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A Strategic Framework for Working toward Zero Waste Societies Based on Perceptions Surveys

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Abstract: The visionary concept of zero waste advocates a systematic process of designing out waste and recovering resources from waste. A strategic zero waste framework (ZWF) is essential for developing and executing systematic waste management activities to achieve the overarching goals. This study identifies the key principles for the development of a strategic ZWF based on a waste experts' survey analysis. Around 68 experts from different regions responded and provided their views on the key elements of a strategic ZWF though an online questionnaire survey. Eighteen strategic elements of waste prevention, management, treatment and assessment were identified as the key principles of the zero waste framework. As the study followed a generalized approach, it is important to acknowledge that all identified and proposed strategic elements may need to be contextualized based on the local conditions in order to achieve zero waste goals. Based on the findings, the study suggests the following three fundamental strategic action plans that need to be implemented simultaneously for moving towards zero waste societies: (i) sustainable production through a cradle-to-cradle design and product stewardship; (ii) collaborative and responsible consumption of natural resources; and (iii) zero waste management through conservation of resources. In addition, a constant evaluation of progress towards zero waste goals is essential. It is anticipated that by considering local circumstances, the proposed strategic guidelines would be beneficial for local authorities and relevant stakeholders while developing their zero waste strategy.

Keywords: guiding principles; questionnaire survey; waste management; zero waste; zero waste framework

1. Introduction

"Zero waste" (ZW) is one of the most studied, yet, the most debated topic of waste management research in the last decades [1–4]. ZW is defined by the Zero Waste International Alliance (ZWIA) as "designing and managing products and processes systematically to eliminate the waste and materials, conserve and recover all resources and not burn or bury them" [5]. Thus, ZW is about waste prevention through sustainable design and consumption practices, optimum resource recovery from waste and not about managing waste by incineration or landfills [6]. It is understandable that ZW strongly supports waste avoidance and prevention approaches rather than waste treatment and disposal. However, it may not be feasible to achieve zero incineration and zero landfill goals under the existing system of resource consumption and waste management practices.

Waste has been treated as a burden and social problem and thus largely managed by "end-of-pipe" solutions such as landfill [2]. With few exceptions in the developed countries in Europe, North America and Asia-Pacific, the traditional waste management system, which primarily relies on landfill, significantly pollutes our environment, and thus an improved and efficient waste management system is required. This study starts from the position that waste is not an "end-of-life" problem alone, but rather waste is an intermediate stage in the transformation of resources that occurs in the

consumption process. The resources that are transformed into "waste" thus need to be redirected in the production process through holistic ZW management systems. In addition, waste is a social problem and it requires social technologies to solve it. Hence the goal of zero waste is to utilize and consume resources within a circular economic model, with minimum environmental degradation using industrial symbiosis, recycling or "up cycling", based on nature's "no-waste" principle [7].

Strategic waste management plans are commonly used by local governments and business organizations for managing waste problems [8]. A strategic waste management framework is essential for a successful implementation of a waste management plan as it is the foundation of an effective planning process [9]. A number of studies have been conducted on the development of waste management frameworks [10,11], including decision frameworks [12], legislative frameworks [13] and hierarchical frameworks [14]. A framework helps decision makers to understand, improve, evaluate and guide waste management systems. This study aims to identify the key guiding principles that help to develop a strategic zero waste framework. The purpose of the strategic zero waste framework is to guide waste management policy and decision makers while developing and proposing waste management strategies and policies.

2. The Key Aspects for the Development of a Zero Waste Strategy

Many local councils set their zero waste goals to "diversion of waste from landfill"; however, diversion of waste alone may not be sufficient as it requires innovative design and sustainable consumption to achieve the long-term goals. The 3R principles (reduction, re-use and recycling) are among the top three in the waste hierarchy and they are considered as the founding principles of sustainable waste management system [15]. In the European Union Waste Framework Directive 2008, the "3R" principles have been extended to five steps of the waste hierarchy: prevention (avoidance), re-use, recycling, recovery (including energy recovery), and disposal [16].

A number of approaches have been identified in various studies such as eco-design, responsible shopping behaviour, etc., in relation to waste prevention and avoidance [17,18]. Waste prevention is one of the most important issues in zero waste and it requires collective social awareness and knowledge on waste and innovative manufacturing and business models [19]. Awareness and transformative knowledge are often believed to motivate behaviour change in relation to pro-environmental lifestyle choice [20].

Responsible and sustainable consumer behaviour is another important issue in waste prevention. Collaborative consumption increases efficiency in resource consumption and enhances social collaboration [21]. The collaborative ownership or collaborative consumption model promotes service-based business and waste prevention [22]. Therefore, re-circulation (circulate the materials in the supply chain for a repetitive use) of post-consumer products through re-use and re-sell is important and it boosts the circular economy and enhances social capital.

Waste management and treatment technologies are used in solving waste problems for more than centuries [23]. Zero waste takes the position that technology alone cannot solve the waste problems sustainably, as it requires community participation, service infrastructure, regulatory policy and environmentally friendly treatment technology. A number of studies have identified that effective collection systems, decentralized waste recycling centres, social technology such as recycling, composting, regulatory policies such as pay-as-you-throw (PAYT) and environmentally friendly advanced waste treatment technologies are the key issues in waste management and treatment [24–27]. The fundamental differences between traditional waste management and zero waste management is that it restricts the application of waste-to-energy (WTE) which burns waste to generate energy (heat and electricity) and landfills in an "ideal" zero waste environment. Therefore, this study is intended to investigate the waste experts' opinion on restricting certain technologies to promote zero waste activities.

Performance evaluation is an integral part of a strategic framework to determine the future direction of waste management systems. Moreover, accurate and reliable data on waste management

systems is utterly important to assess and monitor the overall performance of the waste management strategies and programmes. Zero waste research in relation to data analysis, forecasting waste generation and management trends and continuous improvement in waste prevention and avoidance techniques are also key issues in zero waste management [28,29]. Figure 1 shows the issues in zero waste management.

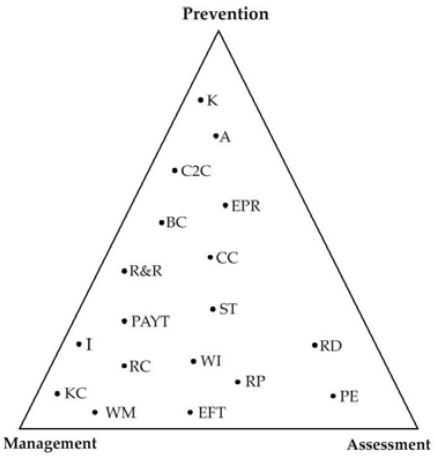

Figure 1. The key issues related to zero waste management, adapted from [30]. K-knowledge; A-awareness; C2C-cradle-to-cradle design; EPR-extended producer responsibility; BC-behaviour change; CC-collaborative consumption; R&R-repair and re-use; ST-social technology; PAYT-pay-as-you-throw; I-infrastructure; RC-recycling/recovery centre; KC-kerbside collection, WM-waste market; WI-waste incentives; RP-regulatory policy; RD-reliable data and PE-Performance evaluation.

Out of all the issues illustrated in Figure 1, only municipal solid waste is considered in this study. Hence, waste categories which are related to municipal solid waste are relevant for this study. Table 1 summarises the key issues of zero waste management based on the literature review completed for this study.

Table 1. The key selected issues of zero waste management.

Phases	Key Aspects of Zero Waste	Relevant Studies
Waste prevention and avoidance	Awareness and education of waste	[31,32]
	Transformative knowledge and willingness to change behaviour	[20,33,34]
	Innovative product design (cradle-to-cradle)	[17,35–37]
	Producer responsibility (take-back scheme)	[38–41]
	Responsible shopping and consumption practices (sustainable consumption)	[25,42,43]
	Collaborative consumption practices	[44–46]
	Extended product lifespan through repair/re-use	[47–49]
	Market creation for post-consumer products re-circulation	[50–53]
Waste management and treatment	New infrastructures (bins, collection vehicles, etc.)	[54–56]
	Effective waste collection services (kerbside waste collection)	[56–58]
	Decentralized recycling and resource recovery centres	[59,60]
	Enabling social technology through community participation (recycling, composting, etc.)	[61,62]
	Improve source reduction through pay-as-you throw principle	[24,63]
	Waste incentives (levy, taxes, token, etc.)	[64–66]
	Environmentally friendly waste treatment solutions	[67–69]
	Regulations on restricted mass use of landfill and waste-to-energy (WTE)	[28,70–72]
Monitoring and assessment	Available and reliable waste data	[73,74]
	Performance evaluation through zero waste research	[75,76]

3. Methods

A questionnaire survey was prepared based on a set of structured questions related to the identified key aspects (in Table 1) of zero waste. The study applied a top-down approach and a survey was conducted among waste experts around the globe to identify the key principles for the development of a zero waste framework. Experts involved in waste management systems in different professions, such as academic institutes, businesses, government agencies, community organizations and environmental organizations were invited to participate in the questionnaire survey to identify the key aspects of waste management systems. The objective of the expert survey was to identify key components of strategic waste management systems.

The survey questionnaire consisted of a number of questions associated with waste prevention and avoidance, waste management and treatment, and monitoring and assessment. As the expert survey required a specific group of people, i.e., waste management experts, the expert survey was done by applying expert sampling methods. In expert sampling method [77], the sample is chosen based on known and demonstrable experience and expertise in some specific area (in this case, waste management). Waste management experts were selected based on available information about their expertise on waste management systems. The study applied a purposive sampling and non-random sampling techniques as the survey was mainly conducted on the waste experts (a specific expert group). Experts were identified and selected based on their (i) contributions to peer-reviewed academic publications identified using Scopus Database; (ii) involvement with waste management organizations and institutions; and (iii) affiliation with waste management policy and decision making processes. The expert group was contacted by email and invited to participate in the survey.

The survey questions used a five point Likert Scale for agreeing or disagreeing any statement, rating the effectiveness (not effective to very effective) of any technique and for identifying the level of priorities or importance (low to very high). There are number of advantages and disadvantages in using a Likert Scale because the outcome of the survey depends on how the ratings are made and the level of understanding by the respondents [78]. One study has shown that there are benefits from using continuous rating scales in online survey research [79]. The questionnaire was validated and tested by applying a pilot survey. The survey results were analysed by a statistical data analysis software (SPSS). SPSS is a common computer application to supports statistical analysis of survey data. Cross-tabulation was used (with a Chi Square test for independence) to explore the relationship between two independent categorical variables. The Chi Square test compares frequency or proportion of cases in each category [80]. As the study investigates the importance of various key priorities given by various waste expert groups, the Chi Square test was applied in this study.

A total of 68 experts (N) from 23 countries participated in the expert questionnaire survey. The questionnaire was sent to around 450 waste experts around the globe and the response rate was 15.1%, which was relatively good as the experts were assumed to be busy in their daily research activities. Most of the participants were from Asia-Pacific, Europe or America. A total of 15 waste experts were from Asia, 20 from Europe, 16 from America, 16 from Oceania. Despite the similar number of the targeted experts from different regions, the survey poorly attracted responses from Africa, as only one expert from Africa participated in the survey. The average year of expertise of the participants was relatively high (7 from 0–5 years, 13 from 5–10 years, 29 from 10–20 years and 19 above 20 years of experience). The survey covered experts from various sectors in waste management systems. Figure 2 shows the affiliation of the participants. The affiliations of the experts are categorized according to the four types: (i) government organizations, including local and central government and policy maker; (ii) business organizations including recycling organization, transporting and landfill business organization and service provider; (iii) academic institutes including research institutes, teaching and training; and (iv) environmental organizations including non-government environmental organizations, community organizations, national and international waste management organizations.

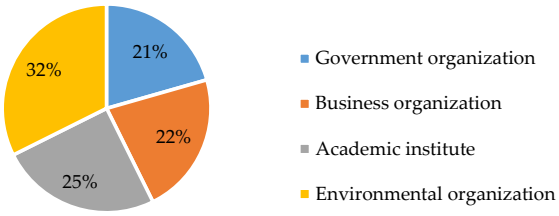

Figure 2. Participants' affiliation.

4. Results and Discussion

The survey results are analysed and presented in the following sections.

4.1. Focus Group Survey Findings

4.1.1. Issues and Factors Relevant to Waste Management System

A number of issues and factors of waste management system, including waste prevention and avoidance, waste management and treatment and monitoring and assessment, were considered in the questionnaire survey, to identify the relevance, important and priorities of different waste management approaches. Table 2 summarises the focus group survey findings.

Over 80% of the all respondents agree or strongly agree on a number of issues such as importance of awareness and education on waste and its influence in behaviour change, cradle-to-cradle design, along with extended producer responsibility and collaborative consumption through a shared ownership of products. Statistically insignificant differences were observed in the responses, which means that there is no statistically significant difference in the experts' opinion.

Whereas statistically significant differences were observed in the responses ($p = 0.05 = 0.05$) on waste incentives (refunds) and penalties (taxes, fees). Waste incentives have significant influence in waste prevention, recycling and management practices [81,82]. Around 60.3% were of the view (agreed and strongly agreed) that a higher incentive (refund/financial benefit) will increase the performance of the container deposit legislation (CDL). About 33.8% of the experts were undecided, and only 5.9% of the experts opposed more incentives for CDL. Similar responses also found on the issues of pay-as-you-throw (PAYT) system. Statistically, an insignificant difference ($p = 0.07 > 0.05$) is observed in the cross-tabulation between the different groups of professionals and their responses to the pay-as-you-throw system. A total of 4.4% experts ranked PAYT as not effective, 13.2% ranked it as slightly effective, 20.6% ranked it as moderately effective, 32.4% ranked it as very effective and 29.4% ranked it as extremely effective for waste recycling systems.

In recent years, a number of studies have been conducted on how to achieve ZW through zero landfill [83–85]. Bans on waste going to landfill and high landfill taxes are necessary for sustainable waste management systems. Statistically insignificant differences were observed in the responses ($p = 0.708, > 0.05$). Table 2 shows that around 63.2% of the experts supported (agreed and strongly agreed) landfill waste bans and high landfill taxes. Around 26.5% of the experts were undecided and only 10.3% were unsupportive of landfill bans and high landfill taxes.

Availability and reliability of waste data are important for measuring progress and developing waste management strategies [86]. Statistically insignificant differences were observed in the responses ($p = 0.753 > 0.05$). Table 2 shows overall around 67.6% of the experts ranked data availability and reliability for waste management as extremely important, 26.5% ranked it as very important and only 4.4% and 1.5% ranked it as moderately important and not important, respectively.

A study identified that research on ZW is essential to achieve overall ZW goals [28]. Statistically insignificant differences were observed in the responses ($p = 0.775 > 0.05$). Table 2 shows that most of the waste experts agreed and strongly agreed (around 85.3%) and only 2.9% disagreed with the need for research on material flow. Around 86.3% experts from academic institutes and about 85.7% government institutes, support such research.

Table 2. Issues and factors relevant to existing waste management system.

Issues and Factors of Waste Management	Likert Scales				
	Strongly Disagree	**Disagree**	**Neither Disagree Nor Agree**	**Agree**	**Strongly Agree**
Importance of awareness and education of waste	2.9%	0%	4.4%	35.3%	57.4%
Proper education and environment for behaviour change	1.5%	0%	7.4%	47.1%	44.1%
Importance of innovative cradle-to-cradle product design	1.5%	0%	4.4%	35.3%	58.8%
Extended producer responsibility (take-back scheme)	1.5%	4.4%	7.4%	48.5%	38.2%
Effective policy on responsible shopping and consumption practices	0%	2.9%	22.1%	42.6%	32.4%
Collaborative consumption or shared ownership of products	0%	2.9%	13.2%	48.5%	35.3%
Importance of market creation for post-consumer products recirculation	1.5%	7.4%	13.2%	33.8%	44.1%
Higher incentives for container deposit legislation	1.5%	4.4%	33.8%	41.2%	19.1%
Restriction on incineration	14.7%	13.2%	25.0%	25.0%	22.1%
High landfill tax and ban on waste to landfill	4.4%	5.9%	26.5%	27.9%	35.3%
Effectiveness of waste management programmes	Not effective	Slightly effective	Moderately effective	Very effective	Extremely effective
Training on correct recycling	0%	4.4%	25.0%	48.5%	22.1%
Individual bins system (organic, recycling, hazardous, etc.)	0%	2.9%	22.1%	48.5%	26.5%
Kerbside or door-to-door waste collection	0%	2.9%	14.7%	44.1%	38.2%
Community recycling centre	0%	4.4%	27.9%	47.1%	20.6%
Priority of issues	No priority	Low priority	Moderate priority	High priority	Extreme priority
Enabling social technology through community participation	0%	0%	8.8%	33.8%	57.4%
Effectiveness to improve efficiency through pay-as-you-throw systems	4.4%	13.2%	20.6%	32.4%	29.4%
Environmentally friendly treatment technology	26.5%	42.6%	14.7%	10.3%	5.9%
Research on material flows and waste performance	0%	2.9%	11.8%	44.1%	41.2%
Priority of data availability and reliability	1.5%	0%	4.4%	26.5%	67.6%
Priority of composting	0%	5.9%	16.2%	38.2%	39.7%
Priority of anaerobic digestion	0%	5.9%	17.6%	60.3%	16.2%
Priority of waste-to-energy technology	8.8%	20.6%	17.6%	36.8%	16.2%
Priority of landfill	26.5%	42.6%	14.7%	10.3%	5.9%

Four selected technologies—composting, anaerobic digestion, waste-to-energy (WTE) and landfill—were rated according to their environmentally friendly waste treatment technology. Composting and anaerobic digestion were rated (around 78% and 76%, respectively) as the higher priority environmentally friendly technologies compared to WTE and landfill (around 53% and 16%, respectively).

Thermal waste treatment technologies are very popular in the European region due to energy provision, despite their various environmentally damaging consequences. Waste experts were asked whether city councils should restrict the mass implication of waste-to-energy (WTE) technologies as they pollute and deplete natural resources. Statistically insignificant differences were observed in the responses ($p = 0.664 > 0.05$). A mixed response to restricting incineration by the experts is shown in Table 2. A total of 47.1% of the experts supported (agreed and strongly agreed) restriction on thermal waste treatment technologies, 25% remain undecided and the remaining 27.9% of the experts opposed the restriction on mass burning of waste which indicates restriction of WTE technologies is not a feasible option under current circumstances.

Around 63.2% of the respondents agreed or strongly agreed on high landfill tax and ban of landfill, however, a significant proportion of the respondents (26.5%) were undecided and the rest of 10.3% disagree or strongly disagree with the statement. It is also important to consider that inert materials need to be disposed to landfill as it is not possible to recycle. Unfortunately, no question was asked in the survey of what would happen if the band and restriction on landfill was truly imposed. Therefore,

restriction of certain materials such as paper, organic, etc., could be possible, but a complete ban on landfill may not be feasible and practical under current management systems.

4.1.2. Key Issues for Zero Waste Strategy

The identified key issues for the development of a zero waste strategy were rated by experts' from less important to extremely important. The mean value of the survey responses (least important to extremely important) were presented in Table 3 and the standard deviation shows the variation of rating from the mean. The key zero waste issues were ranked according to "minimum mean", which is the value of mean minus standard deviation.

Table 3. The key zero waste issues.

Key Issues	Mean	Std. Dev.	Mean − Std. Dev.	Rank
Innovative product design (cradle-to-cradle)	4.5294	0.63412	3.895	1
Transformative knowledge and willingness to change behaviour	4.5441	0.74180	3.802	2
Producer responsibility (take-back scheme)	4.5147	0.76280	3.752	3
Enabling social technology through community participation (recycling, composting, etc.)	4.4030	0.75998	3.643	4
Regulation and restriction on mass-implication of landfill and WTE.	4.4179	0.781398	3.636	5
Available and reliable waste data	4.3382	0.74534	3.593	6
Market creation for post-consumer products recirculation	4.3382	0.765103	3.573	7
Responsible shopping and consumption practices	4.3824	0.81092	3.517	8
Awareness and education of waste	4.3134	0.82036	3.493	9
Decentralized recycling and resource recovery centres	4.3182	0.82572	3.492	10
Performance evaluation through zero waste research	4.2206	0.807531	3.413	11
Extends product life cycle through re-pair/re-use/re-sell	4.2059	0.92331	3.282	12
Improve source reduction through pay-as-you throw principle	4.1765	0.89678	3.279	13
Effective waste collection services (kerbside waste collection)	4.0294	0.809839	3.219	14
Environmental friendly waste treatment solutions	4.0147	0.872339	3.142	15
New infrastructures (bins, vehicles, etc.)	4.0149	0.895993	3.118	16
Collaborative consumption practices	3.9403	0.919166	3.021	17
Waste incentives (levy, taxes, token, etc.)	3.9688	0.991532	2.997	18

The survey findings of the waste experts show that innovative product design using the cradle-to-cradle principle was ranked as the top most important issue in zero waste (also supported in [17,35,37]), followed by transformative knowledge motivating to change behaviour [20,33], producer responsibility, enabling social technology through community participation and so on. Even though a mixed response was received in the question on the restricted use of mass implication of WTE and landfill technology, experts ranked higher on the regulation and restrictions on mass implication of WTE and landfills for achieving the zero waste goal.

Participants associated with environmental organizations had a higher percentage of agreement on the fact that lack of awareness is the key cause of creating waste problems and that creating a positive environment for behaviour change will allow the waste problem to be addressed more effectively.

Experts from government organizations mostly supported various waste policy and strategic issues compared to experts from academic or environmental organizations. For waste collection systems, kerbside door-to-door waste collection systems were supported by most of the waste experts. Most of the experts agreed that there is a need to promote social technologies such as recycling, collaborative consumption, shared ownership, and so on, to reduce waste generation, which is also supported in literature [44,47,61].

The experts provided a mixed response to thermal waste treatment technology. Mostly, experts from business and government organizations supported waste-to-energy technology and experts from academic and environmental organizations were supportive of promoting recycling. In this survey, waste incentive received a mixed opinion on its effectiveness of waste management. However, various studies suggest that waste incentives (financial or moral) can be beneficial for motivating people for recycling waste [87–89].

Interestingly enough, experts gave high importance to key zero waste issues on the available and reliable waste data and zero waste research, which indicates that waste management performance evaluation is important to measure existing waste management systems and improve and guide future direction. It is important to acknowledge that the survey captured a simplistic view of a very complex waste management systems and the number of responses is also an important factor to generalize the survey findings. A comprehensive qualitative (such as survey) and quantitative (life-cycle assessment) analysis is required to identify the most important issues in the development of an environmentally friendly zero waste strategy.

4.2. Development of a Strategic ZW Framework

The study considered all identified zero waste issues as the guiding principles for the development of a strategic zero waste framework. It is essential to acknowledge that the importance and application of each guiding principle would be dependent on the local conditions. Some of the guiding principles are equally important for any geographical location while consigning the zero waste goals, for instance, cradle-to-cradle design, education and awareness of waste. However, priority of the other guiding principles such as zero waste research, environmentally friendly treatment technology, waste incentives, etc., would be different in developed and developing countries. Table 4 summarizes the important guiding principles as the elements of ZW framework (with no particular order).

4.3. Application and Limitations of the ZW Framework

The strategic elements should be implemented by following both short-term (i.e., 1–4 years) and long-term (i.e., 5–10 years) action plans. It is important to acknowledge that the proposed strategic elements and action plans are contextual and may not be applicable to all countries, especially in developed and developing countries, because there would be a significant difference in the priorities in implementing the strategic elements these countries. However, it is anticipated that each strategic element with a consideration of local circumstances would guide to achieve the overall zero waste goals.

The steps in ZW action plans start with the preliminary assessments (clockwise in Figure 3) of existing waste management systems. The preliminary assessment and evaluation is important to measure existing waste management performance. Waste characterization and key problems in achieving ZW goals need to be identified at this pre-evaluation stage. After a comprehensive pre-assessment of the existing waste scenario, the elements of the ZW framework should be implemented in an integrated manner. It is essential to have zero waste goals and targeted milestones in applying a ZW framework for progressing towards zero waste. As explained local authority should prioritize and implement the strategic elements according to their requirements under a comprehensive action plan. After implementing ZW action plans, a post-evaluation of the ZW management performance needs to be carried out.

Table 4. The key strategic elements and action plan for zero waste.

Phases	Strategic Elements	Action Plan
Waste prevention and reduction	Effective public awareness programme on the waste management system should be provided by the governing body (educational institutes, city councils, etc.) through formal and informal education systems.	Inclusion of waste education programmes at the school curriculum and organize awareness promotional programmes on waste avoidance and reduction.
	Zero waste programmes (transformative knowledge) should provide proactive support strategies to motivate behaviour change towards responsible and sustainable resource consumption practices.	Hands-on training and knowledge sharing programmes (short-term and long-term) that motivate behaviour change should be organized.
	Sustainable and responsible living should be embraced and practiced by consumers by focusing on the principle of environmental conservation and stewardship.	Global citizenship initiatives through responsible shopping and consumption behaviour should be enabled.
	Consumption of resource should be improved through a shared-ownership of product service systems.	Collaborative consumption (shared-ownership) activities and services should be promoted.
	Products should be designed by following a cradle-to-cradle design principle so that resource can be recovered at the end-of-life phase.	The designing for disassembly practices at design and manufacturing of products should be promoted.
	As manufacturers are responsible for managing their end-of-life products, waste products should be managed and recycled under the extended producer responsibility principle.	Mandatory take-back scheme for producers, especially for hazardous and non-disassembly products should be introduced.
	The use-life of post-consumer products should be expanded by up-cycling (repairing/reusing) and contributing to the circular economy.	Revitalize social capital in re-use and repair activities to expand the use-life of post-consumer products should be revitalized.
	A favourable market condition for post-consumer goods and recycling materials should be ensured and enabled considered as economically viable commodities.	Regulatory and economic policy to promote completive market conditions for post-consumer recycling products should be introduced.
Waste management and treatment	Appropriate waste infrastructure such as separate bins, kerbside collection system systems should be provided for continuous improvements of waste management practices.	Three bin and kerbside collection systems should be introduced to improve waste sorting, recycling and collection efficiency.
	Local government should provide decentralized recycling and resource recovery facilities within the closed-proximity of the community.	Both community based and remote recycling facilities in urban precincts should be established.
	Empower social technologies such as re-use, re-pair and recycle through community participation.	Activities that promote social technology and enhance social capital should be promoted.
	Source reduction by enabling and introducing regulatory policies and programs should be improved.	PAYT scheme to promote source reduction should be introduced.
	Application of environmentally friendly waste treatment technology to ensure a maximum resource recovery with a minimum environmental pollution should be encouraged.	Environmentally friendly technology such as composting, anaerobic digestion, etc., instead of landfill should be ensured.
	WTE technology should not be applied as a mass-burn solution of waste treatment unless no alternative and feasible solution is available.	The mass application of WTE should be regulated and restricted unless no alternative and feasible solution is available.
	Landfill should be banned and applied as an interim disposal option.	Waste diversion from landfill targets should be introduced.
	Economic incentive mechanisms should be facilitated to motivate and promote effective management practices.	Various economic incentives policies such as refund, landfill levy, etc., should be introduced.
Monitoring and assessment	Annual waste management data should be collected by maintaining a standardized data collection and reporting systems.	Implementation of waste data collection and monitoring systems is necessary in city/municipality level for building national waste database.
	Research on zero waste should be conducted to provide a better industrial design solution for manufacturers and to improve resource recovery efficiency from waste.	National and international collaborative zero waste research activities should be promoted.

Figure 3. Steps in the zero waste (ZW) action plan.

The strategic ZW framework aims to guide existing cities towards a state of zero waste by ensuring and empowering a circular economy. An effective circular economy integrates all cities' stakeholders, including designers, producers, retailers, consumers, policy makers, planners and individuals to maximise the value of resources and thus recycle, recover and conserve natural resources. The performance of these strategies should be measured continuously to evaluate the progress towards the zero waste goals.

ZW needs a new generation of people with clear concepts of what is waste and what is not waste. Without the majority of people having a better understanding of waste, it will be very difficult to follow the ZW path. Education and awareness are thus the first aspect of working towards ZW. The second crucial aspect is the industrial transformation of product design and manufacturing. Without sustainable production processes where products are designed to be disassembled at the end of life, the overall ZW goals will not be possible to accomplish. Finally, the role of global citizens is one of the most important aspects in ZW because ZW is not about managing the waste, but mainly about not creating waste in the first place during the consumption process. Therefore, without responsible global stewardship the visionary ZW goals can never be achieved.

Based on the survey findings and strategic directions, three fundamental strategic action plans that need to be implemented simultaneously for moving towards zero waste societies are suggested as follows: (i) sustainable production through a cradle-to-cradle design and product stewardship; (ii) collaborative and responsible consumption of natural resources; and (iii) zero waste management through conservation of resources. In addition, a constant evaluation of progress towards zero waste

goals is also required. Achieving ZW goals requires a holistic, long-term waste management strategy, thus, it may not be possible to solve waste problems overnight or within a short period of time.

5. Conclusions

A strategic zero waste framework is essential for initiating major activities to achieve zero waste goals. This study tried to identify the key guiding principles for the development of a strategic zero waste framework based on a consensus analysis of waste experts. The key elements of the zero waste framework are identified by the literature focusing on waste prevention and avoidance, waste management and treatment, and monitoring and assessment.

The expert survey identified 18 strategic elements as important guiding principles for the development of a holistic zero waste framework. The study acknowledged that all the strategic elements may not be feasible in all countries, especially in the developing countries where appropriate infrastructure and regulatory policies are not available and for developed countries where associate waste management costs are very high. A further study can be conducted to identify and explain the elements that are appropriate for different economic contexts (developed and developing). It is expected that by considering the local circumstances such as local waste management priorities, waste market and economic condition, the proposed elements would work as guiding principles for achieving the zero waste goals.

The fundamental transformation of existing systems is required and the study concluded that the ZW goals may not be achieved without a closed-loop production system in place, wide application of responsible consumption practices, conservative waste management systems and continuous improvement through monitoring and assessment of waste management performance. The findings of this study are important and can contribute to the knowledge of zero waste management. Therefore, it would be beneficial for local authorities to consider the proposed strategic elements while developing local and national zero waste strategies.

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