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Integration of Quality Function Deployment into Green Marketing: A Case Study of Green Paving Bricks Utilizing PET Waste

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Abstract

This study applies the well-known Quality Function Deployment (QFD)-based ecodesign method for integrating the ecological consideration into the green marketing mix (4Ps) at the upstream stage of the product design process. The suggested QFD-based ecodesign method intends to support the marketing personnel and product designers in identifying a green product, green price, and green place based on the environmental aspects--material and energy efficiency. In addition, the output of this method is to underline the activities or specifications of the marketing mix (4Ps), which potentially creates a great impact on environmental improvement. In this study, the researchers proposed the QFD-based ecodesign method and guideline via a case study of 100 customers exposed to green paving bricks utilizing polyethylene terephthalate (PET) waste.

Keywords: *Ecodesign, Quality Function Deployment for Environment (QFDE), green marketing mix, paving bricks, Polyethylene Terephthalate (PET)*

1. Introduction

Climate change, global warming, and environmental degradation are urgent global problems (United Nations, 2021). The increasing awareness and stricter legislation of environmental issues have brought about many ecological concepts, methods, and tools to support manufacturers in producing more environmental-friendly products. Ecodesign, one of the well-known and impactful environmental approaches, provides a guideline to design more environmental-friendly products by integrating the ecological consideration into the early stage of the product design process, in which the environmental impact can be potentially reduced (Puglieri et al., 2020). In the context of product development, Quality Function Deployment (QFD) is a well-known ecodesign method widely used by product design engineers to translate customer needs into a

product specification. Besides, QFD has also been developed for other applications in a product development process, i.e., identifying marketing mix (4Ps) during the early stage (Huang & Toma, 2010), specifying the production process at the downstream stage (Soheylinia, Kashan & Soheyliniya, 2020), or supporting decision making on a supply chain aspect (Cui et al, 2021). To mitigate the present environmental issue, designers concerned have extensively proposed various QFD-based ecodesign methods in the past two decades (Fargnoli & Sakao, 2017). Puglieri et al. (2020) have listed and analyzed 29 QFD-based ecodesign methods and highlighted the present difficulties of these implementations, such as application time, software requirement, and training cost. Still, there is a further need to develop a QFD-based ecodesign method that is easy to use, low in application cost, and time-efficient in the process stage.

Moreover, only a few studies developed QFD-based ecodesign methods for an upstream application, such as marketing mix (product, price, place, and promotion) identification which is essential to determine the ecological implementation in a manufacturing organization to the target customers. Therefore, this study suggests a simple and inexpensive approach for integrating the ecological consideration into the marketing mix (4Ps) by using the Quality Function Deployment for Environment (QFDE) method. The next section reviews the methods applied in this research, including QFD, QFDE, and a green marketing mix. The researchers will explain research methodology in Section 3, followed by data collection on designed method's implementation from the customers under study. The proposed application of QFDE for green marketing (4Ps) will be demonstrated via green paving bricks using PET waste as a case study.

2. Literature Review

2.1 Quality Function Deployment (Pugh, 1991)

Quality Function Deployment (QFD) is a well-recognized design method that comprises four stages, as shown in Figure 1.

- Design Requirements: The voice of the customer or customer need is translated into product design specifications.
- Part Requirements: Product design specifications are converted to product parts and components' characteristics.
- Manufacturing Requirements: The design and process parameters are identified based on product parts and components' specifications.
- Production Requirements: Production operators' instruction is finally generated for the process and quality control plan.

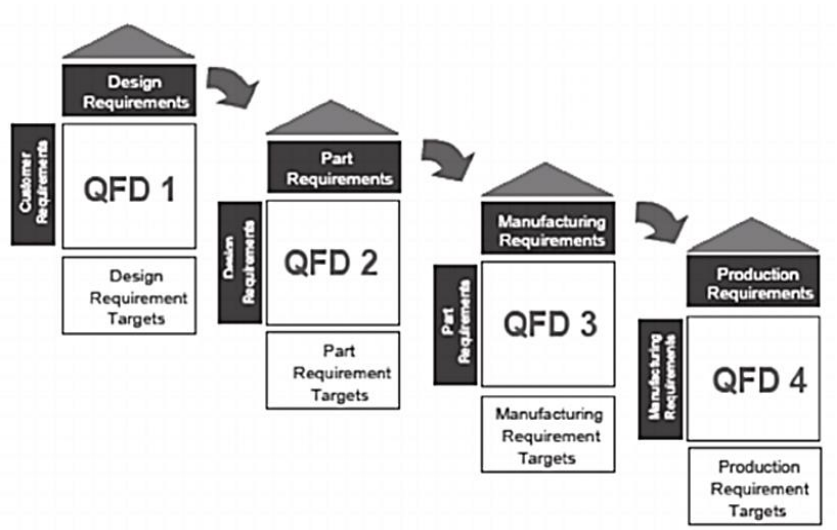

Figure 1: A traditional QFD of Four Phases (Gupta & Srivastana, 2011)

2.2 Quality Function Deployment for Environment (Masui, Sakao & Inaba, 2001)

Quality Function Deployment for Environment (QFDE) is generally developed to embed environmental aspects into a traditional QFD method. The QFDE objective is to identify the product characteristics that crucially impact an environmental improvement. The significant environmental aspects used in this method include the context of Voice of Customer (VOC) and Engineering metrics, as briefly described below:

- Environmental VOC (EVOC) comprises less material use, ease of transport, ease of production, less energy consumption, lengthening product lifecycle, ease of reuse, ease of disassembly, ease of maintenance, ease of recycling, safety in incineration, safety in landfilling, low emission and non-toxicity.
- Environmental engineering metrics include product weight, product volume, number of parts and components, number of material types, product durability, part hardness, product lifetime, energy consumption, recyclability, noise, vibration and electromagnetic wave, air pollution, water pollution, soil pollution, biodegradability, and toxicity of materials.

2.3 Green Marketing (Vaibhav, Bhalerao & Deshmukh, 2015)

Green marketing involves various manufacturing industry activities in providing environmental-friendly products and services to the consumer. These primary activities are related to environmental changes in product, production process, packaging and label design, transportation, advertisement, and other activities related to price, place, and promotion decisions. Vaibhav, Bhalerao & Deshmukh (2015) described the four key elements of green marketing as follows:

- Green Product: The product should be environmental-friendly during the whole lifecycle. The designer should focus on both environmental and traditional considerations, e.g., effective function, user-friendly, and high aesthetic quality as well as cost-effective. The main aspects for

defining a green product are the design of a product, environmental-friendly technology, product usefulness, product value, convenience in use, product quality, and packaging.

- Green Price: A product price is generally based on material and production cost, market share, the value of the product itself and market competition. In practice, the cost of many new green products nowadays appears to be more expensive than the original one due to several causes, i.e., the absence of economies of scale or the high development cost of new technology. However, it has been suggested that green costs should be affordable to all typical customers to motivate the consumption of the environmental-friendly product Vaibhav, Bhalerao & Deshmukh (2015).
- Green Place: Green places can be both physical and virtual stores. Nowadays, the Internet has unlocked a green marketplace, since it has removed several steps transporting a product from a manufacturing factory to a consumer, which in turn helps to minimize an environmental impact along a product lifecycle. Therefore, a green place should be any location that minimizes environmental impact and the efforts of customers and manufacturers in selling products.
- Green Promotion: Three aspects of advertisement consideration have been suggested to improve the environmental aspect of promotion activities. These are a selection of green promotion partners, the use of environmental-friendly material, and a consideration of environmental and societal impact in the advertising message.

3. The Proposed QFDE for Green Marketing Identification

This section describes how the researchers proposed application of the quality function deployment for the environmental aspect of creating a green marketing mix. The method included the following steps:

3.1 VOC Data Collection

The first step was to collect input data using for green marketing identification. In detail, the ranked customer needs related marketing mix (4Ps) was collected from 100 consumers on a voluntary basis. The score of environmental considerations, which is based on Environmental VOC (Masui, Sakao & Inaba, 2001), and impacts of the focus product, price, place, and promotion was ranked by the design and development engineers. These ranked scores were determined and presented in terms of an average weight of VOC and environmental VOC (Score 1-5).

3.2 Rating Impact of VOC and EVOC on Green Marketing Specification

The second step was to rate the impact of VOC and EVOC on a product, price, and place specifications based on a consideration of a particular product.

The rating score for evaluating an impact varies as follows:

- 1 represents VOC quite important with a low impact on the 4P specification
- 3 represents VOC important with a medium impact on the 4P specification
- 9 represents VOC highly important with a high impact on the 4P specification

3.3 Estimating Relative Weight of 4P Specification

This step highlights the significant specifications of the marketing mix (4Ps), which have a high impact on the general VOC and Environmental VOC. The significant specification is represented by its total relative weight (1-5). The total relative weight can be calculated by

multiplying consumer weight with impact rating and divided by the total impact rating of a considered specification. The specification, which has a high value of the total relative weight,

reflects the high impact on VOC and requires an implementation of an environmental-friendly solution.

Voice of Customer (VOC)		Average Weight	Product Metric: Weight	volume	Variety	Product lifespan	Functionality	Material	Packaging and label	Production	Transportation	Maintenance	Branding	Price Metric	Place Metric: Location (Online/Onsite)	Retail cost	Transportation	Product presentation	Promotion Metric: Advertising material	Advertising Method	Advertising Massage	Advertising partner
Product	Aesthetics	Weighting from consumer Score:1-5	9	…																		
	Product strength		3																			
	light weight		1																			
	…		…																			
Price														…								
Place															…							
Promotion																						
Environment	Less material use																					
	Environmental-friendly material use																					
	Ease of transport																					
	Ease of production																					
	Less energy consumption																					
	Lengthening product lifecycle																					
	Ease of reuse																					
	Ease of maintenance																					
	Ease of recycling																					
	Safety in incineration or landfilling																					
	Low emission																					
	Non-toxicity																					
VOC Relative weight																						
Environmental Relative weight																						
Total relative weight																						

Impact Rating:
1 - Low impact on a specification
3 - Medium impact on a specification
9 - High impact on a specification

Figure 2: QFDE for Green Marketing Identification

4. Research Methodology

4.1 Data Collection

In this study, the researchers specified the customer need as input data for demonstrating the implementation of the QFDE for Green Marketing Mix (4Ps). The use of green paving bricks utilizing polyethylene terephthalate waste was selected as a green product case study, since various research studies have reported developments and experiments with this product ready for implementation (Meng, Ling & Mo, 2018). Hence, VOC primary data were collected from 100 people who have experience in purchasing paving bricks. The online questionnaire was used to obtain the needed data. The questions used in the survey were classified into five categories: product, price, place, promotion, and environmental aspects related to paving bricks using PET waste.

4.2 Green Marketing Identification

The proposed QFDE for the green marketing mix was used to identify the impactful green marketing activities based on the customers' data obtained in the previous step. The researchers expected to detect the customers' consideration of the environmental aspects while maintaining their original economic perspective.

5. VOC of a Green Paving Brick Using PET Waste

The results of the distributed questionnaires on the characteristics of respondents are presented in Table 1. The data were from 100 respondents who have experience in purchasing paving bricks. More than half of the respondents were female (56.1%), employed in a business or government organization (69%), and with higher education qualifications (60.2%).

Table 1: Respondents' Characteristics

Respondents' characteristics	*Collected data*	*Percentage*
Gender	Male	43.9%
	Female	56.1%
Age	20-30 years	46.5%
	31-40 years	29%
	Over 40 years	24.4%
Education	High school	28%
	College	11.8%
	University	49%
	Graduate school	11.2%
Occupation	Employee	53%
	Self-employed	18%
	Government staff	16%
	Others	7%
Monthly income	Less than 15,000 THB	17%
	15,000-20,000 THB	22%
	20,000-30,000 THB	35%
	Higher than 30,000 THB	26%

Furthermore, the questions related to product, price, place, and promotion of green paving bricks using shredded PET were concluded and translated into the voice of customers. Then, the result of customer ratings (using a five-score level) was determined as the average weight. These average weights of the VOC of 4Ps and environmental aspects presented in Table 2 showed that the highest average weight of the product aspect was the strength of paving brick (4.11). From a price perspective, the price should be reasonable with a quality of a product in which the average weight is 3.69. Considering the place aspect, the consumers preferred purchasing paving bricks from a construction shopping mall (4.01), where customers can purchase various types of products. According to the promotion results, the customers searched for the product information from the Internet and online source (3.83). As for the environmental aspect, the customers considered environmental-friendly material the most crucial VOC, and ranked it at 5.00.

Table 2: Survey Results of Product, Price, Place, Promotion, and Environment Aspects

Key aspects	*Voice of customers*	*Average weight*
Product	Aesthetics	3.77
	Product strength	*4.11*
	Lightweight	3.94
	Easy to install	3.94
	Durability	3.86
	Easy to clean	4.01
	Water absorption	4.05
	Flame retardant	4.06
Price	Suitable for product size and properties	3.60
	Suitable for product quality	3.67
	Price variety	3.59
Place	Sales agency	3.53
	Online purchasing, e.g., website and shopping application	3.35
	Local Construction store	3.83
	Construction shopping malls, e.g., HomePro, Global House and Thaiwatsadu	*4.01*
Promotion	Radio advertising	2.75
	Television advertising	3.26
	Billboard	3.32
	Paper-based advertising, i.e., newspaper or magazine	2.91
	Internet or Online advertising	*3.83*
	Others, i.e., consumer communication	3.47
Environment	Less material use	4.01
	Environmental-friendly material use	***5.00***
	Ease of transport	4.21
	Ease of production	4.00
	Less energy consumption	3.00
	Lengthening product lifecycle	4.50
	Ease of reuse	4.42
	Ease of disassembly	N/A
	Ease of maintenance	4.01
	Ease of recycling	4.42
	Safety in incineration or landfilling	4.32
	Low emission	4.45
	Non-toxicity	4.40

6. The Application of QFDE for Green Marketing Identification Method

The high impact VOC and EVOC on the marketing mix (4Ps) was defined at this step through the QFDE method. Then, according to the green paving brick using PET waste, the relative weight of each product specification, price, place consideration aspects, and promotion elements were determined as displayed in Table 3.

Table 3: QFDE for Identifying Green Marketing of Paving Bricks using PET Waste

Voice of Customer (VOC)		Average Weight	Product Metric											Price Metric	Place Metric				Promotion Metric			
			Weight	volume	Variety	Product lifespan	Functionality	Material	Packaging and label	Production	Transportation	Maintenance	Branding		Location (Online/Onsite)	Retail cost	Transportation	Product presentation	Advertising material	Advertising Method	Advertising Massage	Advertising partner
Product	Aesthetics	3.77			3		9	3	9	3			9									
	Product strength	4.11	9	3		9	9	9		9	3	3	3									
	light weight	3.94	9					9	9		3											
	Easy to install	3.94	9	3			9	1														
	durability	3.86				9	9	9			3	9	3									
	Easy to clean	4.01				9		9		1		9	1									
	Water absorption	4.05					9	9		1		9	1									
	Flame retardant	4.06				3	9	9		1			1									
Price	Suitable for product size and properties	3.6												9								
	Suitable for product quality	3.67												9								
	Price variety	3.59												3								
Place	Sale agency	3.53													9	9		9				
	Online purchasing e.g. website, shopping	3.35													9	3	9	1				
	Local Construction store	3.83													9	9		3				
	Construction shopping mall e.g. HomePro	4.01													9	9		9				
Promotion	Radio advertising	2.75																	1	9		
	Television advertising	3.26																	3	9		
	Billboard	3.32																	3	9		
	Paper-based advertising i.e. newspaper or	2.91																	9	9		
	Internet	3.83																	1	9	3	3
	Others i.e. consumer communication	3.47																				
Environment	Less material use	4.01	9	9	9			9	9	9		9	3	9	9	3	9	9	9	9		3
	Environmental-friendly material use	5.00	9		9	9		9	9				3	9		3			9	9	1	3
	Ease of transport	4.21	9	3	9		9		9		9			9	9	3	9	3	3			3
	Ease of production	4.00	9	3	9					9				9								
	Less energy consumption	3.00		1				3		9	9	9	3		9	9	3	9		9	1	3
	Lengthening product lifecycle	4.50	9			9		9				9										
	Ease of reuse	4.42			9			9						3					9			
	Ease of maintenance	4.01	3	3			9					9		3							1	
	Ease of recycling	4.42	3		9									3					9			
	Safety in incineration or landfilling	4.32						9														
	Low emission	4.45						1		9	9			9	9		3		9	9		3
	Non-toxicity	4.40						3		9				9								
VOC Relative weight			4.00	4.03	3.77	4.00	3.97	3.99	3.86	4.03	3.97	3.99	3.89	3.63	3.68	3.75	3.35	3.76	3.09	3.21	3.83	3.83
Environmental Relative weight			4.33	3.99	**4.34**	**4.75**	4.11	**4.36**	4.41	3.97	3.88	3.88	4.00	**4.34**	3.92	3.70	**4.01**	3.61	**4.45**	4.12	4.00	4.13
Total relative weight			**4.21**	4.00	**4.31**	**4.28**	4.00	4.17	4.19	3.99	3.91	3.93	3.93	**4.16**	3.80	3.73	**3.83**	3.68	4.09	3.61	3.92	4.08

As shown in the results, the QFDE implementation highlights the hotspot activities or impactful specifications that have an essential impact on VOC and EVOC. These are product variety, product weight, and product lifespan for specifying product aspects. Similarly, when considering the place and promotion aspects, the researchers could recommend with confidence the focus on transportation and advertising material based on environmental material use.

As for environmental consideration, the researchers identified the relative weight of packing & label and the material of paving bricks as vitally important. Therefore, these specifications are worth considering to achieve the focused environmental voice of customers, such as using environmental-friendly materials and lengthening product lifespan.

7. Conclusion

This study proposed the application of QFDE in support of the green marketing mix specification. This application can be verified by VOC data collection, rating of the impact of VOC and EVOC on green marketing specifications, and highlighting the high score marketing or 4P specifications, which can potentially impact substantial VOC and environmental improvement. The implementation of the proposed QFDE for green marketing was demonstrated through the use of paving bricks utilizing PET waste as a case study. In responding to the specified VOCs and VOCs, the researchers suggested a focus on product variety, product weight, product lifespan, price setting, transportation aspects, and advertising material.

After all, it should be noted that these identified green marketing specifications still require further research work for its feasibility of the environmental-friendly production process. The use of green paving bricks utilizing PET waste as a case study was meant to support the application of green products in the industries concerned.

8. The Authors

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