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A Waste Management Behavioural Framework of Singapore's Food Manufacturing Industry using Factor Analysis

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Abstract

There has been a great deal of research interest in applying industrial symbiosis in the food manufacturing industry as part of the industry-wide shift towards sustainable manufacturing. However, an evaluation of its participation rates first requires an in-depth understanding of the factors that influence the manufacturers' waste management behaviours and decision-making process. This paper attempts to propose a comprehensive waste management behavioural framework for the food manufacturing industry by building on the works of previous waste management behavioural studies, most notably Young et al.'s work on employee pro-environmental behaviour. The proposed framework was validated through an exploratory survey conducted on a representative group of waste managers from Singapore's food manufacturing industry. Using exploratory factor analysis, we identified Intention, Perceived Moral Obligation, Company Structure, and Situational Barriers to be the most significant factors influencing the waste manager's waste management decisions. Based on these results, several policy recommendations were proposed which focus on the education of industrial symbiosis to the leaders of the organisation. The findings from this paper will provide valuable insights into the manufacturer's waste management decision-making process, as well as a more human-centric framework for the conduct of future industrial symbiosis studies in the food manufacturing industry.

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1. Introduction

With an increasingly affluent and growing population, over-consumption and wastage have quickly become a significant problem in developed countries. This issue is especially prevalent in Singapore as the country's only landfill is set to run out of space by 2035 [1], prompting an urgency on the local government to encourage a nation-wide adoption of better waste management practices. In the food manufacturing sector alone, around 810,000 tonnes of waste was generated in 2017 with only 16% being recycled [2].

These numbers are particularly worrying when we consider the embodied values of food gone to waste when it is unconsumed and subsequently sent for incineration or landfilling. Therefore, industrial symbiosis was introduced as a potential solution to recover these values through the physical exchange of waste between firms, supported by a collaboration platform, whereby the wastes of one company is treated as resources for another [3].

However, for industrial symbiosis to achieve its desired impact, an extensive network of participating companies is necessary to fulfill their supply and demand for different

resources. Therefore, an evaluation of the participation rates in the collaborative platform for industrial symbiosis first requires an in-depth understanding of the factors that influence the manufacturers' waste management behaviours, and decision-making process. Past conceptual frameworks on waste management behaviour have mostly focused on understanding the waste management intention and behaviours of individual residents in different households [4–6]. Recent works have also begun examining the waste management behaviours of various industries such as the construction industry [7, 8], the healthcare industry [9], and universities [10, 11]. However, due to the lack of information and data availability on the waste management behaviours exhibited in the food manufacturing industry, little is known about the influencing factors of such behaviours.

Therefore, in this paper, we propose a comprehensive waste management behavioural framework for the food manufacturing industry by building on the works of previous waste management behavioural studies, such as Young et al.'s work on employee pro-environmental behaviour (e-PEB) [12]. The Food Manufacturers' Waste Management Behavioural (FM-WMB) framework is validated through an exploratory survey that is conducted on a representative group of waste managers from Singapore's food manufacturing industry. By consolidating and analysing the responses obtained through the survey using exploratory factor analysis, we have identified Intention, Perceived Moral Obligation, Company Structure, and Situational Barriers as the most crucial (or significant) factors influencing waste management decisions made by the waste managers on behalf of the organisation. The findings from this paper will provide valuable insights into the food manufacturers' waste management decision-making process and, at the same time, provide researchers with a more human-centric framework for the conduct of future industrial symbiosis studies.

2. Theoretical Framework

Young et al.'s framework on e-PEB is an extension of Tudor et al.'s examination of the environmental behaviours in large organisations [9]. By integrating the findings from a wide range of studies on environmental performance indicators, the authors presented a revised framework by considering the influences of individual, group, organisation, and external factors on pro-environmental behaviour in the workplace [12]. Given that the e-PEB framework is based on research evidence that demonstrated positive environmental performance rather than solely relying on self-reported methods, it serves as a valuable starting point for our study. On top of that, we intend to revisit and integrate several factors from other frameworks such as Subjective Norms, Perceived Behavioural Control, and Intention to act from Ajzen's theory of planned behaviour (TPB) [13]. Ajzen proposed in TPB that an individual's behavioural Intention and behaviour is affected by the individual's Attitude towards the behaviour, Subjective Norms, and Perceived Behavioural Control. A factor on Perceived Moral Obligation from Philippsen's work on student's recycling intention will also be included in the FM-WMB framework as it was concluded by

Philippsen that Perceived Moral Obligation was one of the factors that significantly predicted the student's intention to recycle [11]. Finally, we will also be including the factor on Situational Barriers from Blok et al.'s work on pro-environmental behaviour of university employees [10] to come up with a comprehensive waste management behavioural framework for the food manufacturing industry.

Due to the general lack of information and data availability of the waste management behaviours exhibited in the food manufacturing industry, few behavioural studies have been conducted in this area, and the existing pro-environmental frameworks that have been developed are unsuitable to be directly applied in our study. It should also be highlighted that our study focuses on the waste management decisions that have a potential impact on the entire company and not just the individual. Therefore, the FM-WMB framework developed in this study can be used to understand the waste management behaviours exhibited in the food manufacturing industry and develop human-centric policies to increase the participation rates of waste management programmes such as industrial symbiosis. The final contribution of our work lies in the validation of the e-PEB framework proposed by Young et al. While the e-PEB framework was developed by integrating the validated works from different studies on pro-environmental behaviour, the framework itself has not been validated in the food manufacturing industry nor by the waste managers. Therefore, using the respondent data that was obtained through the survey, this gives us a rare opportunity to validate the proposed framework in the context of the food manufacturing industry in Singapore.

Figure 1 depicts a graphical representation of the FM-WMB framework. A detailed description of each factor will be covered in the following subsections. In the proposed framework, each of the factors (Individual, Organisational, External) is hypothesised to have an indirect impact on the firm's waste management behaviour through Intention. On top of that, it is recognised by the authors that the different factors may share specific relationships with each other in the proposed framework; however, the study of these interrelationships falls outside of the scope of this study. Furthermore, individual and company demographic information is also collected during the survey to understand their influences on the waste managers' waste management decision; however, the analysis of these influences also falls beyond the scope of this study.

2.1. Individual Factors

In the FM-WMB framework, we are keen on understanding the influence of individual factors such as Environmental Awareness, Attitude, Subjective Norm, Perceived Behavioural Control, and Perceived Moral Obligation on manager's waste management decision. In this context, Environmental Awareness is related to the amount of knowledge a waste manager has on the different waste management options that are available and the positive/negative consequences of each option [12]. This includes knowledge about the different recycling materials, well as recycling and disposal methods. Attitude relate to the

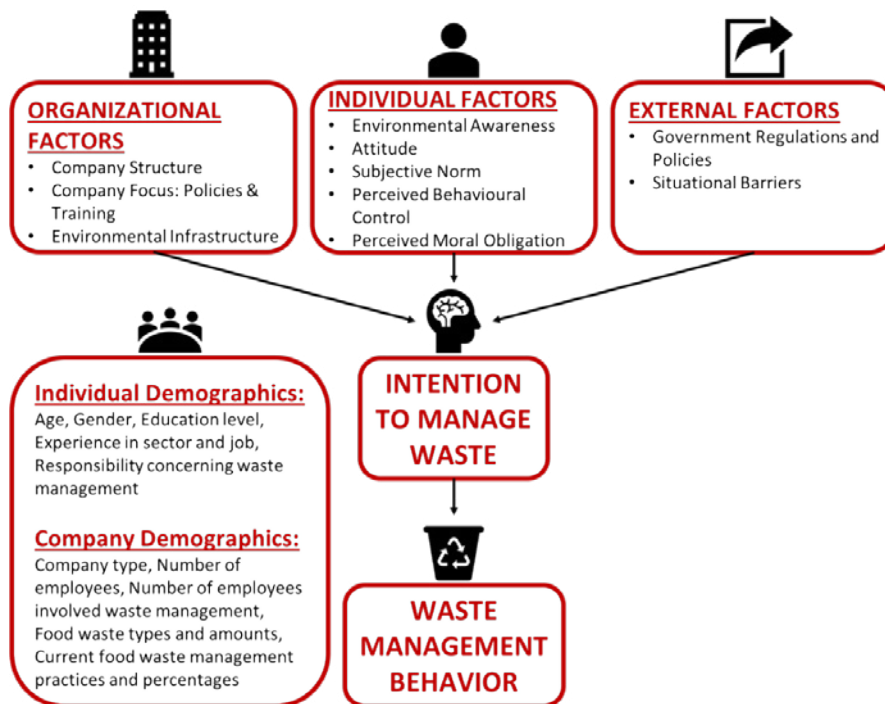


Fig. 1. The Food Manufacturers' Waste Management Behavioural (FM-WMB) Framework.

waste manager's personal belief on whether waste management is cost saving, personally rewarding, or helpful for the environment. Subjective Norm refers to the pressure originating from the waste manager's social circle which could have a positive or negative influence on his/her waste management decisions. Perceived Behavioural Control relates to the waste manager's confidence in implementing a particular waste management decision. Finally, the factor on Perceived Moral Obligation, proposed by Philippsen, is included in the framework to consider the influence of the waste manager's self-expectation on making positive waste management decisions [11].

2.2. Organisational Factors

Several factors have also been proposed to investigate the extent of the organisation's influence on the waste manager, and the waste management decisions that are made on behalf of the company. Under this category, we are interested in studying the influence of factors such as Company Structure, Company Focus in the form of waste management policies or training programmes, as well as the Environmental Infrastructure invested by the company [12]. Company Structure relates to the amount of freedom the waste manager has in making waste management decisions on behalf of the organisation. Company Focus relates to the company's priorities when it comes to making waste management decisions; this involves striking a balance between cost, environmental footprint, labour-efficiency, and company image. Company Focus is usually evident from the waste management policies and training programmes that are introduced by the management of the organisation. Therefore, we are interested in studying the impacts of company-level pro-environmental policies and training programmes on the managers' waste management decisions. Environmental

Infrastructure relates to the adequacy of the current waste management facilities to properly process and store the food waste produced by the company in a safe manner.

2.3. External Factors

External Factors are defined as all other factors that do not fall within the definition of Individual or Organisational Factors. In the context of Singapore's food manufacturing industry, we are keen on determining the effectiveness of potential government regulations and policies on the industry's waste management practices. Such policies include the provision of incentives to encourage the adoption of positive waste management practices or the implementation of regulations to curb negative waste management habits. We are also interested in studying the impact of Situational Barriers, such as time constraints and complexity issues of managing waste, on the manager's waste management decisions. Examples of such barriers include the difficulties in managing the food waste efficiently due to the lack of suitable technology and the inconvenience of engaging an external party for waste management. This definition differs from Blok et al.'s work which defined Situational Barriers as the lack of available opportunities to behave in a pro-environmental manner [10].

3. Research Methodology

3.1. Questionnaire Development

Based on the FM-WMB framework, a detailed questionnaire was designed for the survey, containing five main sections. The first section focused on collecting the waste manager's socio-demographic information, and the

second section contained questions related to Individual Factors and their influence on the respondent's waste management decisions. The third section consists of questions related to the demographics of the organisation that the waste manager is representing, and the fourth section consists of questions under Organisational Factors. Finally, the last section of the questionnaire focused on the questions related to External Factors and their influence on the manager's waste management decisions.

A pilot study was conducted on five waste managers from the food manufacturing industry to ensure the validity and clarity of the questions posed in the exploratory survey. Based on their feedback and suggestions, several questions were refined and adjusted, resulting in a final survey of 24 variables from five sections and 62 questions consisting of short answer questions, multiple choice questions, ranking questions, and questions based on the five-point Likert scale where 1 = Strongly disagree and 5 = Strongly agree.

3.2. Data Collection

As an island city-state, Singapore has a highly industrialised economy with the food manufacturing industry contributing S\$3.8 billion to the total GDP (1%) and employing around 30,000 workers [14]. The survey was targeted towards managers who are responsible for the waste management decisions made in their organisations, ranging from small and medium enterprises (SMEs) to large corporations (LC). SMEs are defined as enterprises with an annual sales turnover of less than S\$100 million or employing less than 200 workers [15], while LCs are defined as large organisations that operate on a larger scale than SMEs. The survey was conducted through an online platform, and the survey link was distributed during a waste management workshop organised by the Singapore Institute of Manufacturing Technology (SIMTech). To further improve the survey response rate, the survey link was also shared through an email blast to SIMTech's various industry partners. In order to solicit a positive response, the identities of the survey respondents were kept anonymous. By the end of the survey, we received a total of 31 validated responses from different food manufacturers in Singapore, with 18 respondents (58.1%) representing SMEs, 10 respondents (32.3%) representing LCs, and the rest of the respondents representing other company types such as food service providers (9.7%). Table 1 shows a portion of the company demographic information that has been collected from the waste managers who participated in the survey.

3.3. Exploratory Factor Analysis

By gathering the responses obtained through the survey and grouping them based on their respective factors (Individual factor, Organisational factor, External factor, and Intention), each group of responses will be analysed using exploratory factor analysis to identify the set of underlying variables within each factor. First, to evaluate the data's suitability for exploratory factor analysis, the Kaiser-Meyer-Olkin (KMO) Measure of Sampling Adequacy and Bartlett's Test of Sphericity was performed. By checking that the KMO

Table 1. Demographic information of companies which participated in the survey (n = 31).

| Characteristic | Category | Values Reported | Percentage |
|--|---------------------------------|-----------------|------------|
| No. of People Involved in Waste Management | SME | 1 to 90 | 20% to 90% |
| | LC | 3 to 250 | 1% to 80% |
| Food Waste Types Produced in the Company* | Fruits, Vegetables & Salad | 3 | 9.7% |
| | Meat & Fish Products | 5 | 16.1% |
| | Dairy Products & Eggs | 6 | 19.4% |
| | Bread, Grains & Bakery Products | 5 | 16.1% |
| | Pasta & Rice | 3 | 9.7% |
| | Coffee Grinds & Tea Bags | 7 | 22.6% |
| | Processed/Prepared Food | 8 | 25.8% |
| Sauces & Spreads | 5 | 16.1% | |

*It is possible for a company to produce more than one type of food waste.

value lies above 0.5 [16] and the significance level from Bartlett's test falls below 0.05 [17], this ensures that the data is suitable for factor analysis. Next, the principal axis factoring method with varimax rotation is employed to extract the latent variables proposed in the FM-WMB framework from the survey responses. To objectively determine the appropriate number of latent variables to extract during factor analysis, we used both the Kaiser eigenvalue-greater-than-one rule and Horn's parallel analysis as an evaluation criterion; any discrepancies between the values reported by both approaches were resolved by taking the average of both values. The purpose of using two different evaluation criteria is due to the tendency of the eigenvalue test to over-extract factors [18] while parallel analysis tends to under-extract factors when the first eigenvalue is large [19]. In Horn's parallel analysis, a factor is retained if its eigenvalue is greater than the 95th percentile of the distribution of eigenvalues computed based on Monte Carlo simulations of randomised data [20]. As a final step, a reliability analysis, based on the Cronbach's Alpha method, was performed on each latent variable to evaluate its overall consistency and reproducibility. In the case of our study, a reliability coefficient greater than 0.5 indicates an acceptable level of reliability [21].

4. Results and Discussion

The analysis in this section was performed using the Statistical Package for Social Sciences (SPSS 25.0). When conducting factor analysis for the Intention-related survey questions, the KMO and Bartlett's test reported a KMO value of 0.735 and a significance level of 0.001, indicating the data's suitability for structural detection. Furthermore, due to the discrepancy between the reported number of latent variables to extract based on parallel analysis and the eigenvalue test, an intermediate value of one latent variable was extracted from the data. This factor of Intention explained 51.3% of the total variance in the data and consisted of three Intention-related questions. Table 3 shows the factor loading matrix for the Intention-related questions. Finally, the reliability analysis of the results reported a Cronbach's Alpha value of 0.834,

Table 2. Combined analysis results for Intention, Individual, Organisational, and External Factors.

| Factor | Latent Variables | No. of Questions | KMO Value | Bartlett's Test | Cronbach's Alpha | % of Variance |
|----------------|---------------------------------|------------------|-----------|-----------------|------------------|---------------|
| Intention | Intention | 3 | 0.735 | 0.001 | 0.834 | 51.3 |
| Individual | Perceived Moral Obligation | 3 | 0.575 | 0.001 | 0.817 | 28.2 |
| | Environmental Awareness | 3 | | | 0.877 | 14.3 |
| | Perceived Behavioural Control | 2 | | | 0.772 | 10.3 |
| | Subjective Norms | 1 | | | - | 7.7 |
| Organisational | Company Structure | 1 | 0.544 | 0.001 | - | 22.8 |
| | Environmental Infrastructure | 2 | | | 0.719 | 18.5 |
| | Company Focus | 2 | | | 0.782 | 15.4 |
| External | Situational Barriers | 3 | 0.613 | 0.001 | 0.843 | 36.0 |
| | Government Regulations & Policy | 1 | | | 0.597 | 20.7 |

Table 3. Factor loading matrix for factor analysis of Intention (Extraction method: Principal Axis Factoring)

| Question | Latent Variable 1 |
|--|-------------------|
| Intention I intend to put in great personal effort to manage my company's food waste as much as possible. | 0.702 |
| I am willing to manage our company's food waste better if I am more aware of the efficient waste management practices. | 0.892 |
| I intend to apply new food waste management practices in my company if I was given the opportunity. | 0.793 |

indicating a high level of reliability. The same series of analysis were conducted on the responses related to Individual, Organisational and External Factors separately. Their combined results are presented in Table 2.

The results from Table 2 shows that the waste manager's Intention to manage the company's waste is a significant factor in predicting the firm's waste management behaviour. This result agrees with the hypothesis that is made during the development of the proposed framework and is in line with literature which suggests that Intention is the strongest predictor of pro-environmental behaviour [22].

Under Individual Factors, the results showed that the waste managers are more likely to be influenced by their moral expectation when making waste management decisions as compared to the influences from their social groups. Furthermore, given that the top three most significant Individual Factors for pro-environmental behaviour are the waste manager's self-expectation to make sustainable waste management decisions (Perceived Moral Obligation), his awareness of the impacts of those decisions (Environmental Awareness), as well as his confidence in implementing those decisions (Perceived Behavioural Control), the local government can intervene by conducting educational programmes, either through the company's leadership or the various local agencies, to improve the food manufacturing industry's overall awareness and adoption of sustainable waste

management initiatives such as industrial symbiosis. However, it is worth noting that the waste manager's Attitude was found to be an insignificant factor in predicting his waste management decisions. While one might expect Perceived Moral Obligation and Attitude to be closely correlated, this contradiction could be explained by the influences of the organisation's expectation on the waste manager, such as to keep cost low, which is internalised and translated into the waste manager's self-expectation while his attitudes towards waste management remained unchanged.

An examination of the analysis results from Organisation Factors lends some weight to the above argument as Company Structure was found to be a very significant factor in predicting the waste manager's waste management decisions. This result shows that the waste manager's decisions are still heavily influenced by the company's leadership and that the support of the company's top management is crucial in ensuring the long-term adoption of sustainable waste management initiatives. Therefore, by moving in line with the previous recommendation on government-led waste management education programmes in the food manufacturing industry, the local government should put in a special effort and additional resources to reach out to the leaders of each company as they serve as role models for the rest of the organisation. In successfully doing so, we can expect these same ideas of sustainable waste management to permeate through the organisation in the form of additional infrastructure investment for food waste storage and processing facilities (Environmental Infrastructure), or the development of waste management training programmes and policies (Company Focus). Both of these factors have a significant influence on the waste manager's waste management decisions. Furthermore, with the appropriate amount of managerial support, we can also expect an increasing trend in the company's adoption of sustainable waste management practices on the ground level.

Finally, the analysis results for External Factors conclude that both Situational Barriers and Government Regulations and Policies have a significant influence on the company's waste management decisions. As many survey respondents reported complexity issues when attempting to manage their food waste effectively, the local government needs to address this

situation by having an open and honest conversation with the food manufacturing industry on what can be done to eliminate those barriers and guide companies towards the adoption of more sustainable waste management practices. In the context of industrial symbiosis, it is also generally agreed among researchers that government involvement is necessary to create a nurturing condition for industry-wide adoption [23]. This involvement includes the conduct of education programmes to inform the food manufacturing industry of the benefits of industrial symbiosis, encouraging companies to reuse their by-products through more strategic means, serve as a bridge for the coordination of materials exchange between two participating firms, and the breaking down of sectoral boundaries to encourage cross-industry participation [23]. Government intervention can also come in the form of traditional approaches of introducing regulatory requirements to pressure the industry into avoiding unsustainable waste management practices or through the introduction of incentive programmes that encourages positive waste management habits.

5. Conclusion

In this paper, we have proposed a comprehensive waste management behavioural framework for the food manufacturing industry and validated it through an exploratory survey conducted on a representative group of waste managers from Singapore's food manufacturing industry. By analysing the survey responses using exploratory factor analysis, we have identified Intention, Perceived Moral Obligation, Company Structure, and Situational Barriers to be the most significant factors influencing the waste manager's waste management decisions. On the other hand, the individual's waste management Attitudes were found to have an insignificant influence in driving the waste management decisions made by the waste manager.

Through this study, several policy recommendations were proposed where the central theme involves the conduct of educational programmes initiated by the local government to improve the food manufacturers' overall awareness and adoption of sustainable waste management practices such as industrial symbiosis. It was also concluded that such programmes should target the leaders of each company as they serve as positive role models for their respective organisations.

The findings from this paper provide valuable insights into the significant factors influencing food manufacturers' waste management behaviours and guide the design of future government policies on waste management in the manufacturing industry. The FM-WMB framework also provides researchers with a more human-centric approach during the conduct of future industrial symbiosis studies.

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