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Impact of Plastic Packaging Design on the Sustainability of Plastic Recyclers

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Abstract: Plastic waste that has low quality and economic value at its end of life may affect the plastic recyclers' production rate in the raw material aspect. Moreover, limited availability of good raw materials may lead to low economic product value and affect the producers' profit margin. This research aims to prove the impact of material value conservation (MVC) design principle implementation on the flexible plastic packaging on sustainability of plastic recycling plants based on economic, environmental, and social factors. It is found that the repetitive implementation of MVC design principles on plastic packaging may increase the economic sustainability of recycling plants through increasing income, which analyzed using feasibility study method. The increased margin was obtained through increasing availability of good quality of plastic waste to be produced continuously. The environmental sustainability impact obtained through the reduction of extraction of non-renewable raw materials which produce plastic original, unproductive land due to waste accumulation, and reduce the amount of plastic waste thrown into the ocean. Meanwhile, social sustainability impact obtained through the increasing employment absorption and earnings of local communities.

Keywords: Sustainability; flexible packaging; recycle; design; plastic waste.

1. Introduction

Plastic is a type of material that is inexpensive, durable, lightweight, and can be used for multi-functional applications [1, 2]. This material can be easily made into various shapes and usage [3, 4]. Moreover, plastic packaging is still become the most favorite product-packaging material based due to it will require three times of volume and mass of other materials to replace it for the same purposes [5]. Moreover, within the various benefits, plastics also give a large negative impact on the environment, nature, and human. Total energy use (around 8%) and environmental pollution during the production, usage phase, and distribution of plastic are very dangerous for the preservation of the environment, natural ecosystems, and society itself [6]. Furthermore, plastic waste accounts for extensive negative impact to the unproductive area, marine habitat, and human consumption through micro plastic hazards due to the waste accumulation [7, 8].

The need for plastic raw materials in Indonesia is quite large, with total demand of 5.6 million tons per year to produce various plastic products. At present, only 1.1 million tons of raw material fulfillments obtained from the recycle industry with 1.67 million tons of plastic waste imported per year [9]. Recycling is one of important activity that can minimize the production of original plastic and the spread and accumulation of plastic waste [10, 11]. Therefore, recycling plants play

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a vital role to meet several gaps regarding plastic waste phenomena, then, it is needed to ensure the economic sustainability of the plant through the availability of good quality and economic value of raw materials for the continuous recycling production. Furthermore, environmental and social sustainability impact should be revealed as well as the part of sustainability assessment factors [12, 13, 14].

There is a new design for sustainability (DFS) [15] principle which aims to increase the end of life value [16] of a product especially plastic packaging product, named material value conservation. Therefore, this research will assess the impact of MVC design principle implementation on flexible plastic packaging on the sustainability of plastic recycling plants through the economic, environmental, and social factors. The economic factor will be assessed using feasibility study method, with the assumption of increasing good quality and economic value of plastic waste through the increasing number (scenario) of packaging which applies the MVC principle.

2. The Principle of Design for Material Value Conservation

Material value conservation paradigm is an implementation of various approaches, design principle of product and process, materials process or treatment, and other efforts to minimize value degradation and maximize the residual value, and therefore may increase its life cycle and the overall value [17]. Meanwhile, most of the current design of flexible plastic packaging resulted in low economic and acceptance of its waste for recycling purpose therefore requires new approaches to avoiding the source of problems in order to increase its value [18]. Therefore, MVC design principle aims to increase the residual value of a product to keep it has good quality and economic value at its end of life phase [19, 20], the case in this research is the implementation on flexible plastic packaging product. Table 1 shows the plastic packaging waste category in Indonesia.

Table 1. Plastic packaging waste category in Indonesia [17].

Category	Residual Value	Description	Example
1	High	o No printing ink and color pigment on the high and medium quality of packaging. o Easy to remove plastic or paper labels, which used for branding and product information.	o Transparent plastic packaging product.
2	Medium	o Light or transparent color pigment on the high and medium of plastic packaging. o Use of limited printing ink and easily separated plastic sheet.	o Light color and/or printing ink only on the front sheet or < 50% of the plastic sheet.
3	Low	o The deep color pigment used on the high and medium of plastic packaging. o Printing ink on more and spread part of the sheet, not an easily separated label.	o Deep color and/or printing ink on most or the whole sheet.
4	No residual value,	o Multi-layer material on the high and medium of plastic pellets. o Degradable agents, low value of plastic pellets, dark or black color pigment used. o Toxic or other dangerous materials used.	o Plastic with a multi-layer application, black or dark color pigment, and/or usage of toxic materials.

This research will only focus on the waste category #1 (one) due to its quality and economic value does not much degrade (still has good overall value) compared with the original product [17]. Moreover, the recycled pellets product of this category still has a competitive selling price compared with another category in order to maximize the profit of plastic recycling plant. The increased margin will be considered in the feasibility study calculation as the economic sustainability assessment factor [21].

3. Methodology

Plastic-type or #RIC number used in this research is #4 Low-Density Polyethylene (LDPE) and #5 Polypropylene (PP) due to these are the most suitable packaging materials for food-based products containment and based on the survey, mostly found are #4 and #5 type of plastic used as the packaging in the actual market. In order to be more precise, this research is carried out through several steps:

3.1 Data Collection

The data of this research is divided into main and secondary data. The secondary data is needed in order to support the validity of the data in the research calculation, which obtained through some trusted literature. The main data were obtained from 250 different brands observed from several traditional markets and supermarkets who sell food-based containment of plastic packaging products. The purpose is to mapping the distribution of plastic packaging materials with some categories and to know the percentage of current plastic packaging distributed in the market which applies the MVC design principle (coincidentally). The mapping data categories observed are:

- Brand name, design type (divided into MVC and non-MVC design criteria), plastic type (Resin Identification Code), characteristics of the product contained; solid, liquid, powder, soft material, etc., the colour, printing ink, and label applied on the packaging, expiry date (assume that the expiry date of the product is the maximum or equal lifetime of the packaging due to after the product released or expires, the plastic will be in its end of life), type of product packaged (food-based material), and volume or weight of the product.

3.2 Interview with the expert

The interview was conducted with the chairman of the Indonesian plastic recycling business association as well as a plastic mechanical recycling business owner which produce plastic waste into plastic pellets. The data obtained in this step is considered as the main data related to the economic calculation of the actual condition of the plastic recycling plant in order to determine the economic sustainability factor. Moreover, with the expert's experience and knowledge, we can further discuss the environmental and social sustainability impact of the design principle (with the scenario of an increasing number of recyclable plastic packaging waste availability) if applied repetitively.

- The expert's thought on the attractiveness of plastic recycling businesses in Indonesia and the availability of good quality of plastic waste today as the raw materials for the recycling plant
- The Investment needed to open a plastic recycling plant, an example of his own business capital
- The production machine lifetime as the investment time estimation
- Production cost, include direct and non-direct labour
- The actual raw material price and selling price of the plastic pellets under 3 (three) conditions named transparent, white, colour (red, green, and blue), and black materials of #4 and #5 type
- The conditions of plastic that are harder and easier to find in the actual condition
- Under what condition and requirement if we will increase the production capacity of the plant

4. Result

4.1 Environmental Sustainability Impact

The economic sustainability analysis of this research was conducted by using the feasibility study method through the calculation of the number and percentage of profit margin, Net Present Value (NPV), Internal Rate of Return (IRR), and Profitability Index (PI) with Discount factor (i) = 10% due to current bank interest standard is 0.85% per month or around 10% per year. Some results obtained:

Table 2. Indonesia's plastic production materials needs.

Number	Description	%	Volume (Ton)	Source
1	The number of Indonesia's yearly plastic production materials needs		5,600,000	[9, 22]
2	The number of Indonesia's yearly materials needs for plastic packaging production	40	2,250,000	[30]
3	The number of Indonesia's yearly material needs for flexible plastic packaging production	42	945,000	[31]
4	Survey result of Percentage of MVC design principle applied (coincidently) in the market	7	66,150	

Based on the survey result, 7% of the total product observed has applied the design principle proposed by MVC which later the waste will be included in waste category #1, means that, if all of the flexible plastic packaging utilized or being recycled, then, there will be only 66,150 ton of plastic waste inputted as raw material for plastic recycling plants. Moreover, as gathered from the secondary data, Indonesia currently still lack 600,000 Ton of materials to be produced as plastic products (to fulfil Indonesia's yearly plastic production materials), due to current recycling materials only fulfil 1.1 million ton per year of 5.6 million ton materials needed per year [9, 22].

Subsequently, the 7% will be considered as scenario 1, is the actual current condition of plastic packaging which already applies the proposed criteria, next will be converted to the scenario of an increasing number of flexible packaging to implement the MVC design principle become 40% as scenario 2 and 70% as scenario 3. The 40% scenario is set to fulfil 50% of the annual shortage of Indonesia's demand for plastic production, then, the scenario 3 settled to fulfil the 100% of the annual shortage of Indonesia's demand for plastic production. Furthermore, is assumed that 7% of the current packaging has been utilized and included in the current country's recycling materials contribution.

Table 3. Scenario 1: 7% availability of good overall value of plastic waste obtained.

Good plastic waste availability (kg / year)	Good plastic waste availability (kg / month)	Good plastic waste availability (kg / day)	Divided equally to 300 plastic recycling plants (kg / day)	Divided equally to 300 plastic recycling plants (kg / month)
66,150,000	5,512,500	22,019	707 (696)	18,099

Table 4. Scenario 2: 40% availability of good overall value of plastic waste obtained.

Good plastic waste availability (kg / year)	Good plastic waste availability (kg / month)	Good plastic waste availability (kg / day)	Divided equally to 300 plastic recycling plants (kg / day)	Divided equally to 300 plastic recycling plants (kg / month)
378,000,000	31,500,000	1,211,538	4,038 (3,978)	103,425

Table 5. Scenario 3: 70% 7% availability of good overall value of plastic waste obtained.

Good plastic waste availability (kg / year)	Good plastic waste availability (kg / month)	Good plastic waste availability (kg / day)	Divided equally to 300 plastic recycling plants (kg / day)	Divided equally to 300 plastic recycling plants (kg / month)
661,500,000	55,125,000	2,120,192.31	7,067 (6,961)	180,994

The good plastic waste availability means that there will be new high quality and economic (overall) value of plastic waste available to be reproduced as recycled plastic pellets as the raw materials to produce plastic product. So forth, with the increased availability of good materials will decrease the number of low-quality plastic waste (coloured and black colour materials) and even those which thrown into the environment due to unrecyclable packaging materials.

The percentage scenario settled in this research will be converted to current Indonesia's total material needs for flexible plastic packaging production which is 945,000 ton per year. For example in scenario 2, the number of materials applies the proposed design principle of MVC will be increased from 7% become 40% of 945,000 ton of plastic packaging produced per year, then, there will be 378,000 ton availability of high quality and economic value of raw materials to fulfil 50% of lack of Indonesia's plastic production materials of 600,000 ton per year. Moreover, it is similar thinking way of scenario 3 which leads to new high quality and economic value of materials availability to fulfil 100% of lack of Indonesia's plastic production materials per year. The increased percentage of plastic packaging to implement MVC proposed design principle is intended to turn the unrecyclable or low value of plastic waste into high quality and economic value of materials to be reprocessed as recycled plastic pellet materials which can be used to fulfil the needs of current country's plastic production.

The daily number of waste availability (kg per year) is obtained from the assumption of 26 days of plant operation per month. Moreover, in the actual recycling process, there will be around 1.5% shrinkage of raw material, for example, in scenario 1, from 2,019 kg of raw materials, then, there is only 1,989 kg of materials effectively produced. Furthermore, in this scenario calculation, the total daily plastic waste availability is divided equally to 300 plants; from the number of member of Indonesian plastic recycling association, which is around 300 recycling plants operated in the country

Table 6. The economic feasibility factor assessment result of the settled scenarios.

	Scenario 1: 7% (,000,000)			**Scenario 2: 40%** (,000,000)			**Scenario 3: 70%** (,000,000)		
	Trans-parent	Colour	Black	Transpa-rent	Colour	Black	Transpa-rent	Colour	Black
Present Value				9,606	4,883	2,909	25,552	17,288	13,155
Investment				4,000	4,000	4,000	7,000	7,000	7,000
NPV				5,606	883	(1,090)	18,552	10,288	6,155
PI				2.40	1.22	0.73	3.65	2.47	1.88
PP				2.56	5.03	8.45	1.68	2.49	3.27
IRR				37.46%	14.93%	3.19%	58.83%	38.66%	27.99%
Decision	Not Feasible. Production cost higher than revenue			Feasible	Feasible	Do not Feasible	Feasible	Feasible	Feasible

The feasibility decision is determined according to some requirements that should be met, those are, the revenue should be higher than production cost, NPV value > 0, Proficiency Index (PI) > 1.00, Payback Period (PP) has positive value, and IRR > Discount Factor. If one of the requirement does not fulfill, then, the investment or project do not recommend to be conducted, or it means that it does not sustainable for the economic factor. Moreover, plastic recycling plants to produce plastic pellet requires medium-level of enterprise due to the investment is quite high with machinery lifetime or investment for 10 years period of time, then, it requires good consideration of economic sustainability to open plastic recycling plant, especially for plastic pellets as the end product.

In scenario 1, it does not feasible to be conducted if only has 0.7 ton of recyclable plastic waste available as raw materials due to the production cost will be higher than plants' revenue. That is why the good quality of material availability plays a vital role in recycling plants of their economic certainty in the matter of continuous production. Then, scenario 2 shows that it is strongly recommended to produce the transparent product due to it has the highest overall value, like NPV and IRR percentage which higher 27% than the 10% of discount factor. In the colored product, even though still feasible, but, the IRR only shows slight 4%-5% higher than the DF standard, means that it does not really recommend to produce "colored product" with the similar quantity of raw materials due to will only have slight margin. Moreover, the black-color product in scenario 2 does not recommend to be conducted or invested due to it has negative Net Present Value (-1,000,000,000), then, the IRR also only around 3%, which lower 7% than the standard value. Furthermore, scenario 3 gives the best condition of the plastic packaging plant to be conducted or do investment for, even with all of those 3 (three) types of products to produce, but, the transparent product may give the highest profit margin for the plant as their economic sustainability certainty assessment.

Overall, Table 6 concludes that with the scenario of calculating 3 (three) different colors of materials, each of it are feasible or strongly recommend running under scenario 3, this is due to the number of materials produced of the scenarios is high. But, there are a quite big number of margins or profit differentiation will be obtained if the plant produces a higher quality of raw materials as intended by material value conservation waste category #1 principle if compared with the lower quality. It can be seen in the comparison of the transparent material with colored or black-color materials. For example, in scenario 2, the present value and IRR percentage of transparent are 200% higher compared to the calculation of the black-color material.

4.2 Environmental Sustainability Impact

There are various phenomenon that may support the environmental sustainability assessment [23] and the impact obtained from the increased number of the application of MVC design principle in the plastic packaging products. If analysed from the plastic life cycle sequence, in the first phase, there will be fewer non-renewable resources and energy extracted which intended to produce plastic *virgin* products [24]. This is because the original products will be replaced by the recycled pellets. Furthermore, there will be less impact pollution to the air, landfill, and water due to petrochemical activity to produce the original products [25]. Moreover, the increasing number of recyclable plastic waste availability means that there will be fewer materials directly thrown away to the environmental and the ocean. Therefore, it can minimize the number of unproductive landfill due to plastic waste accumulation and also it can minimize the negative impact of micro plastics on the marine habitat and human health through food consumption [26].

4.3 Social Sustainability Impact

The proof of increased economic sustainability factor of plastic recycling plants may impact social sustainability from the informal and formal factors. In the informal factor, there will be a higher employment rate, also, at the same time reducing the unemployment of the local people [27]. Formal factor aspect can encourage more of medium or even large enterprises in the plastic recycling industry that can reduce social inequality in society. Basically, the more enterprise operate in a country, then, will be more welfare the people, then, this is the true social sustainability impact can be achieved.

5. Discussion

Plastic waste management becomes an attractive topic lately, due to its various benefit and application, but at the same time, it gives a huge negative impact if do not manage properly. It is shown that the MVC design principle may provide a good impact on the economic sustainability of plastic recycling plants and the application may increase the available number of good end of life value of plastic waste.

Moreover, it requires active contributions of the stakeholders of plastic product, named the legislator institutions, government institutions that acting as a regulator or promoting agencies, law-enforcement institutions, plastic packaging producers, and households in order to make the scenario settled in this research can work properly [28, 29]. Furthermore, as the number of material availability increased means that the production capacity should be upgraded and it requires more investment for the machine, area expansion, raw material storage, end product storage, and more labours needed.

6. Conclusion

Material value conservation intend to maximize the residual value of a product at its end of life phase, one of the ways is through the design principle implemented to the product. Has been proven that the proposed principle of MVC may leads to a good impact on the economic sustainability of plastic recycling plant through the increased of profit margin. Therefore, the stakeholders of plastic packaging products, especially the flexible packaging may consider implementing the design principle of MVC intentionally and repetitive implementation to encourage the increased availability of good quality of recyclable plastic waste. Subsequently, more sustainable of environment and society can be realized in the future.

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