	0.0758	0.2273	0.6713	3
	A3	0.0686	0.2059	0.6081	4
	A4	0.1129	0.3386	1.0000	1

Figure 1: The structure of the AHP analysis and the order of the alternatives

Source: (HOANG and FOGARASSY, 2020)

It can be seen from Figure 9 that the study identified the sequence of the alternatives as follows A4, A1, A2, A3, which means that Alternative A4 is the highest ranking for choosing the best sustainable municipal solid waste management system in Hanoi by 2030. In this case, the mechanical-biological treatment facilities will be used to mechanically separate the household waste and classify the organic components for composting, after which the refuse-derived fuel fraction will be incinerated in a dedicated waste-to-energy plant. This method will help decrease the massive amount of waste buried and minimize adverse impacts on the environmental impact.

4. CONCLUSIONS AND RECOMMENDATIONS

The focus of this thesis was on researching the transition towards the circular economy in developing countries with the central aspect of an area so-called waste management, which faces many problems worldwide, especially in the emerging nations. Deriving from the fact that there has been lack of data and analysis as well as exploration on CE in developing countries compared to the overwhelming focus on this field in EU and China, this research has conducted the comprehensive investigation about the CE approach in these nations to have the full pictures of competitive advantages, challenges, and actions for accelerating CE. Besides, this thesis also takes the waste management issue in Hanoi, Vietnam as the case study to research the transition towards CE and sustainable development.

This study, first, has identified that the previous economic structures of wastewater treatment systems worked with conventional linear methods. It produces more wastes and does not use recycling or any other circular economic properties. It can be defined that, the circular transformation could solve the problem of linear treatment systems by a new economic method with circular economic focus points. These seem to be the places where the wastewater system could improve by biological regenerable materials (such as composts, biological degradable sources, algae or any other biosorbents). The new structure follows the standard new-wave economic models and gives a future applicable methodology to get more effective urban (or industrial) treatment systems. In order to strive for the environmental sustainability of urbanization processes, the use of closed-flow technologies is important. The research has pointed out that wastewater treatment technologies using closed material flows not only result in good cleaning efficiency but also create favourable cycles from an economic and social perspective. Efforts should be made to apply clean technologies with zero-waste production and fully enclosed material and energy flows, so I consider it is important to pursue the circular transformation of all available wastewater treatment methods (not only biological ones but conventional techniques). Conventional business models used in wastewater treatment were evaluated for transformation possibilities. It is important to emphasize that current methods of wastewater treatment do not fully and reassuringly meet the sustainability criteria. It should be understood that cleaning methods focus on efficiency, and closed flow systems are less important in implementing research and development programs. The Business Model Canvas was modified and developed using the ReSOLVE framework and Mapping method. The circular blocks were determined, which could be useful for improving the Business Model Canvas for circular economic transformation in the design of wastewater management technology systems. With new business concepts developed in this way, it is feasible to reconsider and redesign the technology already introduced and present circular business models highly effective in terms of sustainability. The circular novelty of technologies can be defined or redefined by the Canvas model from a business point of view.

In the next steps, this study investigated the current situation of solid waste management in Hanoi from the collection, transportation, and processing. After expanding the administrative boundaries in 2008, Hanoi-the capital of Vietnam became one among the 17 largest capital cities in the world, with nearly 8 million people. The high rate of urbanization and the booming of urban residents have put tremendous pressure on infrastructure systems, including municipal solid waste treatment systems. Hanoi's current municipal solid waste management technologies and strategies are outdated, and most municipal waste that is not classified at source is disposed of in landfills. This leads to serious congestion of existing landfills and adverse environmental impacts on air, soil, and water. Therefore, Hanoi urgently needs to select and implement sustainable municipal solid waste management strategies and programs to reduce the negative environmental impact of inefficient solid waste management and exploit energy from these waste treatment activities. It is clear that Hanoi needs to combine multiple technologies yields an integrated solid waste management system leading to zero waste for sustainable resource utilization. The composting technology followed anaerobic digestion technologies and incineration with energy collection are found to be the most sustainable for solid waste in the Hanoi in the condition of segregation of the waste at source, while the last option is the sanitary landfill.

I would like to make suggestions on which of the twelve development goals (presented by Table 9. in Results chapter) will strengthen prevention, e.g. minimizing the amount of waste and implementing the zero waste strategy. Primarily waste production should be reduced, because if less waste is generated in the system, waste management can be more efficient. It is important to note that which part of the business models could be the prevention and how they relate to the circular economy concept. It is important to define the prevention levels of the circular economy, therefore the development needs at the three transition management levels: governmental, enterprise and personal levels.

This study assesses the sustainability of the municipal solid waste management system in Hanoi, taking into account five main criteria, fourteen sub-criteria and four alternatives using the AHP model with the Super Decision program as a tool to make the pairwise comparison for ranking the alternatives. The results of this study have revealed the best alternative for the current municipal solid waste management system of Hanoi until 2030. This is the scenario in which mechanical–biological treatment facilities are used for the separation of the household waste mechanically, as well as to classify the organic part for composing and the refuse-derived fuel fraction for incineration in dedicated waste-to-energy plants. The advantage of these scenarios is that it will help decrease the amount of waste being buried and reduce the negative impact on the environment. In addition, the energy generated from the waste-to-energy process can be used for various purposes.

Analytical indicators included sustainability criteria in the traditional sense but did not include circular principles. By studying the European literature, it is clear that the development strategies of developing countries (such as the conversion of waste into energy) can be sustainable in their traditional interpretations (fully proven in our analysis). However, without circular principles, they will not promote the local adaptation to climate change and do not support the global climate goals either.

5. NEW SCIENTIFIC RESULTS

The significance of this research is the contribution it makes to the existing literature on examining the socio-economic characteristics of developing countries to analyze the opportunities and challenges as well as the competitive advantages of these countries and the necessity of the transition towards the circular economy and sustainable development. Based on the results and discussion, the new scientific results drawn from this research are as follows.

1. To deal with the massive waste discharged to the environment, especially with wastewater, as the consequence of the conventional business models (by a linear economic model), this research presents a circular economic transformation method to get a more effective and cost-efficient wastewater treatment system by business model development with low cost and effective, economic background. Using the RESOLVE framework and mapping methods, I propose each technology's main circular points (focusing on the Regenerate part) for the effective application of treatment solution. Besides, this research has improved the Business Model Canvas, and the main economic transformation points were given by the framework. By making these approaches, this study answers how to minimize wastewater production by business model development with low cost and effective economic background. The study clearly shows that economic operators and supply chain members integrate their resources into the circular system. After that, the business ecosystem can be continually redesigned, creating dynamically and efficiently self-regulating systems. The finding of this study confirms that a new business concept and innovative circular model (through a significant reduction in water consumption) could resolve the wastewater problems instead of only exclusively technological development.

2. The Analytical Hierarchy Process (AHP) method that I used combines the data to get the rank of alternatives. Finally, sensitivity analysis can be performed to investigate the consequences of a weight change of a criterion. With sensitivity analysis, it is possible to measure the robustness of the solution and identify criteria that are more relevant to the final result. A large number of studies have concluded that AHP is a powerful decision-making tool that can support decision-makers in adopting sustainable waste management alternatives. During the research, I realized that the hierarchical structure of the AHP model allows decision-makers to easily understand the circularity problems in terms of the relevant criteria and sub-criteria. Other additional criteria can be put on the hierarchical structure for further comparison. By making the pairwise comparison between the criteria and sub-criteria with the alternatives, this model can help to prioritize and give optimal and sustainable solutions based on this information. The amount of information increases the accuracy of the model, a property that is a

key consideration in determining the order of priority of circular preferences to determine the relationship between criteria and subcriteria.

3. The transition management approach (from linear to circular) can support to enhancement of municipal solid waste management in individual cities and urban areas. The obsolete technological solutions for waste management cannot support efficient and sustainable urban waste management processes. This research has provided a possible solution for improving the municipal solid waste management system in a high-density city, Hanoi (Vietnam). To develop a sustainable and efficient municipal waste management system in the current situation of Hanoi, the study found the transformation possibilities simultaneously with intervention tools at all three decision levels, including governmental, enterprise, and personal levels. It puts forward proposals for transformation at both the technological and the residential (personal) level in order to develop a sustainable and efficient municipal waste management system. It should be emphasized that zero waste strategies need to be focused on in developing countries, which is a complicated task, and it is challenging to explain the related priorities to decision-makers. However, the apparent situation is that if there is less or no untreated wastewater related to the increase in the standard of living, no unique technology is required, and waste management systems can be operated at a low cost.

4. This research takes the waste management issue in Hanoi, Vietnam, as a case study to investigate the transition toward a circular economy and accomplish the national strategy for the general management of solid waste until 2025 with a vision toward 2050. The research indicated that "Mechanical Biological Treatment (MBT) plants for classifying, composting, and Refuse-Derived Fuel (RDF) for waste-to-energy/incineration plants" has the highest ranking in terms of a sustainable solution for the municipal solid waste management system. Although the circular innovation program and the action plan of the EU may be contrary to this trend, the waste-to-energy solutions are appropriate and should be applied to Hanoi and major megacities in Asia and Africa. At the same time, sustainable development should strive to continuously reduce the ratio of waste to energy through the planned reuse of materials that can be recycled by industry.

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BOOK CHAPTER

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