

Economic Practices in Plastic Industry from Raw Material to Waste in Pakistan: A Case Study

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Abstract: The global trade economy is worth \$12 trillion per annum with \$3 trillion dedicated to materials only. A significant amount of almost 75% of global waste is produced during materials processing and after their use. While considering materials, plastic in specific did modernize the way product manufacturing was done in earlier times. Keeping in view the significance of plastic and its ever embryonic trend in terms of its end-user demand, results of a detailed study based on extensive surveys from six different industrial estates are presented highlighting economy practices adopted at industry and societal level, sources of raw material, manufacturing practices, organizational size, demographical product distribution, variety of plastic types and products, plastic waste reprocessing and management, analysis of plastic production in Pakistan in addition to the global trends. It is concluded that in Pakistan plastic industry still mostly follow the linear economy practices at large. However, a need for circular economy practices implementations is recommended based on its existence at some scales to address the challenges ahead.

Key words: Plastic, linear, circular, economy, waste, practices.

Introduction

It is generally observed that most of the product's composition gets tagged as waste and left unattended in the environment after its utilization (Yuan et al., 2006).

Linear vs. Circular Economy Practices

Circular Economy concept presented is observed distinct from the rest of material management concepts for the utilization of resources for a sustainable tomorrow. This is attributed to the adaptive practices for product development from design to discard, with specific focus on the utilization of manufacturing materials repeatedly for the longer period, if not forever. Before evaluating the circular economy principles, it is important to consider the ongoing industrial and societal practices.

Although most present industrial practices claim to be efficient in terms of labour cost, product quality, production rate and logistics etc., still major percentage of industries during each manufacturing cycle, follow linear approach and utilize virgin resources, which are a finite and are depleting over time. End users consume products until the end of their useful life and replace them with a new one. Linear approach jeopardizes the prospect demand and consumption cycle, which are diligently aligned with the economic equilibrium and environmental concerns. Hence waste generation in the current era has longitudinal projections depicting wastes to be tripled by the year 2100 (Hoornweg and Bhada-Tata, 2013). Linear economy approach is shown in Figure 1.

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Figure 1: Linear economy.

The concept of recycling is adopted at the end of useful life of any given product when utilizable proportions for a product are damaged beyond the repair threshold. Recycling is observed advantageous in contrast to considering products as a total waste (White et al., 2012; Guerrero et al., 2013). Circular economy practices retain product's value throughout its life cycle and are accomplished by strategic planning for product design, manufacturing and consumption. In comparison to inferiorly graded recycling practices which are globally deployed for most part, circular economy is concluded a proactive approach rather than a reactive one towards minimization of economic resources spent on the product development (Ghisellini et al., 2015). Therefore implementation of circular economy practices would boost up the global economy by \$1 trillion considering materials only: job prospects by a count of 100,000 with subsequent accumulated saving up to 100 million tons of material within next five years (Waghay, 2014).

Role of Linear and Circular Economy for Plastic Material and Plastic Waste

Keeping in view the above mentioned economy practices, present study is focused on plastic as material which is extensively used in the form of different products and plastic being waste has its subsequent impacts. Being an industry projected to worth a total of \$ 654.38 billion, plastic has ascertained its sustainability in the global market for the years to emanate (Grand View Research, 2015). Over time plastic has evolved in terms of its compositional attribution through consistent research adaptations and has substituted itself for other equivalent material types (fabric, glass, rubber, ceramics, metals) being inexpensive, lightweight, resilient, long-lasting, anti-corrosive, electrically innocuous, heat resistant and variety of applications from grocery handbags to biggest flying machines in aeronautics (Thompson et al., 2009).

Realizing versatility of application of plastic products, within a time span of last 50 years the plastic has exponentially grown in its demand by 20 folds; production cycle is projected to further double up its current capacity within next two decades and quadruple by year 2050. The global production of plastic per annum in the era of 1950's was merely around 0.5 million tons per annum and has increased to 260, 299 and 311 million tons per year in 2008, 2013 and 2014 respectively, showing almost 4-5% steady rise per year (Neufeld et al., 2016). Overall an increment of 500% of plastic production has been observed in the past three decades, showing projected demand till 2050 to be as high as 850 million tons per annum (Kreiger et al., 2014). This is attributed to the higher consumptions of plastic products by the end users, which on wider spectrum are being dealt with same linear practices, thus adversely contributing towards the availability of raw resources and alarmingly raising the environmental concerns.

Another major concern in the escalating trend is the consideration of how plastic economy is proportionally aligned towards the altering demographical trends. Keeping in view the global socio-economic trends, 3.2 billion individuals from middle class of economy will be accommodated by the end of year 2030 (Kharas and Gertz, 2010), which earlier was estimated as 1.8 billion in the year 2009. Relating to Pakistan, 5.92 million of individuals moved within the country, of which 87.6% opted for urbanization while 12.4% preferred over the contrary. Of the total population more than 50% are as of today settled in the cities (Jamal and Ashraf, 2011). This on one hand is a good indicator as an improvement on economic grounds and quality of living standards, but at the same time, it provides challenges for a sustainable supply of demands and reutilization of present resources, controlling resources depletion and costs deemed for exploration of newer potential alternates.

Plastic Material Consumption, Plastic Waste, Plastic Recycling and Environmental Concerns

The linear trend towards material consumption can be deduced from the fact that, of the cumulative 2.6 trillion pounds of trash produced globally, a mere 1% of it is being recycled. Figure 2 shows practices followed by both the developed (high income) and underdeveloped (low income) countries to discard wastes as landfills to open dumps at large (Siddique et al., 2008; Hoornweg and Bhada-Tata, 2012).

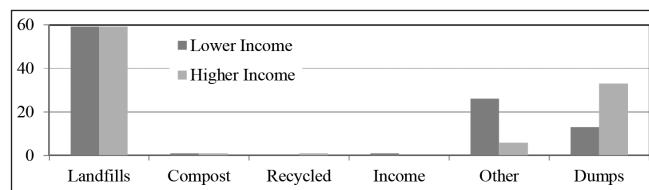


Figure 2: Pollutant handling countries with higher income and lower income.

Keeping in view the linear consumption of plastic, it takes significantly longer time up to 450 years for its particle diffusion into the environment (Kreiger et al., 2013). In equivalently given timeline excessive amount of plastic will probably get riled up and will scale up the concerns. Plastic is observed to share 1% of carbon budget globally and is projected to be at 15% in year 2050. Regarding adaptability of linear approach towards plastic utilization cycle, it is realized that the oceans which do cover 71% of earth in total are presently polluted by 88% (PNAS, 2014). As a pollutant, globally plastic discards are eight million tons per annum in oceans (Lebreton et al., 2012; Eriksen et al., 2014; Jambeck et al., 2015) and alarmingly the projected amount in oceans will be up to 10 folds in next five years i.e. by year 2020 (Harse, 2011; Becker et al., 2012). Plastic as a distinct environmental pollutant contributes 10% of the total hazards (organic 46%, metals 4%, glass 5% and paper 17%) (Hoornweg and Bhada-Tata, 2012). It is expected to cumulate as high as 300 million tons of discarding per annum (Panda et al., 2010; Jambeck et al., 2015; Seigné-Itoiz et al., 2015).

Mismanagement so far observed in the plastic utility cycle is observed responsible for momentous environmental concerns worldwide. Regarding resource consumption, plastic takes a dedicated share of 8% of total global oil production (4% gets utilized as feedstock and 4% during manufacturing process) (Plastics Europe and EPRO, 2008; Bhatti, 2010). With the ever growing demands of plastic products, the projected estimations of oil consumptions for the year 2050 is as high as 20% (Group and MacArthur, 2013).

In order to meet the future plastic material demands by preserving virgin resources, it is proposed to collect recyclable plastic waste from the environment and after being duly processed it must be put to use as a supply for the prospected development endeavours. But the fact is that the world today has been able to engage even less than 5% of plastic produced internationally, into the global recycling trade of which not all the plastic gets absolutely recycled (Velis, 2014).

In terms of classifying, the waste Europe predominantly demarcates packaging materials as a focused area where we can get out most of our recyclable material requirements from. Table 1 shows widely conducted European post-consumer waste analysis results and assuming that condition might be more or less the same for other demographics (Lazarevic et al., 2010; PlasticsEurope, 2015).

Table 1: Post-consumer waste analysis

<i>Categories</i>	<i>Post-consumer waste (%)</i>
Agriculture	5
Houseware, leisure, sport	3
WEEE	5
Automotive	5
Building and construction	6
Packaging	63
Others (Furniture, housing etc)	13

All mentionable globally utilized plastics can be categorized into the ratio contrast, enabling to understand the potential utilizable proportion available for the targeted industry. PET, HDPE, LDPE and PP with significant accumulated percentage to 59% are mostly considered ecologically innocuous and recyclable and potential indicator for recyclable industry (Table 2) (Guess and Haberman, 1968; Andrady and Neal, 2009). Table 3 shows demographical distribution for plastic production with China as a global leader followed by Europe and NAFTA (Europe, 2010; PlasticsEurope, 2012; PlasticsEurope, 2015). Pakistan imports plastic waste primarily from China and Middle East. This raises environmental concerns but at the same time provides potential opportunity in the form of increase in recyclable resources (Wath et al., 2010). Hence, with more plastic discards getting imported at national level, the fewer products have to be produced from virgin plastics, which would otherwise demand more economic, energy and time resources.

Table 2: Plastic types and their consumption

<i>Plastic type</i>	<i>Consumption (%)</i>
PET	7
HDPE	12
PVC	11
LDPE	18
PP	19
PS	7
Others	20

Table 3: Demographical distribution for plastic production

<i>Country</i>	<i>Production (%)</i>
China	24
Japan	5
Middle East, Africa	7
CIS	3
Europe	20
Latin America	5
NAFTA	20
Other Asian Territories	16

Japan is taking the lead in plastic recycling recently up to 77%, which was 39% and 73% in year 1996 and year 2006 respectively. This significant increase is because of the awareness programmes initiated and making effective regulations and their implementations closely aligned to the manufacturer's interests. In terms of recycling rate, Japan in comparison is far ahead of developed nations such as UK by taking a lead of an approximate 50%, while USA still being highly dependent upon landfills is lagging at a mere percentage of 20% (Japan, 2013; Japan, 2014).

Present Practices in Pakistan Regarding Plastic Products, Waste and Recycling

In Pakistan, solid waste generated is observed increasing at the rate of 2.4% per annum (Pakistan, 2015). Table 4 shows results of ministry of environment for solid waste produced per annum for urban and rural areas of Pakistan. Plastic being a proportionate of solid waste is known to transpire through three chief sources, which may include industrialized rejects, civic solid waste and agriculture waste rated at 16%, 21%, and 63% respectively. Pakistan is contributing 1.32 million tons per annum plastic waste, more than 50% of which are left unattended even after measures taken by the local government and related services (Yasmeen Ashraf Moten, 2013).

Table 4: National solid waste

<i>Area type</i>	<i>Tons per annum</i>
Urban areas	
Bannu	8760
Faisalabad	329230
Gujranwala	224475
Karachi	2420680
Hyderabad	275940
Peshawar	205860
Queeta	90155
Sibi	9855
Other cities	5261110
Rural areas	10624420
Sub-Total	19450485
Hazardous waste (3%)	583635
Total	20034120

For Faisalabad, Gujranwala, Hyderabad, Karachi, Peshawar and Quetta the respective percentages of plastic in solid waste observed are 4.80%, 5.5%, 3.60%, 6.40%, 3.70% and 8.20%. Pakistan faces significant inconsistencies between the values of the waste generated and the amount of it that does get reached to the re-processing units. Due to no proper system in place for waste management, difference is constantly increasing. The percentage of waste collected through different sources especially on account of the local scavengers also holds a lot of significance because of the contribution these individual entities put forward to keep environment relatively clean and encouraging the circular economy practices though at an elementary scale. These unorganized waste handlers do vary from city to city based on the utilizable waste. As a general consideration counts for cities of Faisalabad, Gujranwala, Hyderabad, Karachi, Peshawar and Quetta are 1500, 1200, 1200, 7000, 800 and 600 respectively (Yasmeen Ashraf Moten, 2013). Economic contribution by this informal sector is vindicated by the sum of collects that do later gets sold at competitive rates to be reused or get reprocessed (Shah et al., 2008). Plastic wastes that get locally treated are handled with poor practices by mixing different qualities of plastic (disregarding their inorganic compositions or thermo-dynamical perspective), resulting in substandard granularly formed plastic. The products made from these hazardous recycled wastes raise concerns for the end-user's health.

In Pakistan plastic raw material is mostly imported and manufacturing is also aligned using virgin material rather than recycled utilizations (Pakplas, 2016). Reuse, up-cycling and recycling practices are utilized in different sectors of Pakistan from individual to organization level. Recycling is observed practiced more in Pakistan, but mostly with quality compromises by not assessing the material types and compositions, resulting in lower grade quality products.

Pakistan is emerging at an impressive incremental rate of 16% per annum in the South East Asian market (Pakplas, 2016). On global scale employment count of plastic industry is around 1.45 million, 0.90 million and 0.37 million in Europe, USA and Germany respectively (Europe, 2015; Invest, 2015). Pakistan is at relative rate of 0.6 million, compensating both the skilled and non-skilled workers. In plastic industry, the workforce on provincial levels in Pakistan is summarized in Table 5 (Pakplas, 2016) showing Punjab is the hub and national leader in terms of plastic industrialization and post-consumer material management. There are almost 6000 established plastic product manufacturing units. Annual investment is \$206 million, out of which 49% is foreign direct investment (FDI). This shows that the potential of investment in plastic industry of Pakistan is quite high and can help revolutionize the industry to efficient standards. Out of total 6000 operational units, there are 5300 small and medium sized (SMEs) plastic manufacturing units in multiple localities nationwide (Pakplas, 2016). A total of 624,000 metric tons per annum plastic products are currently being produced in Pakistan. Out of this production, 49-95% gets realized in real terms, depending on variable factors. For this production, approximately 80-90% of the raw material being consumed is imported. In addition, per annum raw material production and consumption on local basis are 543,000 metric tons and 450,000 metric tons respectively (Table 6). PET is observed the most prioritized consumer plastic type in the country (Pakplas, 2016). Reference to the end user's perspective, per capita consumption of plastic in a developing country like Pakistan is 3-4 kg per individual (Pakplas, 2016), compared to a developed country like USA is 100 kg per individual (Gourmelon, 2015).

During this study, a survey questionnaire was developed to assess plastic utilization by manufacturers, distributors and garbage handlers. In first phase survey was conducted from 31 manufacturers (small to enterprise scale) of six industrial areas in twin cities

Table 5: National workforce in plastic industry

<i>Province/State title</i>	<i>Workforce (%)</i>
Khyber Pakhtunkhwa	7
Punjab	60
Baluchistan	3
Sindh	30

Table 6: National plastic resin production

<i>Plastic type</i>	<i>Local production (MT)</i>
PET	253000
PVC	156000
GPPS, HIPS, EPS	100000
Methanol Urea Melamine	34000

of Pakistan (Rawalpindi and Islamabad). Survey's questions included types of plastic used, quantity of raw material used, source of plastic resins, environmental hazards, quantity of recycled material, type of manufacturing process, source of power to run the manufacturing plants and methods adopted by industries to handle their rejects. Total utilization, commitment towards manufacturing and post consumption efficiency of plastic is determined. In second phase, survey was conducted from 15 garbage handlers to recognize and gauge the measures taken by them to manage postconsumer rejects and material recycling to get it back to the consumers again.

Results and Discussion

Based on the surveys, results summarized are discussed in detail as follows:

1. Operational size of plastic manufacturing establishments in Rawalpindi and Islamabad was determined keeping in view the European Union Standards i.e. employees count. This will enable to determine the factual position of manufacturing advancements made on the local level. It is observed that the sum of small and medium sized establishments is approximately 83% of the total establishments in the targeted area (Table 7). This trend is observed similar to the trends observed in the European plastic industry, dominated by the SMEs concluding sustainability of this industrial sector (Europe, 2015).

Table 7: Organizational size in Rawalpindi and Islamabad

<i>Size</i>	<i>Count</i>	<i>EU standards</i>
Micro	0	<10
Small	21	<50
Medium	4	<250
Large	5	<1000
Enterprise	2	>1000

- Commercial strength of these designated units was determined by defining a criterion to classify product reach of these organizations in terms of the client scope. With SMEs being occupant of the major market share, it is encouraging to observe that the surveyed organizations are capable to produce as per consumer's demands on national and international scales.

Table 8: Organizational scope

<i>Distribution reach</i>	<i>Count</i>
Inter city	3
Inter district	5
Provincial	4
National	15
International	5

- Origin of materials for plastic manufacturing industry is identified. It is observed from survey's results that 81.25% of raw material is imported from international sources and 18.75% is utilized from national sources and is observed in line with the published reports. Only 3.125% of manufacturers utilize recycled materials. This concludes that plastic industry in Pakistan is highly dependent on imports to fulfill national and international customer demands of plastic products. This shows implementation of linear approach for production and end-user's consumption. This needs careful consideration from economical perspective and plan for the recycling or up cycling considering circular economy trends.
- The variety in types of plastic products being manufactured by the industry are identified as packaging = 75%, pipes = 13, footwear = 9% and automobile = 3%. The trend for maximum proportion of manufacturing packaging provisions in Pakistan is observed similar to the projections made by European studies in which post-consumer waste was dominantly preoccupied by packaging

sector by 63%. The major reason is that packaging itself has been the top consumer demand ever since the start of plastic as industrial utilization.

- Classification of plastic types i.e. HDPE = 11%, LDPE = 8%, PP = 22%, PET = 34%, PVC = 25%, PS and others = 0% based on the graphical depiction from surveys. The highest production rate was observed for PET known as plastic Type 1 by 34% followed by PVC known as Type 3 by 25%. Trends show that the industrial establishments and national production trends are aligned with the demands as mentioned in Table 6. It is also observed that plastic is the top consumer demand and PVC has demand in the construction industry in the country.
- Regarding identification of energy source for plastic manufacturing industry, 93.75% of industry relies on hydroelectricity and 6.25% rely on natural gas. To cater energy demands of increasing plastic industry this needs careful consideration.
- Injection molding is identified the mostly used manufacturing process through surveys [Table 9] and is observed similar to the global trends. Although injection molding process adopted by industry follows linear approach, it is known to accommodate most resin types, fast production rate, high volume production, higher design flexibility and lower labour costs (Ruprecht et al., 2002; Rosato and Rosato, 2012).

Table 9: Manufacturing process

<i>Manufacturing process</i>	<i>Count</i>
Blow Molding	9
Extrusion Molding	10
Injection Molding	11
Thermoforming	2

- It was important to assess whether manufacturers agree for production considering standards, safety, environment and recyclable materials. Regarding this during visits and surveys, almost all industries assured of adopting technically defined safe practices to ensure environmental safety. A total of 33,642 tons of plastic products (cumulative of all the plastic types being utilized) were being developed by the surveyed manufacturing industries and all utilized the virgin materials. The rejected items produced during production are handled and considered differently because each plastic type does vary in their composition and manufacturing process and percentage of rejected parts as per

survey is summarized in Table 10. This represents a good trend in the plastic manufacturing community as it does represent that no rejects do get dumped as a surplus to the already existent environmental and economic concerns. Considerations selling the rejects to the lower tier market or opting to recycle the material again both encourage circular economy practices to a certain extent and enable to keep them in the material utilization cycle for longer periods.

Considering economic factor selling the discards into market onto cheaper rates, itself is an reassuring practice, because it enables product developers to utilize recyclable materials in the developmental processes instead of utilizing the virgin material which would cost higher. Regarding recycling material it must be considered that plastic reutilization into the manufacturing process is dependent upon the plastic type as plastic in general does lose a percentage of its compositional strength when reutilized. Moreover, a discarded unit of plastic can't be processed as whole at once, rather it needs to be mixed up with a proportion of virgin material to compensate the material strength. This practice was observed adopted by most of the surveyed manufacturers of the twin cities. Due to this, amount of industrial waste ending up in environment is observed less resulting in rheostat of economics.

Table 10: Rejected material reprocessing

<i>Type</i>	<i>Rejections (%)</i>
Environmentally dumped	0
Sold in market on cheaper rates	16
Recycled into manufacturing process again	84

9. Material management practices at the end of product's due life in Pakistan are mostly handled by the self-employed community scavengers working mostly on individual level. These individuals belong to the lowest economical background and in order to survive these individuals do opt for making nominal fortune from the societal material rejects. It is very unfortunate that the major percentage of this community can be categorized as child labour involved in this non-recognized or non-registered profession. This community endeavours at dawn by visiting dump sites in their surroundings and do look for utilizable items. These individuals working on a significant scale do in real terms put a great favour towards the society by reducing the waste proportion from the environment by collecting it and most importantly segregating the

objects in terms of their material types, which is an efficient cost factor in the material reprocessing techniques. The collected material from environ later get accumulated by the subjected mass to local collection points which again is managed by private entities. Here once collected material items are amassed in terms of the segregated material types. Later these accumulations are further preceded to the designated reprocessing plants, which do accomplish the technical proceedings of cleaning, shredding, melting and material granulation. This concludes the comprehensive view of the broadly applied post-consumer material handling cycle implemented on the national scale.

10. In this study a total of 15 surveys were collected from the individuals managing the garbage collection points in the twin cities of Pakistan. Major garbage collection observed was paper, glass, metal and plastic with maximum proportion collected as waste was plastic. As in plastic manufacturing industry, PET (SP-1) is the maximum utilized material in Pakistan, so similar trend is observed at the post-consumer utilizations because PET was the leading plastic type in the plastic discards and was also collected by the garbage collection individuals. It was observed that at each garbage collection point an average of 7.5 tons of plastic per annum was segregated and delivered to the reprocessing units in Pakistan. This bring significant amount of material shares back into utility cycle.
11. Regarding attitudes of end users i.e. the general population is observed linearly aligned. The cumulative depiction of the plastic consumption observed on both the industrial and societal level is presented in Figure 3. Based on the surveys from manufacturers and self-employed garbage handlers it is encouraging to observe that the practices in place by them do involve circular economy concept. However, challenge lies to give awareness to the end user in the society to manage the discards in a proper manner.

Conclusion

- Based on the detailed study, circular economy practices are observed present on industry and individual levels. However, linear practices are mostly deployed in the surveyed industries in Islamabad and Rawalpindi areas with similar trends observed on the national level. Due to this material

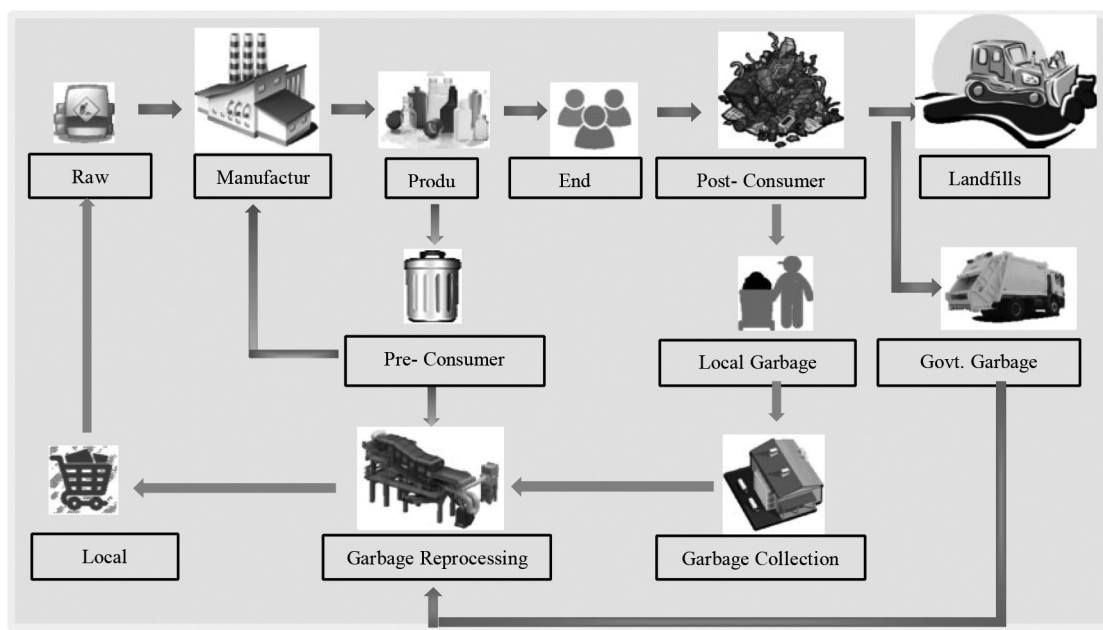


Figure 3: Plastic consumption cycle.

management issues need attention on broader implementation scale to be resolved.

- Manufacturers prefer to recycle the rejects or sell them to relevant market on comparatively low rates, hence justifying partial adherent towards the circular economy principles. It is also encouraging that the manufacturers adhere to the EU standards and infrastructure and anticipated that the country will soon adapt the environmental and economy supportive practices adopted internationally.
- Contrary to the developed countries, in Pakistan in addition to government services for waste collection, individuals do collection of majority of waste and its subsequent segregation for its reprocessing and ultimate inclusion back into the consumption cycle. These individuals take on a reactive stance towards the linear practices opted on the societal level, at large; but play a pivotal role to support circular economy to a significant extent by reducing man-hours in later reprocessing stages and by being unceasing source of recyclable provisions. This sector needs attention for proper employment to utilize their full potential being experienced and can help in circular economy for wastes handling.
- On governmental scale multiple projects are currently being supervised for post-consumer waste management, but need more on broader spectrum to attain tangible achievements.
- Education and awareness of general public through curriculum, media advertisement, public seminars

and campaigns is recommended to take proactive approach to manage their discards in a responsible manner.

- Overall, policies must be implemented on all stakeholders (government to the individuals) for the betterment on multiple societal scales.

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