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

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ABBREVIATIONS

3R:	Reduce, Reuse and Recycle
AfDB:	African Development Bank
AHP:	Analytic hierarchy process
BAU:	Business As Usual
BMC:	Business Model Canvas
BMW:	Biodegradable Municipal Waste
C&D:	Construction and Demolition
CAP:	Common Agricultural Policy
CE:	Circular Economy
CPTPP:	Comprehensive and Progressive Agreement for Trans-Pacific Partnership
DSW:	Domestic Solid Waste.
EMF:	Ellen MacArthur Foundation
EU:	European Union
EVFTA:	European-Vietnam Free Trade Agreement
GDP:	Gross Domestic Product
GEF:	Global Establishments Facility
GHG:	Greenhouse gases
HHW:	Household Hazardous Wastes
ICT:	Information and Communication Technology
KPI:	Key Performance Indicators
LATS:	Landfill Allowance Trading System
LCA:	Life cycle assessment
MBT:	Mechanical–Biological Treatment
MCDA:	Multi-Criteria Decision Analysis
MSW:	Municipal Solid Waste
NDCs:	Nationally Defined Contributions
NGOs:	Non-government Organizations
PAYT:	Pay-As-You-Throw
PSS:	Product Service System
PV:	Photovoltaic
R&D:	Research and Development
RDF:	Refuse-Derived Fuel
SDGs:	Sustainable Development Goals

SMEs: Small and Medium-sized Enterprises

SRF: Solid Recovered Fuel

UN: United Nations

WHO: World Health Organization

1. INTRODUCTION

1.1. Problem statement

A perspective of 'transition thinking,' as a reformed initiative of scientific thinking, was created as an academic concept during the early 1990s in the Netherlands. Its sphere of influence expanded slowly, but was more or less integrated at the establishment level in 2001, in the form of the Dutch Knowledge Network and Research Program for System Innovations and Transitions. The main goal of this program was to make the sustainable innovation process easier to understand and make people able to identify the factors that influence this transition. To make the process of sustainable transition interpretable scientifically as well, many activities including ecology, complexity theory, sociology, history, leadership, and management theory, and knowledge related to innovation processes were integrated into the analyses step by step (STERRENBERG et al., 2010).

Transition thinking and management radically serve the description and improvement of realistic and inspirational goals and narratives. Long-term visions are matched with short-term operative projects in transition thinking and performing local and global processes, and their connections into the equation become attainable with this approach. Moreover, it offers guidelines and guidance on assembling either structural forms or cooperation programs, which can prove efficient in reaching regional or national goals set in terms of sustainability (WITTMAYER et al., 2016b). These aims are principally technological innovation, green innovation or climate-friendly system development projects. Accordingly, the engine of transition processes is made up of innovation programs, but in these cases, transition thinking also requires a new, system-level interpretation (KEMP et al., 2007b).

With the signing of the Paris Agreement on Climate Change and the setting of Sustainable Development Goals (SDGs) in 2015, the international community recognizes that the change in the way we use natural resources is prerequisite conditions for a prosperous, safe and resilient society. Experience from the economic development of most countries around the globe has shown that the growth based on resource-intensive exploitation always leads to a substantial environmental cost. Together with the demand to deliver the infrastructure and services needed for supporting growing economies and populations in developing countries, the need for a revolution in models of resource use is emerging to deal with climate change and maintaining ecosystem stability.

There is increasing excitement about the possibility of developing more 'circular'- and sustainable - models to achieve this revolution 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). Analyses of the CE, its development, and implications have focused overwhelmingly on the EU and China, which have the most advanced legislative frameworks in this area (TÜRKELI et al., 2018; KALMYKOVA et al., 2018). Until now, few other emerging nations are included in existing macroeconomic models of the impact of moving to a CE. At the same time, the national-level assessments of resource efficiency or policies for the circular economy were only carried out for a few high-income countries: Austria, France, Germany, Japan, South Korea, Sweden, and Turkey (MCCARTHY et al., 2018). Further data on a larger number of countries are available in input-output models. However, these data are often aggregated to just a few economic sectors, limiting the effectiveness of the process for CE monitoring (KALMYKOVA et al., 2018).

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. Some developing countries are actively pursuing national CE policies like Nigeria, Rwanda and South Africa launched the African Circular Economy Alliance in 2017, while India has set out a strategy for resource efficiency which recognizes the role of the CE in achieving this (AAYOG, 2017).

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. Research by the Indian Council for Research on International Economic Relations found that economic development is slower in cities that are not growing in a ‘compact’ way (TEWARI and GODFREY, 2016). These cities face severe natural resource constraints, infrastructure deficits, and mounting pollution crises.

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 percent 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. McKinsey Global Institute (DOBBS et al., 2016) estimates that by 2025 the global consuming class will have an additional 1.8 billion people, of which 1 billion will live in the emerging world. If there is to be a fundamental shift in consumption and production patterns, the success of CE models in these countries will be key.

Vietnam is an S-shaped country (a long, narrow nation shaped like the letter ’s’) located in the centre of South-East Asia which has 3,730 km mainland border with China in the North, Laos and Cambodia in the West. The total land area of 330,967 km2 with a population of approximately 94,666 million in 2018 (GSOVN., 2020). Vietnam is developing rapidly and undergoing urbanization with current GDP of about 193.6 billion US$.

The generation of solid waste results from human activity in its production and consumption cycle. Due to Vietnam's rapid urbanization and industrialization, thousands of tons of municipal solid waste (MSW) are generated daily. In 2018, Vietnam generated over 27.8 million tons of waste annually, 46% from municipal sources and the rest from agriculture and industry. The five biggest cities - Hanoi, Ho Chi Minh City (Ho Chi Minh City, former Saigon), Haiphong, Da Nang, and Can Tho account for around 70% of total waste generation. Municipal solid waste comprises 60% to 70% biodegradable waste by wet weight. The Vietnam Environment Administration has found that the country's municipal solid waste generation is increasing by 10% to 16% each year (REPORTLINKER, 2020). The Covid-19 pandemic has had a negative impact on the waste management market in Vietnam, which is driving the plastic products market for prevention, testing, and treatment worldwide. The safe disposal of plastic waste piles is a major problem for many countries (MARKETS, 2021). The growing generation of MSW has become a new environmental problem faced by the Vietnamese authorities (LUONG et al., 2013). The increase in the amount of waste negatively affects the environment and human health due to inappropriate waste disposal (NGOC and SCHNITZER, 2009). In addition, 80% of MSW is disposed of in landfills instead of being recycled, reflecting the loss of material and energy to 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. Considering the nine goals, it can be concluded that Vietnam has been limited progress in achieving the 3R goals of Ha Noi Declaration. Only Goal 11 "biomass waste utilization" has achieved some progress, while the others are still far from the expected targets (THANG, 2017). Currently, Hanoi's municipal solid waste management system is ineffective due to the lack of financial, technical, and human resources as well as 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. LITERATURE REVIEW

2.1. Transition and transition management

2.1.1. Transition and sustainability transition - Definition

The term “transition” describes the process of moving from one state or condition to another. A common use of the term transition in science mainly indicates when chemical substances move from solid to liquid to gas phases. In other areas, the term is used in a similar way to represent the movement between qualitatively different states (LOORBACH, 2007). As such, the "transition" of social research is the transformation from a relatively stable societal state to another and can be defined as a societal change process, in which the social structure (or a sub-system of society) substantially changes (LOORBACH, 2007).

The current movement to sustainability has emerged as a form of socio-technical transformation in response to environmental challenges in recent decades and the need to enhance the overall performance of the linear production and consumption model (GEELS, 2011). Such transitions involve variations in technical and social and assets which can be considered as interacting systems of actors (such as producers or consumers, companies and other organizations, collective bodies), institutions (social and technical rules, regulations, standards of good practice), materials artefacts and knowledge (MARKARD et al., 2012; MARKARD, 2011; GEELS, 2004; WEBER, 2003) and aims to move towards more sustainable models of production, consumption and living.

The adoption of more sustainable and cleaner production structures entails changes in companies in the way of doing their business (BRESSANELLI et al., 2017; MASI et al., 2018) and their activities in terms of improvements of the design of products as well as of equipment and production processes, adoption of new technologies, product modifications (e.g. product life extension), internal and external management of waste (HENS et al., 2018). In society, more recent activities may require new infrastructure and organizations to collect and process waste, while releasing new sustainable products could lead to changes in consumers behavior (MUGGE, 2018).

At present, the introduction of new sustainable products and services is competitive with the existing products and services (KORHONEN et al., 2018). In this phase, the formers are partly complementing and partly substituting conventional products and services (MARKARD et al., 2012). These dynamics show that sustainability transitions are complex processes and the path towards the goal of sustainable development as a new state of dynamic equilibrium (BOSMAN and ROTMANS, 2016) could require considerable time as in the nature of socio-technical transitions (GEELS, 2011). Many countries worldwide are also establishing policy agendas in favour of the move to a circular economy (CE), in order to further support the transition to sustainable development (EC, 2019) and at the same time to meet the targets of global sustainable development agenda by 2030 according to the United Nations Sustainable Development Goals (UN, 2020). The CE implementation could contribute directly and indirectly to achieves such goals (SCHROEDER et al., 2019).

The CE is based on a robust and multidisciplinary theoretical background (KORHONEN et al., 2018; SAUVÉ et al., 2016; ANDERSEN, 2007), on clear principles related to the use of natural resources (non- renewable and renewable), on the optimization of resources' use including a new concept of waste and finally on the improvement of the functioning of the markets to spread more social welfare (GENG et al., 2016).

2.1.2. The models and processes of linear and non-linear innovation

Fundamental innovation theories have grown significantly over the last few years, but sadly, the innovation policies we currently apply are mainly dependent on the traditionally accepted innovation theory - the linear innovation model. In this model, the process of innovation produces the final result of a new product or process, which is fundamentally a research result, or a product of the new technological solution. The primary linear-sequential mechanisms (BROOKS, 1995) of the innovation process are sustained by the advancement of new technology.

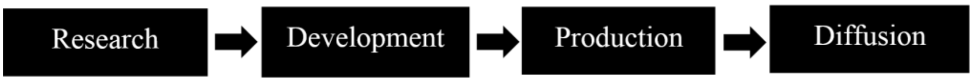


Figure 1: The non-linear transition process

Source: (FOGARASSY et al., 2018)

The linear model proposes that the most significant actors in the innovation process are researchers and entrepreneur-developers. Later research verified the fact that this linear model is too simple. The most common actors in the process are the following: banks, shareholders, suppliers, funding organizations, NGOs, suppliers, the government, and customers/end users.

Hence, the non-linear innovation model has various actors, which makes it capable of not (only) producing a new technological solution, or product, but facilitating a complete transformation process. This non-linear transition process can be observed in Figure 1. Its basic rules are determined by the partners and their interrelationships. Therefore, innovation itself is a transition that influences the general behavior of economic and social actors and, with luck, it can provide a solid foundation for long-term sustainable and evolving structures (HORVATH and MAGDA, 2017; KOT, 2018).

In a nonlinear-innovation model, the financial system actively generates financial support for the innovation or incubation process. At the same time, customers use consumption activities to support market integration, and political or social actors partake in the transition management process through flexible efforts in regulation conditions (FOGARASSY et al., 2018).

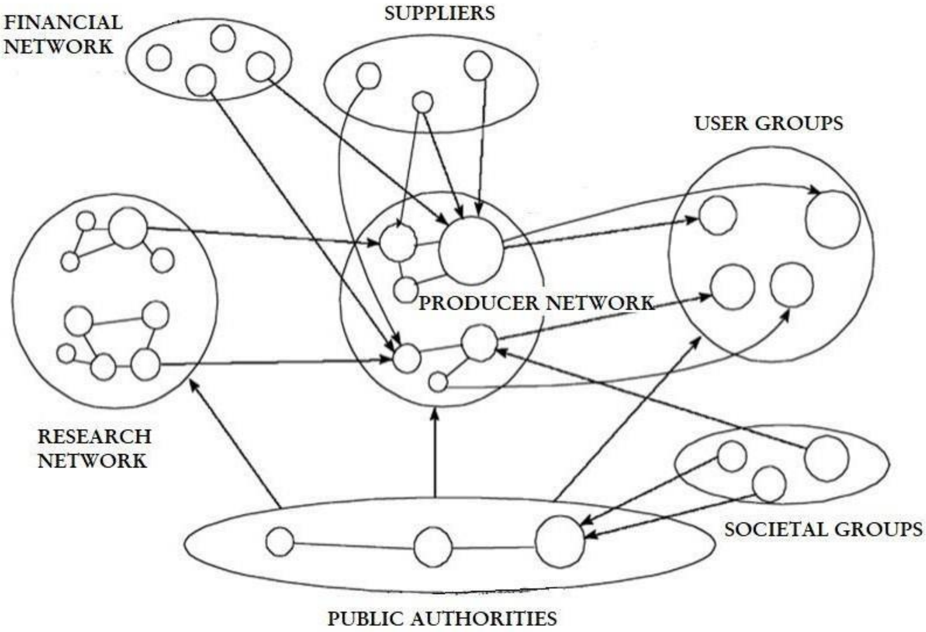


Figure 2: Actors in the transition process

Source: (FOGARASSY et al., 2018)

The business sector recognizes the promotion of eco-efficiency as its role concerning sustainable consumption. Most market players are settled for the provision of mass consumption and the necessary associated inducement to ever-increasing levels of consumption. There is a limited "niche" in which companies can differentiate themselves or their products based on social and environmental behavior, regulations, and standards with corresponding price margins. Both buyers and firms influence the government's standpoint on sustainable consumption (STERRENBERG et al., 2013).

2.1.3. The transition process and sustainable transition management

"Transition thinking" is a normative and practice-oriented approach to achieving sustainable development that implements knowledge from various fields of science, extended with practice experience (FOGARASSY et al., 2014). The theories of "transition thinking" and "transition management" originate from a basic idea, retraceable to the studies of complexity and ecosystem theory, which argue that sustainability consists of fundamental and system-level changes that depend on multiple participation and whose connections are a decisive factor in the dynamics of transition processes (RYAN, 2013). The establishment of a low-carbon (low material-and energy-requirement) society, which is planned to be achieved in one or two generations could produce an equilibrium of numerous states in society, which can be witnessed in our own ecosystems as well. This description is connected in the process of transition management, with its multi-actor network ideas and multi-level process management (e.g., the Multi-Level Perspective) (STERRENBERG et al., 2013). Transition management basically distinguishes between the states of a process: the initial phase, the acceleration phase, and the stabilization phase (the new equilibrium), which can be seen in Figure 3. We can apply the economic-social systems we evaluate to the innovation curve of the system seen in Figure 3, which can outline the characteristics and intervention points to be used for the transition. The primary questions of transition management are as follows: How can the attitude of society, currently not sustainable, shift to a sustainable one? When and how can this transition be estimated? (LOORBACH and ROTMANS, 2010). It is difficult to obtain the answer to the first question because the group of innovation criteria comprises many factors which we are not able to handle with enough confidence. The non-generic lifestyle control in question depends on how conscious the shareholders and actors are of the consequences of their own actions, which influence the improvement and innovation processes conducted on multiple levels of society. If the actions of actors are more in sync and well-structured, then we are on the road towards transition, where processes are simple to control and can be accelerated well (ROORDA et al., 2012).

The theoretical inventions and practical experiences correlated to transition management achieved during the last decade show that the following four different activities can be determined within the contexts of actors' behaviour, and social transitions, (LOORBACH, 2010): strategic, tactical, operative, reflexive.

Strategic transition: Processes occurring on a social level, which have a long-term actualization result, are associated with structuring complex social problems and constitute an alternative outlook on the future.

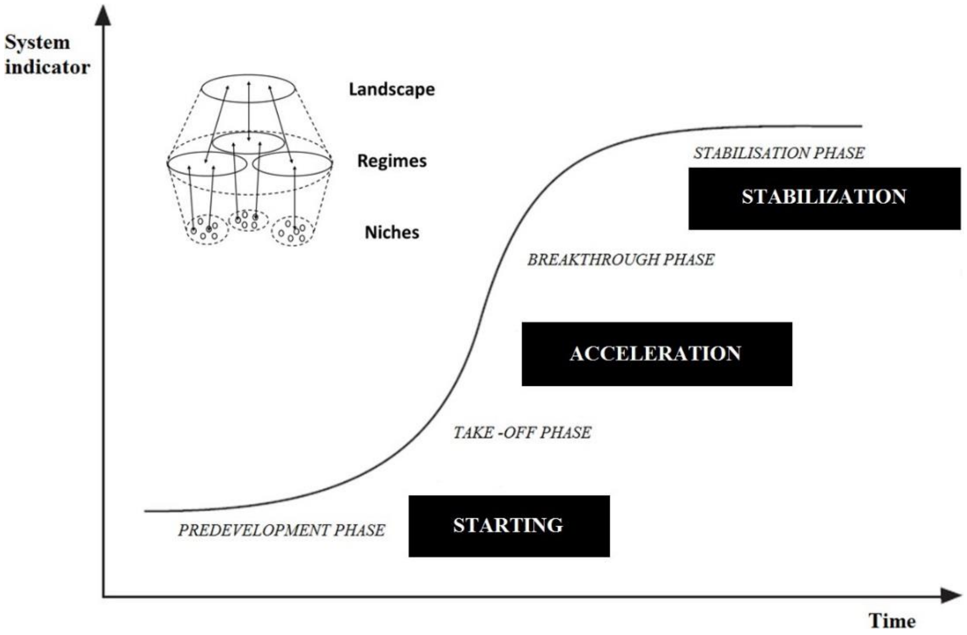


Figure 3: Phases of transition management

Source: (FOGARASSY et al., 2018)

The Common Agricultural Policy (CAP) system can also be called a strategic or landscape planning level phenomenon because its regulatory elements implement a framework for agricultural production and innovation for a specified period in the EU (LEFEBVRE et al., 2015).

Tactical transition: Activities that happen on the level of society, which develop in the long-term, are correlated to the appearance of complex social problems, and create an alternative future as a result of organic development. Without innovation programs, these activities cannot perform properly, which is why green or low-carbon strategic solutions make up the specifics of the innovations. A good pattern of this is when GHG emissions are priced so that the level of the system calculates extra costs to the system users, so these are taken into account in their decisions. The same effect can be witnessed for foods as well, if we increase the price of products by regulation, their consumption reductions (MÁTÉ et al., 2017). By artificially decreasing prices (e.g. with a Value Added Tax increase), their preference increases.

This is most notable in developed societies. Tactical activities are executed on a sub-system level and are related to the construction and deconstruction of the system's structure (institutions, regulations, physical infrastructure, financial infrastructure, etc.).

Operative transition: Activities linked to short-term and everyday decisions and actions. On this level, the actors either rethink or reconstruct the structures of the system; moreover, they determine if they should restructure, or only partially replace them. The decision-makers usually alternate regulation systems and generic base structures during the transition processes and generate new systems in the hope of attaining sustainability. These transformation processes are signified by, for instance, state interventions in the form of privatization or de-privatization (e.g., reorganizing the ownership of land), or introducing new structures, or exchanging the old ones. The most notable fields subject to these are waste management, wastewater treatment, health care, communal feeding, and agriculture.

Reflexive/retroactive transition: The multi-level evaluation of existing states and their detrimental by-products. Social events continuously structure themselves through the mediation of arguments, structured evaluation, analysis, and research, while those influenced rethink and treat problems. Learning from our own mistakes typically embraces this transition. In this control process, we can often detect phenomena where decision-makers recognize, or sense the consequences of, incorrect development processes, and thereby try to manage the processes of transition towards the right route using changes in their current routes, or their goal system. Due to this sensing of disadvantageous feedback, all improvements or innovations are the results of multi-level evaluation processes (ILLÉS et al., 2015). Through discussions/arguments and analyses, social events continuously restructure themselves, and problems are rethought and handled using the effects sensed. Similar effects can be seen during the processes of alternative energy source developments, where the management of prioritized programs generates different effects in the different EU Member States. In the case of different nations, mixed-up regulations, market preferences, or different lobby activities for the same goal system (f. e. EU 20-20-20) produce completely different social and economic reactions (Figure 4). National strategic targets should not be confused with tactical level targets. The tactical level is meant to serve the needs of identified targets, which is the key to distinguishing between national strategic targets and tactical level goals. When the strategic, tactical and operational levels harmonize with each other, the transition process takes place in a reflexive way.

Figure 4: Strategic, tactical and operational levels of the EU 20-20-20

Source: (FOGARASSY et al., 2018)

"Transition management" supposes that these activities should offer specific attributes in terms of what actors are partaking in the process, what processes they are interlinked with, and what type of product or service they generate, which can make the design of specific system tools and process strategies possible. As an example, we could mention changing partakers (designating a target group), defining the challenge in the specific transition process, the type of processes required for success, or the use of process regulation tools (WITTMAYER et al., 2017).

However, several authors note that different economic and social development are generating processes at different speeds during the transition process. Due to conscious but too fast or slow developments may lead to undesirable and non-sustainable transformations (WITTMAYER et al., 2017; CAMPOS and CORICELLI, 2002).

2.2. The circular economy

The basic idea of CE is the transformation from a system that extracts resources and turns them into products and ultimately disposes them into a system that preserves resources at the highest value possible. This may include reusing and repairing products, or recovering their component materials for each product at the end of its life for repurposing into new goods or for new uses. The circular economy recycles products at the end of their life cycle, thereby reducing waste generation and resource usage. Likewise, CE may mean restructuring industrial or agricultural systems, so that the waste from one process becomes the feedstock for another process or the replacement of non-renewable materials with renewable and biological materials. Overall, the CE approach can significantly reduce the utilization of key resources and the use of energy inputs.

2.2.1. Basics of circular economy

The main advantage of circular economic models is that they prefer a holistic approach to development branches, where the cooperation between market actors, the stable and long-term operation of local systems and markets based on local resources, and the innovative mobilization of the labour market are the primary points. When designing models, scientific adequacy, and an interdisciplinary approach are necessary. The bio-economics and low-carbon economy stated above are partially integrated into circular economies, via indicator systems. Circular economic systems close material flows to two main cycles - one of which is determined by periodic processes of biological cycles, while in other closed systems, the processes of the technological cycle are sustainable systemic solutions (Figure 5).

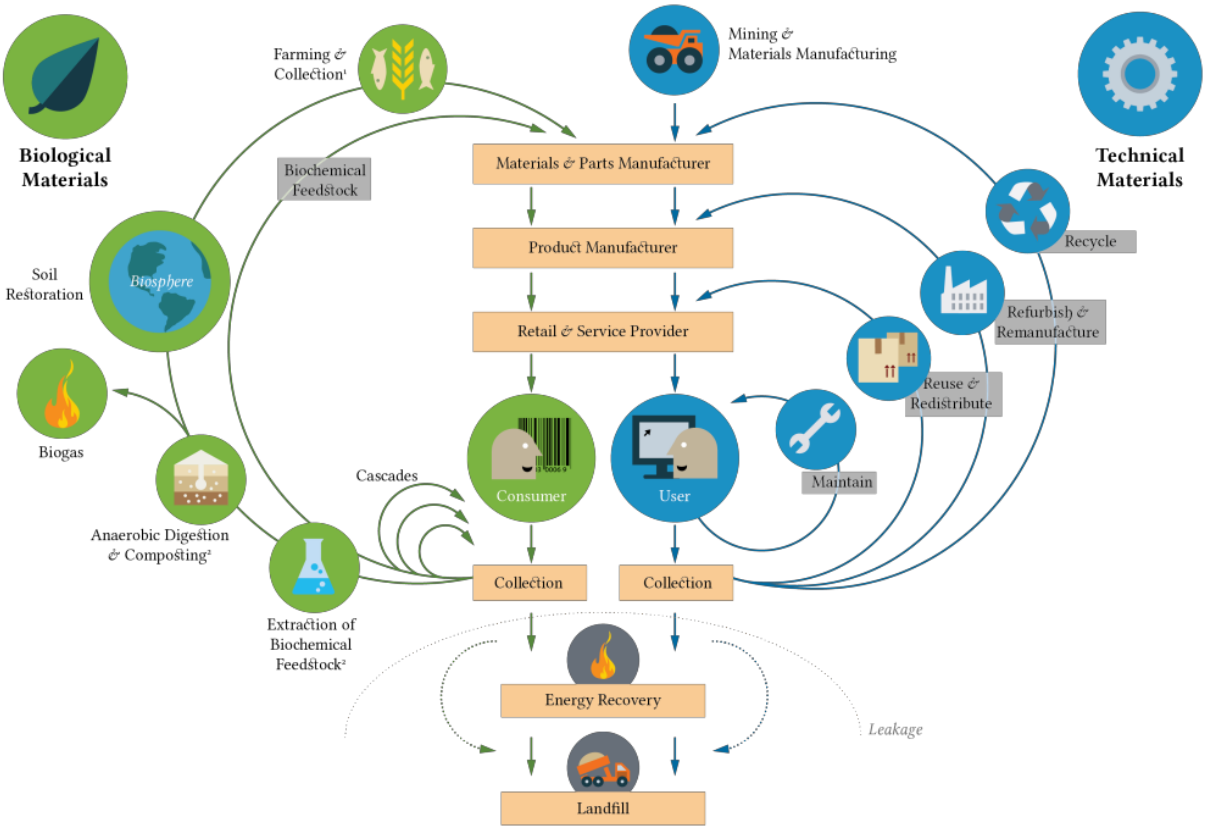


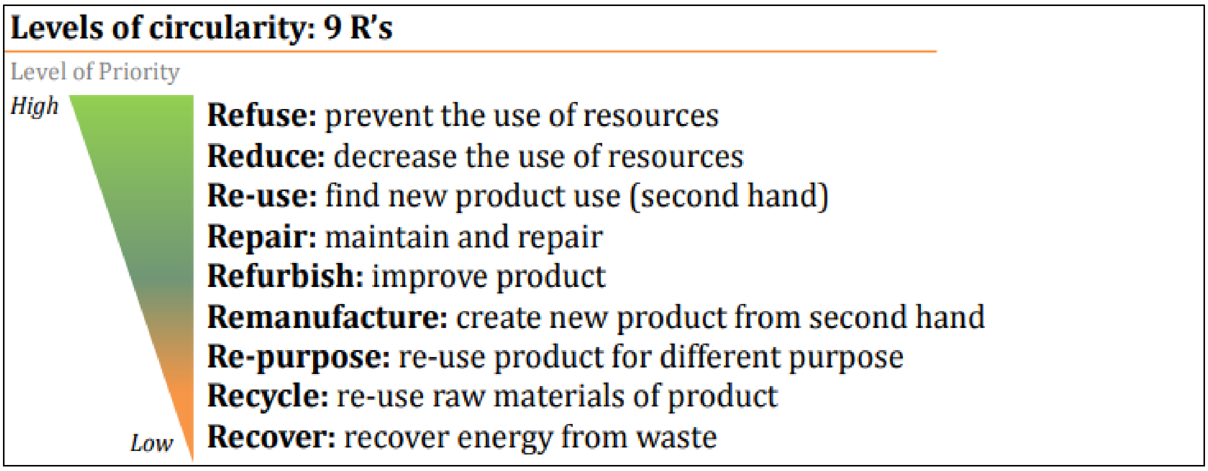
Figure 5: Biological and technological cycles of circular economy

Source: (EMF, 2012)

2.2.2. Priority levels for circular solutions

The approach which gained fame as '3R' has been in the curriculum of public education since 1818 and means the three basic capabilities (Reading, wRiting, aRithmetic), promoting their importance. After a while, environment conservation activists also created their own 3R - to symbolize their priorities - which means Reducing the quantity of waste which was on the rise rapidly during the second half of the XX. Century, recycling it, or completely preventing its creation by reusing products.

During the design of circular theses, researchers based on the previously introduced, 'R-signed' methods to expand the toolset of waste treatment and prevention 9R nowadays, which are called the priority levels of circulation (Figure 6).



Levels of circularity: 9 R's

Refuse: prevent the use of resources
Reduce: decrease the use of resources
Re-use: find new product use (second hand)
Repair: maintain and repair
Refurbish: improve product
Remanufacture: create new product from second hand
Re-purpose: re-use product for different purpose
Recycle: re-use raw materials of product
Recover: recover energy from waste

Figure 6: Priority levels of circulation

Source: (FOGARASSY et al., 2017)

Advances in digital technology constitute important enablers for CE business models (MACARTHUR and WAUGHRAY, 2016). With affordable 'asset-tracking' technology and predictive analytics, for example, it is possible to optimize when products should be repaired, upgraded or recycled. Managing product-sharing between consumers using digital platforms improves each product's "utilization rate" while reducing the total number of products needed. Companies that lend products to consumers through the so-called "product as a service" model also have incentives to make those products more durable and easier to repair (LACY and RUTQVIST, 2015).

Despite this growing dynamics, many obstacles prevent companies from seeking to achieve the value found in modeling exercises. Developed economies, in particular, are locked into existing resource-intensive industrial systems and infrastructure. For larger enterprises, insufficient consumer awareness of the CE concept is one of the reasons for caution when investing in new product lines. Still, perhaps the biggest challenge is how to introduce new business models without compromising existing revenue streams.

If it is expected that developing countries will only follow in the footsteps of developed economies, then the CE would be decades away. Fortunately, this is a plan where developing countries can pave their paths with the support of cooperation with others.

2.2.3. Barriers for CE

CE is getting more and more attention from audiences and academia, especially research by practitioners and scientists on this topic has increased dramatically (MURRAY et al., 2017). Much of the CE's current enthusiasm seems to be driven by its alleged benefits for sustainable development (HOMRICH et al., 2018). Although many companies and policy departments have announced their support for CE, its implementation is still in the early stages (GHISELLINI et al., 2016; STAHEL, 2016). Many scholars have attributed the limited progress in CE implementation to a variety of CE barriers with a specific literature having developed around CE barriers in recent years (KIRCHHERR et al., 2018). Specifically concerning barriers to implementing the CE, a report for Chatham House (PRESTON, 2012) identified the following: high up-front costs; complex international supply chains; resource-intensive infrastructure lock-in; failures in company cooperation; lack of consumer enthusiasm, and; limited dissemination of innovation, across both emerging economies and developed countries. In other reports, concerning the potential of the CE, and policy options, (BICKET et al., 2014) surveyed the available literature and analysed the fourteen most relevant studies. They identified a number of factors: insufficient investment in technology; economic signals that do not encourage efficient resource use, pollution mitigation or innovation; minor consumer and business acceptance; lack of awareness and information, and; limited sustainable public incentives. (KOK et al., 2013) produced a report commissioned by Circle Economy and presented one of the first analysis of barriers for a circular economy. They discuss the need for a CE, as well as the necessary steps required to adopt a CE. The barriers were grouped into five categories namely: financial, institutional, infrastructural, societal and technological. Many other researchers also identified and sorted almost the same barriers for implementing CE into the defined categories, like financial, structural, operational, attitudinal and technological (RITZÉN and SANDSTRÖM, 2017; SHI et al., 2008).

Deriving from the point that “CE must be understood as a fundamental systemic innovation instead of a bit of twisting the status quo” (KIRCHHERR et al., 2017), the CE requires essential changes in current production and consumption patterns. According to this approach, the procedure for CE including some steps: *first*, novel technologies will be needed for this latter system; *second*, the players in the market will need to change avariety of their activities for this novel system and thus their interplay; *third*, novel policies must be adopted to regulate the novel technology; *fourth*, cultural shifts are needed. (KIRCHHERR et al., 2018) in their research has categorized the CE barriers and put in a sequence of their relevance such as ‘cultural’, ‘regulatory’, ‘market’ and ‘technological’ barriers. The author has analyzed deeply these four barriers and 15 sub-barrier. Other novel authors in this field (DE JESUS and MENDONÇA, 2018) distinguishbetween soft and hard barriers that impede the implementation of CE as a systemic innovation. The detailed factors for hard barriers are technical and economic/financial/market, while those soft barriers including institutional/regulatory and social/cultural factors.

Concerning the CE atcompanies and Small and medium enterprises (SME’s) level, many research has conductedthe empirical analysis to investigate the barriers that hinder the adoption of circular business model. After investigating 12 Danish companies including a cross-case analysis across start-ups, incumbents and across different company sizes, industries and customer segments (GULDMANN and HUULGAARD, 2020) showed that most companies experienced barriers at all socio-technical levelsand, overall, most barriers are encountered by companies at the organisational level, followed by thevalue chain level, the employee level and, finally, the market and institutional level. However, there aresignificant variations between the case companies regarding what barriers are encountered and howmany in total. The cross-case analysis shows that factors other than company size, industry and customersegment affect what barriers are encountered.The SMEs should have the most important influence on the pathway of transitting towards CE with the relevant impact of SMEs in environmental problems, such as 70% of industrial pollution 40–45% of all industrial air emissions, water consumption and energy consumption in the EU, as well as 60–70% of industrial waste produced in France (ORMAZABAL et al., 2018). Implementing the CE approach in SMEs requires that numerous barriers be overcome such as barriers under company environmental culture (refer to the philosophy, habits, and attitudes of the company (manager and employees) towards implementing circular economy business practices) (RIZOS et al., 2016; LIU and BAI, 2014); Lack of capital including financial support and financial resources (RIZOS et al., 2016; ORMAZABAL-GOENAGA et al., 2016; GENG and DOBERSTEIN, 2008); Lack of technology and technical resources (RITZÉN and SANDSTRÖM, 2017; PRESTON, 2012; SHI et al., 2008; RIZOS et al., 2016); Lack of government support/effective legislation (through the provision of funding opportunities, training, effective taxation policy, laws and regulations, etc.) (RIZOS et al., 2016; CALOGIROU, 2010; VAN BUREN et al., 2016). Additionally, SMEs face administrative burdens associated with green business practices, such as monitoring and reporting environmental performance data. The lack of support from the supply and demand network essentially means that SMEs are dependent on suppliers’ and customers’ engagement in sustainable activities (RIZOS et al., 2016).

From the perspective of waste management moving toward the circular economy, (WANG and GENG, 2012) in their research have shown that the main barriers to the implementation of integrated MSW management are fragmented management structure, ineffective and inefficient enforcement of relevant regulations, backward technologies, limited financial resources and lack of public participation. In another article, (LIU et al., 2017) has reviewed waste prevention through reducing, reusing, and recycling under the concept of circular economy in China and pointed out that the circular economy can tackle the problems caused by waste generation e.g. environmental degradation and resource scarcity. However, existing obstacles such as inadequate regulations and management policies inhibit the realization of a zero-waste society and widen the gap between China and developed countries in the development of a circular economy in waste management. Concerning solid waste management, such as construction and demolition (C&D) waste, (MAHPOUR, 2018) found that the transitioning to the circular economy in C&D waste management is hindered by barriers which could be categorized under three dimensions of behavioural, technical, and legal. .

2.2.4. The transition towards a circular economy

Although there are still obstacles and challenges on the path to the circular economy, as discussed above, this economic model continues to attract worldwide attention to succeed in the current production and consumption model, which are based on continued growth and increased resource throughput. Lessons learned from successful experiences have pointed out that the transition to CE has proven to be the result of the participation of all actors in society and the ability to connect and establish appropriate models of cooperation and communication (GHISELLINI et al., 2016). It means that the transition towards a circular economy requires systematic changes and extensive cooperation between stakeholders (such as authorities, companies, academia, and consumers) (VANHAMÄKI et al., 2020). Furthermore, to achieve a CE, (GEISSDOERFER et al., 2017) emphasized that it is essential for national, regional and local authorities and governments to enable such transition. This transition requires the implementation at all levels including macro, meso and micro for promoting the CE models (SU et al., 2013; GHISELLINI et al., 2016; PRENDEVILLE et al., 2014; WEN and MENG, 2015; YU et al., 2015; DUPONT-INGLIS, 2015; TUKKER, 2015; KRISTENSEN and MOSGAARD, 2020). On a macro-level, the approach comprises policychanges at national, regional and city levels. Industrial symbiosis (a model in which one company uses the surplus energy or resources of the another), ecosystems and networks between firms constitute the meso level, while the micro level focuses on individual companies and consumers (KIRCHHERR et al., 2017).

First, at the macro level, a bunch of decisions related to many areas such as economic, trade and environmental policy integration, sustainable development strategies and action plans and national waste management and resource conservation policies need to be made. The main emphasis of this level is on (material) exchanges between the economy and the environment, on international trade and on material accumulations in national economies, rather than on flows within the economy. At this level, another issue raised was the important role of governments in providing context; ensuring coordination, and; leading the way in the promotion of new industrialisation models that are more efficient, less polluting and involve less exploitation of resources. Progress in science, technology and innovation is identified as a way for developing countries to advance their overall catch-up process (since they have the potential to leapfrog, at least in the environmental-economic nexus), and also a way for developed countries to increase well-being and reduce vulnerability to resource price shocks (GENG et al., 2012). Governmental action is, therefore, considered fundamental in managing “different initiatives, enacting appropriate regulations, stipulating feasible guidelines and standards, providing substantial financial support and carrying out international collaboration” (GENG et al., 2010). When the CE context cannot be "enabled," government action seems to be the main driving force and an obstacle to building CE-friendly behavior and transition-friendly networking capabilities (BERGQUIST et al., 2013). Since the CE concept is still under construction, it may cause misunderstandings and unbalanced policies. The regulatory framework (i.e., taxation and incentives) must provide clear goals in terms of environmental performance, which helps to address market failures and enable CE initiatives to flourish.

At the same time, public agencies play a crucial role in ensuring planning and institutional guidance (for example, infrastructure provision and a conducive legal system), as well as by providing R&D support, enabling information exchange, encouraging the engagement of actors and promoting awareness, e.g. amongst enterprises, universities and wider society (CUONG and YE, 2015).

Second, meso level of the transition to CE focuseson networks and interactions. In particular, as a comprehensive multi-actor approach, the nature of the CE points to the importance of networks for building capacity, promoting research and investment cooperation, sharing materials and by-products, managing common facilities and infrastructure. The creation of these networks is usually driven by agents interested in cost reduction, economies of scale, and less effect on resource price fluctuations, and is a determining factor in real CE implementation. At a meso level, the CE links with several concepts related to the establishment of cooperation and alliances, from which the corpus emphasises those in or within: industry (e.g. industrial symbiosis and eco-industrial parks); value chains (e.g. sustainable, environmental and “green” supply chains, and extended producer responsibility); local-government initiatives (e.g. eco-towns and urban symbiosis) (DE JESUS et al., 2018).

(GENG et al., 2014) suppose that the industrial symbiosis is a concept which is based on an “industrial systems integration” approach and it plays an important role in the transition towards sustainable development (BALDASSARRE et al., 2019). It focuses on the possibility of exchanging materials and by-products between networks and managing shared facilities for water, energy, and waste among multiple participants (VAN BERKEL et al., 2009). The sharing of services, such as transportation, infrastructure, and the brokering of by-products (so that the waste generated from one industry becomes the input of another) can reduce pollution, decrease the use of materials and energy, and lower costs, thereby achieving economic and environmental benefits. A specific example of industrial symbiosis development is the eco-industrial park, which uses a waste exchange model between industries to improve resource efficiency and reduce environmental impact (GENC et al., 2019). Eco-industrial parks retain the positive externalities of industrial parks, which arise from: businesses being located close together; economies of scale; inter-firm communication; centralised transportation, and; waste disposal infrastructure.

However, it also increases the possibility of symbiosis with environmental factors, which relate to minimizing the negative impact on local resource depletion and pollution. Despite geographical specificity (given the definition and implementation of industrial symbiosis and ecological industrial parks vary from country to country) (BOONS et al., 2011) and in various stages of development (CHERTOW and EHRENFELD, 2012), it was found that eco-industrial parks could promote symbiotic networks of cooperation between companies (YU et al., 2015), thus actively promoting CE at the industrial level (ZHU et al., 2015). The existence of these tools such as industrial symbiosis and Eco-Industrial Parks also identified as the essential factors to the evolution of CE (SAAVEDRA et al., 2018).

Finally, micro-level of the transition towards CE focuses on the specific decision processes at business, local level or concerning the specific substance or individual products with the emphasizing on cleaner production, eco-efficiency, eco-design andcircular business models. Cleaner production emphasises the application of processes, technologies and practices for minimising resource and energy consumption, as well as pollution, in order to accomplish a better overall efficiency within the organisation (GENG et al., 2010). It includes green design or design-out waste as well as the introduction of clean energy and waste management technologies (BASU and VAN ZYL, 2006). Other practices such as eco-efficiency (i.e. production of goods or services with fewer resources and waste), and eco-design (i.e. design for the environment), similarly aim to design products with environmental considerations throughout their whole life-cycle, thus ensuring energy savings and pollution reduction (COLLADO-RUIZ and OSTAD-AHMAD-GHORABI, 2013; SANYÉ-MENGUAL et al., 2014). Besides that, designing products in a smarter way, extending their useful lives and changing the role of such products within the system will be crucial to the achievement of a circular economy (DE SCHOENMAKERE and GILLABEL, 2017).

In terms of circular business models, there are many pieces of literature has researched in this topic and it contains a variety of different typologies. According to (OECD, 2019), there are five types of headline circular business models with the business-centric perspective: (i) circular supply models, (ii) resource recovery models, (iii) product life extension models, (iv) sharing models, and (v) product service system models. The circular supply business models involve the replacement of traditional production inputs with bio-based, renewable, or recovered materials. The resource recovery business models include the production of secondary raw materials from waste streams with three main activities namely the *collection* of the waste materials generated by households, businesses, and industry; the *separation* of a particular waste stream into its constituent materials and the *secondary production* by transforming of sorted waste material back into finished raw materials. With product life extension models, the products, and the materials embedded in them, remain in the economy for longer, and thereby potentially reduce the extraction of new resources. Sharing models, or sharing economy or sharing platform models as they are sometimes called, involve using under-utilised consumer assets more intensively, either through lending or pooling. These models focus on the replacement of capital ownership and proprietary models. In areas as diverse as housing, transportation and communication, these business models promise more efficient use of resources, extended lifespan of products, and greater reuse of materials at the end-of-life of products (SHORT et al., 2014). Finally, the Product service system (PSS) models combine a physical product with a service component. It is separated into three main variants: product-oriented, user-oriented, and result-oriented PSS models.

2.3. Circular economy approaches in developing countries

2.3.1. Competitive advantages of developing countries for CE

Nowadays, those countries with lower- and middle-income are in many ways more ‘circular’ than their counterparts in the developed areas. Many economic activities related to ‘circular’ behaviour going around repairing and reusing or sorting waste are increasingly popular in those countries. One example is the practice of reusing and recycling textiles: currently, this is more economically viable where low-cost labour is abundant, as is the case in many developing countries (MORLEY et al., 2009). Making the transition towards a CE might also be more ‘intuitive’ in developing countries, in the sense that it may require less of a change in behaviour than in many advanced economies.

CE activities may also increase the competitiveness of developing countries in export-oriented sectors. Circular farming methods, such as recycling of nutrients and organic matter to reduce the use of synthetic fertilizers, or the practice of crop rotation and cover cropping that minimize tilling and retaining natural capital, can play important role to increase farmers' resistance and increase yields for farmers. Introducing resource-efficient practices has led to record rice yields in some of India’s poorest regions (EMF, 2016a).

Besides, by taking advantage of the waste streams transition or new business models emerge, the potential for employment coming from circular activities, particularly around waste management, is already clear in many developing countries, although the jobs involved are largely in the informal sector. According to (VELIS, 2015), the percentage of the urban population who found to be working ininformal-sector recycling worldwide is around 0,5%. The remanufacturing and repair of products tend to require more labour than does manufacturing from raw materials (KRISTINA DERVOJEDA and LAURENT FRIDERES, 2014). Deconstruction, a necessary prerequisite to scaling up the reuse of building materials, is typically more labour-intensive than demolition (COOPER et al., 2016). Resource-efficient and organic farming practices also tend to require significant labour, particularly in rural areas, and could thus help to support more balanced economic growth (HETEMÄKI et al., 2017). Many CE ideas that have been discussed for decades are today being made possible by the digital revolution (EMF, 2016b). For example, mobile technology and social media have enabled start-up companies like Uber and Airbnb to disrupt incumbent businesses by unlocking underutilized assets. Process of 'Trace and return' already allows firms to track their products while in use, optimizing the timing of repairs and upgrades. The so-called 'internet of things' will bring a step-change in our ability to know where materials and products are in the economy or to trace products along supply chains with end-to-end certification – including using distributed-ledger technology to help curb corruption and ensure environmental integrity (SAVEEN A and RADMEHR, 2016). Some companies in developing and emerging economies – such as Alibaba, Tencent and Huawei in China, or Safaricom in Kenya – are well placed to deal with this digital disruption.

However, the employment opportunities in correlation with the variety of skill levels are concerning issues that need to take consideration. There is a fact that collecting, handling and processing waste will offer low-skilled employment (MORGAN and MITCHELL, 2015) while remanufacturing requires a skilled workforce. Besides, many studies conducted on the quality of jobs in sharing economies have shown that these are often jobs with fewer benefits, lower security, and fewer opportunities for improvement and skill development (RETAMAL and DOMINISH, 2017). A the same time, the CE may have a negative impact on the employment of heavy industries, which are usually critical regional employers and politically sensitive sectors.. In China, for example, because of the massive overcapacity, China had to lay off 1.8 million workers in coal, steel sector (BRUN, 2016). Although higher-value-added opportunities for products from these industries could create more jobs overall, incumbent sectors may push to delay or weaken policy frameworks for the CE. This is similar to the situation in the energy sector, where some countries have tried to hold back renewable energy for fears of the impact on existing fossil fuel generators and grid companies.

Because of the fact mentioned above, the developing countries need to carefully approach to avoid rapidly dislocatingemployment in informal sectors which are happening in many countries.

2.3.2. Challenges for developing countries to scale-up CE

On the pathways towards CE, the developing countries also have to confront all barriers, as mentioned above. However, with the typical characteristics in terms of resources, history, demography, religion, and politics, those countries still face up with challenges for scaling-up CE like developed-country experience, including the constrain of capacity and finance for implementing CE strategies, as well as the informal conditions of economics and the deficit in infrastructure coupled with the growing urbanization.

2.3.2.1. Constrain in capacity and finance

The *governance capacity* always plays a vital role in managing or solving societal and administrative problems for all countries. Therefore, if the developing countries do not have robust governance frameworks, they will face the risk of installing cheaper but limited-quality technologies and equipment under the manner of a CE. Take waste-to-energy technologies reliant on incinerators as an example. There is evidence that this equipment in some case lack of proper testing facilities or obsolete technology and would not be approved for use in the countries in which they are made, however, they even still are sold for developing countries.Besides, the limited ordinance also causes the low standard in construction, a sector in which the design and governance of new building stocks and assets will be critical to enabling longer asset lifetimes and the future refurbishment and reuse of material (WINDAPO and ROTIMI, 2012). For example, research from (JAWAID et al., 2018) has shown that with almost 90 per cent of the residential built stock in the informal building sector in India is free from regulation, it has caused an increase in unplanned growth and settlements.

Going through a long history with the linear economy model and resource-led development, most developing countries need a significant shift in infrastructure, industrial processes, and innovation priorities to restructure economies to accommodate more ‘circular’ activities.According to (HUMPHREY, 2018), the developing countries are already facing a significant infrastructure investment gap in the order of $1 trillion a year between now and 2030. Many lower-income countries lack even necessary solid-waste management infrastructure that leads to generally rely on open dumping, with 93 percent of waste is dumped (KAZA et al., 2018). To date, the lack of access to finance has been a major challenge for smaller firms and individuals seeking to implement innovative business models and practices in low-income countries.

2.3.2.2. Economic structure

Informal-sector employment and resource-intensive are two dominant characteristics of developing countries compare to developed nations. Although informal area with waste management as the principal activities in a particular aspect is a competitive advantage of developing countries in terms of creating more jobs and promoting CE at a low level, more formalized processes that may be better suited to recycling waste cannot source enough feedstock to recycle these products economically. For instance, (PARK et al., 2017) in their research has shown the fact that many formal facilities in China could not compete with the advantages of the informal sector, because of the large and efficient collection as well as the low operating costs networkthey have established.

Besides that, the natural resource in almost developing countries constitutes a high proportion of GDP and employment or both as well as the revenue fromit plays a key driver of development gains and economic growth to date for those economies. Therefore, in those countries which have many reserves of minerals and hydrocarbon, the economic model of extractives-led growth has been promoted by national governments, multilateral organizations and donor agencies for a long time (LAHN and BRADLEY, 2016). The CE with its potential benefit as analyzed above for creating new additional valuable opportunities and employment by fundamental decoupling of economic growth from resource use may likely meet the resistance from governments and industry. Without meaningful dialogue at the national and international level around future growth pathways, there is a risk that natural resource-exporting countries will see the CE not as an opportunity for economic diversification but as a threat to continued growth.

2.3.2.3. Urbanization and deficit of infrastructure

Today, the developing countries are facing greater industrialization and urbanization challenges than developed countries did. However, so far, the critical infrastructure in those areas has not kept pace with the rapid development mentioned above. This problem has borne the brunt of this expansion: at least 881 million people in the developing world are now living in slums where secure housing and essential services are severely lacking (ALMANAC, 2016). This development raises the high demand to invest in new infrastructure and building stock for a huge amount of projected residents potentially living in slums by 2050 with as many as 3 billion people and the expectation of $60 trillion by 2030 to meet the UN Sustainable Development Goals (SDGs) in developing countries (LEHNE and PRESTON, 2018). To meet the need forconstruction and related infrastructure service, it is projected to urgethe amount of material extraction to double from 79.4 billion tonnes in 2015 to 182.8 billion tonnes by 2050 (SCHANDL et al., 2016).

2.3.3. Actions for accelerating CE in developing countries

Based on the competitive advantages and the challenges for scaling-up CE strategies in developing countries as analyzed in the previous sections, the governments in those economies should release the suitable actions to accelerate this model for more sustainable development. Many pieces of literature have investigated this point to suggest that the action should have three fronts including the straightening of the CE strategy with current policy priorities, spending more in the fundamentals to promote the shift to the CE and participating more to the global CE agenda.

2.3.3.1. Straightening of the CE strategy with current policy priorities

a. Diversifying economic models

Countries where their development mainly relied on resources should have a plan to expand the value chain by step-by-step shifting from raw materials and agriculture exploitation to higher value-added industrial activities such as production and, in the long run, are high-tech and service-oriented businesses.Transitioning to CE may provide opportunities to diversify the economic structure and access to higher-value markets.

By taking advantage of the existing production facilities with skilled-labor and infrastructure, these countries should transform industrial assets and resource-processing facilities into re-processing and re-manufacturing centers. This approach can assist in moving away from resource export-oriented towards value-added strategies. The notable value of raw, primary, or scrap metals can be added through processing and reproducing into usable goods and materials, whereas the export of them will have only relatively low-value. One of the dominant examples of this strategy is the use of scrap steel sheets to produce car doors.

b. Advancing CE strategy for agri-food system and energy

Agriculture always plays a vital role, and it is known as the backbone of developing countries. Therefore, integrating CE with agricultural development plans and food security can provide an attractive policy path for those nations. The approach for CE in this area should focus on minimizing input requirements while adding value to agricultural output and creating new asset loops throughout the food value chain, from production to processing and, finally, consumption (See Table 1) (PRESTON et al., 2019). Some practices in this area have long been the focus of policymakers at local and global levels seeking to increase productivity and reduce food loss and waste (ROOD et al., 2017).

Table 1: CE approach for each stage of increasing food value chains

Stage	CE strategy	Example initiatives
Production	Reduced resource inputs	Precision agriculture using sensors and data analytics to monitor and apply resource input
	Yield improvements	Breeding strategies to improve yield and resilience to pests, disease and climate impacts
	Reduced on-farm losses	Sensors that monitor and prevent weather or pest damage to harvests and on-farm storage
	Asset sharing	Leasing of agricultural equipment
	Recovery and reuse of agricultural inputs	Closed-cycle production methods, e.g. aquaponics
	Recovery and reuse of waste streams from other sectors	Recycling of wastewater for use in agriculture
	Minimization of food surplus	Subsidy reform to discourage overproduction and promote quality over quantity
	Use of food and agricultural by-products	Production of biochemicals and bioplastics from waste biomass
Processing and distribution	Reduced food loss in storage and transit	Improvements in, and roll-out of, cool-chain technologies
	Reduced inputs	Plastic-free biodegradable packaging
	Reprocessing of food waste into new products	Reprocessing of fruit peels into fabric and paper
	Improvements in traceability for food safety	Product tagging, which can be underpinned by blockchain technology, to monitor environmental conditions as food moves from 'farm to fork'
	Shared logistics	Interconnected storage and transportation system across companies in the food, logistics and cool-chain industries
	Remanufacturing of food retail and storage equipment	Refurbishment and remanufacturing of refrigerated display cabinets
Consumption	Extended food lifetimes	Smart packaging solutions that preserve the quality and safety of foods by absorbing atmospheric compounds – oxygen, ethylene, moisture, etc. – that cause food to perish
	More sustainable consumer behaviour	Nudging tactics to reduce food waste
Post-consumption	Redistribution of food waste	Food surplus redistribution schemes
	Organic waste management	Policies and legislation to encourage separation and differentiated recovery of household waste
	Recovery and refinement of food waste for human consumption	Production of value-added surplus products (VASPs) that make use of food that is safe to eat but generally considered to be waste (e.g. carrot peel that is processed into a powdered soup mix)
	Recovery and refinement of food waste for animal feed and energy	Use of food waste in the production of biofuel and bio-products, including fertilizer

Source: (PRESTON et al., 2019)

Besides, the application of new technologies for the treatment of waste generated from the agriculture and food industry, such as anaerobic digestion, waste-eating microbes, and carbon recovery, will bring an excellent opportunity to create value-added from discharged waste. Many developing countries have applied such technologies or introduced legislation for this perspective, for example, the National 3R Strategy in Thailand to raise the utilization of organic waste by 50 percent from 2012 to 2026 (SHARP, 2012) or using modern biodigesters to convert waste disposal of organic material like animal waste, human waste, or other organic materials (from agricultural waste, slaughterhouses, etc.) or even recycled plastics to generate energy like biogas or electricity for many purposes from cooking to easy transport and installation. This transformation has successfully applied in some countries in Africa like Burkina Faso, Ethiopia, and Kenya under the program funded by the World Bank (FREEMAN, 2019). In addition to collecting and reusing waste, CE approach in agriculture can be seen at the production point to promote greater resource efficiency. Some of the closed-loop systems, such as aquaponics and hydroponics, which require a drastic reduction of soil, fertilizer, and water inputs or vertical farming, are being trialled and received certain success in developing countries.

Together with the exploitation of energy from organic waste as analyzed above, the CE approach can provide strategies for energy security via reducing the demand for raw materials and capture potential energy in other types of waste. Many CE activities, including reducing consumption, reusing, sharing, and recycling products, minimizing production losses - will limit the overall demand for primary production and thus reduce the energy needs of production.Using Waste-to-energy technologies is one of the typical examples of this approach. This is a good option for developing countries as these measures can alleviate the pressure on resource-limited waste management programs in low-income countries, where facilities often struggle to manage an increased quantity of unmanaged waste. Waste can be recovered and purified to produce energy through thermochemical processes (using high temperatures to extract energy, for example, through pyrolysis or gasification), chemical processes (for example, using a chemical reaction between alcohol and acid to extract energy, as in the production of biofuels from agricultural by-products) and biochemical processes (extracting energy through composting biodegradation, for example in biogas production through anaerobic digestion or bioethanol through fermentation).

2.3.3.2. Investing in fundamentals

With the increasing enthusiasm about CE of policy, business and development communities and the challenging for scaling up this strategy in developing countries, it is necessary to consider the conditions under which CE can thrive while fulfilling current international commitments for sustainable development and climate mitigation. The policymakers need to make robust regulations to create appropriate incentive structures for the transition to CE as well as mitigate the challenges mentioned above.

a. Putting the right policy structure in place

The robust regulations will be needed in developing countries to deal with challenges, as discussed in section 2.3.2. With the hight demand for material for urbanization and industrialization in developing countries, the durability, reusability, and recyclability standards are especially outstanding in the construction sector as the essential requirements to incorporate CE design principles into buildings and infrastructure. These appropriate construction standards will help the developing country governments, and urban planners encourage long-term construction, easy maintenance and refurbishment, and easy repair in case of climate-related damage.

Regarding employment in the informal sector in waste management, it is recognized with both opportunities and challenges for low- and middle-income countries seeking to move to CE. Careful approaches are needed to avoid the rapid replacement of jobs in the informal sector and the loss of skills and resource efficiency associated with such employment. The most interesting opportunities to harness the capabilities of informal workers without having to replace jobs quickly seem to lie in hybrid approaches that provide financial access to the informal sector and apply taxation and fiscal structures that tax resources instead of people, thereby reducing rental costs and increasing costs associated with resource extraction and waste generation (SCHRÖDER et al., 2019).

Applying flexible domestic trade policies are likely to provide an essential means by which national governments can encourage and incentivize a transition to more circular approaches among local actors while creating an attractive investment environment for foreign investors. According to (OECD, 2018; YAMAGUCHI, 2018) it is crucial to ensure the mutual supportiveness of circular economy policies and trade policies and meet the requirements as follows: Energy-efficiency requirements for second-hand imported vehicles; a minimum percentage of recycled content in plastic waste; health and safety standards for recycled or recycled products and materials; and quality, health, and safety standards for reproducible products.Many countries have imposed strict controls and import restrictions on old and second-hand vehicles to meet their nationally defined contributions (NDCs) under the Paris Agreement (BRANDI, 2017). However, in developing countries, import duties can have a significant impact on access to affordable inputs for CE activities. Therefore, reducing or eliminating import duties on primary goods used for pollution management and resource management - such as equipment used in recycling plants - or on secondary materials may reduce capital costs of CE infrastructure and raw materials in import-dependent countries and increase the competitiveness of downstream CE activities.

b. Promoting innovation and investment activities

In emerging and developing economies, the importance of innovation is widely recognized, and innovation policies play a central role in their development plans and strategies. It is also considered to be the key to addressing urgent social issues such as pollution, health problems, poverty and unemployment. Governments in developed countries have all the tools at their disposal to encourage companies to invest more in research and innovation. These instruments involve direct and indirect support to R&D and innovation as well as competitive and institutional financing tools and supply-side and demand-side measures. In contrast, due to the decreased fiscal space with limited tax revenues, in part as a result of the large scale of their informal economy, governments in developing and emerging countries have fewer opportunities to manage. Besides, governments in developing and emerging countries do not have the same latitude as those in developed countries to grant tax credits, subsidies or government procurement contracts, companies in these countries rely heavily on themselves to build a stock of technological knowledge. Instead of investing in R&D, to a large extent, these companies strive to reap the benefits of catch-up through the adoption and international transfer of technology.

Emphasis should be placed on emerging countries to achieve R&D levels as well as to provide suitable framework conditions to stimulate the process of innovation and dissemination of knowledge: political stability and institutional support; excellent and extensive technical and tertiary education to enhance absorption; reliable and widespread necessary infrastructure; providing excellent ownership of information and communication technology (ICT), and stronger links and interactions between publicly funded research institutes and private companies.

Therefore, the innovation policy for developing and emerging economies must necessarily be diverse and complex, involving aspects of education policy, industrial policy, and national trade policy, and many other institutional reforms. With limited budgets, most countries will have to make difficult choices about where to invest in making the most of their available human resources and natural resources and competitive advantage. Smart specialization options can also be made in cooperation with other countries. The final policy mix will depend on the broader development goals of a nation and will have to be done in collaboration with all stakeholders to maximize the chance of success. Therefore, proper coordination between ministries and between the private sector and the government is essential. In other words, the systematic nature of innovation policy needs to be strengthened.

Investing in digital accessibility and digital knowledge will be another critical component of government strategies to encourage innovation in CE. Digital technologies are likely to play an essential role in promoting the increase of circular activities, not just because the barriers to entry are relatively low (PAGOROPOULOS et al., 2017). Besides, ensuring equitable access to these technologies, and job opportunities as well as resource efficiency for all workers, especially in rural and disadvantaged areas, is a crucial task that the governments need to take into account (CHETTY et al., 2018).

Along with technology, CE innovations will need to come with innovative financing mechanisms if they are applied (HIEMINGA, 2015). Many efforts to establish large-scale financial institutions for CE in developing countries have not yet been operational, due to the absence of a robust system of suitable projects. Circular investment is often considered a high-risk, due to their novelty and uncertainty surrounding the pricing and insurance of repaired products. Product-as-a-service models require new forms of lease and insurance policy and often require long-term financing. Similarly, the circular business models often rely on the cooperation of a network of suppliers; therefore, banks can seek assurance that no single dependency point in a given system poses a threat to other participants. Innovative finance mechanism will also be required to ensure that local entrepreneurs and small and SMEs are supported in the transition to CE.

Financial instruments with new risk-sharing mechanisms can help strengthen cooperation along the value chain. Such tools can assist in sharing supply chain risk information or strengthening revenue-sharing or buy-back arrangements to alleviate losses for any actor in case of a supply or demand disruption (LI et al., 2015). A variety of financial organizations will likely need to cooperate, providing not only blended finance but also guidance on how to structure and operationalize circular value networks.

c. Approaching the social aspects of CE

Besides the technical and engineering aspects, social norms and consumer behaviour are the keys to a successful transition from linear to a circular and sharing economy model. Generally, those who live in low-income areas tend to present more "circular" behaviours than those who live in higher-income economies. Furthermore, although there are significant differences, resource consumption per capita is generally lower in developing countries compares to those in developed nations (SERI, 2009). Therefore, developing country governments also need to take policy measures to address inequalities in access and use of resources, between low- and high-income groups and between genders, to ensure that the benefits of CE are widely and fairly reaped.

2.3.3.3. Participating more in the regional and global CE agendas

Strategies at the national level of each country to promote the shift to CE have the potential to bring industrial growth to minimize adverse environmental impacts. However, if there is no parallel investment in regional and global circle value chains, and in knowledge sharing and innovation, the transition to CE will be challenging to reach a meaningful scale. A transformation is necessary not only at the level of the domestic industry but also on international supply chains of supplies and resources. In this case, the cooperation between the government-to-government will play an important role, through bilateral investments and cross-border partnerships to foster the emergence of regional and international circular value chains.

Developing countries should take advantage of the support from multilateral development banks and donors through their CE investments in creating a lower risk environment. An equally important approach might be to reorient investment strategies and modify eligibility criteria to allow CE projects to benefit from existing programs, such as Global Establishments Facility (GEF). The seventh framework program GEF has CE as one of the Impact Programs. This facility has helped promote cooperation related to the African Development Bank (AfDB), World Economic Forum and the World Bank in fostering and strengthening national-level support (GEF-7, 2017); for example, in January 2019, the Nigerian government announced a $ 2 million (£ 1.53 million) initiative, supported by the GEF and the UN Environment, to launch recycling of electricity waste and electronics (DICKINSON, 2019).

The Forum about CE at a regional level in developing countries should actively promote knowledge and lessons sharing for other nations in this area. For instance, the Regional 3R Forum in Asia and the Pacific should investigate possibilities to distribute experiences from its collaborative approach to policy coordination, investment in pilot and research projects - including through political missions and convening an international meeting and building the success of its own annual conference. The African Circular Economy Alliance should work with regional and international civil society organizations to facilitate cooperation between cities, universities, and startups and search chances to connect robust local networks with international focused forums. Multilateral organizations should facilitate this participation through technical assistance and, where necessary, financial investment.

2.3.4. Potential scopes for transiting towards the circular economy in Vietnam

Over the past 30 years, Vietnam has recognized as a remarkable development with the growth of GDP per capita since 1990 is one of the fastest countries in the world. This growth has contributed to an important development in decreasing poverty and increasing the quality of life. However, this increase also creates challenges related to environmental degradation. The quality of the environment of Vietnam, including air, soil, and water, has deteriorated significantly. Air pollution has touched alarming levels in cities like Hanoi and Ho Chi Minh City. Water pollution and water scarcity are rising concerns, notably in urban areas. The proportion of informal solid waste recycling in the metropolitan area and craft villages is relatively high that leads to hazardous emissions and severe health threats. Although the regulations and policies are applied in Vietnam to provide a solid foundation for green growth, law enforcement is still lacking. Vietnam also is facing a lot of negative effect of climate change due to its long coastline. The risks of flood and salinization penetration in agricultural regions, particularly in the Mekong Delta, are an increasing concern. Therefore, adaptive development with climate change will become an inevitable trend in Vietnam.

Circular strategies with its benefits can deliver a sustainable solution for some challenges coming from the socio-economic and environmental issues in Vietnam. Based on the current status of the circular economy in Vietnam, this study focuses on four potential areas, including agriculture, logistics, renewable energy, and water management. This study will briefly analyse the characteristics, challenges and opportunities for transiting to the circular economy in each of the above areas, in which waste management issues for each sector will be emphasized in looking for a solution for this transition.

a. Agriculture

Vietnam is still a predominantly agricultural society with a relatively large proportion of the population living in rural areas (76%), and labour working in the farming area makes up 52% of the labour force. In general, agricultural production in Vietnam is decentralized and fragmented with smallholders. Currently, the proportion of agriculture in the national GDP is nearly 20%. Nevertheless, it is projected that in the coming year's work in the central agriculture sector will reduce due to the diversification of rural livelihoods, resulting in a decline of 0.5% yearly contribution to national GDP (WB, 2016). The income discrepancy between rural and urban areas continues to increase in absolute terms, although the ratio between the two sides remains relatively stable (WB, 2016). Labour force in the agricultural sector has become unstable; more and more people are withdrawn and moved to cities to look for a better job. In recent years, there has been a growing penetration of larger private enterprises that have more available resources and readiness to invest in this sector.

The agricultural sector in Vietnam is confronting with some *challenges*, possibly influencing some Sustainable Development Goals (SDGs):

The productivity of agriculture, in general, is relatively low

Agricultural growth is primarily associated with a growing of cropping area or using more inputs like fertilizers, chemicals, and natural resources like water, soil. At the same time, this sector also has to compete with other areas (industry, services, urban development) for employing labour, land, and water. This negatively affects farmers' earnings and hampers the potential of economic growth.

Fertilizers, herbicides, and pesticides are excessively used

Due to most of the agriculture production in Vietnam is small-scale by smallholder, the farmers tend to overuse of inputs to maximize their harvest. Furthermore, smallholder farmers lack the money to spend on effective technologies to decrease the usage of these inputs. This negatively affects farmers' revenue, limits the chances for rural poverty reduction, and lifts the soil and water pollution. Besides, these factors have induced the low quality and safety of food and negatively impacting the health and well-being of consumers.

The agricultural sector is vulnerable by climate change

Vietnam's agriculture sector has been impacted negatively by climate change and it is projected that this sector will likely continue to be affected by the rising temperatures and sea-level, disruption of rainfall patterns, and the extreme weather as well. Drought and saline penetration are two visible major impacts of climate change affecting Vietnam's agriculture these days.

Circular economy opportunities

Based on the characteristics and challenges of the agriculture sector mentioned above, many opportunities to move to a circular economy model can be realized:

Producing and trading organic fertilizer locally.

Although the application of chemical or synthetic fertilizers is now widespread, concerns related to human, animal, and environmental health are pushing growth for organic fertilizers. The growing market brings more business opportunities for players in the organic fertilizer business. The sources of this kind of compost can be obtained locally in Vietnam in the waste streams of agricultural residues.

Using more robust seeds to reduce the excessive utilization of fertilizers, herbicides, and pesticides.

By using more energetic seeds that can be more resistant to disease, the necessity to use too many chemical inputs will be reduced. This performance will benefit both agricultural entrepreneurs and the environment as well.

Applying a variety of technologies in agriculture to improve efficiency and sustainability

Given that Vietnam's agricultural sector is dominated by small-scale production, most technological improvements in this sector are inaccessible to farmers. In order to foster sustainable and circular practices, there is a demand for smart applications that can be adopted by small farmers to grow the productivity and sustainability of their production activities. One of the useful technologies is small-scale drip-irrigation (which can be controlled via smartphones) can bring immense benefits to local farmers while restricting input used for production.

In addition, climate-controlled agriculture with greenhouse technologies gives many possibilities concerning improving agricultural production while limiting input. In the condition of changing weather is increasingly widespread in Vietnam with many negative impacts on the agricultural sector, production in a controlled climates offers clear benefits, especially with high-value products. For certain crops, greenhouse technology can bring good business chances for medium and large-scale agricultural producers in Vietnam.

Waste management

Discharge of water from agriculture and aquaculture often pollutes the ecosystem. With increasingly stringent regulations on water discharge, there is a great potential for wastewater treatment technologies to be deployed in the fields of agriculture and aquaculture.

Besides, being an agricultural country, Vietnam has access to a large number of agricultural residues. The biomass waste stream can be used for several purposes such as biomass combustion or gasification. For instance, the Heineken brewery in Hanoi uses agricultural waste stream as raw material for anaerobic digestion, so it is used to generate heat to be used in the brewery. Another opportunity is rice husk. Each year, Vietnam produces 23 million tons of straw and 8-9 million tons of rice husks. Only half of the rice husk is used for domestic cooking, for ceramic/brick kilns or back to the fields as fertilizer, and more recently, in some rice husk burning plants in the Mekong Delta.

b. Logistics

Vietnam has witnessed strong growth in trade for the coming years, which will support the continued development and expansion of the logistics industry. The logistics industry in Vietnam can be divided into three main categories: Transport, Logistics, and Warehouse. This industry is one of the fastest-growing industries in Vietnam, but poor infrastructure is raising its costs. The main logistics centres can be found in the North (Hanoi - Hai Phong area) and the South (the larger Ho Chi Minh City area, including Dong Nai, Binh Duong and Ba Ria/Vung Tau). Currently, the logistics industry makes up 18% of GDP in Vietnam (STOXPLUS, 2018). Especially, investments in manufacturing have been driving demand for international logistics and transportation services. Furthermore, a growing middle-class and a growing population have fueled demand for domestic transport and logistics services in the country.

Although many multinational logistics companies have started to establish businesses in Vietnam, this sector is still dominated by small-scale companies (STOXPLUS, 2018). Because Vietnam's logistics industry was just in the early stages of development, warehousing facilities were fairly undeveloped. Warehouse facilities and freight stations are not user friendly and often ineffective due to the lack of centralized warehouses and areas with strategic locations, synchronized with the system of ports, airports, and highways as well as production facilities; Supply and demand imbalance in southern ports (VU, 2019). Moreover, because business-to-business communication is lacking, many companies keep large quantities of products to address any increase in demand. This causes an inefficient warehouse system where large inventories are stored.

The logistics industry in Vietnam is facing some *challenges*, potentially affecting some of the Sustainable Development Goals (SDGs):

Advancement in the national road infrastructure is needed to meet the needs of the growing logistics industry.

The growth of the Vietnamese economy, combined with its geographical location, creates a growing demand for long-distance freight logistics. Vietnam's road system is about 258,200 km long, of which 19% are paved, and 40% of the system is in poor condition. Although the roads that connect big cities are generally well-shaped, those facilities which connect to the industrial and economic zones, airports, and seaports are not well maintained and well-serviced. This makes the total logistics cost in Vietnam comparatively high compared to other companies in the same industry (STOXPLUS, 2018).

Significant environmental impacts have accompanied the development of logistics.

Many vehicles being used for transporting on the road are inefficient second-hand trucks, have caused a significant impact on the environment in terms of greenhouse gas emissions and air pollution. This has become a severe health problem in Vietnam, especially in and around major cities. Besides, the inefficient warehouse makes the logistics industry in Vietnam relatively energy-intensive and thus expands the environmental impact.

Circular economy opportunities

With the characteristics and challenges of the logistics sector mentioned above, many opportunities to move to a circular economy model can be realized:

Apply more advanced technology in some essential parts

With the growth of logistics, several related industries are growing together. The packaging industry is one of the fast-growing sectors that has received little attention in Vietnam. Packaging services are necessary for many industries in Vietnam, and the packaging materials are overused. Hence, there is good potential for a packaging service provider to enter this area and provide a sustainable packaging service.

Besides, after signing CPTPP, EVFTA Vietnam concentrated more on exporting, especially products of horticulture and aquaculture. Vietnam has already exported a lot of seafood, vegetables, flowers, and also imported processed food products and pharmaceuticals. This generates a high demand for cold storage, and business opportunities arise for sustainable climate-control logistics service providers. Effective climate-control logistics can enhance logistics efficiency while reducing inputs and losses during logistics.

Scaling up applying sharing platforms

The sharing economy with its benefits will bring a big chance to optimize resources through the efficient use of excess capacity. Two platform Uber and Grab - a trendy Singaporean transport application in Southeast Asia - are being used in the market over the past two years has led traditional taxi drivers, often made up of men with limited resource threatened. Local sharing platforms can also have a positive impact on the Circular Economy and the local Vietnamese economy. Socioeconomic incentives for investment in shared platforms will focus on developing smart cities, improving access to services (reducing inequalities), and economic development through smart solutions (for example, reducing congestion in the city through car-sharing).

Recycle used (cars) products (such as cars, tires and electronic waste)

The majority of domestic and regional transportation in Vietnam takes place via road by trucks. This not only causes tremendous environmental impact but also creates waste streams.

Waste tires are a stream of waste from trucks that can be collected and recycled. With a large number of annual waste tires available in Vietnam, the establishment of a waste tire recycling facility in Vietnam shows good business potential. The drivers for investment will be economic development (new business) and health benefits through the reduction of health hazards in the recycling of electronic waste from the informal sector of craft village.

c. Renewable energy

Over the past decades, Vietnam has experienced a rapid development stage in many socio-economic aspects, including industry, urbanization, risen transportation demands, increased access to energy, and improved living standards. These changes lead to high demands for energy consumption.

According to the Vietnam Energy Prospect Report 2019 (EREA, 2019), 2019), in the 2007-2017 period, the total primary energy supply of Vietnam increased by 4.7% per year. Hydropower had the highest growth rate of 14.5% p.a., accompanied by coal at 11.3% p.a. The proportion of coal grew from the third-largest fuel source in 2007 to the largest in 2017. Meanwhile, the biomass rate decreased from the most important contribution in 2007 to the third-largest in 2017. Oil, rising at a rapid rate of 4.3% per year, is the second-largest fuel source. Solar and wind power historically only contribute a tiny part in the total primary energy supply.

Traditionally, Vietnam has been exporting energy, however, in recent years, energy exports have decreased, and coal imports have increased. The increasing demand for energy has left Vietnam unable to satisfy its own energy needs and began importing coal to burn in coal-fired plants to generate electricity. Because of this shortage, Vietnam has been a net energy importer since 2015, with a rate of net import about 5% of total energy supply (MOIT, 2017).

The demand for electricity is increasing rapidly. Due to both prompt industrialization and exceptional economic growth, domestic energy consumption will be increasingly increased. In the period 2016-2035, it is forecasted that the demand for energy will increase by 4.7% / year in the baseline scenario (in the Low and High scenarios, the increase is 3.7% / year and 5.5% / year, respectively). In the BAU scenario, with economic sectors, the transportation sector is projected to achieve the highest growth rate of demand for energy with an average rate of 5.7% / year in the period 2016-2035, followed by service and industry sectors with a proportion of growth is 5.0% / year (MOIT, 2017).

Although Vietnam's current non-hydro renewable energy development level is low, Vietnam has great potential for renewable energy. This country has enormous solar energy resources that can be used to develop the solar energy industry successfully. Current scientific estimates of Vietnam's total solar energy resources indicate that most areas in southern, central and even northern Vietnam average 4-5 kWh/m2/day (total 1,460-1,825 kWh/m^2)/year and average peak irradiation levels up to 5.5kWh/m2 /day in some Southern regions (total up to 2,000 kWh/m2 /year) (FMEE, 2016). These solar irradiation levels are comparable to most countries in the world in which the south has the highest potential with annual solar irradiation, similar to Spain and the north also shows the potential for disseminating solar energy, with annual solar radiation similar to Germany (NEEFJES and THU, 2017).

Wind resources have been assessed by various organizations and show significant potential for onshore wind and Vietnam has one of the most significant offshore wind potentials in Southeast Asia, with average wind speeds up to 11 m/s, resulting in a power factor greater than 4500 h per year (TESKE, 2019). Therefore, Vietnam has great potential to develop and generate wind energy. Both onshore and offshore winds have good potential with adequate wind year-round. Notably, in the southern-central provinces and the Mekong Delta, it shows the right conditions to develop wind energy.

The agricultural activities cause a large volume of available biomass. Accordingly, Vietnam has a relatively high potential to generate biomass energy in the form of agricultural waste. Especially in the Mekong Delta and the Red River Delta region, there has a high volume of agricultural waste (respectively 50% and 15% of the country's total agricultural waste). Some of the significant agricultural waste streams with potential for energy generation are rice husks, coffee husks, and bagasse. It is evaluated that nearly 90% of domestic energy consumption in rural areas is derived from biomass such as firewood, agricultural residue, and charcoal. Furthermore, biomass fuel is also an essential source of energy for small industries located mainly in rural areas. According to a report of the Vietnam Energy Association, in total, biomass could amount to up to 9 billion kWh in 2020 and 80 billion kWh in 2050 (EKN, 2018).

The sector of renewable energy in Vietnam also faces some*challenges*, potentially affecting some of the Sustainable Development Goals (SDGs):

Firstly, with the widespread deployment of the coal-fired power plants and the high proportion of this kind of energy in the total energy supply, in recent years, these plants are increasingly worsening the environment and human health.

Secondly, environmental threats from agricultural biomass are growing concerns. While biomass is currently underdeveloped as a power source, many feedstocks are not only available but are also a threat to the environment. Rice husks, straw, coconut husks, bagasse, and coffee wastes: these waste streams are not currently treated in an environmentally sound manner, e.g., directly discharged into waterways or dumped. Therefore, the use of these resources is a business opportunity, as well as an environmental benefit. Rice straw can be said to have the highest potential in this regard, but also presents the most significant challenge.

Circular economy opportunities

With the characteristics and challenges of the renewable sector discussed above, some opportunities to shift to a circular economy model can be realized:

Investing more in producing bio-energy from the existing feedstocks

Vietnam has a large volume of agricultural waste that can be used as input materials for producing renewable energy like biogas and biofuel. Some enhanced technologies like pelletizing, briquetting, as well as combustion and co-generation, are not widely available in Vietnam. Investing in these technologies and applying more efficient business models to distribute the generated energy to the national grid is desirable.

Improving energy efficiency

Energy efficiency in Vietnam is an underdeveloped concept. Vital benefits can be gained by using energy-saving technologies in the Vietnamese industry. With increasing energy taxes, energy efficiency can bring a good business opportunity for the growing manufacturing industry. The current manufacturing industry in Vietnam is relatively energy-intensive and therefore offers business opportunities for energy-efficient technology and service providers to enhance energy efficiency.

Using more solar PV (photovoltaic) with network metering

With the advantages of solar irradiation levels presented in the previous part, the development of solar power, including solar power systems on the roof of houses is considered to have a lot of potentials. For each household and companies, it is possible to produce electricity using solar power and sell surpluses to the national grid. Moreover, there is a business opportunity for a service provider that provides rooftop solar plant extraction services to the operating company. An additional focus on the use of PV systems in Vietnam may be the recovery of rare metals from discarded PV systems. The increasing use of PV systems is expected to create a growing scarcity of the metals used in these systems.

Municipal solid waste into energy

Managing solid waste, including municipal solid waste (MSW), is a significant challenge in urban areas of most parts of the world, including Southeast Asia. Due to the lack of effective management programs, regulations and policies; The waste is posing severe health risks including several infectious diseases, odours, nuisances and environmental impacts, such as water, soil and air pollution. In Ho Chi Minh City, about 8,175 tons of solid waste were generated every day in 2014, including 6,800-7,000 MSW, with a waste emission of 1.02 kg/capita/day. MSW of Ho Chi Minh City contains 65-90% of biodegradable matter, which can be digested into biogas and compost, while the currently common practice of solid waste management in Ho Chi Minh City is landfill (VERMA et al., 2016). Despite being the least preferred circle option, waste into energy can be a solution for all non-recyclable waste streams, better than the landfill and plastic ending in the ocean.

d. Water management

Water plays a vital role not only in daily life but also in the growth of the Vietnamese GDP. It is of primary importance for food and health as well as an important resource for economic activities. The proportion of water used in the agricultural sector is 81%, followed by 15% of industrial and the rest of the household (3%) or service (2%), respectively (WB, 2016).

Most of the drainage and sewage systems in major cities in Vietnam were built over three decades ago, and more than 90% of the wastewater is carried by combined wastewater systems, which serve primarily as storm-water drainage and "taking away" domestic wastewater to prevent road flooding. Some newly developed urban areas use separate sewage and drainage systems; however, since most municipal wastewater is untreated, both rainwater and domestic wastewater are ultimately released together into nearby water environments like lakes, rivers, and canals. In the meantime, the interest in sewerage and wastewater treatment is still rather low compared to the drinking water. Provincial or city-owned companies typically manage these sewage systems (sometimes referred to as "state-owned companies").

The water sector in Vietnam is confronting with some *challenges* as follows:

The pollution of water is at a high level

Water pollution is one of the most severe environmental problems in Vietnam. Water quality has worsened worryingly, with a trail of toxicity created by the cities, industry and agriculture. Rivers that flow past big cities are heavily polluted. In many regions, groundwater is contaminated with a number of surface pollutants. In the Mekong and the Red River, these problems are exacerbated by the penetration of seawater.

Municipal wastewater contributes to a significant part of water pollution in many areas of the country. In 2018, only 46 % of urban households are connected to a sewage network, and in just 12.5 % of urban wastewater was treated (WB, 2019). Wastewater of each family is primarily processed in a household septic tank before being emptied into combined sewage systems (which carry both wastewater and rainwater). After that, it is released directly to lakes, rivers, and canals without additional processing, except in some large cities like Hanoi and Ho Chi Minh City, where discharge around 700,000 to 900,000 cubic meters of wastewater into the ecosystem every day (WB, 2019). Almost 90% of households in municipal areas have septic tanks. Less than half of Vietnam's hospitals have appropriate wastewater treatment systems (WB, 2016). All of this is the result of the low connection rate to sewer networks; extensive underinvestment in the collection, treatment and disposal of wastewater; Neglecting the potential for reuse of wastewater; low tariffs that do not reach the costs; and a dysfunctional regulatory system.

The industry produces vast amounts of potentially highly polluting wastewater, much of it from chemicals that are difficult to process. The need for water is increasingly high due to rapid industrial growth. The state sector, which still makes up around 40 % of GDP, bears much responsibility, as many state companies are among the most environmentally harmful industries in the country. Water pollution from craft villages is also a severe and increasing problem. There are 5,000 craft villages in Vietnam, of which over 65% are located in the Red-Thai Binh River Basin. These villages usually discharge untreated wastewater directly into water bodies without any treatment (2030WRG, 2017).

With the aquaculture production sector, a vast amount of wastewater is threatening water quality. In some rural areas, there are problems in managing water quality - particularly the harmful effects of fertilizers and agrochemical runoff. Vietnam consumes approximately 11 million tons of fertilizers annually, 90% of which is inorganic fertilizers and 10% organic fertilizers (NGUYEN, 2017). Rice consumes 65% of the total fertilizer consumed in Vietnam, and it is found that most rice farmers use fertilizers that are well above the recommended amounts (NGUYEN, 2017). Only about 45 to 50% of the fertilizer is used effectively. The rest will be washed out in runoff (WB, 2019). In addition to fertilizers, Vietnam also saw a sharp increase in pesticide consumption: 31% of pesticides used by farmers in the Red River Delta were classified as "highly dangerous" in the WHO classification, while 54% were categorized as "moderately hazardous" (NGUYEN, 2017).

Municipal solid waste is another threat to surface water. The reasons that allow solid waste enters the waterways are illegal dumping, unsanitary and poorly managed landfills near waterways and a lack of solid waste collection. Over half of the plastic that gets into the ocean comes from only five rapidly developing economies-China, Indonesia, the Philippines, Thailand, and Vietnam (MCKINSEY, 2015). For Vietnam, this is the result of an estimated 1.83 million tons of plastic that are poorly managed in coastal areas. This waste can eventually reach the ocean via inland waterways, sewage drains, and wind or tidal transport (JAMBECK et al., 2015).

The efficiency of water usage remains low with increasing water pressure

Industries such as textiles, food processing, and leather estimate the potential savings of an average of 30% for the water without investing heavily in infrastructure (WB, 2016). Overexploitation of groundwater in Ho Chi Minh City for domestic and industrial usage has reduced the groundwater level and caused significant impacts for the quality of it due to salinity intrusion. It also leads to a shortage of water throughout the dry season in Ho Chi Minh City. Cities in the river basin are currently under water stress, and water tensions will soon become serious; this will also affect the hydropower supply of these cities. Water stress will hurt local economic development and human health in general (VAN LEEUWEN et al., 2015).

Vietnam is facing an urgent need to achieve universal access to sanitation in urban and rural areas for environmental and health reasons. The level of wastewater treatment needs to increase significantly from 10% in recent years (WB, 2016). Sludge from sewage treated in Ho Chi Minh City is not allowed to be used for agriculture because of the high densities of heavy metals, persistent organic pollutants, and pathogens. Energy recovery and nutrient recovery from wastewater are absent or almost zero in Ho Chi Minh City (VAN LEEUWEN et al., 2015).

Climate change risks and salinity incursion

Climate change will significantly increase salinity incursion in coastal areas. Salinity incursion has occurred throughout the dry season, significantly reducing crop yields. Climate change and sea-level rise will affect the yields and production of major crops, such as rice, maize, cassava, sugarcane, and coffee. In the Mekong Delta, aquaculture is particularly crucial for rural employment and income. Higher temperatures, greater storm frequency, rising sea levels and other impacts of climate change are likely to affect fish physiology, ecology, and aquaculture practices. The main impacts of climate change on aquaculture may be due to increased flooding and salinity.

Circular economy opportunities

Strategies for circular economy-related to water management can provide to alleviating many of the environmental and socioeconomic challenges described, for example, by increasing water reuse (reducing water stress), wastewater processing and nutrient recovery from wastewater (reducing water pollution). This research focuses only on water management related to the element of 'water-smart city,' including processing wastewater and producing drinking water. Resource-efficient measures such as rainwater harvesting, prevention of leakage/water loss, measures to use water efficiently, and reduced consumption are also part of the shift to a circular economy.

A water-smart city is an approach to integrating urban planning and sustainable water management to minimize the hydrological impacts of urban development on the surrounding environment (HATTUM et al., 2016).

Some 'water-smart cities' solutions can be considered as a circular approach, including restoring the natural drainage capacity of cities by introducing nature-based solutions (replacing technical solutions and reducing of resource inputs) and closing of urban water cycles (including water storage, water treatment, water reuse and reuse of wastewater).

Opportunities concerning climate adaptation focusing on desalination (due to water use and climate change) are also part of the Mekong Delta planning initiative. This means that, at this point, circular economy opportunities in water management in Vietnam should be considered as the opportunities in the exploration and pilot phase, which raises awareness and creates best practices.

Water-smart city consumption

The circular elements of a water-smart city concept that can be explored/provided include the usage of nature-based solutions to collect water (e.g., permeability, water holding by the green roof, etc.), water storage and water treatment, including resource and energy recovery. The first step of this approach is to make a basic assessment of the challenges and opportunities (water supply) at the city level and then many complicated steps followed by the design, development, and construction of buildings and areas with multifunctional green spaces, infiltration systems, sustainable urban drainage, and storm-water harvesting systems.

Wastewater management and septic tank filtration technology

Septic tanks are widely used in Vietnam, and wastewater from these tanks is drained without further processing (except in large cities such as Hanoi and Ho Chi Minh), resulting in groundwater pollution. Therefore, opportunities exist with water filtration techniques adapted to septic tanks usage. This provides circular opportunities related to septic tanks and septic management, and opportunities related to additional techniques, such as aerobic systems. Septic management can be presented as an indispensable part of a smart city or the water-smart city approach.

Invest in wastewater treatment and recovery energy and resources from wastewater.

Opportunities exist in wastewater treatment and nutrient recovery techniques as part of the improvement of eco-industrial parks in order to make existing industrial parks more sustainable. Besides, the demand for water cleaning solutions to remove solid waste from water (such as plastic) and wastewater processing technology can bring excellent business efficiency. By recycling solid waste into commercial products (e.g., plastic into building materials), a business case can be created. Another opportunity may arise when a private water supply company (with a concession agreement with the government) provides water to the public while generating revenue by collecting plastic waste on the river. This addresses both water scarcity and waste challenges.

3. MATERIALS AND METHODS

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

3.1. 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 under the 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 2) 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 2: 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 outsourcing activities
	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)

The table shows that the ReSOLVE acronym is composed of the first names of the activities supported by the circular economy. In this structure, (EMF, 2015) summarized the most important principles of the circular concept and the processes that contribute to its implementation. (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. Table 9. in the Results section presents the results of the applied Mapping method. The application shows the results of a conceptual analyze of new water treatment structure and we could focus on necessary improvement points with that results.

3.2. 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

3.2.1. 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.

With these outcomes, the supportability estimation of all elements (key, strategic, operational, and reflexive) and structure squares (offer, cost structure, and income streams) were appropriately decided. The outcomes picked up indicated the overwhelming component and the legislative administration field where cognizant intercession is needed to quicken the disguise of externalities by waste management and process, to achieve the most cost-productive and best social transitions towards the supportable execution of bond firms, and from which the most influenced members of this progress can likewise be specified. To translate our outcomes, illustrative web charts were utilized in all the four instances of on-screen characters' conduct.

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 7) 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 7: The transitional matrix of municipal solid waste management on each level.

Source: (NGUYEN HUU and NGUYEN DUC, 2019)

3.3.2. 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. To be able to select appropriate criteria and technologies, it is essential to have data on the current situation of the local solid waste management. Background data comprise sources of generation, quantity, and composition of solid waste, the current status of treatment technology, financial resources, stakeholder participation, institution framework, and policies/regulations. From these primary data, it is possible to identify the challenges and opportunities of solid waste management systems and from which all solutions can be identified. Solutions implemented for solid waste management include management plans and technological options. Management options include 9Rs (refuse, reduce, redesign, reuse, repair, refurbish, remanufacture, repurpose, recycle and recover), public-private partnerships, awareness-raising, education and training, and economic tools. With the change in the pattern of resource consumption and economic development, this becomes very important for the reduction and reuse of resources. Besides, waste can be converted to other types of resources such as compost, biogas, and energy. The conversion of waste into other energy sources will reduce the amount of solid waste to be disposed into the landfill, which should be the least preferred option in waste management.

Although many solutions have been applied in solid waste management, not all of them may be feasible for adoption. Therefore, it is necessary to assess the suitability of each solution according to a set of criteria and conditions shown in Table 10. According to the circumstances and conditions of solid waste in each city, the criteria used for SWM are versatile and dynamic.

This study applied twelve essential management criteria for five operations and usage technologies. The twelve criteria are technology development, types of solid waste, operating scale, success factors, final products, capital investment, operating cost, land requirement, needed operating skills, possible adverse impacts, and contribution to energy and food security. The five extended SWM utilization techniques and operation are including composting, anaerobic digestion, mechanical-biological treatment, landfill, incineration, refuse-derived fuel (RDF) or solid recovered fuel (SRF), pyrolysis, and gasification. After conducting the assessment of the appropriateness of technology, the decision-making process of appropriate solutions is implemented.

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.

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

3.3.1. Research Materials

This research concentrates on analysing the municipal solid waste management system in Hanoi, the capital of Vietnam. According to the Vietnamese General Statistics Office (GSOVN., 2020), Hanoi covers an area of about 336,000 hectares and has around 7.52 million inhabitants in 2018. The city is recorded among 17 capital cities with the biggest area globally. There are 29 departmental divisions at the county and municipal level, as well as 584 communes, wards and town. Hanoi is ranked as one of the fastest-growing cities in Vietnam. Since 2015, Hanoi's urbanization rate has reached 47.55%, which is 1.42 times higher than the national average (33.40%), with an annual growth rate of 1.89%. The urban area has 3,699,500 residents, representing 49.2% of the total population. Data from rural areas are 3,823,100 people (50.8% of the total population). As shown in Table 3, from 2018 to 2030, the urban population is expected to increase, and rural communities may continue to decline.

Table 3: 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)

The current system of waste collection, transportation, and treatment in Hanoi includes some steps as listed below.

First collection: The main methods used in Hanoi for waste collection are pushcart system or wheeled bin, container system, and direct truck collection. The pushcarts are used in narrow roads where garbage trucks are difficult to pass. In these areas, waste collectors push wheeled collection containers into residential areas to collect solid waste. These wastes are put into small plastic bags purchased by residents, and these bags fall on the street.

The pushcarts are applied to collect trash at least once a day, and sweepers clean the main street several times every day. Therefore, in general, residents often use a top waste collection service. However, this system requires many workers to work and causes environmental problems at the transfer point. The direct truck collection includes small and large vehicles that use small vehicles to collect plastic garbage bags that residents discard on the street and other large vehicles used for direct transportation to landfills or processing facilities. The container systems are put in front of the large (e.g., high-rise) residential buildings, offices, shops, etc. for containing the waste placed by the citizens who live in these areas. After that, these wastes are collected and transported by truck to the landfill or treatment plant.

Transfer points in the streets. When the carts are full, they will be placed in different free zones on the sidewalks/pavements. The pushcarts are usually unloaded directly into waste collection/transport trucks at collection points. However, when the number of vehicles is insufficient, they will remain at temporary transfer points on the ground, where the waste will be kept until it is collected by the trucks before they are transported to the landfill or treatment plant. This condition will cause serious environmental problems at the transfer point. Therefore, there is a high demand for well-planned and accurately designed, well-constructed transfer points at curbsides to put the pushcarts and containers, and empty and clean them from excess solid waste more efficiently.

Secondary collection. Small and medium-sized compact trucks are often used to transport waste from chosen areas to landfills/processing facilities as a secondary collection. Unlike hazardous waste, the municipal solid waste collection does not require an exclusive license. Many collection trucks are outdated and have to be replaced with new/additional compaction one.

Recycling. It is estimated that about 10% of municipal solid waste to be recycled in Hanoi. The private and informal sectors carry out most of the recycling activities.Recyclable materials and packaging residues are collected and processed in informal areas before entering official collection channels. Some items are classified at the source, while workers handle others during collection and transportation. These collectors sort, package, and sell waste for the treatment industry. To a large extent, recyclable waste is handled in handicraft villages without any oversight of operational practices. These activities seriously polluted the air, water, land, and seriously affected workers' health in these areas.

Disposal/treatment. After collection, most of the waste is transferred to the Nam Son landfill site for disposal. The total land area of this landfill is about 84 hectares, which is highly overloaded and needs urgent expansion to contain the current volume of waste.

Institutional. Many companies/entities are involved in waste collection, transportation, and disposal in Hanoi. Thirty-one utterly independent service providers collect waste from urban and rural areas. URENCO Hanoi is responsible for waste collection from four downtown districts, and ten other local companies deal with the remaining urban communities and 20 other local joint-stock companies that collect waste from all rural areas.

Financial. The average waste collection fee for each family in Hanoi is EUR 1.028/family/month, which equals EUR 0.257/person/month. These fees only meet 64% of the reinvestment needs for garbage collection and treatment activities (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 8). 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).

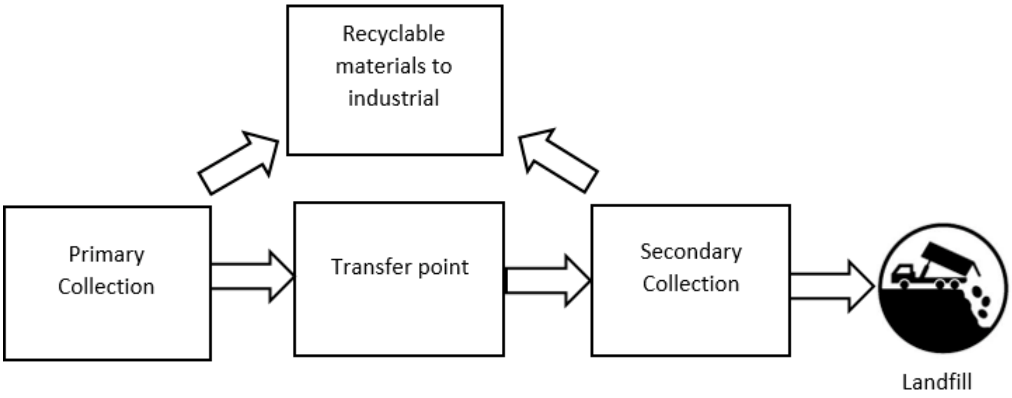


Figure 8: Components in Alternative 1

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 9).

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.

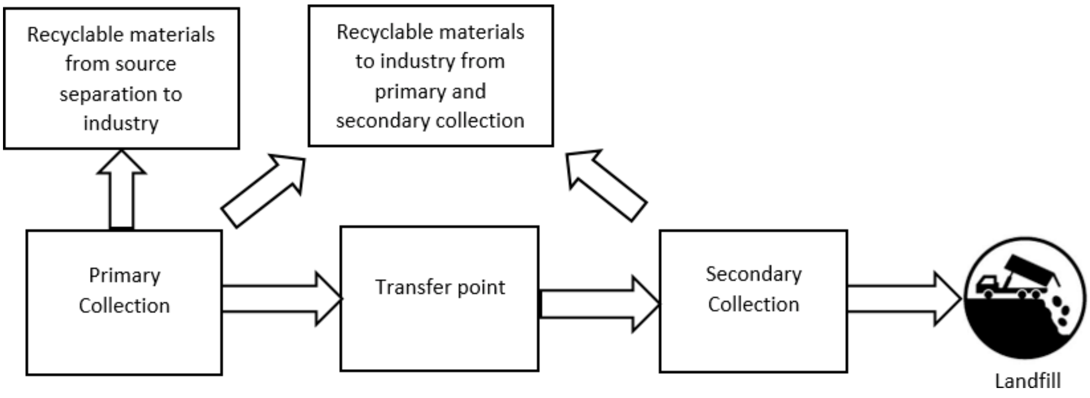


Figure 9: Components in Alternative 2

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 10). 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.

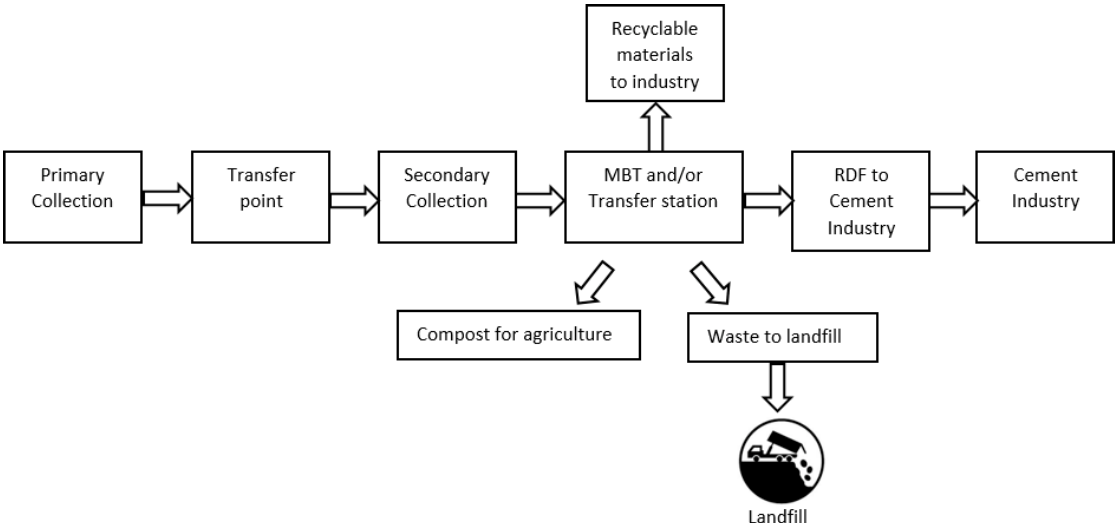


Figure 10: Components in Alternative 3

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 11).

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.

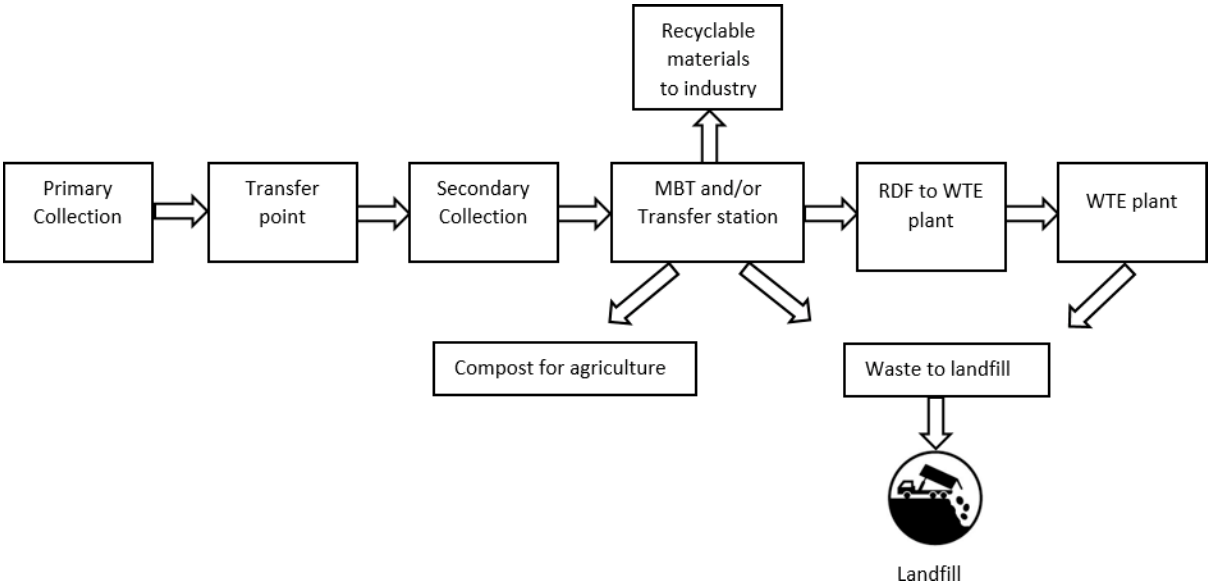


Figure 11: Components in Alternative 4

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 4).

Table 4: 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.

Although AHP is a long-standing MCDA method, it is still used in many fields such as manufacturing, environmental management, waste management, power, and energy industry, transportation industry, construction industry, etc. to resolve complicated decision-making problems. In waste management, the AHP method is widely used to evaluate and select a solid waste management strategy in Bosnia and Herzegovina (VUČIJAK et al., 2016), to determine the best solid waste management strategy (JOVANOVIC et al., 2016), or to analyze policy influence potential for solid waste management decision-making (SU et al., 2007). This method is also applied to determine the best alternatives for energy recovery from solid waste (NIXON et al., 2013), to evaluate solid waste treatment technology, or to rank suitable solid waste facility sites (HERVA and ROCA, 2013). Contreras et al. (CONTRERAS et al., 2008) used the AHP to select between different waste management plans to perform in Boston, USA. A large number of studies have concluded that AHP is a powerful decision-making tool that can support decision-makers to adopt sustainable waste management alternatives. The hierarchical structure of the AHP model allows decision-makers to easily understand the 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 the optimal solutions based on this information.

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, which is a simple, easy-to-use package for building decision models with dependencies, feedback, and computing results using the supermatrices of the Analytic Hierarchy Process; this study will propose the best sustainable solid waste management system in the specific context of Hanoi, Vietnam.

This methodology initially requires the definition of an objective to guide the analysis, which is defined as the choice of the best alternative for sustainable MSW management in the situation of Hanoi. These alternatives are mentioned above, namely, improving the current system for waste collection and transportation; reducing, reusing, and recycling waste at source; MBT plants for classifying, composting, and refuse-derived fuel (RDF) for cement industry; and MBT plants for classifying, composting, and RDF for waste-to-energy/incineration plants. Further, criteria are defined to evaluate these options. They are: the waste flow in 2018 and forecasted data to 2030; necessary equipment and facilities from 2018 to 2030; total investments estimated for municipal solid waste collection and disposal; the annual cost of operation and maintenance for municipal solid waste collection and disposal; and the total average costs per capita per year. This research conducted an expert-roundtable. The expert-roundtable or evaluation team includes Vietnamese Ph.D. researchers with extensive experience in transition management and waste management process analysis. Two major researchers with experience in the Climate Change Economics Research Center have a background in AHP practices and publications, regulatory issues, and waste management. All three Ph.D. researchers have knowledge of waste and energy management in developing countries. During AHP, we 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 5. 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 5: 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 12). 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.

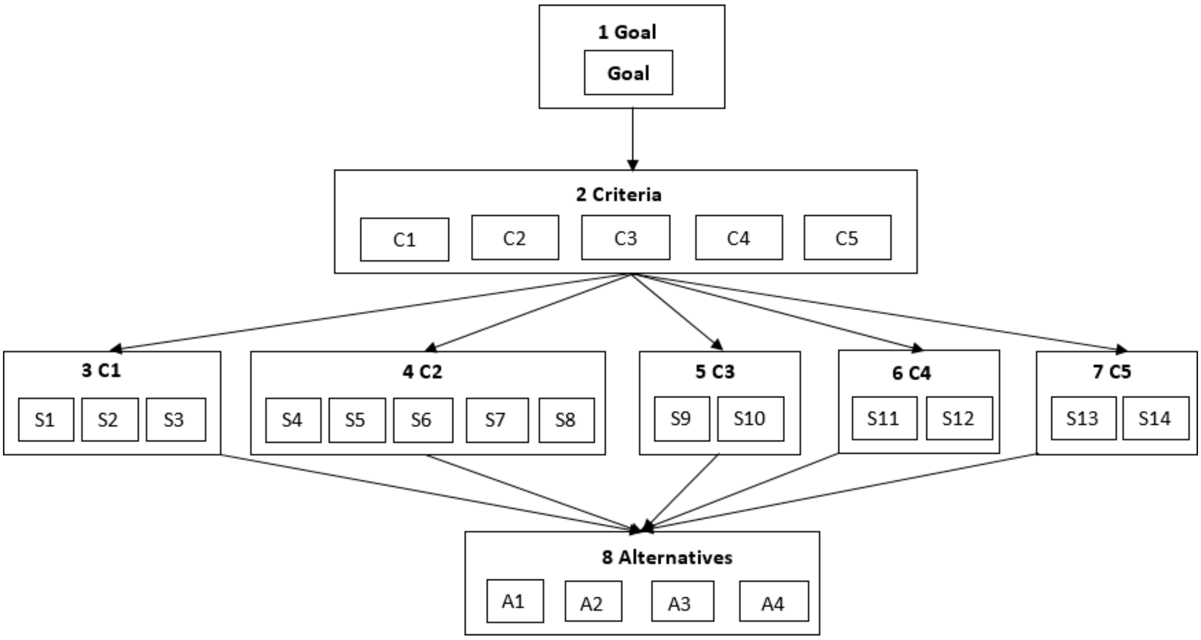


Figure 12: Structure of AHP analysis for sustainable municipal solid waste (MSW) management in Hanoi.

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 6).

Table 6: 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

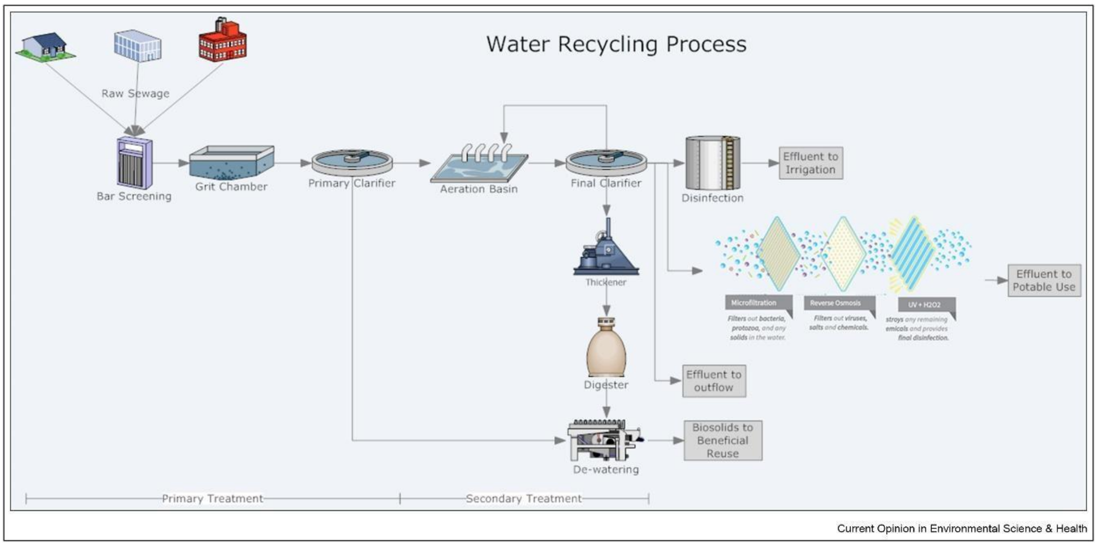
Saaty′s major scale (SAATY, 2000) was adopted for the comparisons between criteria and the alternatives related to each criterion (in this case: A1, A2, A3, A4) for each leaf criteria (C1…C5) and sub-criteria (S1…S14). Finally, the Super decision software will help to synthesize and give the rank of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

4. RESULTS AND DISCUSSION

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

4.1.1. 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. This system does not advocate the sustainability aspects of the environment and our natural resources and does not show material recycling. 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 13). 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.



Current Opinion in Environmental Science & Health

Figure 13: Conventional two-stage biological wastewater treatment and potential options for circular wastewater reuse.

Source: (CZIKKELY et al., 2019)

These cycles regenerate biological systems, such as soil (irrigation), that provide renewable resources (biogas systems) for the economy. Technological cycles restore and recycle products, components and materials through strategies such as reuse, repair, remanufacturing or recycling (technology water using) (TUKKER, 2015). The increase in wastewater amount can cause environmental and economic problems. The former conventional business models could not give answers for each environmental and economic questions, because the linear structure of wastewater treatment could not utilize innovative methods and new economic solutions (e.g., reuse of primary raw materials, recycling of all reusable waste of treatment processes) (NUßHOLZ, 2017). We recommend using circular improved blocks to develop a business model and declare each point, which may add value to the circular structure. The development of the Business Model Canvas and the improvement of circular economic units for each part of the treatment process can achieve higher scientific value for an effective and sustainable economic structure. Our business results appear to be useful for future applications in municipal wastewater treatment systems. This research hopes to provide a new solution for the more effective wastewater treatment process and determine economic answers and business resolutions for human inquiries about wastewater reduction and social environment. Within this topic, the author does not wish to introduce new technological innovations because the modern structure of environmental remedies does not only mean the development of technology. Innovative circular models and new business structures can be more useful for rethinking economic loop and solutions. This research would like to analyze and demonstrate the potential applications of new circular economies and business structures for urban sewage treatment systems.

The product lifecycle is a fundamental issue in circular process analysis. According to some approaches, the life cycle extension of products is a slowing down operation, which in the case of a slowing cycle, the "closing" element is recycling. An artificial extension of the useful life of products is a viable option to some extent, but sooner or later products end up in their life cycle (BAUTISTA and PEÑA-GUZMÁN, 2019). In this case, it is questionable how these products can be (as efficiently) used as secondary raw materials. An essentials basis of the circular economy model is that not only should product life be extended as efficiently as possible, but it should also be available to reuse raw materials at the end of its life cycle. The circular economy utilizes minimal or zero waste generation and resource recovery. Therefore, the product can be easily recycled at the end of its life cycle. The circular concept is waste reduction and reuse, as well as recycling and repair (BOAIT et al., 2019).

It is important to note that there is no representative volume of literature available for the water management sector, which is intended to provide a detailed presentation of the applied business models (MÜLLER et al., 2016). However, some communications (mainly on behalf of the European Union) have emerged, which has somewhat affected the business structure. The most prominent example in this regard is the study of (HOFFJAN et al., 2014), which introduced the business models (Business As Usual - BAU) that can be adapted to the field of water management. Müller et al. (MÜLLER et al., 2016) also proposed the introduction of business models for urban water management systems, including municipal wastewater treatment. In their work, it is described that systems can be interpreted at three levels from a business perspective: strategic, economic and operational. Wastewater treatment plants also need to carefully coordinate regulatory requirements (quality and economic regulation), retail preferences, risk management and willingness to pay. Many sector-specific properties characterize water management and water treatment. Independently of countries, the structural aspects of the business are divided into technological, economic and social parts. The most relevant features are as follows (MÜLLER et al., 2016; CHESBROUGH, 2010):

- Technological part: environmentally acceptable efficiency, renewability in continuous operation and the pursuit of recyclable material production;
- Economic part: high capital requirement, limited proactive intervention, significant cost requirements (in terms of material costs), cost efficiency issues;
- Social part: endeavour to reduce human health risk, but at least reduce the risk of pollutant emissions below the norm.

The structure of the traditional business model used in urban wastewater treatment closely follows the previous economic system. There are examples of attempts to demonstrate circularity at certain treatment levels, but in most cases, it is clear that grey and black water can be reused (TÓTH et al., 2018). This means the possibility of reusing the product and does not carry the wrapping of the technological process. As a result, the cleaning process generates waste (typically chemicals and chemical precipitation) (CZIKKELY et al., 2018b; CZIKKELY and FOGARASSY, 2018; CZIKKELY et al., 2018a) which could not be used by the municipal wastewater treatment system. Current attempts have shown that circular wastewater treatment is one of the cornerstones of circular water management systems (MAGARIL et al., 2019; KOT, 2018). Therefore it is important to combine sustainability, eco-efficiency and high- effective treatment technologies. For this, continuous and prominent development of business models and the inclusion of circular concepts as value creation in the business planning process are essential. Instead of technological innovation, a new business model innovation must be used which could reduce costs and produced wastewater amount. This is not a well-researched field in this context.

The emergence of circular economic aspects in business models

The prevailing economic concepts led to the degradation of our Earth's biodiversity and overall ecological status (CZIKKELY and FOGARASSY, 2018), as companies failed to take sustainability considerations into account and did not integrate them into their corporate governance concepts. Schaltegger et al. (SCHALTEGGER et al., 2012) distinguish “sustainable enterprise” from “sustainability enterprise” (BOCKEN et al., 2019). While the former is a financially stabilized initiative, the latter has already seen the environmental and social aspects. That is in close relations with eco-management and modern corporate governance behaviours. It is important to emphasize an approach that urges that business models should play a key role in corporate sustainability and circular economic innovation. Compared to previously applied product development and technology innovation, changes in the business concept of a water business system are more critical to market competitiveness. This economic concept has become the basis for business model research which necessarily means a circular trend in model development (GUNAWAN and HUTTER, 2017). Schaltegger et al. (SCHALTEGGER et al., 2012) explain the growing role of business planning in corporate sustainability implementation. Numerous studies have reported practical experience for successful and resilient businesses of social and environmental value. However, achieving environmental sustainability and goals by developing the business model remains a subject of professional discussion (NOSRATABADI et al., 2019). Ilinova et al. (ILINOVA et al., 2018) examined the aspects of rethinking business models through economic incentives. (ARMAS-CRUZ et al., 2017) focused on the potential for expansion of eco-businesses and concluded that the simple profitability of such business models does not make business decision-makers interested in "frequently used business practices" (Business as Usual – BAU - forms) - or also known as "best practice" models are being transformed into sustainability considerations. The same idea is supported by Ferreira et al. (FERREIRA et al., 2019) argue that "traditional" businesses only respond to emerging market needs. Business model development and the coordination of sustainability, social and ecological aspects are a common interest, otherwise, sustainability-focused businesses will remain only business opportunities and not future models of economic planning (LAKNER and POPP, 2014). When defining the concept of circular business models, Scott (SCOTT, 2017) claims that such initiatives should either use recyclable biological raw materials or the continuous reuse of raw materials used for the technology.

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

Transition management and thinking are structure-based processes. Progress considering and the board generally help the depiction and improvement of practical and persuasive objectives and stories. Long-term goals are matched with momentary employable activities experiencing significant change considering, and executing nearby and worldwide procedures and their associations into the condition wind up conceivable with this methodology. In addition, it provides rules and guidelines for the collection of auxiliary structures or cooperation programs that can prove to be useful in achieving the support goals of a particular region or country (WITTMAYER et al., 2016a). These goals are mechanical improvements, green developments, or atmosphere neighborly framework improvement projects. Therefore, the motor of progress forms consists of development programs, but in these cases, changing the mindset requires additional translation at the framework level (KEMP et al., 2007a). Key progress forecasts have changed radically over the last few years, but unfortunately, the current development methods are mostly based on generally accepted development assumptions - the direct advancement show. In the straight model, the procedure of development creates the final product of another item or procedure, which is essentially an examination result, or a result of the new innovative arrangement. The entire direct successive system of progressive procedure (BROOKS, 1995) is maintained through improvement innovation. The transition management supposes that these exercises should offer explicit characteristics as far as what on-screen characters are sharing simultaneously, what forms they are interlinked with, and what sort of item or, on the other hand, administration they create, which can make the plan explicit framework apparatuses and process methodologies conceivable. For instance, we could refer to evolving partakers (assigning an objective gathering), characterizing the test in the particular progress process, the sort of procedures required for progress, or the utilization of procedure guideline apparatuses (WITTMAYER et al., 2016a).

Figure 14 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.

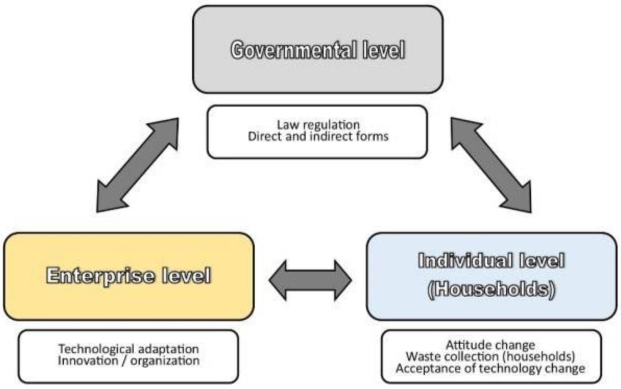


Figure 14: The main levels of transition thinking

Source: (NGUYEN HUU and NGUYEN DUC, 2019)

The following table (Table 7) presents the levels of circularity and sustainability from value 1 to value 5. The KPI – Key Performance Indicators (which is presented by Table 7) define key system performance metrics based on a sustainable Business Model Canvas results, with a five-grade scale. The five-level KPI values are based on expert judgement, it is construed as an objective indicator system. The expert compilation strives to find the most important indicators of the conditions for mitigating environmental externalities. Based on the KPI structure, the transition management should focus on the circular concept also. The higher circulating level of a municipal waste management system results in more effective and sustainable overall operation. Therefore the information of Table 7 presents the values and properties of circularity, which should be combined with the sustainability and economic structures. By establishing circular levels, it is possible to transform the system towards the highest level of circularity.

Table 7: 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)

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

The solid waste management system is one of the main important systems in urban development processes. Municipal solid waste treatment technologies could be transformed by many kinds of special urban properties. The current status of solid waste management system in Hanoi could not be utilized efficiently, because the system could not follow the changes of population and type of each municipal solid wastes. The habitat of people and the technological process of waste management causes problems, which should be solved by the transition of the management system.

In recent years, due to economic growth, household solid waste management in emerging countries has become increasingly urgent, and the accelerated consumption has led to the expansion of waste generation. A large amount of waste generated has caused to a serious shortage of landfills and increased waste management costs (TSYDENOVA et al., 2018). MSW is also one of the public management aspects that play a vital role in grasping opportunities and minimizing municipal and rural difficulties concerning the negative aspects of increasing urbanization. This is a widespread issue affecting everybody in the world. Poor waste management has polluted the world's oceans, blocking drainage channels, causing floods, and spreading transmitting infection through the breeding of vector. Besides, it diffuses airborne particles through the air from burning waste, causing unintended damage to the organisms that consume waste, leading to increased respiratory disease and affecting economic development (such as low tourism). (KAZA et al., 2018; HOORNWEG and BHADA-TATA, 2012). Waste generation is increasing day by day; it accounts for a large number of local budgets and government work in its treatment and significantly affects public health as well. Waste management is the highest single funding area for all governments in low-income countries, accounting for around 20% of the substantial budget. In middle-income countries, solid waste management usually represents at least 10% of solid funds, while in high-income countries, it is about 4% (KAZA et al., 2018). The cost of waste management in developing countries is expected to increase 3-4 times, from about US $ 20 billion in 2010 to about US $ 80 billion in 2025. Less developed countries have a higher rate of increased costs (HOORNWEG and BHADA-TATA, 2012). Therefore, for those countries with poor municipal solid waste management performance, it is essential to find feasible and knowledge-based solutions.

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 et al., 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). Landfill is a potential source of contamination as well as toxic substances, which can find their way into the natural environmental (soil and groundwater) by air (dispersed compounds) as well as by runoff (KODA et al., 2017; YANG et al., 2017; ADAMCOVÁ et al., 2017; ELIA et al., 2017; VAVERKOVÁ et al., 2018). The MSW landfill area also releases the odours consisting of a complex mixture of organic compounds, hydrogen sulfide (H2S) and ammonia (NH3) which are the source of annoyance to nearby urban populations (MORENO et al., 2014; CHENG et al., 2019). It is demonstrated that the impact of the landfill goes outside of the sanitary security zone, so which may result in the corrosion of the calibre of drinking water, atmospheric air, sanitary and hygienic condition of agricultural lands on adjacent rural regions (MAKARENKO and BUDAK, 2017). 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).

Each country will determine its strategy for a sustainable urban waste management system based on specific circumstances. For instance, the landfill directive promoted biodegradable municipal waste (BMW) management systems is applied in Austria, Netherlands; economic instruments including Pay-As-You-Throw (PAYT) and an organic waste tax are applied in some of the EU member states; both BMW system and Landfill Allowance Trading System (LATS) in the United Kingdom (UK); Green Dot system in Germany (PIRES et al., 2011; NEUMAYER, 2000). In Asian countries, the municipal waste management systems are being oriented to concentrate on sustainability issues; mainly through the incorporation of 3R (reduce, reuse and recycle) technologies (SHEKDAR, 2009). The solutions for these countries are social and technical approaches with social approaches are changing the public behaviour by improving the community through training, and encouraging partnerships with decentralized solid waste management, and the technical approaches are reducing biodegradable solid waste at the source, converting waste to energy, and using simple technology (DHOKHIKAH and TRIHADININGRUM, 2012).

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). Some assessments have been made based on the application of sustainability indicators to evaluate and improve the urban waste management system from different perspectives. For instance, when assessing performance, including achieving policy objectives such as "waste awareness" benchmark indicators, Chandigarh presented an inferior performance in terms of environmental controlled waste processing, waste disposal methods, and the 3R strategy for Surat (second-tier cities) in India in comparison to other cities (RANA et al., 2015; WILSON et al., 2015; ZAMAN, 2014). Some other studies conducted in Romania (CĂILEAN and TEODOSIU, 2016), in the Lombardy region of Italy (RIGAMONTI et al., 2016), and in the ABC Paulista region of Brazil (FRATTA et al., 2019) have shown the applicability of indicators for assessing the sustainability of a MSW management system. Of all indicators applicable to the sustainable management of urban solid waste, it is crucial to establish appropriate policies and implementation plans to reduce the amount of waste generation by installing a waste separation system at the source and educating the citizens to raise their awareness of waste classification (YUKALANG et al., 2018).

In 2015, the European Commission formulated a regulatory proposal for the horizontal implementation of the circular economy plan outlined in the Action Plan for member countries. They were building new synonyms for sustainability. The new committee, elected in 2019, has continued developing the plan, which has made it a key component of the EU Green Deal Program to prioritize circular business models. The concept supports material cycling and short cycle material conversion to save materials and energy. This concept is fascinating because this development trend does not consider waste to energy methods as a part of sustainable development (EUROPE, 2019). 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).

Much research has been done to identify sustainable decision-making models to assess alternative waste management options, such as the Life Cycle Assessment (LCA), cost-benefit analysis and multi-criteria decision analysis (MCDA) (MILUTINOVIĆ et al., 2014). The LCA will assist decision-makers in selecting the best management plan with the least environmental impact (KHANDELWAL et al., 2018). From a life-cycle perspective, the comprehensive MSW management system includes all core operating units from the collection, transport, processing, recycling, and disposal.The LCA studies the environmental impact of all waste treatment operations from “cradle to grave”; cost-benefit studies examine financial aspects, while MCDA studies economic, social, and environmental criteria (MORRISSEY and BROWNE, 2004). MCDA is commonly used for waste management, and this method is suitable for assessing the sustainability of waste management systems. The advantage of multi-criteria analysis when evaluating sustainable alternatives is that both quantitative and qualitative criteria can be applied. It also allows the cooperation of various decision-makers, even if the intention is inconsistent with the identification of indicators and decisions. The literature review, which has conducted, has shown that MCDA is often applied as a good model for decision-making in waste management.

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

In the following, this study intends to present the business development opportunities that can form the circular blocks of the built Business Model Canvas through the current wastewater treatment business model. The technologies currently used are typically linear economic approaches. After removal of hazardous contaminations by artificial substances (chemicals and chemical charges), chemical precipitate containing pollutant concentrated impurities are removed from the system and treated as waste. Removal chemical compounds should also be excluded, as they can in themselves constitute 'pollution'. If we analyze this economic structure from the business perspective, it can be seen that circularity does not appear at this level. In the following, this study would like to point out the upgrading elements of the revised models, harmonizing the presentation of linear and new circular business solutions.

4.2.1. 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. 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 8: 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 andAlternative 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.*

4.2.2. 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 9 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 9: 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 9: 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)

4.3. Results of choosing municipal waste management options for sustainable transition in Hanoi, Vietnam

4.3.1. Systematic approaches to waste management criteria's

Twelve criteria and five technical alternatives (SHARP and SANG-ARUN, 2012) to manage solid waste are presented in Table 10. 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 10. 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. These techniques are paired with different criteria that can be used as a benchmark for a solid waste treatment technique. The level of impact is assessed by the score, scale of each criterion range from 1 to 5; on which level of circularity is fit for each method. Each criterion is attributed to a value based on its score and presented in the table. From the total score of each plan, the local government or waste management units can quickly determine the technical method of treating solid waste by local conditions. Therefore, to ensure the effectiveness and feasibility of a solid waste management system, responsible state management agencies and stakeholders need to coordinate and consider all factors before deciding on the criteria and technical plans for solid waste treatment and score (scale). Table 10. presents the basic guidelines for the selection of suitable solid waste treatment options.

Table 10: 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 10. - Values of each circular levels. Abbreviations: VP – Value proposition; RS - Revenue streams; CS – Cost structure.

4.3.2. 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 11 shows the overview of each circular blocks of transitional management with values of circularity. With these results, we 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 11: 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 11 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.

Value proposition:

The transition thinking (about solid waste management) on four levels means the new value production with structural development. The current waste management system could not treat the whole amount of municipal waste and the rest could not manage with a circular loop. The value proposition means sustainable thinking also and this new idea causes more improvement necessary in the waste management system. On a strategic level, the improvement means a new observing system from waste production until collection and final reuse and recycle. The current value proposition is the linear structured system and could not works sustainably and circularly.

Cost structure:

The cost structure of the current waste management system could not support the total sustainable and circular development, because works with non-efficiency methods. The low percentage of recycled rests of the total waste amount and the proportion of reusable first raw materials needs a new cost structure. The governmental decisions mean a maximum medium circular and sustainable efficiency. The costs of an eco-friendly working system and production of reusable and recyclable materials have to be considered, and the costs of education and training of human thinking and habit also. Communication between each segment of a new business model, e.g. key partners and customer segments are also important because their behaviour and reactions also increase the total costs of the system.

Revenue streams:

The decision segments of the system should find new solutions and opportunities even at the technological level to earn new revenue streams by a circular transformation in the operational field. This importance also presented by the observed literature and also focuses on their strategic facts. The sales revenue and cash flow also increase in the long-term run with the awareness of public and firm thinking. In the beginning, it can cause monetary and indirect revenue streams.

4.3.3. 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. In Vietnam, the choice of technology also considers the national strategy for integrated solid waste management. In case of Hanoi city, five of the eight solid waste treatment technologies are selected such as (1) Compost; (2) Anaerobic digestion; (3) Sanitary landfill (with biogas collection system) or biological landfill; (4) Incineration (Incinerator); (5) fuel production from waste (RDF) or (SRF). The selection of these five technologies is based on their wide application in many countries around the world as well as in Hanoi. Five technologies were compared based on 11 criteria as mentioned in Table 12, in which the multi-sector involvement criterion was rejected because it was considered the least important one in the Hanoi's condition. The calculation was performed using scoring system of 1 to 5 scores (5 = most favorable, 4 = favorable, 3 = Medium, 2= less favorable 1 = unfavorable). The point for each criterion is based on the consultation with experts, performance, on-site survey, and results of environmental monitoring. The total final score for each technology can be used as a "Sustainability Index" of technology. If technology has a high score, sustainability is high and vice versa. Based on the current status of solid waste management in Hanoi City, two scenarios assessing the suitability of solid waste treatment technology are given. Results of assessing the appropriateness of solid waste treatment technology presented in Table 12 (*Scenario 1*) with commingled waste and Table 13 (*Scenario 2*) with segregated waste.

As shown in Table 12, 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 12: 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.

The composition of commingled solid waste in Hanoi also contains a certain amount of household hazardous wastes (HHW) and many non-recycling components. Also, the composition of the solid waste amount of Hanoi has a high biodegradable organic fraction (64.8-74.3% of wet weight) and high moisture (55-65%) so that sanitary landfill (with the collection of biogas) is a sustainable technology for solid waste management in Hanoi at present. Amount of non-recycling fraction (about 25% including plastic, diaper, textile, rubber & leather, styrofoam, wood) with high calorific value has increased significantly, and the biodegradable organic fraction has decreased from 2009 to 2015. Due to the lack of available land, incineration technology was ranked second with the possibility of energy recovery. However, the high moisture content of the solid waste and the highest investment and operation costs may limit the utilization of this technology.

The composting technology is ranked the third because the waste is commingled and therefore the separation step has to be carried out before the waste is composted and this step is labour-intensive. At present, the quantity of solid waste at two composting plants takes at 35-64%, and the remaining non-compostable (taking 36-65%) are buried at a sanitary landfill or burned by the incinerator. Also, the quality of compost using commingled waste is low because the end product is mixed with scrap glass and plastics making it difficult to consume. RDF technology ranked fourth. The anaerobic digestion technology has the lowest score due to uncertainties regarding investment and operation costs, low energy prices, damaged reputation due to unsuccessful plants as well as this technology need source-sorted organic. These results are consistent with the set targets for the management of solid waste in Hanoi as according to National strategies on integrated management of solid waste.

Table 13: 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 13 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.

The potential demand for organic fertilizers and soil conditioners in the surroundings of Hanoi is very high and exceeds the actual supply. With source-separated clean, biodegradable organic fraction, the composting technology is the most suitable because of its simplicity, low cost, and high demand for composting products. The anaerobic digestion can produce green energy and soil conditioner from biodegradable organic fraction, and it is ranked the second after composting technology because of its higher complexity and cost compared to the composting technology. The bioreactor landfill or sanitary landfill with the collection of biogas requires a large amount of land, generate leachate and emit an odour, and thus it has the lowest score. Components of remaining solid waste after separation (plastic, diaper, textile, rubber, leather, etc.) with high calorific value can be incinerated with energy collection and thus obtains higher score compared to RDF technology.

4.3.4. 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.

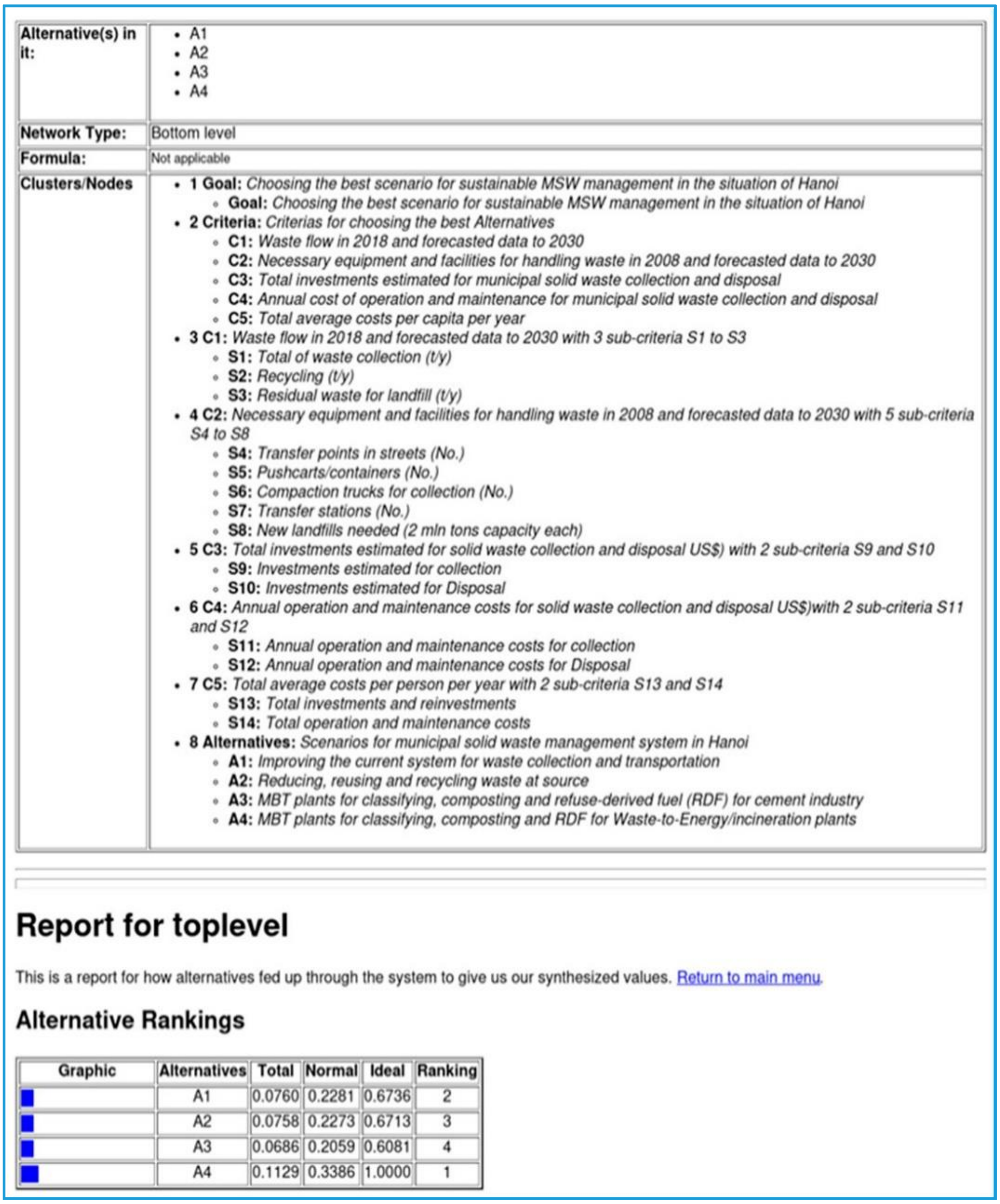
4.4. Results for selecting the best sustainable solid waste management system for Hanoi

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.

It can be seen from Figure 15 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.

This scenario will lead to an increase in the recycled materials from 245,147 tons per year to about 1,068,744 tons annually in 2030. By 2030, 1,045,227 tons of compost will be produced per year, and 3,285,000 tons of material will be incinerated, with the data reduced from 2.1 million tons annually to 320,000 tons annually in 2030 (VAN DEN BERG, 2018).

Due to the significant positive effect of composting and incineration in waste-to-energy plants, the amount of waste in landfills would be decreased from about 87% in 2018 to 6% in 2030. In addition, the number of landfill facilities will be significantly decreased with the need of only six sites by 2030. This is an excellent effect of this scenario because the land for landfill facilities in Hanoi is no longer sufficient, and the negative environmental impact of these facilities is increasing (VAN DEN BERG, 2018).



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 15: The structure of the AHP analysis and the order of the alternatives

Source: (HOANG and FOGARASSY, 2020)

In this scenario, the transfer stations are integrated into the MBT facilities; this means that investment in equipment and facilities needed for the modernization of the collection, transport, and disposal required in each of the four-year periods to 2030 will be considerably decreased compared to the remaining scenarios.

As with the first two options (A1, A2), the investment in the first four years' waste collection will be high because of the supply of new pushcarts/containers and trucks. In the following years, the mechanical-biological treatment stations and waste-to-energy plants will be gradually introduced. This introduction is the main cost drivers because the new and environmentally sanitary landfill capacity required is considerably less in this alternative (only six landfills). For

A1 and A2, the transformation process is slow, and it can be assumed that this type of waste management conversion requires the lowest investment, but has the highest operating cost. Due to the dumping of large amounts of waste, the system itself may cause serious environmental and health problems. With the Alternative A3, it has to be taken into account that the cement manufacturing facility has been optimized differently during their design. Poor efficiency of combustion and unfavourable greenhouse gas (GHG) emissions ranked the A3 alternative in the lowest position. Regarding the A4, besides the waste collection and recycling options, the cost-benefit analysis results also play an important role in the evaluation. The employment and average family income growth are two important aspects of the system being established. The results table in Appendix A clearly indicates which sub-criteria qualify for Alternative 4 (mechanical–biological treatment plants for sorting, composting, and refuse-derived fuel for waste-to-energy/incineration plants), or which the implementation of the A4 program is neutral or unfavorable. To summarize, it can be said that based on the existing knowledge, experts believe that avoiding the construction of additional waste landfills, increasing waste collection and selection, and increasing the recycling rate are the most effective solutions. However, it should be emphasized that the waste-to-energy incineration system associated with the system solution has higher investment and operating costs (S12, S13, S14) than other alternatives. This is important because income levels and waste volumes are not growing at the same rate, so residents are unlikely to be able to cover the cost of waste management. Higher-income is correlated with increased consumption, but the non-environmentally friendly consumption system will have many negative externalities, and waste management costs will rise faster. Compared to international data, there is a big difference between household income and waste management costs.

The average salary in Vietnam is EUR 188.04 per month. International standards indicate that the cost of an affordable waste management service is 1 - 1.5% of the average household income. If only one person earns income in the family, then the reasonable cost is almost EUR 1.879-2.819 per family per month. For a normal family with four members, the affordable annual fee per person would be EUR 5.645-8.468. This covers only 16-25% of the average cost, as shown above, and is an acceptable fee for inhabitants of Hanoi (VAN DEN BERG, 2018).

5. CONCLUSIONS AND RECOMMENDATIONS

The focus of this dissertation 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 bya 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. To assess and select the appropriateness of solid waste treatment technology that can be applied in the conditions of Hanoi, this research applied benchmarking model with five of the eight solid waste treatment technologies which are widely used in many countries around the world such as (1) Compost; (2) Anaerobic digestion; (3) Sanitary landfill (with biogas collection system) or biological landfill; (4) Incineration (Incinerator); (5) fuel production from waste (RDF) or (SRF) and 11 criteria including (1) Solid waste characteristics; (2) Waste quantity; (3) Compliance with standard/regulation of National Technology of Vietnam; (4) Time-consuming for the entire process; (5) Complexity and required skills; (6) Demand for final products; (7) Initial investment; (8) Operating cost; 9) Land requirement; (10) Possible adverse impacts, and (11) Public acceptability. Based on categorizing two scenarios of characteristics of waste such as mixed and separated, this paper resulted that the scenario 1 (commingled waste) has the technology's sustainability index with 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. The case for the scenario 2 (separated 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. 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 10. 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. Based on the author's suggestion, it is necessary to focus on the following target areas in order to strengthen prevention as the key to system development.

- Solid waste characteristics

The heterogeneous composition of municipal waste results in the prevention and making possible to operate efficiently the planned waste management system.

- Waste quantity

The increasing amount of waste strengthen prevention.

- Public acceptability

The prevention increasing the acceptability of the developed municipal waste management system.

- Demand for final products
- Operating cost
- Complexity and required amount of raw materials

Besides,development environments for waste management systems are often inadequate in developing countries. Limited financial resources, low awareness, high levels of corruption, lack of appropriate management tools, dependence on imported equipment, and inadequate technology solutions are problematic. Poor collection and disposal of urban solid waste results in aesthetic degradation of the environment and increased contamination of environmental compartments. The climatic effects (floods, fire cases, dust and air pollution, temperature extremes) as the source of dangers play in the development of appropriate technologies, in the process of adaptation. These problems also lead to human health damage, which can only be reduced by implementing cost-effective technical and policy measures. Many inadequate technologies used in waste management directly endanger human health and the environment. According to the hierarchy of the waste management, the most common way of disposing of municipal solid waste is to bury unprocessed waste, which has been replaced in developing countries by rapidly growing and efficient waste-to-energy systems. They can be called safer systems, but the material and energy losses in this technology are very high. According to EU waste management principles, the technology of transforming waste into energy is not part of the sustainable development process, because all recyclable materials are lost in this process, and only a small amount of energy can be obtained from this treatment. The saving of materials and energy are highlighted in the EU Circular Economy Action Plan as a prominent feature of the EU's Green Deal policy. The innovation of municipal solid waste management systems in developed and developing countries is going in the opposite direction; this is because consumers have different consumption and waste selection habits.

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.

6. 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.

7. SUMMARY

Developing countries face many sustainability challenges associated with urbanization and industrialization, including pollution, a severe shortage of natural resources, a lack of infrastructure, and a mounting pollution crisis. The growing waste crisis in these countries has a serious impact on the environment and public health. These challenges point to the need to find new ways to achieve development goals while reducing resource consumption. In addition, these countries are the main production and future consumption centers of the global economy. With a systematic approach to resource efficiency and referring to changes in business models and allocation of assets to individual ownership, the circular economy model may be the key pattern these nations should apply. However, developing countries pay less attention to discussions on CE issues than developed countries. The lack of data and analysis on CE in most developing countries misrepresents important opportunities for accelerating a transition to circular activities and value chains. Thus, the first goal of this thesis is to analyze the potential for circular economic transformation focused on the wastewater management system to get more effective and cost-efficient. Using the ReSOLVE framework, the Mapping method, and presenting each technology's main circular points (in the focus of the Regenerate part), this thesis has improved the Business Model Canvas and introduced the main economic transformation points. This research shows that economic operators and supply chain members integrate their resources into circular systems, then business ecosystems can be continually redesigned, creating dynamically and efficiently self-regulating systems. The modern structure of environmental treatment methods does not mean exclusively technological development; the new business structure and innovative circular model could be more useful to rethink the economic loop and cascade solutions.

The second goal is to highlight the level of decision-making processes of transition management that should be applied from the perspective of municipal solid waste management in the individual cities and city regions to interpret circular business models. By examining the case study of solid waste management in Hanoi, 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. In addition, the study addresses the need for transformation at the technological and residential (individual) levels to develop sustainable and efficient municipal waste management systems.

The third goal is to look for a sustainable solution for the municipal solid waste management system, which is appropriate and should be applied to the megacities in developing countries like

Hanoi or other major cities in Asia and Africa. The study collected secondary data from the World Bank report produced in 2018 and assessed options and courses of action for implementing Vietnam's national solid waste management strategy. Based on the data provided and scenarios supported by the AHP and Super Decision software, the results of this study show the best alternative to the current Hanoi MSW management system by 2030. This is the scenario in which mechanical–biological treatment facilities are used to separate the household waste mechanically and classify the organic part for composing and the refuse-derived fuel fraction for incineration in dedicated waste-to-energy plants. The advantage of these options is that they reduce the amount of waste in landfills and the negative impact on the environment. In addition, the energy generated from the waste-to-energy process can be used for a variety of purposes. According to the study, the alternative " Mechanical–Biological Treatment (MBT) plants for classifying, composting, and RDF for waste-to-energy/incineration plants" has the highest ranking for a sustainable municipal solid waste management system solution. Although the EU's circular innovation program and action plan can counter this trend, waste-to-energy solutions should be suitable and applied to Hanoi and other major cities in Asia and Africa.

8. APPENDICES

8.1. Appendix (1) References

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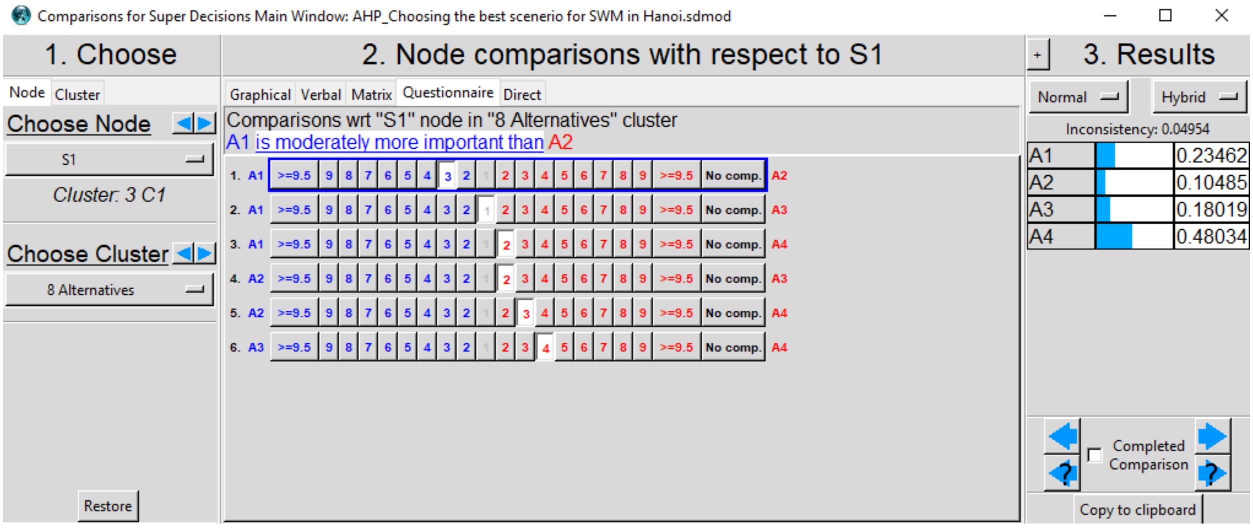
8.2. Appendix (2) Result charts of Super Decision Software Node comparisons


Comparisons for Super Decisions Main Window: AHP_Choosing the best scenerio for SWM in Hanoi.sdmod

1. Choose

2. Node comparisons with respect to S1

3. Results

Choose Node: S1

Cluster: 3 C1

Choose Cluster: 8 Alternatives

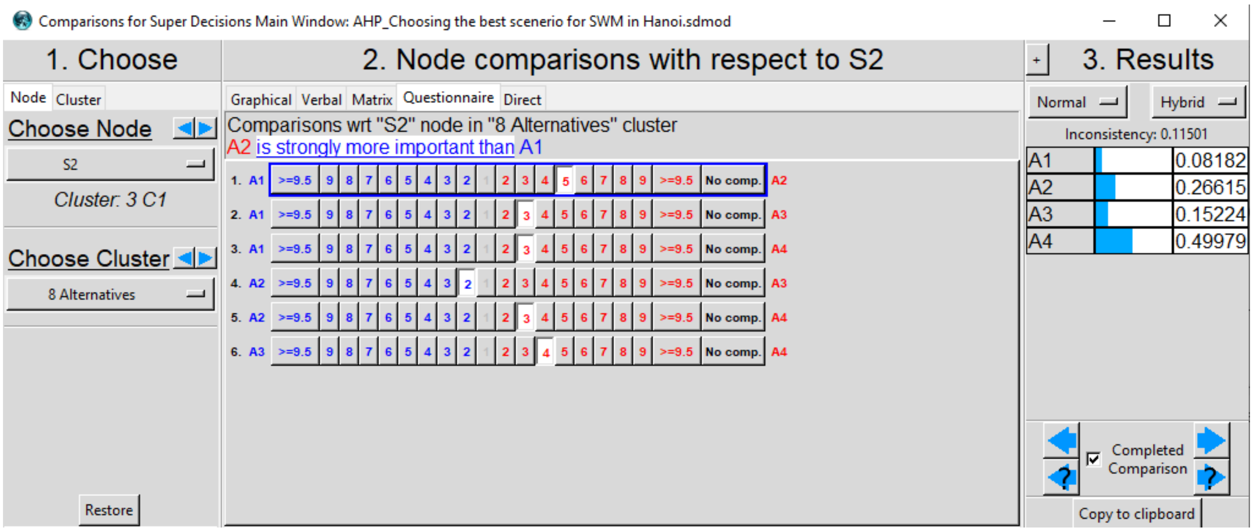
Comparisons wrt "S1" node in "8 Alternatives" cluster

A1 is moderately more important than A2

Inconsistency: 0.04954

A1	0.23462
A2	0.10485
A3	0.18019
A4	0.48034

☐ Completed Comparison


Comparisons for Super Decisions Main Window: AHP_Choosing the best scenerio for SWM in Hanoi.sdmod

1. Choose

2. Node comparisons with respect to S2

3. Results

Choose Node: S2

Cluster: 3 C1

Choose Cluster: 8 Alternatives

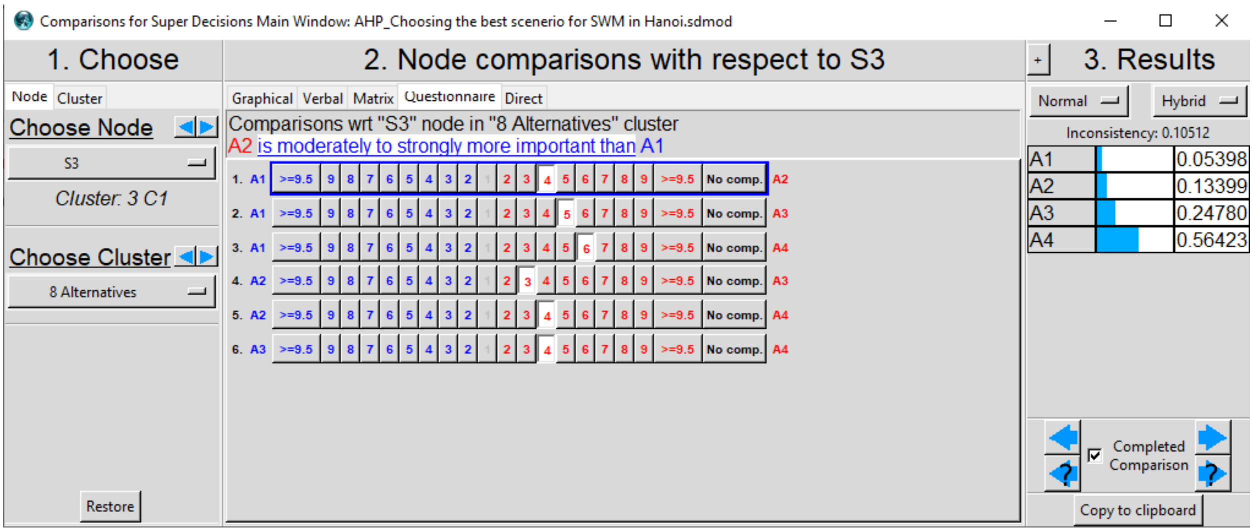
Comparisons wrt "S2" node in "8 Alternatives" cluster

A2 is strongly more important than A1

Inconsistency: 0.11501

A1	0.08182
A2	0.26615
A3	0.15224
A4	0.49979

☑ Completed Comparison


Comparisons for Super Decisions Main Window: AHP_Choosing the best scenerio for SWM in Hanoi.sdmod

1. Choose

2. Node comparisons with respect to S3

3. Results

Choose Node: S3

Cluster: 3 C1

Choose Cluster: 8 Alternatives

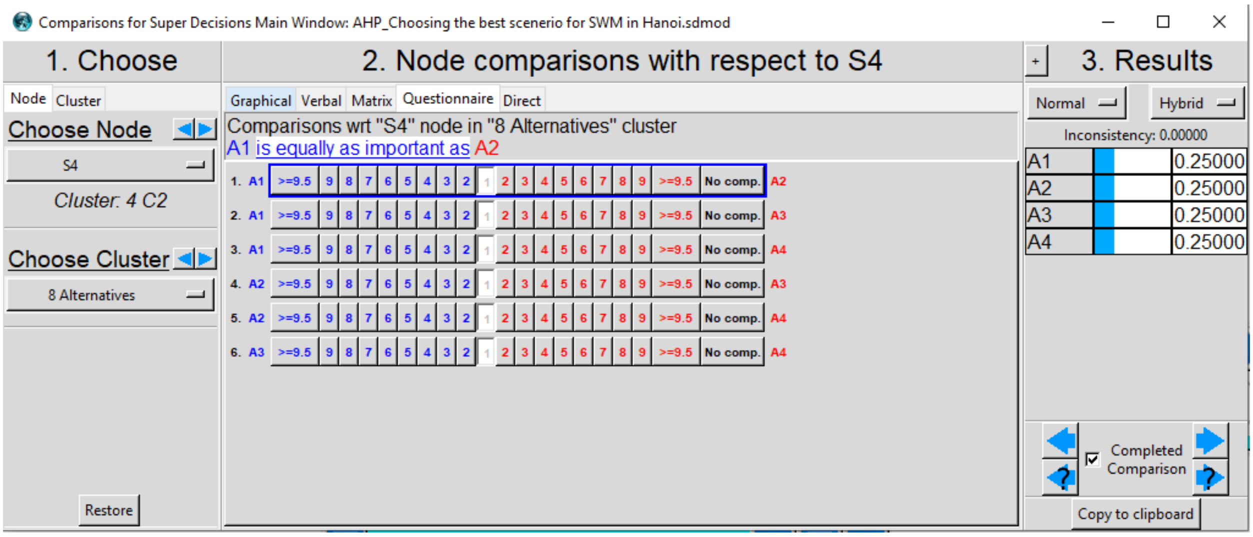
Comparisons wrt "S3" node in "8 Alternatives" cluster

A2 is moderately to strongly more important than A1

Inconsistency: 0.10512

A1	0.05398
A2	0.13399
A3	0.24780
A4	0.56423

☑ Completed Comparison


Comparisons for Super Decisions Main Window: AHP_Choosing the best scenerio for SWM in Hanoi.sdmod

Choose Node: S4

Cluster: 4 C2

Choose Cluster: 8 Alternatives

Comparisons wrt "S4" node in "8 Alternatives" cluster

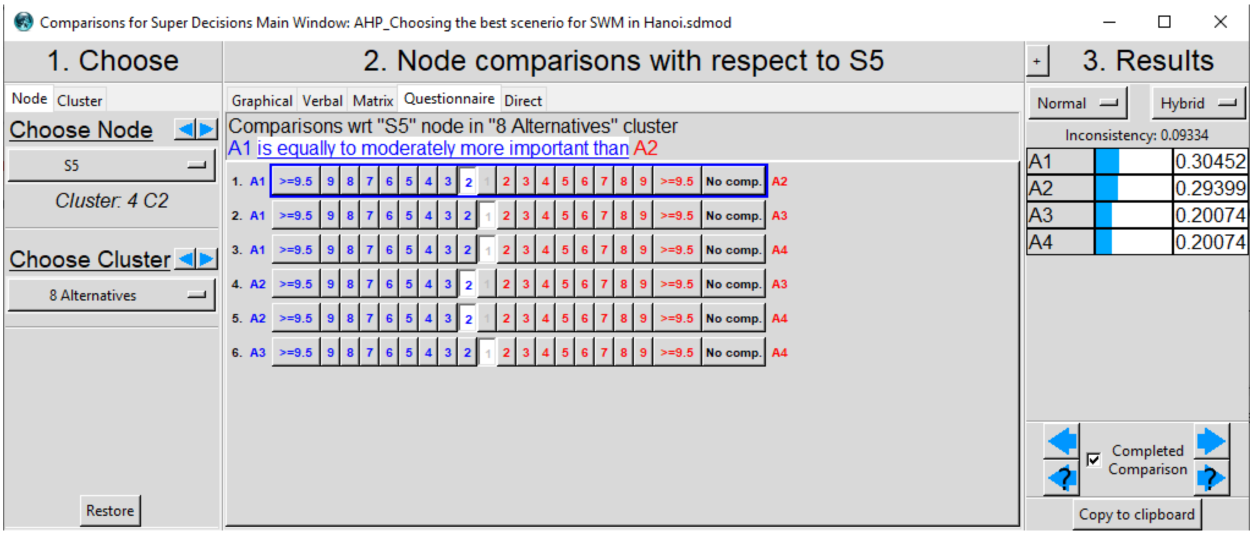
A1 is equally as important as A2

1. A1 >=9.5 9 8 7 6 5 4 3 2 1 2 3 4 5 6 7 8 9 >=9.5 No comp. A2
2. A1 >=9.5 9 8 7 6 5 4 3 2 1 2 3 4 5 6 7 8 9 >=9.5 No comp. A3
3. A1 >=9.5 9 8 7 6 5 4 3 2 1 2 3 4 5 6 7 8 9 >=9.5 No comp. A4
4. A2 >=9.5 9 8 7 6 5 4 3 2 1 2 3 4 5 6 7 8 9 >=9.5 No comp. A3
5. A2 >=9.5 9 8 7 6 5 4 3 2 1 2 3 4 5 6 7 8 9 >=9.5 No comp. A4
6. A3 >=9.5 9 8 7 6 5 4 3 2 1 2 3 4 5 6 7 8 9 >=9.5 No comp. A4

Inconsistency: 0.00000

A1	0.25000
A2	0.25000
A3	0.25000
A4	0.25000

☑ Completed Comparison


Comparisons for Super Decisions Main Window: AHP_Choosing the best scenerio for SWM in Hanoi.sdmod

Choose Node: S5

Cluster: 4 C2

Choose Cluster: 8 Alternatives

Comparisons wrt "S5" node in "8 Alternatives" cluster

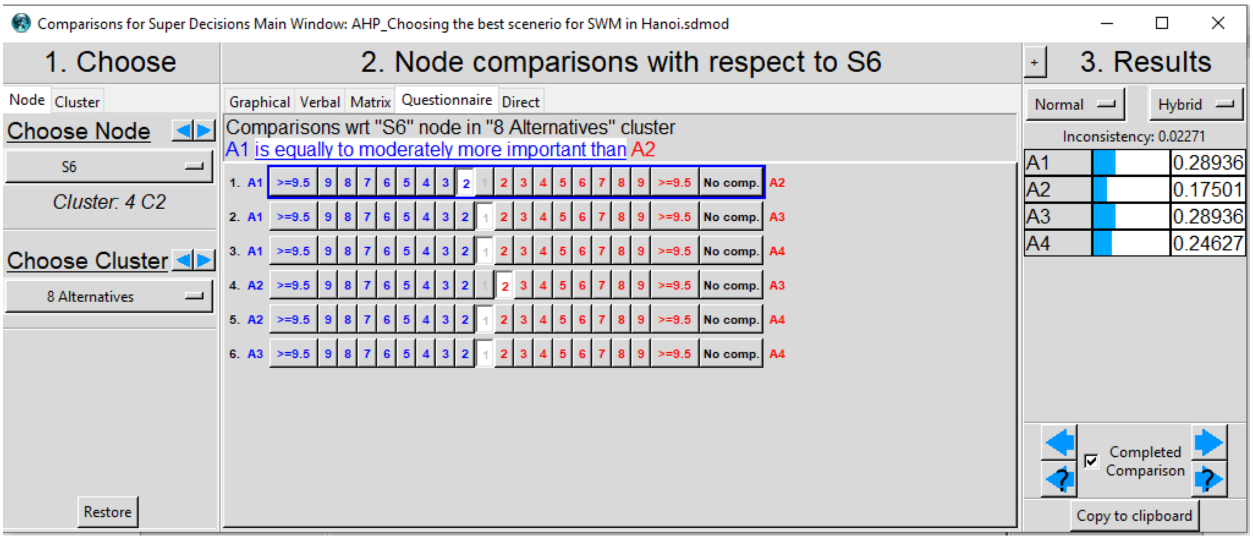
A1 is equally to moderately more important than A2

1. A1 >=9.5 9 8 7 6 5 4 3 2 1 2 3 4 5 6 7 8 9 >=9.5 No comp. A2
2. A1 >=9.5 9 8 7 6 5 4 3 2 1 2 3 4 5 6 7 8 9 >=9.5 No comp. A3
3. A1 >=9.5 9 8 7 6 5 4 3 2 1 2 3 4 5 6 7 8 9 >=9.5 No comp. A4
4. A2 >=9.5 9 8 7 6 5 4 3 2 1 2 3 4 5 6 7 8 9 >=9.5 No comp. A3
5. A2 >=9.5 9 8 7 6 5 4 3 2 1 2 3 4 5 6 7 8 9 >=9.5 No comp. A4
6. A3 >=9.5 9 8 7 6 5 4 3 2 1 2 3 4 5 6 7 8 9 >=9.5 No comp. A4

Inconsistency: 0.09334

A1	0.30452
A2	0.29399
A3	0.20074
A4	0.20074

☑ Completed Comparison


Comparisons for Super Decisions Main Window: AHP_Choosing the best scenerio for SWM in Hanoi.sdmod

Choose Node: S6

Cluster: 4 C2

Choose Cluster: 8 Alternatives

Comparisons wrt "S6" node in "8 Alternatives" cluster

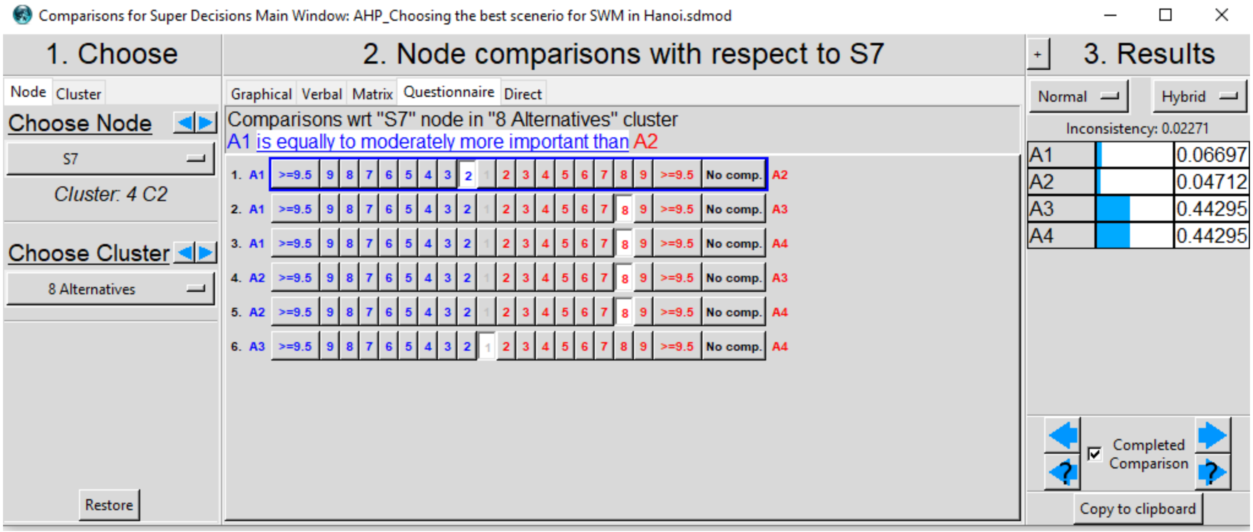
A1 is equally to moderately more important than A2

1. A1 >=9.5 9 8 7 6 5 4 3 2 1 2 3 4 5 6 7 8 9 >=9.5 No comp. A2
2. A1 >=9.5 9 8 7 6 5 4 3 2 1 2 3 4 5 6 7 8 9 >=9.5 No comp. A3
3. A1 >=9.5 9 8 7 6 5 4 3 2 1 2 3 4 5 6 7 8 9 >=9.5 No comp. A4
4. A2 >=9.5 9 8 7 6 5 4 3 2 1 2 3 4 5 6 7 8 9 >=9.5 No comp. A3
5. A2 >=9.5 9 8 7 6 5 4 3 2 1 2 3 4 5 6 7 8 9 >=9.5 No comp. A4
6. A3 >=9.5 9 8 7 6 5 4 3 2 1 2 3 4 5 6 7 8 9 >=9.5 No comp. A4

Inconsistency: 0.02271

A1	0.28936
A2	0.17501
A3	0.28936
A4	0.24627

☑ Completed Comparison



Comparisons for Super Decisions Main Window: AHP_Choosing the best scenerio for SWM in Hanoi.sdmod

2. Node comparisons with respect to S7

Choose Node: S7

Cluster: 4 C2

Comparisons wrt "S7" node in "8 Alternatives" cluster

A1 is equally to moderately more important than A2

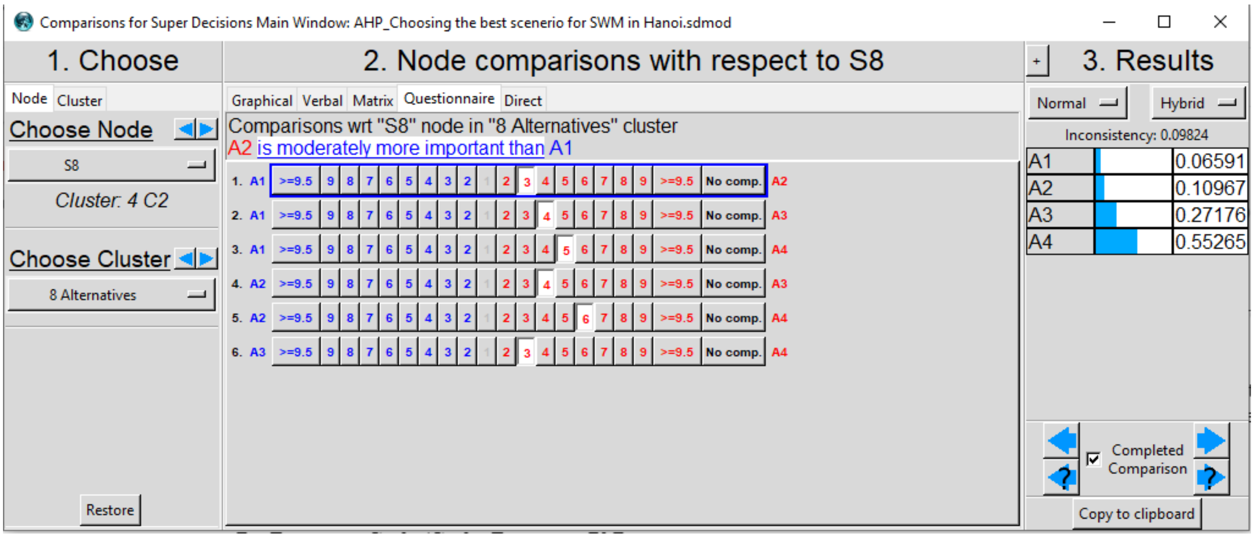
1. A1 – A2
2. A1 – A3
3. A1 – A4
4. A2 – A3
5. A2 – A4
6. A3 – A4

3. Results

Inconsistency: 0.02271

A1	0.06697
A2	0.04712
A3	0.44295
A4	0.44295

☑ Completed Comparison



Comparisons for Super Decisions Main Window: AHP_Choosing the best scenerio for SWM in Hanoi.sdmod

2. Node comparisons with respect to S8

Choose Node: S8

Cluster: 4 C2

Comparisons wrt "S8" node in "8 Alternatives" cluster

A2 is moderately more important than A1

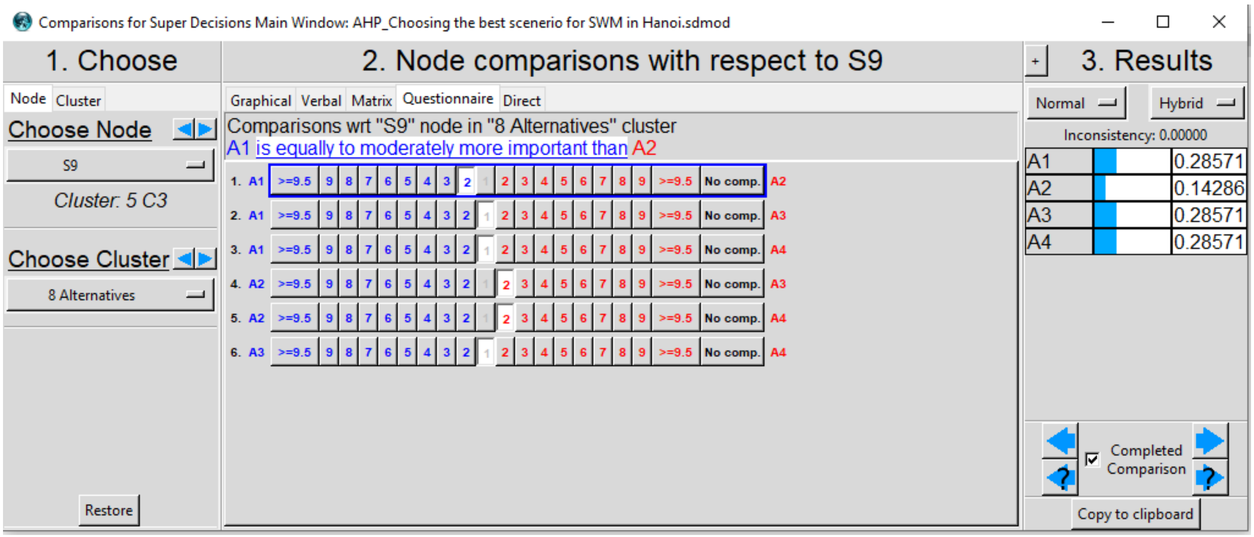
1. A1 – A2
2. A1 – A3
3. A1 – A4
4. A2 – A3
5. A2 – A4
6. A3 – A4

3. Results

Inconsistency: 0.09824

A1	0.06591
A2	0.10967
A3	0.27176
A4	0.55265

☑ Completed Comparison



Comparisons for Super Decisions Main Window: AHP_Choosing the best scenerio for SWM in Hanoi.sdmod

2. Node comparisons with respect to S9

Choose Node: S9

Cluster: 5 C3

Comparisons wrt "S9" node in "8 Alternatives" cluster

A1 is equally to moderately more important than A2

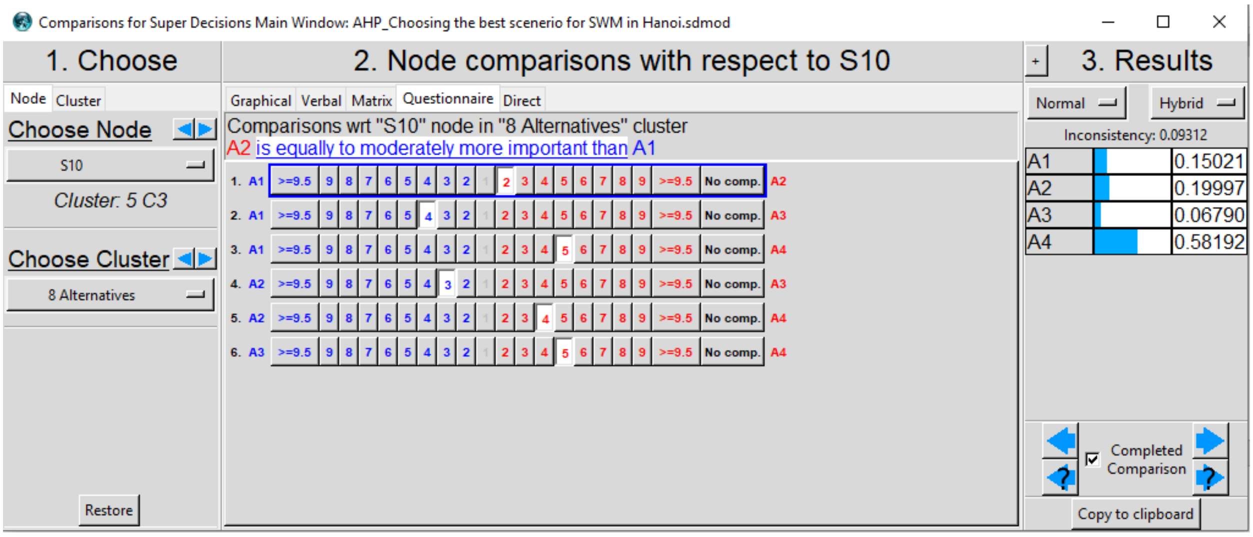
1. A1 – A2
2. A1 – A3
3. A1 – A4
4. A2 – A3
5. A2 – A4
6. A3 – A4

3. Results

Inconsistency: 0.00000

A1	0.28571
A2	0.14286
A3	0.28571
A4	0.28571

☑ Completed Comparison



2. Node comparisons with respect to S10

S10

Cluster: 5 C3

8 Alternatives

Comparisons wrt "S10" node in "8 Alternatives" cluster

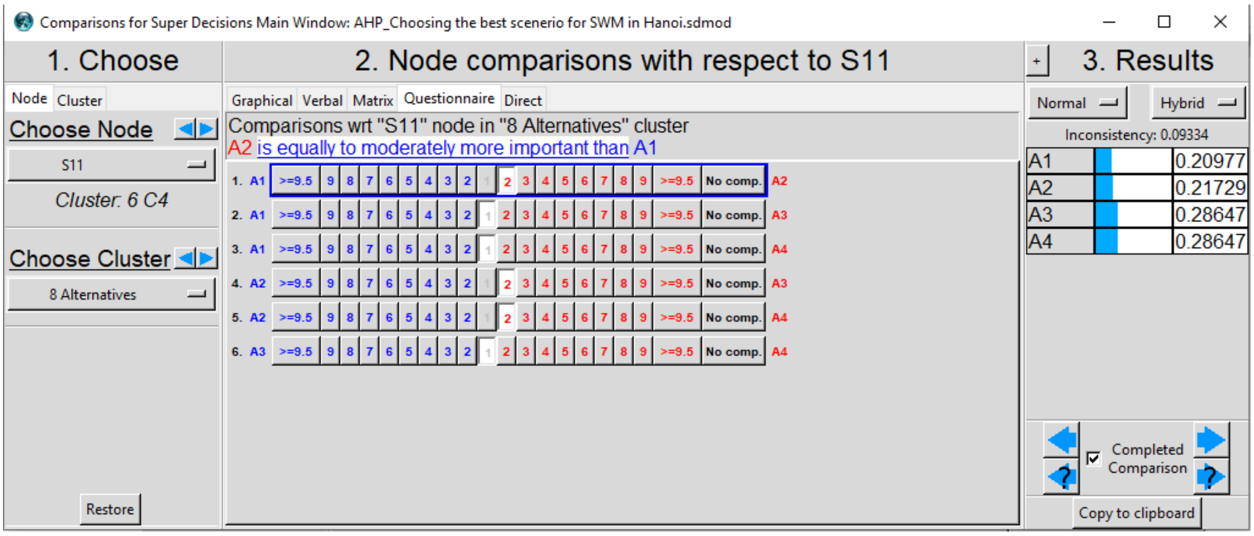
A2 is equally to moderately more important than A1

1. A1 >=9.5 9 8 7 6 5 4 3 2 1 **2** 3 4 5 6 7 8 9 >=9.5 No comp. A2
2. A1 >=9.5 9 8 7 6 5 **4** 3 2 1 2 3 4 5 6 7 8 9 >=9.5 No comp. A3
3. A1 >=9.5 9 8 7 6 5 4 3 2 1 2 3 4 **5** 6 7 8 9 >=9.5 No comp. A4
4. A2 >=9.5 9 8 7 6 5 4 **3** 2 1 2 3 4 5 6 7 8 9 >=9.5 No comp. A3
5. A2 >=9.5 9 8 7 6 5 4 3 2 1 2 3 **4** 5 6 7 8 9 >=9.5 No comp. A4
6. A3 >=9.5 9 8 7 6 5 4 3 2 1 2 3 4 **5** 6 7 8 9 >=9.5 No comp. A4

Inconsistency: 0.09312

A1	0.15021
A2	0.19997
A3	0.06790
A4	0.58192

☑ Completed Comparison



2. Node comparisons with respect to S11

S11

Cluster: 6 C4

8 Alternatives

Comparisons wrt "S11" node in "8 Alternatives" cluster

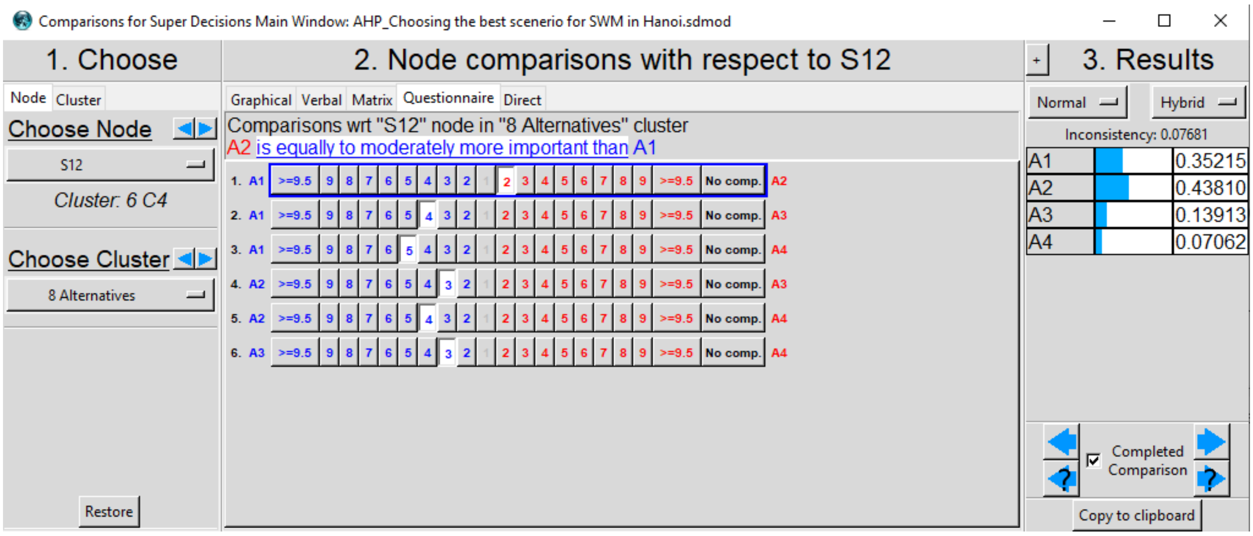
A2 is equally to moderately more important than A1

1. A1 >=9.5 9 8 7 6 5 4 3 2 1 **2** 3 4 5 6 7 8 9 >=9.5 No comp. A2
2. A1 >=9.5 9 8 7 6 5 4 3 2 **1** 2 3 4 5 6 7 8 9 >=9.5 No comp. A3
3. A1 >=9.5 9 8 7 6 5 4 3 2 **1** 2 3 4 5 6 7 8 9 >=9.5 No comp. A4
4. A2 >=9.5 9 8 7 6 5 4 3 2 1 **2** 3 4 5 6 7 8 9 >=9.5 No comp. A3
5. A2 >=9.5 9 8 7 6 5 4 3 2 1 **2** 3 4 5 6 7 8 9 >=9.5 No comp. A4
6. A3 >=9.5 9 8 7 6 5 4 3 2 **1** 2 3 4 5 6 7 8 9 >=9.5 No comp. A4

Inconsistency: 0.09334

A1	0.20977
A2	0.21729
A3	0.28647
A4	0.28647

☑ Completed Comparison



2. Node comparisons with respect to S12

S12

Cluster: 6 C4

8 Alternatives

Comparisons wrt "S12" node in "8 Alternatives" cluster

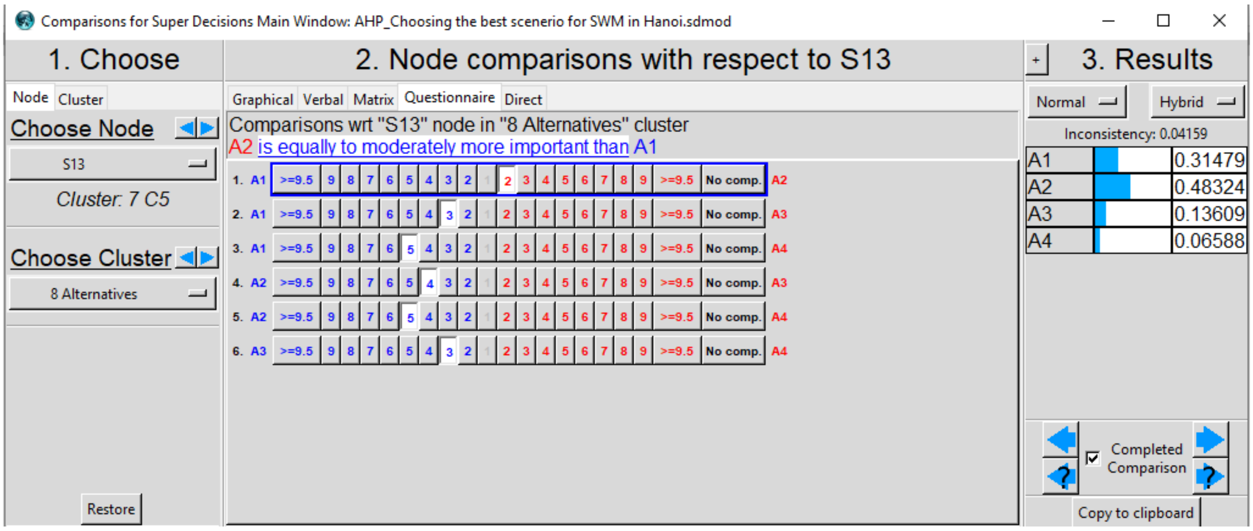
A2 is equally to moderately more important than A1

1. A1 >=9.5 9 8 7 6 5 4 3 2 1 **2** 3 4 5 6 7 8 9 >=9.5 No comp. A2
2. A1 >=9.5 9 8 7 6 5 **4** 3 2 1 2 3 4 5 6 7 8 9 >=9.5 No comp. A3
3. A1 >=9.5 9 8 7 6 **5** 4 3 2 1 2 3 4 5 6 7 8 9 >=9.5 No comp. A4
4. A2 >=9.5 9 8 7 6 5 4 **3** 2 1 2 3 4 5 6 7 8 9 >=9.5 No comp. A3
5. A2 >=9.5 9 8 7 6 5 **4** 3 2 1 2 3 4 5 6 7 8 9 >=9.5 No comp. A4
6. A3 >=9.5 9 8 7 6 5 4 **3** 2 1 2 3 4 5 6 7 8 9 >=9.5 No comp. A4

Inconsistency: 0.07681

A1	0.35215
A2	0.43810
A3	0.13913
A4	0.07062

☑ Completed Comparison



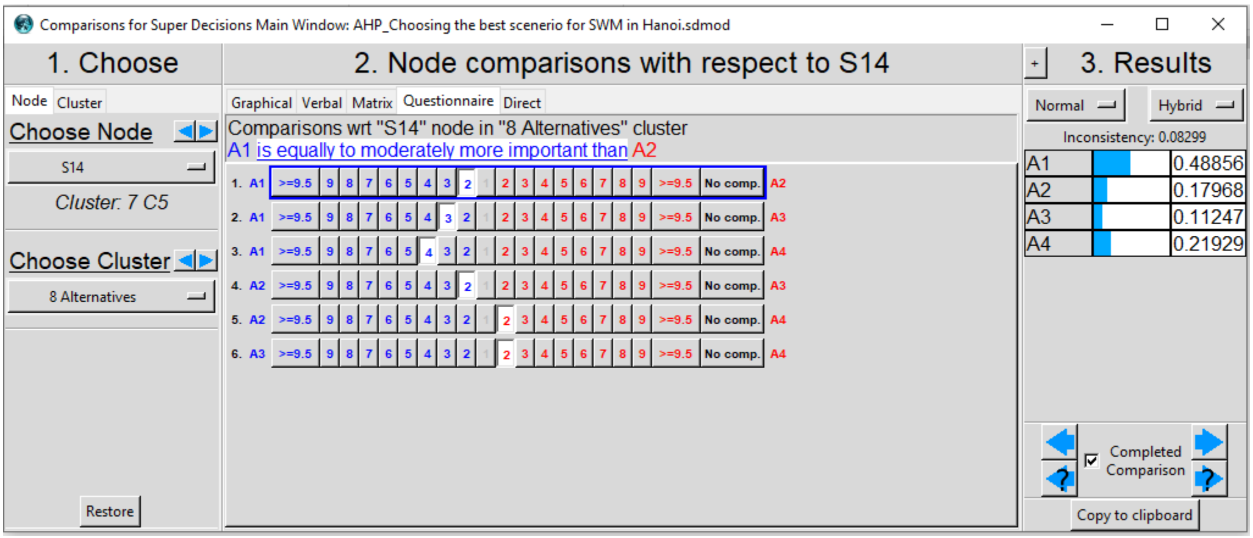
Comparisons wrt "S13" node in "8 Alternatives" cluster

A2 is equally to moderately more important than A1

1. A1 >=9.5 9 8 7 6 5 4 3 2 1 2 3 4 5 6 7 8 9 >=9.5 No comp. A2
2. A1 >=9.5 9 8 7 6 5 4 3 2 1 2 3 4 5 6 7 8 9 >=9.5 No comp. A3
3. A1 >=9.5 9 8 7 6 5 4 3 2 1 2 3 4 5 6 7 8 9 >=9.5 No comp. A4
4. A2 >=9.5 9 8 7 6 5 4 3 2 1 2 3 4 5 6 7 8 9 >=9.5 No comp. A3
5. A2 >=9.5 9 8 7 6 5 4 3 2 1 2 3 4 5 6 7 8 9 >=9.5 No comp. A4
6. A3 >=9.5 9 8 7 6 5 4 3 2 1 2 3 4 5 6 7 8 9 >=9.5 No comp. A4

Inconsistency: 0.04159

A1	0.31479
A2	0.48324
A3	0.13609
A4	0.06588



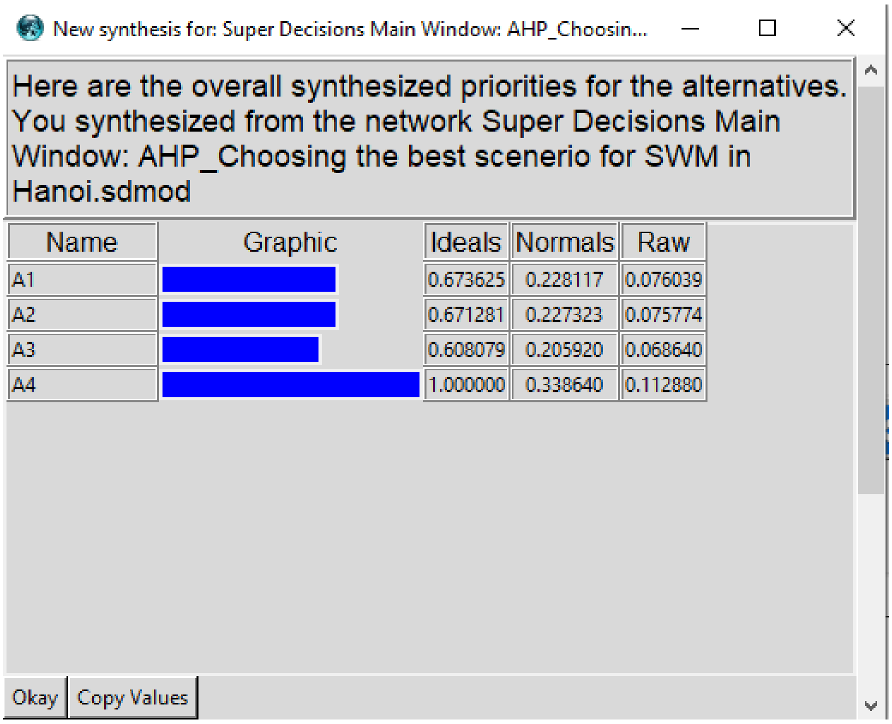
Comparisons wrt "S14" node in "8 Alternatives" cluster

A1 is equally to moderately more important than A2

1. A1 >=9.5 9 8 7 6 5 4 3 2 1 2 3 4 5 6 7 8 9 >=9.5 No comp. A2
2. A1 >=9.5 9 8 7 6 5 4 3 2 1 2 3 4 5 6 7 8 9 >=9.5 No comp. A3
3. A1 >=9.5 9 8 7 6 5 4 3 2 1 2 3 4 5 6 7 8 9 >=9.5 No comp. A4
4. A2 >=9.5 9 8 7 6 5 4 3 2 1 2 3 4 5 6 7 8 9 >=9.5 No comp. A3
5. A2 >=9.5 9 8 7 6 5 4 3 2 1 2 3 4 5 6 7 8 9 >=9.5 No comp. A4
6. A3 >=9.5 9 8 7 6 5 4 3 2 1 2 3 4 5 6 7 8 9 >=9.5 No comp. A4

Inconsistency: 0.08299

A1	0.48856
A2	0.17968
A3	0.11247
A4	0.21929



Here are the overall synthesized priorities for the alternatives. You synthesized from the network Super Decisions Main Window: AHP_Choosing the best scenerio for SWM in Hanoi.sdmod

Name	Graphic	Ideals	Normals	Raw
A1		0.673625	0.228117	0.076039
A2		0.671281	0.227323	0.075774
A3		0.608079	0.205920	0.068640
A4		1.000000	0.338640	0.112880

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