

# Eco-Impact of Plastic and Paper Shopping Bags

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## ABSTRACT

This article describes the study of the eco-impact of plastic and paper bags using the life cycle impact assessment (LCIA) technique under three different options: usage and disposal criteria with the existing usage behavior to reuse and governmental policies to recycle (option1), usage and disposal criteria as per consumers' perceptions if systems are in place (option2) and usage and disposal criteria in case of absence of recycling systems (option3). The first stage, which was the baseline for other options, comprised of the study of the eco-impact of plastic and paper bags in the manufacturing phase, without considering the usage and disposal phases. LCIA was performed by the Eco-indicator 99, a damage oriented method for LCIA in SIMAPRO 7.1. The single score values calculated by the Eco-indicator'99 were considered as a directive to compare the environmental impact made by plastic and paper bags and a detailed explanation of the results is provided in this article. The next stage was the study of the eco-impact of these bags including their usage and disposal phases. This was undertaken with the three different options as stated above and the results derived were compared with the results derived from the baseline study, which is the main focus of the study under discussion. The values for usage and end-of-life phases were obtained from the questionnaire survey of different user groups of shopping bags in China, Hong Kong and India. The results of this study show that the eco-impact of plastic and paper bags was very high if there were no usage and disposal options provided. When the eco-impact values from options of existing possibilities and consumers' perception were compared, the eco-impact value was lower in option 1 in all the three countries for both types of bags, which is mainly attributed to the fact that in option 1, a higher percentage of reuse is preferred to recycle and disposal to landfill categories. Also the eco-impact of these two types of bags was studied with and without the presence of recycling systems in China, India and Hong Kong, where the eco-impact was lower due to the presence of recycling systems. The results

indicate that a higher percentage of reuse could significantly trim down the eco-impact of plastic and paper bags. Consumers' perceptions and usage behaviors in connection with respective government's policies and implementation of recycling systems could be highly decisive in reducing the eco-impact of plastic and paper shopping bags.

**Keywords:** Plastic bags; Paper bags; Life cycle impact assessment; SIMAPRO; Eco-indicator'99; Reduce; Reuse; Recycle; Disposal to Landfill.

## INTRODUCTION

To cater to the different shopping needs of people, there are many types of shopping bags available in today's market. An endless variety of raw materials and technologies is employed to manufacture them. The most popular ones are plastic and paper bags and they are also the ones subject to a number of constructive criticisms as well [1-15]. This is a hot topic of the day to conclude which one is better in terms of environmental impact [1-15].

Plastic bags are made from non-renewable resources, where the key ingredients are petroleum and natural gas. Polyethylene - High Density, Low Density, linear low-density polyethylene (LLDPE) are the raw materials widely used for the manufacture of plastic bags [16]. The shopping bags used by supermarkets are ideally produced out of LLDPE to get the desired thickness and glossy look. And if one needs very thin and gauzy bags then LDPE would be an ideal choice [17]. Plastic bags seem to be slender and light and hence are easy to carry. As per Arlington, Virginia-based American Plastics Council, plastic bags are cheap to produce and that they have occupied as high as 80 percent of the grocery and convenience store markets [18].

Paper bags are made out of Pulpwood from trees, which is a renewable source. However, we get paper bags from felling of a tree which blemishes both

plants and animals and also their production process engrosses energy created by coal or natural gas. The created pulp will be converted into a paper bag by different processes and machines after consuming tremendous amount of energy from fossil fuels, electricity, various chemicals, etc. [1].

Both plastic and paper bags are used by most people for shopping needs, although frequency and percentage of use differs between individuals. Since both of them are professed to be a symbol of a throw-away society, quantification of environmental impacts made by them is mandatory and life cycle assessment is one of the useful tools to decipher the same. A life-cycle assessment (LCA) is an analytical tool which can help researchers to understand the environmental impact of a product from the acquisition of raw materials to final disposal [19]. In accordance with the definition given by The Society of Environmental Toxicology and Chemistry (SETAC), LCA is an iterative process to evaluate the environmental burdens associated with a product, process or activity by identifying and quantifying energy and materials used and waste released to the environment; to assess the impact of the energy and materials used and released to the environment; and to identify and evaluate opportunities to effect environmental improvements. The assessment includes the entire life cycle of the product, process or activity, encompassing extracting and processing raw materials; manufacturing, transportation and distribution, use, reuse, maintenance, recycling and final disposal [20]. According to ISO 14040, an LCA study essentially consists of four interconnected steps/phases [21]:

- Goal and scope definition
- Life Cycle Inventory (LCI) analysis
- Life Cycle Impact Assessment (LCIA)
- Interpretation

Further details about Life cycle assessment (LCA) can be found in [19-23].

Some of the previous studies [24-27] dealt with LCA comparison of plastic and paper shopping bags and have brought out some issues and concerns. Different conclusions were drawn from the above studies, which are given below:

1. The study by Franklin Associates, which compared the impact of single-use paper and polyethylene bags in the USA, assumed a ratio of 2 plastic to 1 paper bag and concluded that plastic carry bags had lower environmental

impacts and used less energy at current recycling rates [23, 25-26].

2. From the study carried out by Bentley West Management Consultants, South Africa, contradictory results were presented and also it was advised to conduct a streamlined LCA study to conclude which one is more environmentally friendly in the South African context [24].
3. Ecobilan study concluded that except for the production of waste and risks linked to discarding, the environmental advantages of paper carrier bags are primarily related to energy consumption: low consumption of non renewable energy, low contribution to the greenhouse effect and limited photochemical oxidant creation in comparison to plastic carrier bags [27].

The above said studies are some of the important studies earmarked for dealing with only plastic and paper bags. There are many studies that have investigated the environmental impacts of various shopping bags and included plastic and paper bags too [28- 33]. In some of these studies [29-33], an end-of-life assumption was included to model the LCA of shopping bags to exemplify the cradle-to-grave assessment of shopping bags. However, to have a better understanding of eco-impact of various shopping bags, the cradle-to-grave study must employ real data of recycling/reuse/landfill options, taken from the consumers of shopping bags. This current article bridges the above mentioned gap and describes the eco-impact of plastic and paper bags with the end-of-life scenarios modelled from the actual results which come from the users of plastic and paper shopping bags.

Consumer behavior and governmental policies play an important role in the disposal stage of shopping bags. Usage and disposal stages consist of three important platforms – reuse, recycle and disposal to landfill. Notwithstanding the capability of certain types of bags to be recycled and reused, it is in the hands of customers to reuse a bag until it can be discarded or recycled, i.e. to reuse shopping bags many times till they can be disposed of and to keep them in recycling bins provided by the government, rather than disposed of to landfill, which is detrimental to the environment as far as eco- impact is concerned. It is the responsibility of the government to provide more recycling options and viable policies to set things in place in terms of recycling. Frequent promotion of recycling options by the government and the behavior of the consumer to reuse the shopping bags till they can be discarded becomes crucial to reduce the eco-impact.

This research study investigates the consumer behavior and governmental policies in China, Hong Kong and India by the following three options:

1. Usage and disposal options in China, India, and Hong Kong according to the existing usage behavior and governmental policies (Option 1).
2. Usage and disposal options in China, India and Hong Kong according to consumer's perception (Option 2).
3. Usage and disposal Options in China, India and Hong Kong if there is no recycling system provided by government (Option 3).

## EXPERIMENTAL

### Exploratory Study Of LCIA Of Plastic And Paper Bags

This current study revolves around the life cycle impact assessment (LCIA) of plastic and paper bags. The initial step of this study is the collection of the secondary data for LCI which was obtained from the final report prepared for Environment Australia in 2002 [30]. The same data can also be referred from an updated version of this study published in 2004 [31].

Data pertaining to this study focuses on main issues such as material consumption, energy needed for manufacturing process, green house gas emissions.

The goal of the study is to analyse the eco-impact of plastic and paper bags with the available data (cradle to gate) in the first step. During the second step, to study the effect of consumer's attitude and policy dimensions on eco-impact of them (cradle to grave). The scope of this study includes the LCA obtained from the available data, and other areas formed the related boundaries. The functional unit of this study was derived from the literature of relevance [30-32] i.e. sufficient capacity for a household consuming approximately 70 grocery items which were carried away from a supermarket in shopping bags every week for 52 weeks.

The forte of this study is the usage of actual data on disposal scenarios collected through a survey from the actual users of plastic and paper bags in China, Hong Kong and India amongst different user groups of shopping bags, which differentiates our work from the previous studies mentioned earlier [28- 33]. The results from the survey are used in Life Cycle Impact calculations in usage and disposal states under three categories: usage and disposal criteria with the existing possibilities to recycle/reuse, usage and disposal criteria as per consumer's perception if systems are in place and usage and disposal criteria in

case of absence of recycling systems. These stages are compared with the life cycle stage without usage and disposal criteria.

### Life Cycle Inventory

The energy and pollutants data for plastic and paper bags for the functional unit considered was taken from the previous studies [30-31] as tabulated in *Table I*.

*Table I* shows that plastic bags consume significantly less energy than a paper bag does. This is applicable to green house gas emissions as well.

TABLE I. Life Cycle Inventory data of plastic and paper bags.

Alternative	Weight/bag	Bags/year	Material Consumption	GHG(CO <sub>2</sub> emissions)	Primary Energy
Plastic bag	6 Gms	520	3.12 Kgs.	6.08 Kgs.	210 MJ
Paper bag	42.6 Gms.	520	22.15 Kgs.	11.8 Kgs.	721 MJ

### Survey Results Of Usage And Disposal Behavior Of Plastic And Paper Bags

The major focus of this current research is to investigate the study of influence of human behavior and governmental policies on the eco-impact of plastic and paper bags. A survey was conducted among students, home makers, employed professionals in various professions of different age groups, who are the users of shopping bags and who have the knowledge on the usage and disposal behavior of the same in China, Hong Kong and India. This survey was mainly aimed at understanding consumers' perceptions of reuse, recycle and disposal to landfill, recycling possibilities with existing government provisions/policies for recycling, willingness to support recycling systems/policies to reduce the percentage of landfill and so on. Further details about this survey can be found from reference [34]. The major results extracted from this survey are presented in *Tables II-IV* and VI.

From the survey results, usage and end-of-life disposal values can be deduced to the following options:

1. Usage and disposal options in China, India, and Hong Kong according to the existing usage behavior and governmental policies (Option 1) (*Table II*)
2. Usage and disposal options in China, India and Hong Kong according to consumer's perception (Option 2) (*Table III*).
3. Usage and disposal Options in China, India and Hong Kong if there is no recycling system provided by government (Option 3) (*Table IV*).

According to *Table VI* (which will appear later), one proportion of people from each country (In cases of China and India, it is half of the proportion nearly) said that there is no provision in their country to

recycle. If this holds good, then the values for usage and disposal should be different from the previous categories and the values are tabulated in *Table IV*.

TABLE II. Values for usage and disposal option according to existing possibilities.

Percentage	Plastic bags			Paper bags		
	China	Hong Kong	India	China	Hong Kong	India
Recycle	21%	22%	18%	31%	25%	25%
Reuse	46%	42%	55%	42%	38%	28%
Sent to Landfill	33%	36%	27%	27%	37%	47%

TABLE III. Percentage of shopping bags that can be recycled/ reused/sent to landfill according to consumer perception.

Percentage	Plastic bags			Paper bags		
	China	Hong Kong	India	China	Hong Kong	India
Recycle	24%	21%	33%	46%	45%	47%
Reuse	32%	30%	31%	32%	38%	22%
Sent to Landfill	44%	49%	36%	22%	17%	31%

TABLE IV. Values in case of absence of recycling system.

Percentage	Plastic bags			Paper bags		
	China	Hong Kong	India	China	Hong Kong	India
Recycle	0%	0%	0%	0%	0%	0%
Reuse	46%	42%	55%	42%	38%	28%
Sent to Landfill	54 %	58%	45%	58%	62%	72%

## RESULTS

### Life Cycle Assessment Analysis and Results Without Usage and Disposal Options (Cradle to Gate Stage)

This section describes the processing of energy and pollutants data by one of the commercial LCA softwares – SIMAPRO 7.1. The Eco-indicator 99, damage oriented method for LCIA is employed to assess the environmental impact. Eco-indicator'99, models the life cycle of a product in five stages, such as Characterisation, Damage Assessment, Normalisation, Weighing, Single Score Analysis and a detailed explanation of the working principle of the same can be referred from [35-38]. Results of the analysis are tabulated in *Table V* and given in *Figures 1-4*. Plastic bags score out paper bags in terms of reduced environmental impacts. The detailed results

of this analysis and a comprehensive interpretation of results can be found in [23].

### Life Cycle Assessment Analysis and Results With Usage and Disposal Options (Cradle to Grave Stage)

The results of these three options 1, 2 and 3 were employed to find out the eco-impact of plastic and paper bags and were compared with the results obtained from without disposal options (baseline study). For this category, only single score results in numerical format are presented and they are compared with the results from without disposal options in numerical format listed in *Table V* and also illustrated in *Figures 5-7*.

## DISCUSSIONS

Table V and Figure 5 explain the comparison between without and with usage and disposal options according to existing consumer behavior and government policies. In all the cases, the eco-impact values are lesser than those without usage and disposal options. When the comparison is made

between the options from three countries under discussion, it can be seen that for plastic bags, the eco-impact values from India is less compared to other countries, which is due to the fact that the reuse option is most selected by Indians.

TABLE V. Comparative results of eco-impact of plastic and paper bags.

Total Points	Without Usage and Disposal Criteria	China Option 1	China Option 2	China Option 3	HK Option 1	HK Option 2	HK Option 3	India Option 1	India Option 2	India Option 3
Paper Bags (Pt)	126	72.9	85.5	73.0	78.0	77.9	78.1	90.6	98.1	90.7
Plastic Bags (Pt)	36	19.3	24.3	19.5	20.7	25.0	21.0	16.0	24.5	16.3

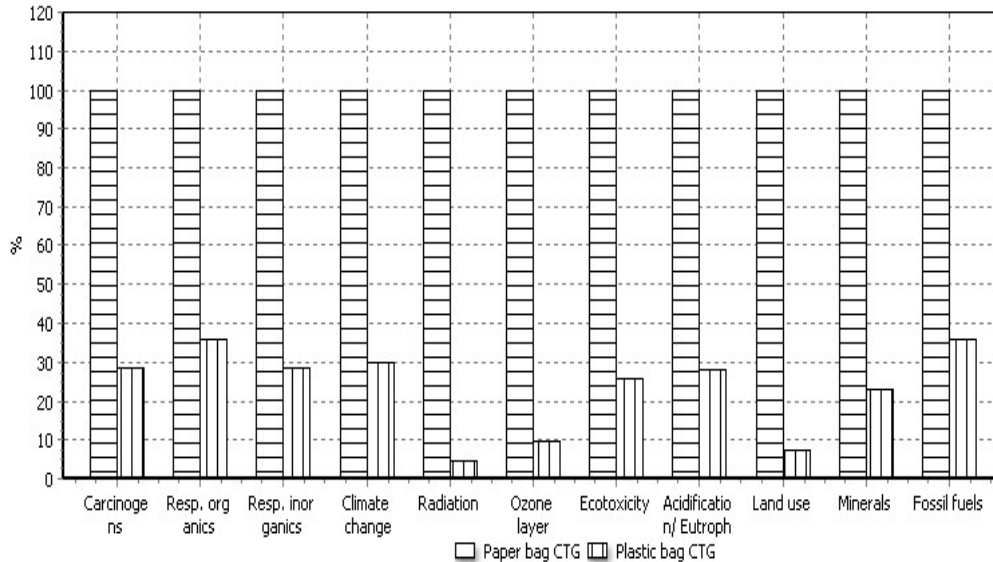


FIGURE 1. Characterization values.

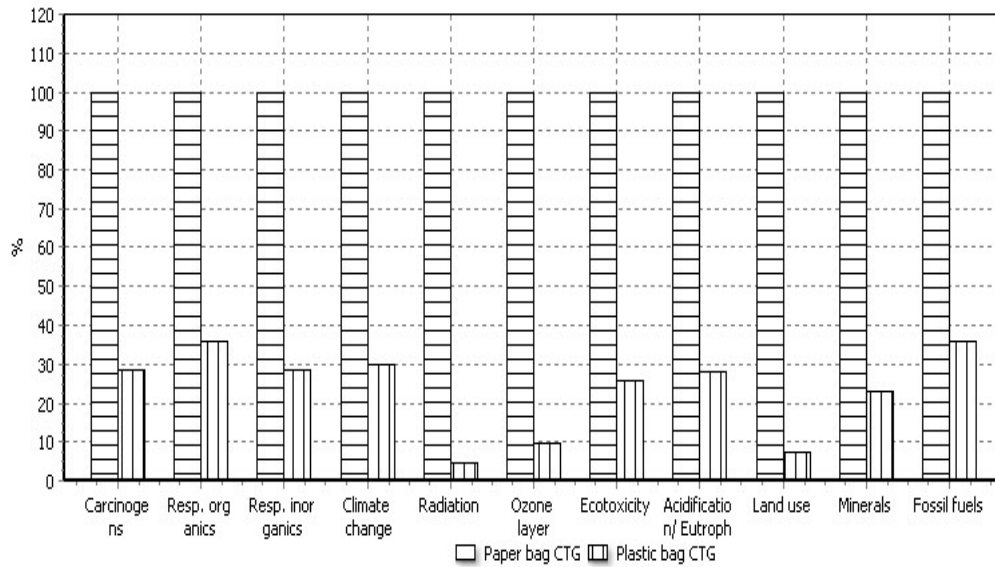


FIGURE 2. Damage Assessment results.

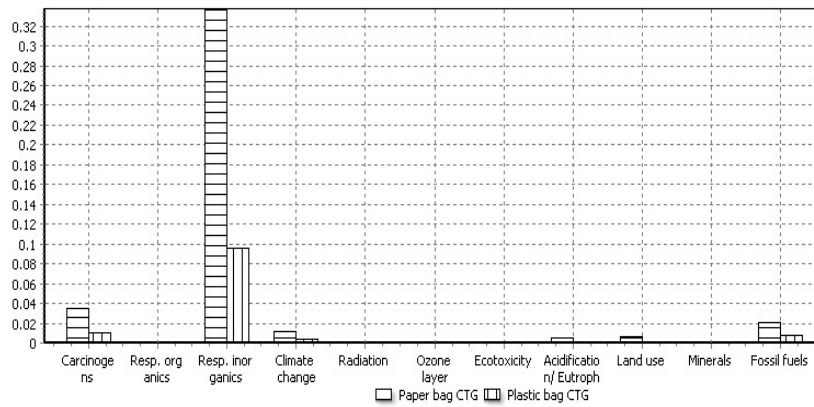


FIGURE 3. Normalization values.

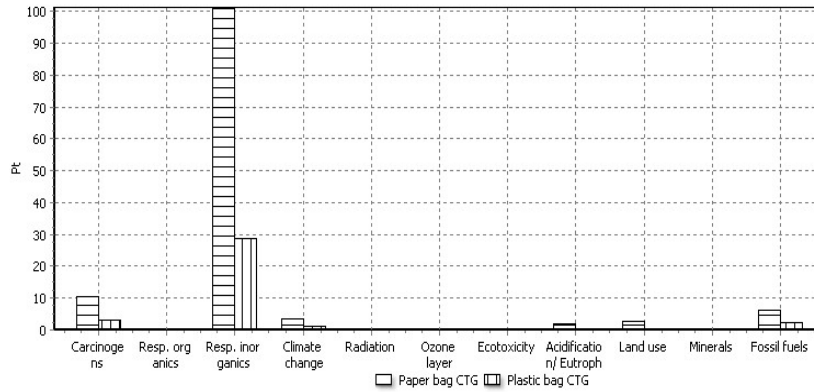


FIGURE 4. Weighing values.

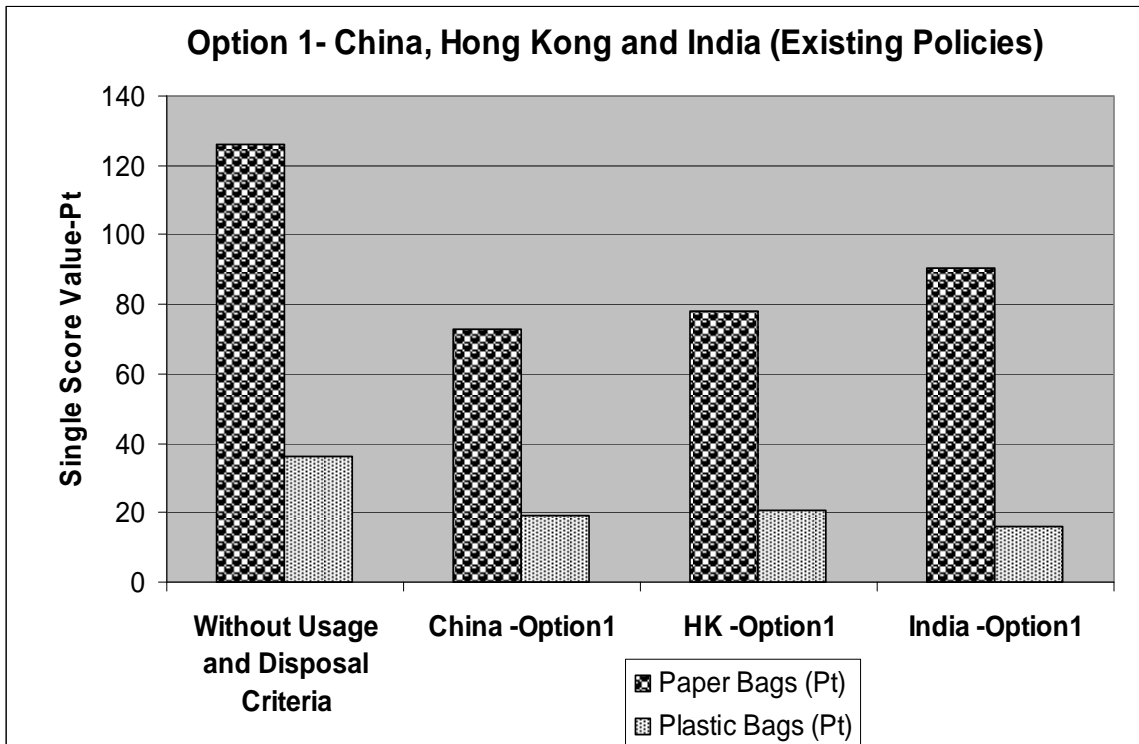


FIGURE 5. Option 1- China, India and HK (Existing Policies).

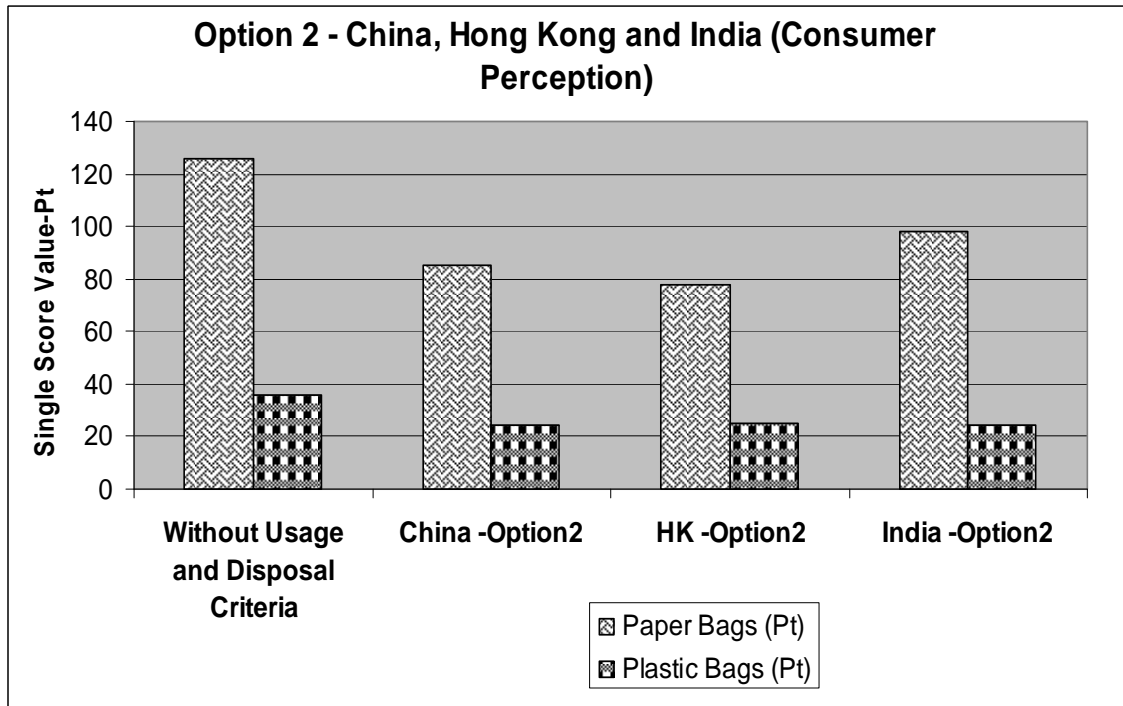


FIGURE 6. Option 2 - China, India and HK (Consumer Perception).

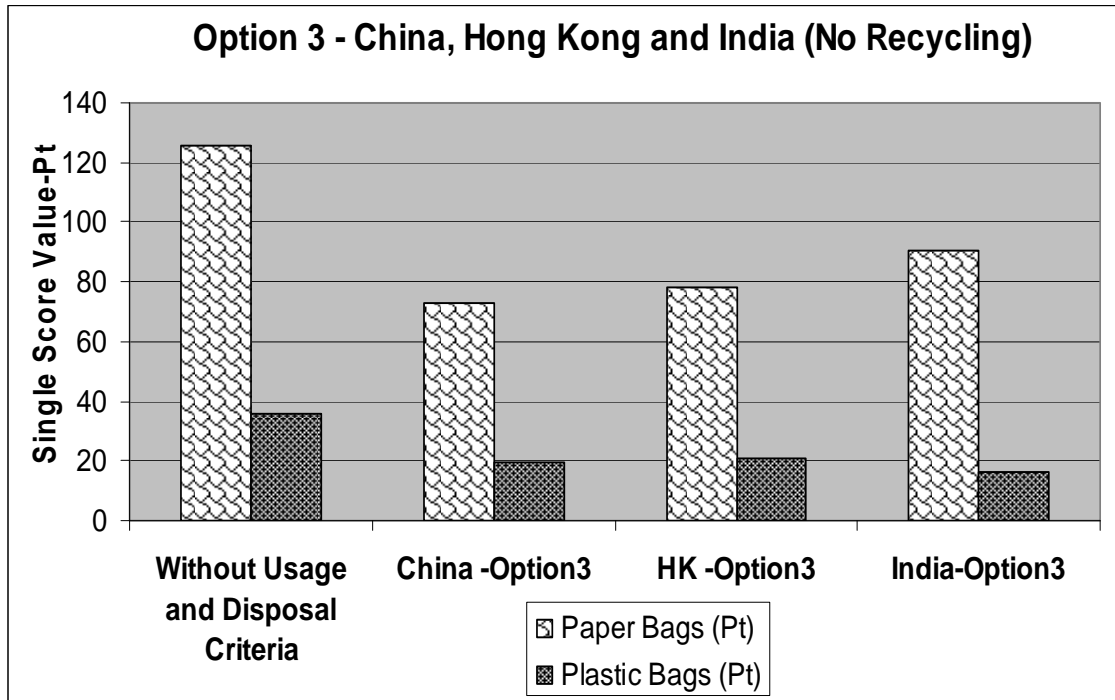


FIGURE 7. Option 3 - China, India and HK (No Recycling).

The influence of the reuse option is the same for paper bags in China and Hong Kong compared to India. Based on the above results, one important point to be noted here is that if any product is not reused till the end of its life, the concerns on environmental impact is huge. If the bags are not recycled and sent to landfill more, the eco-impact concerns are more acute than the manufacturing and usage state. Hence, usage and disposal of shopping bags or any other product assumes greater significance in eco-impact.

Table V and Figure 6 describe the comparison between without and with usage and disposal options according to the consumer's perception on usage and disposal values. In all the cases, the eco-impact values are lesser than those without usage and disposal options here too. But if the eco-impact values between options 1 and 2 are compared, the eco-impact value is comparatively less in option 1 out of the values from different countries for both bags, which shows the existence of difference in values out of perception and actual scenario. This is mainly attributed to the fact that in option 1, more percentage of reuse is opted than the recycle and landfill categories. Similar to the comparison made in option 1, if the eco-impact is compared between three countries under option 2, China has lower eco-impact than other two for plastic bags, due to the same reason discussed in option 1, and the same case can

be observed for paper bags in Hong Kong compared to its counterparts. It is mandatory to reuse the bags until they are completely discarded at the end-of-life and they can be forwarded to other options, where recycling is a better choice. The same is confirmed from this study also that more the percentage of reuse opted; less is the eco-impact.

Table V and Figure 7 emphasize the comparative look between without and with usage and disposal options in case of absence of recycling systems. Similar to previous options, in this option also, the eco-impact values are lesser than that of without usage and disposal options in all cases. From the survey results explained (Muthu et al 2010), one of the essential parts to be recollected here is the provision of recycling systems in India, Hong Kong and China. The values for this category are given below in Table VI.

The important quintessence of governmental policies lies in the values of options 1 and 3. To compare the options 1 and 3, the following weighted average equations are employed from Tables V and VI:

$$\text{China: } 54\% * SSV_1 + 46\% \text{ of } SSV_3 \quad (3)$$

$$\text{Hong Kong: } 66\% * SSV_1 + 34\% \text{ of } SSV_3 \quad (4)$$

$$\text{India: } 53\% * SSV_1 + 47\% \text{ of } SSV_3 \quad (5)$$



where SSV represents the Single Score Value.

The results according to the above said equations are tabulated below in *Table VII* and illustrated in *Figure 8*.

*Table VII* and *Figure 8* highlight the difference between the eco-impact values in case of presence/absence of recycling systems among three countries chosen for this study. It can be well understood from the results that the absence of recycling systems causes the material to be sent to landfill, which actually contributes more to eco-impact values rather than having a recycling system in place. If policies of these governments have been reconsidered and recycling systems are encouraged and if they are in their appropriate places, the percentage of recycling options will increase and it is beyond anybody's doubt that the eco-impact will come down enormously.

TABLE VI. Provision of recycling system.

Recycling provision	system	China	Hong Kong	India
Yes		54%	66%	53%
No		46%	34%	47%

TABLE VII. Comparative values for options 1 and 3.

Impact Score in Pt	China	Hong Kong	India
Paper Bags	72.95	78.05	90.64
Plastic Bags	19.39	20.84	16.08

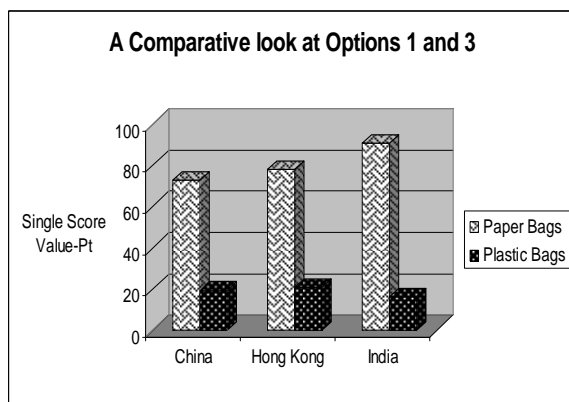


FIGURE 8. Options 1 and 3 – A Comparative look.

It was estimated that 100 billion to 1 trillion plastic bags are produced worldwide per year [39-41] and majority of them were discarded [41]. It was reported that China consumes up to 3 billion plastic bags daily [42]. Landfill survey Environmental Protection Department of Hong Kong indicated that some eight billion plastic shopping bags are disposed of at landfills every year. This translates into more than three plastic shopping bags per person per day in Hong Kong [43]. India produces 2 million tonnes of plastic bags and the per capita consumption is 2 kg [44]. In all the three countries under discussion, there are stringent rules to consume and manufacture ultra-thin bags to combat against the pollution due to the disposal of plastic bags [45]. Introduction of levy on plastic bags in China could save about 2.4 million to 3.0 million tonnes of crude oil every year and cut 7.6 million to 9.6 million tonnes of carbon dioxide emissions every year [46]. Nearly 4 billion trees or 35% of the total trees cut around the world are used in paper industries on every continent [47]. Each year, Americans use about 10 billion paper bags, which results in the cutting down of 14 million trees [48-49]. It takes 14 million trees to make the 10 billion paper sacks used in the US. The average family uses 400 paper bags per year [49]. Enormous natural resources are being spent to manufacture both of these bags and it is our responsibility to reuse them to the maximum possible extent to curtail down the environmental impacts to the minimum possible extent.

The emphasis on interpretation phase of this analysis is not to conclude which one is much better. The conclusion needs to be drawn on how to reduce the environmental impacts by both of them. One of the possible ways to decipher this is by means of finding ways to reduce, reuse and recycle both of them. Many retail stores have started utilizing this philosophy of reducing, recycling and reusing the grocery bags. Building up public awareness and motivation to reduce, reuse and recycle both these bags will definitely help to resolve the environmental problems to a greater magnitude.

## CONCLUSION

Among different phases of a product's life cycle, disposal phase assumes greater significance as far as the eco-impact is concerned. The peculiar part of the disposal phase is, it is mainly decided by consumer behavior and governmental policies to decide upon the end-of-life scenarios. In this study, an exploratory study was performed to analyse the life cycle impact assessment study of paper and plastic bags by using secondary data for LCI till manufacturing phase. As far as the end-of-life phase is concerned, it is mandatory to use real values rather than assumptions.

The values for this phase should be obtained only from the actual users, since it solely lies on the hands of the consumers. Hence the inputs from public opinion were employed to deduce the values for end-of-life scenarios. In the first stage of LCA modelling without disposal options, according to the LCI data and the software used for this study, which also has certain hypotheses and assumptions, plastic bags are found to be little better in terms of environmental impacts compared to paper bags. However this stage of conclusion solely depends upon the secondary data and the LCA software employed for the study. Public opinion was used to model the usage and disposal values of LCA, where the eco-impact of both bags was less in all cases. As expected, it was found that the more the option of reuse is chosen, the lesser is the environmental impact and this is proved in all of the options under study in this research work, which was described in detail. This has been very clearly illustrated between different options (options 1, 2 and 3) and even between different countries under the same option too. Consequently, the key here is people must reuse the bags till they are discarded. Once they decide to discard, the other best option would be sending to recycling rather than throwing it to landfill. Also the eco-impact values were plotted with and without the presence of recycling systems in China, India and Hong Kong, where the eco-impact is lesser in case of the presence of recycling systems, which enlightens the importance of the presence of recycling systems in reducing the eco-impact. Hence the consumer's behavior and governmental policies are pivotal to plunge the environmental impacts made by these two bags. Though it is inevitable to accept certain environmental impacts until the manufacturing stage of these two bags; further reduction of environmental impact by means of reusing the bags until they attain the last point of life entirely lies in our hands. It is mandatory to preserve our living planet and we have no choice except conserving our planet.

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