FROM WASTE TO HOUSING:

USING PLASTIC WASTE TO BUILD SUSTAINABLE HOUSING IN HAITI

by

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This thesis was prepared under the direction of the candidate's thesis advisor, Dr. John Renne, School of Urban and Regional Planning, and has been approved by all members of the supervisory committee. It was submitted to the faculty of the College for Design and Social Inquiry and was accepted in partial fulfillment of the requirements for the degree of Master of Urban and Regional Planning.

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ABSTRACT

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This thesis examines the scope of the plastic waste management and housing problems in Haiti. It makes a case for plastic waste to be recycled into sustainable housing as a solution to both issues. For better understanding, it first analyses the scope of the plastic waste pollution and housing problems in developing countries. It then ascertains innovative ways waste managers, and planners have solved it in these nations. Thirdly, based on case studies in Colombia and India, this thesis ascertains how using plastic waste in construction, is a potential solution for better waste management and better housing in Haiti. In the end, this thesis recommends the construction of a plastic waste recycling plant in Port-au-Prince to help solve both their waste and housing problem. Since Port-au-Prince lacks a central sewage system, this thesis also recommends investment in water infrastructures to eliminate the need for plastic bottles in the long run.

DEDICATION

This manuscript is dedicated to my parents, Carlo and Kettline Estil, who have supported me all my life and always know the right words to say when I need it the most.

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LIST OF TABLES

LIST OF FIGURES

CHAPTER 1: INTRODUCTION

In a world driven by consumerism and overproduction, the surplus of waste produced creates a significant waste management problem. Waste management in urban planning is becoming a critical issue, particularly in developing countries such as Haiti, whose population keeps on increasing (Catania & Ventura, 2014). Countries like the United States and Canada have so far managed their waste by outsourcing most of their recycling to other countries. This solution might, however no longer be feasible since, in recent months, China has stopped importing recycling, which is causing a significant problem for those countries that export waste (Katz, 2019).

Adequate plastic waste management is challenging in developing countries, mainly due to their lack of infrastructure to accommodate their growing quantities of waste. The rapidly growing populations and rise in community living standards of urban cities of the developing world have increased the rate of their municipal solid waste, causing management to be a significant worldwide challenge (The World Bank, 2018). The collection of garbage causes an even bigger problem since, in many areas, municipal authorities of developing countries are either unwilling or unable to provide waste collection services to all residents in their jurisdiction. Nations like Haiti in the developed world, also have limited opportunities to create sustainable waste management systems because government budgets are limited, thus causing them to overlook regular waste collection.

The many recent natural disasters in Haiti have also increased their need for adequate housing. Even before the 2010 earthquake that devastated the country, roughly 70 percent of Port-au-Prince's population lived in informal settlements, often lacking essential services (USAID, 2018). Over the next ten years, the Government of Haiti estimates that the country will need up to 500,000 additional housing units to make up for the pre-earthquake housing shortage and accommodate the high amount of predicted urban growth (USAID, 2018).

RESEARCH QUESTIONS

For narrower questions regarding waste management and the need for sustainable and adequate housing to be addressed, this thesis will be answering three main research questions.

RQ1. What is the scope of the plastic waste pollution and housing problems?

RQ2. How are waste managers and urban planners dealing with this problem?

RQ3. How can using plastic in construction be a potential solution to plastic waste management and the need for housing?

CHAPTER 2: METHODOLOGY

The purpose of this thesis is to examine the problems of waste management and affordable housing in Haiti. This thesis will explore the possibility of using recycled plastic waste to aid in the construction of housing in the country. Through a case study analysis of the waste management process of countries such as India, and Columbia, this thesis will gain a better understanding of the measures being employed by other developing countries to successfully or unsuccessfully manage plastic waste. This thesis also examines how these countries have found ways to use plastic as a raw material to construct housing.

India and Colombia were picked for the case studies because both countries share similar problems of waste management and housing as Haiti. According to the Central Pollution Control Board (CPCB), in 2012, India generated close to 26,000 tonnes of plastic a day. Out of this amount, a little over 10,000 tonnes a day were not collected and ended up in landfills (Aravind, 2019). According to a report on urban housing shortage done by the government of India in 2018, 63.67 million urban and rural households across India do not have adequate housing (D'Souza, 2019). This massive number is a cause for concern and is another reason why India is a good case study for this thesis.

According to the supervisory authority “Superintendencia de Servicios Públicos Domiciliarios” (SSPD), Colombia generated 26,528 tons of waste daily in 2014. This number was, however, just an estimate and did not account for illegally disposed waste.

Out of this estimate, only around 7% of it was recycled (Global Recycling, 2019). Colombia's housing problem is the other significant cause for concern. Over the past five decades, the country has been experiencing violent internal conflicts, causing the displacement of millions of Colombians (Habitat for Humanity, 2019). Haiti also faces constant internal conflicts, which is another reason why Colombia is an appropriate choice for a case study. Furthermore, the objective of this thesis is to determine whether these measures are implemented to the degree that is necessary to minimize and reuse plastic waste, and the role of the urban planner in the process. In assessing the implementation of these policies, this thesis seeks to define ways the planning profession can better assist communities regarding plastic waste management and its application in Haiti. These issues will be discussed in chapters 3, 4, and 5, which consist of a literature review into the matter, a case study analysis of how India and Colombia both manage their plastic waste problems, and field data from organisations in Haiti that have dealt directly or indirectly with the issues of plastic waste and housing.

The literature review of chapter 3 will be addressing research question 1: what is the scope of the plastic pollution, and housing problems. This chapter will report on the current knowledge regarding the range of plastic waste in Haiti and other developing countries, as well as report on the scale of the housing problem in Haiti and other developing countries. Chapter 3 will also report on current knowledge regarding how plastic is being recycled in construction. The case studies of chapter 4 will answer research question 2: How are waste managers and urban planners dealing with the problem of housing and plastic waste? These case studies specifically focus on how India and Colombia have dealt or failed to deal with their plastic waste and housing problem.

The case studies will also answer research question 3: How can using plastic in construction be a potential solution to plastic waste management and the need for housing? Chapter 4 will answer this question by looking at examples of how waste managers in these countries have already started using plastic waste in construction as a partial solution to both housing and plastic waste problem.

The Field data in chapter 5 will be all about analyzing organizations that have been directly or indirectly involved in waste management and housing in Haiti. By talking with organizations that are present and working in the country, this thesis gains a more in-depth understanding of the scope of the waste management and the housing problems that Haiti is facing.

One of the businesses providing field data is located in Haiti and is owned by the parents of the author of this thesis. They have lived in Haiti all their lives and have been in business for over 30 years. They have also been involved in construction in Haiti for over 30 years since they have overseen themselves both the construction of their privates residences as well as their business. They were picked for their expertise in construction and the housing market in Haiti, as well as the fact that they are currently living in Haiti. However, some biases that might arise from interviewing them could be that they might not have provided the same information that they would have provided to a stranger. To overcome these biases, the researcher looked at all the information given objectively and attempted to fact check everything when possible. However, since many data on housing and construction in Haiti aren't readily available, data directly from the field, from people living in the country is the best option for this thesis.

Chapter 6, the conclusion, provides concluding remarks, recommendations for planning professionals, and implications for future waste management and housing planning efforts in Haiti.

CHAPTER 3: LITERATURE REVIEW

This literature review addresses **RQ1** by examining the scope of the plastic waste management and housing problems. This chapter reports on the current knowledge regarding the range of plastic waste in Haiti and other developing countries, as well as the scale of the housing problem in Haiti and other developing countries. This chapter also reports on current knowledge regarding how plastic is being recycled in construction, and how some countries in the developing world have used plastic waste as a solution for their housing shortage.

PLASTIC WASTE POLLUTION IN THE DEVELOPING WORLD

According to data published by the World Bank in 2015, with the largest population, China produced the most substantial quantity of plastic, approximately 60 million tons. The United States followed this at 38 million, Germany at 14.5 million, and Brazil at 12 million tons. India produced 4 million tons, Mexico 3 million, Colombia 2 million, and Haiti produced less than 1 million (Ritchie & Roser, 2018). Figure 1 represents their total plastic waste generation per capita and does not account for differences in waste management, recycling, or incineration, which would explain why plastic waste pollution is more visually noticeable in certain countries as opposed to others.

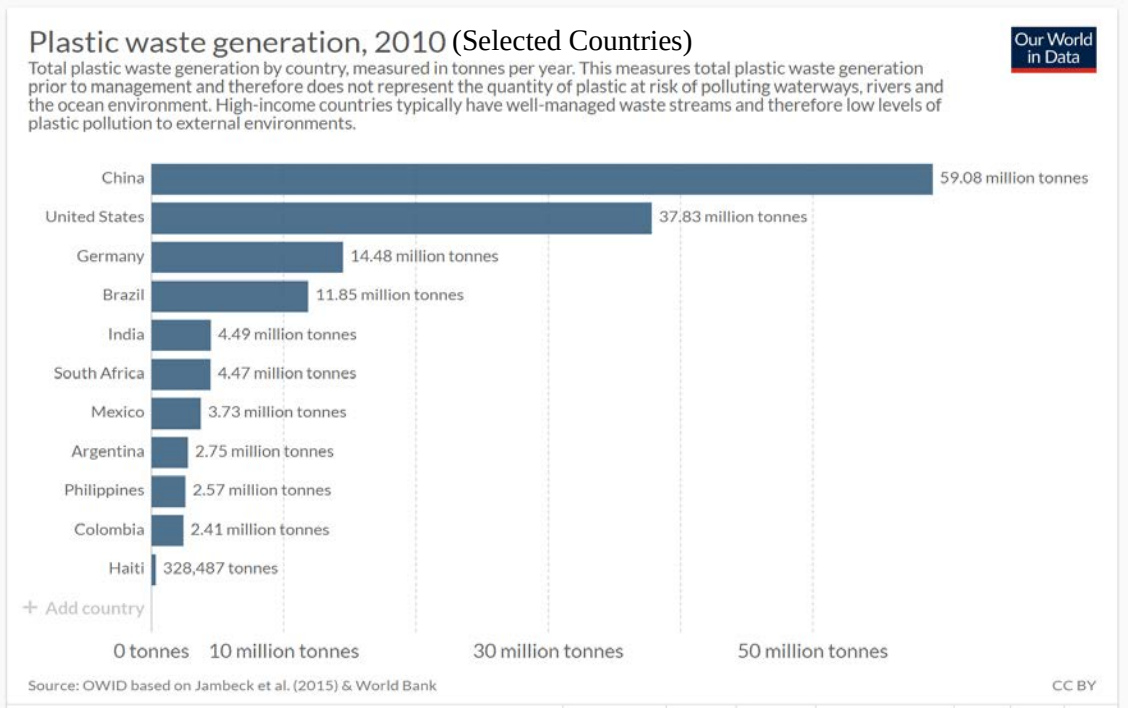

Figure 1. Plastic Waste Generation 2010. Source: (Our World in Data, 2019)

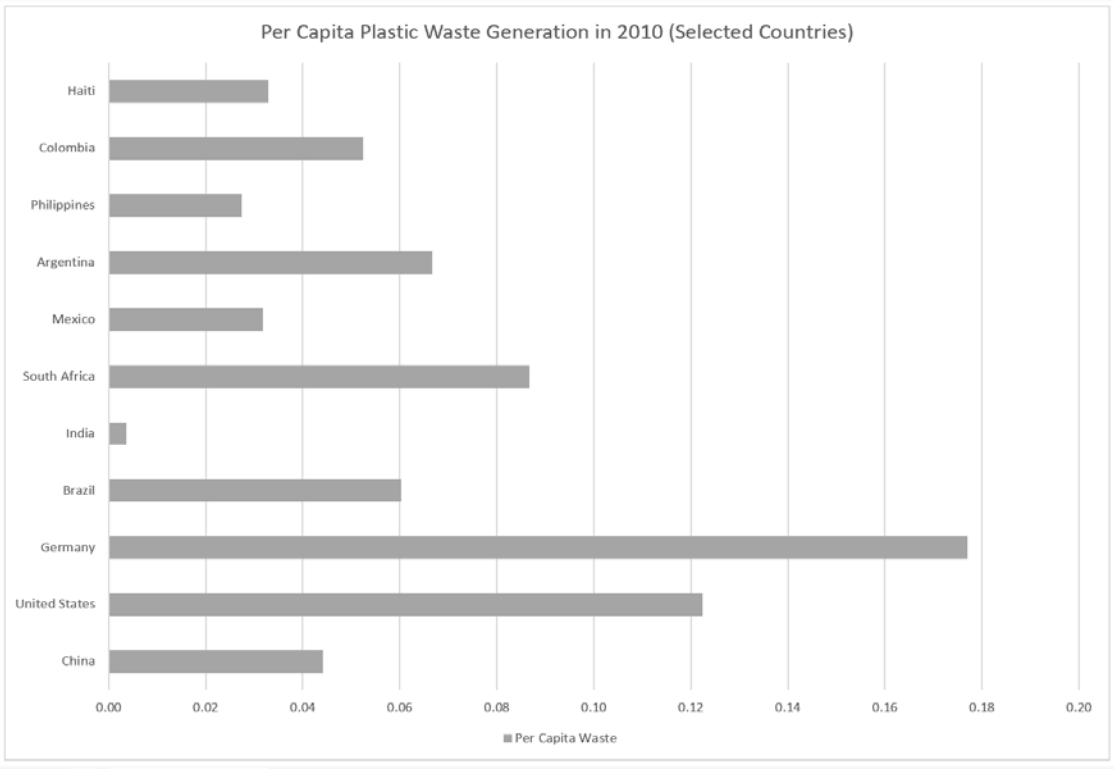

Figure 2. Per Capita Plastic Waste Generation (The World Bank, 2019)

Figure 1 and 2 shows the amount of plastic waste generated in 2010 in the selected countries overall, as well as how much plastic waste each person generates. Out of this list, India and China had the highest population for that year. In 2010, China's population was 1.338 billion people, and India's population was 1.231 billion people (The World Bank, 2019). Interestingly, with the second-highest population, India has generated the lowest amount of waste per person in 2010 at less than 0.02 tons per person. Some theories to explain this phenomenon could be because China is more industrially and economically advanced than India, causing them to produce more plastic waste per person. Another reason could be because until 2019, China used to be the go-to place for countries looking to recycle their plastic waste, which would have definitely spiked their yearly amount of plastic waste generated.

With one of the lowest populations for a developed country, Germany with a population of only 81.8 million in 2010 produced over 0.16 tons of waste per person, which is the highest waste number in that list. Even with their high plastic production rate, Germany until recently was known to be the "World's Best Recycler" due to the country's strict trash-disposal rules (Dobush, 2019). However, in June 2019, researchers from the Heinrich Böll Foundation published a report revealing that most of the country's recyclables are incinerated in Germany or shipped abroad to poorer countries, where it's sometimes dumped or burned illegally (Heinrich Boell Foundation, 2019).

Many developing countries find their plastic pollution problems aggravated overnight due to developing countries like Germany dumping their waste on them. Since China stopped accepting recycling from the US, activists from GAIA (Global Alliance for Incinerator Alternatives) say they have observed a pile-up of plastic waste in

developing countries. Because of the plastic waste trade, exporting countries could send lower-quality plastic waste to private entities in developing countries without getting approval from their governments (Holden, 2019). In May 2019, however, in Geneva, Switzerland, 187 countries agreed to add plastic to the Basel Convention, a treaty that regulates how hazardous waste moves from one country to another. Thanks to this amendment, exporters will now need to obtain the consent of receiving countries before shipping contaminated, mixed, or unrecyclable plastic waste. This amendment is providing an essential tool for countries in the developing world, to stop the dumping of unwanted plastic waste into their country (GAIA, 2019).

This amendment gives developing countries a fighting chance against their internal source of plastic waste. According to a new report released on March 7th of 2019th by GAIA, Filipinos use more than 163 million plastic packets, 48 million shopping bags, and 45 million thin-film bags daily (GAIA, 2019). India's per capita consumption of plastic is 11 kilograms, compared to the United States, where it is the world's highest at 109 kilograms, according to figures released by the Federation of Indian Chambers of Commerce and Industry (FICCI) in 2017. According to FICCI’s data, the world average is about 28 kilograms, and consumption in India is projected by the government to increase to 20 kilograms by 2022 (AFP, 2019).

Single-use disposable plastic is problematic, and the greatest obstacle to waste management, which is why developing countries around the world are starting to ban it. Rwanda, a pioneer in banning single-use plastic bags, is now one of the cleanest nations on earth (UNEP, 2018). Ever since their ban in 2008, as part of a revival plan from the economic and emotional destruction of genocide in the mid-1990s, the streets in the

country have gotten cleaner, especially the capital city of Kigali. Rwanda's law prohibits the use, manufacture, sale, and importation of plastic bags. Any businesses in violation of the ban face up to a year in prison, and anyone caught carrying a bag face hefty fines. Companies that openly disregard the rules are raided, even travelers who enter Rwanda's borders are subject to searches. Plastic bag manufacturers were also encouraged through tax incentives and recycling contracts to convert their businesses, resulting in less ire from them (Kardish, 2014).

South Africa was also a pioneer and introduced a ban on plastic. By the late 1990s, plastic bag litter had become so widespread in South Africa that plastic bags were referred to as the "new national flower" (UNEP, 2018). In 2003, the Government of South Africa introduced a ban on single-use plastic bags. They combined the new regulation with a tax on retailers of ZAR 0.04 (roughly $0.04) on 24-liter bags. After only three months, the charge was reduced to ZAR 0.03, due to pressures from plastic-bag producers. According to critiques, the tax only affected the food sector, excluding other industries, such as clothing retailers. The charge seemed to be particularly problematic for poorer segments of the population, which use plastic bags as affordable means to carry goods over long distances. Despite the initial success, with little to no awareness of why the tax was being implemented, consumers started to budget for plastic bags into their shopping, and the number of bags consumed slowly returned to pre-tax levels. There was also mismanagement of the revenue produced by the tax, resulting in questions been raised in Parliament on how the fee was being utilized and the benefits (if any) to the local waste and recycling sector (UNEP, 2018).

Developing countries in Asia have also tried to ban single-use plastic. In 1999 the Chinese government banned the production and use of all single-use plastic tableware, but the ban was never effectively enforced, and it was officially lifted in 2013 (China File, 2013). To curb the production and consumption of plastic bags, in 2008, the Government of China introduced a ban on bags thinner than 25 microns and a tax on thicker ones, promoting the use of durable cloth bags and shopping baskets (Xanthos, Dirk, & Walker, 2017). One year after the introduction of the legislation, the distribution of plastic bags in supermarkets fell on average by 70% (UNEP, 2018). However, plastic bags do remain common, especially in rural areas and farmers' markets, due to weak enforcement (Zhu, 2011). In January 2018, China recently introduced a ban on the import of plastic scraps. The impact of the ban on the global plastic recycling industry has not yet been estimated.

In 2002 in Bangladesh, after plastic bags were found responsible for exacerbating the deadly flooding of 1989 and blocking drainage systems in 1998, the government banned all shopping bags made of polyethylene (PE). After the implementation of the ban, the government promoted a campaign informing citizens that offenders could face fines of up to $71 and six months in jail (UNEP, 2018). Despite public support, the ban was not strictly enforced, and plastic bags are still widely used in Bangladesh, especially in food markets. Activists found that the lack of cheap alternatives largely contributed to the failure of the policy.

In Haiti, "The Plastic Bank," an organization founded by international firms pays people to collect waste to reduce pollution and poverty. According to a report by Sabine Streich, there is no functioning garbage collection system in Haiti, resulting in trash

landing in the streets and the rivers. “The plastic Bank” hires out Haitian workers (The Plastic Pickers of Haiti) to pick out plastic waste that the organization then recycles. The initiative is, however, at its infancy and is not easy to implement in reality (Streich, 2018).

THE NEED FOR HOUSING IN THE DEVELOPING WORLD

The worst of the housing crisis in the world reside in the rapidly urbanizing cities of developing countries, where hundreds of millions of people live in substandard housing, lacking running water, electricity, or basic sanitation (Florida & Schneider, 2018). According to “The World Health Organization,” adequate housing is right for your health because it protects against diseases, provides protection against injuries, and reduces psychological and social stresses. In developing countries like Haiti, housing available to low-income families are usually cramped, crowded, and unsanitary settlements, in conditions that weaken energy and reduce national productivity (Grimes, 2012). Families that live in inadequate dwellings in developing countries face the threat of eviction, as well as scarcities of water, sewage, and transport on a constant level. Often, under the disguise of slum clearance, low-income groups are moved to higher-quality dwellings that are located far from income-earning opportunities. The rent in these new dwellings is usually higher than what these families can afford (Grimes, 2012).

As of 2015, every seventh person around the world lives in an informal urban settlement, equaling up to 850 million people globally. In the major cities of developing countries, almost 80% of the total population lives in slums. Fast urbanization in developing countries is expected to add up to 1.5 billion people living in slums in 2025 (Sticzay & Koch, 2015). The global housing crisis faced by those 850 million people who

live in informal housing, equals more than the populations of the U.S. and the European Union combined (Florida & Schneider, 2018). The map in figure 2 below from the Bloomberg Global City Housing Affordability Index shows that as dire as the housing affordability crisis is inside expensive cities, it is even worse in the rapidly urbanizing cities of the developing world, where rents average 100 percent, 150 percent, 200 percent, or even higher your share of income. The most expensive and desirable cities in North America and Europe are far more affordable by comparison (Tartar & Lu, 2017).

The cost of housing in developing countries can exceed 100% due to the privatization of housing. Investors controlling the housing sector take advantage of the problem of overpopulation in these locations by increasing rent. Housing is an industry that accounts for 217 trillion dollars or 60% of total global income (World Affairs, 2018). Private companies in developing countries who have invested in the housing market, have increased not the number of affordable housing, but the number of high-end luxury units that are only viable for the ultra-rich. This phenomenon creates a burden for people in the lowest income who aren't able to keep up with the price increases. The high rate of unemployment in Haiti is another reason why the cost of housing can exceed 100%. Haiti's unemployment rate in 2019 was at 14%, this was one of the highest in the Americas, compared to the United States at 3.6%, Mexico at 3.8%, Canada at 5.5%, the Dominican Republic at 5.8%, Puerto Rico at 8.20%, Jamaica at 7.8%, and Chile at 7% (Trading Economics, 2019).

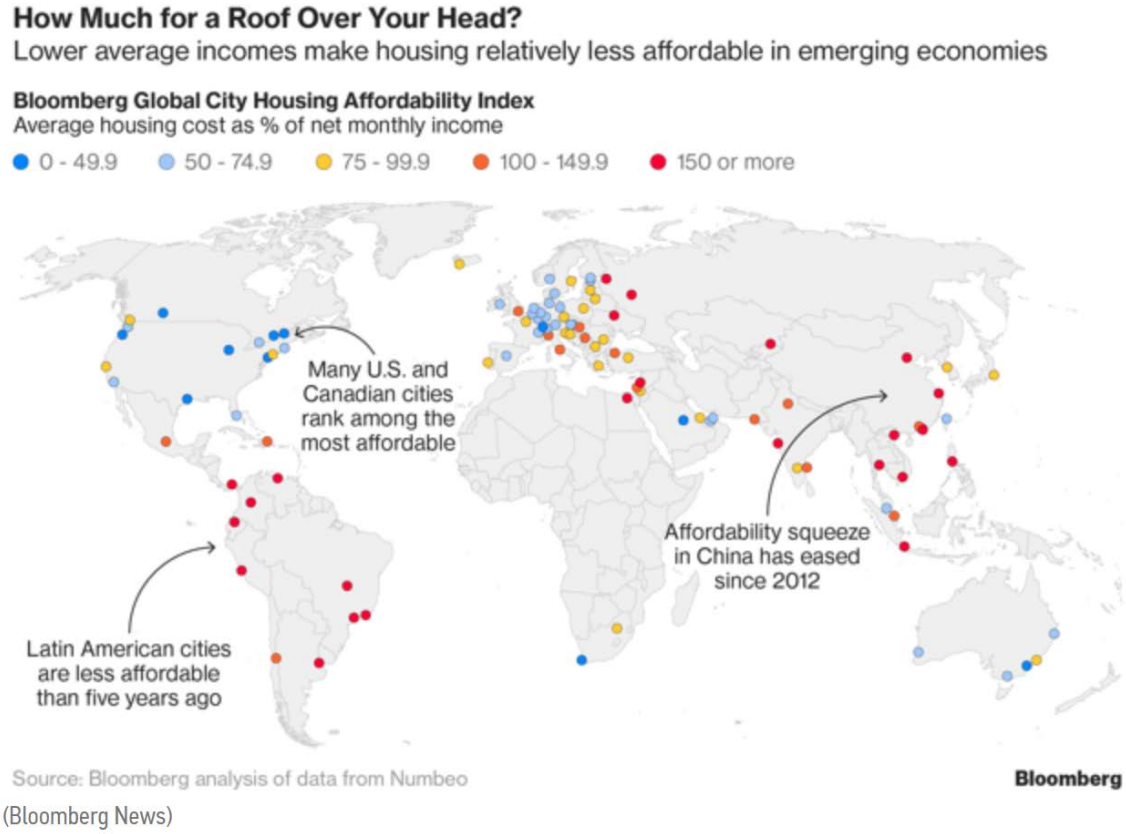

Figure 3. Bloomberg Global City Housing Affordability Index. Source: (Bloomberg 2018)

According to this metric, cities in the Global South (made up of Africa, Latin America, and developing Asia, including the Middle East) are the most unaffordable cities in the world. In cities like Hanoi, Mumbai, Bogotá, Buenos Aires, and Rio de Janeiro, housing costs exceed 200 or 300 percent of incomes (Florida & Schneider, 2018). The most unaffordable city is Caracas, the capital of Venezuela, where average housing costs exceed income by more than 3,000 percent (NUMBEO, 2019).

In Haiti, even before the 2010 earthquake, the country faced a severe housing shortage. After the quake, nearly 190,000 houses and 105,000 more were destroyed, adding to the pre-existing backlog of 300,000 homes required to meet the growing shelter needs of the country. Combined with Hurricane Matthew in 2016 that directly hit the

south department, the housing needs have vividly increased. Insecure land tenure, lack of access to building materials, and a shortage of builders trained in disaster-resistant construction are also significant roadblocks to building homes in Haiti (Habitat for Humanity, 2019).

PLASTIC IN CONSTRUCTION

Plastic is a versatile material, most products today, likely have a plastic component to it. Plastics are being used today in the construction industry thanks to several of their properties. The wide variety of uses for plastic in the construction industry range from thermal insulation to plumbing, sinks, and baths to roof coverings. Plastic can be a chemically resistant, ductile, stable, and fire-resistant material. Its shapeshifting abilities allow it to be used in electric insulation, and wall finishing (see table 1), suitable pigments can also be added in the process of manufacturing of plastic materials to get a more attractive result for a building structure (The Constructor, 2019).

Table: Uses of Plastics in Building Construction

No.	Plastic Material	Uses	Form in which it is commonly used	Normal colour
1	Expanded polystyrene	Thermal insulation	Thin sheets in slabs 12mm thick	White
2	Expanded polyvinyl chloride (PVC)	Thermal insulation	Boards 20 to 50 mm thick	Yellow brown
3	Foamed urea formaldehyde	Thermal insulation	Foamed in situ	White
4	Foamed phenol formaldehyde	Thermal insulation	Sheets and blocks	Deep red
5	Foamed polyurethane	Thermal insulation	Sheets and blocks or foamed in situ	Brown
6	Expanded ebonite	Thermal insulation	Sheets	Brown or black
7	Polythene	Damp-proofing, plumbing	Thin sheets, pipes, cisterns	Transparent to black
8	Polypropylene	Domestic drainage, but water overflow tanks		
9	Unplasticised PVC	Rainwater goods, ventilation, ducts, pipes of water mains		
10	Acrylic resins	Sinks and baths		Various
11	Nylon	Cold water fittings, window furniture		Various
12	Phenolic resins	Adhesives for laminates		Dark
13	Melamine	Laminates	Sheets	Many

Table 1. Uses of Plastics in Building Construction. Source: (The Constructor, 2019)

Currently, plastic materials find use in buildings, mainly in thin coverings, panels, sheets, foams, pipes, etc. However, more skillful use of plastics can one day expand the usefulness and durability of conventional building materials and help them to function more efficiently and economically (The Constructor, 2019). Plastic is even being used to reinforce concrete. The next evolution in the technology of cement and demands for

delivering more ecofriendly and sustainable construction projects paved the way to the idea of disposing of post-consumer waste plastics into structural concrete. The raw plastic granulate is used as a partial substitute for sand aggregate, which treats concrete as a medium for disposal of waste in the amounts that do not significantly affect its strength. Previous research has proven that concrete reinforced with plastic fibers is a more resilient building material than plain concrete, opening the door to the recycling of plastic to produce fibers to be used as secondary reinforcement for concrete along the traditional steel rebars (Ninoslav, Stana, Reyes, & Panos, 2019).

Many architects around the world have also started using plastic as a way to build low income and sustainable informal settlements in developing countries. A German national Andreas Froese invented the technique which involves the use of disposable PET bottles, debris, and earth as raw material for construction. PET bottles are filled with sand or soil or landfill dirt or mud and are used as bricks to construct houses. The technology has been adopted in different countries, including Nigeria, South Africa, the Philippines, and India. Thanks to this technique, more than 300,000 PET bottles have been reused in more than 50 construction projects in Honduras, Columbia, Bolivia (Muyen, Barna, & Hoque, 2016).

In Bogotá, Colombia, architect Oscar Mendez started a company, “Conceptos Plasticos,” that transforms plastic and rubber waste into construction material that they use to build houses for those who need it across Colombia (Winkless, 2016). One Mexican national Carlos Daniel Gonzalez founded a company in Mexico “EcoDom” that works with local trash collectors in the city of Puebla to achieve its goals of reducing plastic waste as well as improving Mexico’s economy through affordable housing made

from plastic waste. So far, the startup has built more than 500 houses out of recycled plastic.

Another company building homes out of recycled plastic is “Eco-Inclusion” in Argentina. This NGO fabricates bricks out of recycled plastic waste. Founded in 2014 by entrepreneurs Leandro Miguez, Leandro Lima, and Fabio Saieg, the organization works to have a social impact in Argentina by providing affordable and sustainable housing. The plastic bricks that “Eco-Inclusion” creates have the same characteristics as a regular brick; they are also light, insulating, and are made with a production process that does not damage the environment (Ledur, 2018). The NGO has 45 plastic collecting spots in four cities throughout the country, and turn every 20 plastic bottles into one brick and can produce 20 bricks in one hour.

This literature review answered **RQ1** by illustrating plastic waste management as a global problem, and housing as a problem more prominent in developing countries. Before the UN added plastic to the Basel Convention in May 2019, developed countries were able to hide their waste problem by outsourcing most of their plastic waste to developing countries, hence one of the reasons why plastic waste management issues are more visible in these nations. The problem of housing, however, is much more significant in developing countries. Income in these nations is not proportionate to the cost of housing, rendering the cost of living in the most expensive cities in Europe, and North America far more reasonable by comparison. This literature review also illustrates the many applications of plastics in construction projects around the world, which adds more credibility to the idea of recycling plastic waste to build housing.

CHAPTER 4: CASE STUDIES

This chapter covers case studies on Colombia and India. These two countries are both developing nations that share similar plastic waste and housing problems as Haiti. These case studies look at how these two nations manage their waste and housing problems and how they have found ways to successfully or unsuccessfully deal with is. This chapter answers **RQ2**: How are waste managers and urban planners dealing with the problem of housing and plastic waste? As well as **RQ3**: How can using plastic in construction be a potential solution to plastic waste management and the need for housing? This chapter answers these questions by looking at examples of how waste managers in these India and Colombia have already started using plastic waste in construction as a partial solution to both housing and plastic waste problem.

PLASTIC WASTE MANAGEMENT IN COLOMBIA

Solid waste generation in Colombia is around 32.000 tons a day, equivalent to 11.3 million tons per year (Consutores, 2011). Waste management and recycling there is very informal. Currently, these tasks are done primarily through private companies. There are more than 100 organizations that group around 5.000 recyclers in charge of helping manage waste throughout the country (Consutores, 2011). Between 40% and 60% of recycled solid waste are collected by informal and formal recyclers who do this job to make a living, and plastics make up 11,15% of the recycled materials (Consutores, 2011)

Recycling is a hard task in Colombia with numerous issues. Some of the problems in the supply chain are the involvement of children, low pay, and lack of safety. Small companies receiving the materials to be recycled also face issues such as high prices, high levels of intermediation, and a lack of incentives to use recycled material. To address the challenge of overbearing plastic waste, Colombia has started promoting eco-friendly options as substitutes for single-use plastic. Beginning January 2017, single-use plastic bags smaller than 30x30 cm has been banned by the Colombian government. This ban alone resulted in a 27 percent reduction in plastic use in the country (UNENVIRONMENT, 2017). In July of that same year, the government also introduced a tax on single-use plastic bags. The goal of this legislation was to encourage the use of reusable bags. In the future, the government will keep increasing the tax by 50 percent to deter from using single-use plastic bags.

Government statistics and World Wildlife Fund figures for Colombia depicts the annual average consumption is about 288 plastic bags per person. With this new policy, the Government is trying to reduce this type of single-use plastic by 75 percent. Such a drastic reduction could lead to social, environmental, and economic benefits of up to $825 million (UNENVIRONMENT, 2017). Ecological leaders in Cartagena Colombia, are hoping for this new policy to change consumption patterns, reducing plastic pollution in the Caribbean, which today ranks as one of the seas most damaged by human activities (Iaccino, 2014). To show its commitment to combat their plastic waste problem, Colombia even recently joined the UN Environment #CleanSeas campaign, which aims to reduce the use of microplastics and single-use plastics significantly.

PLASTIC WASTE FOR HOUSING IN COLOMBIA

In recent years, volunteers and environmental organizations have addressed the challenge of plastic waste management in Colombia by raising awareness of responsible consumption, reuse, and recycling and organizing beach clean-ups. In 2015, in Tierra Bomba, a Colombian island off the coast of Cartagena, the Bahía Foundation and partners collected 96 tons of mainly plastic waste. Even though this was a massive amount of trash for such a small town without access to public services, these efforts alone were not enough to stop the litter coming through sea currents, or from the city water sources (UNENVIRONMENT, 2017).

In Bogota, the capital of Colombia, 700 tons of plastic is discarded daily, with only 100 tons of that recycled (Winkless, 2016). Oscar Mendez, a Colombian architect, has found a way to recycle all that plastic into low-income housing. His company, Conceptos Plásticos, transforms plastic and rubber waste into a construction material used to build houses across Colombia. The company has been tackling two problems: one, the growing mountain of plastic waste in landfills; and two, the rapidly growing populations in cities across Latin America. A report launched at the World Economic Forum in January 2016 confirmed that in 2014 alone, around 309 million tons of plastic were manufactured globally (EllenMacarthurFoundation, 2016). A recent report from TECHO (a youth-led non-profit organization present in Latin America & the Caribbean) showed that 80% of Latin America's population now lives in cities (Moloney, 2015).

To build housing with plastic, Conceptos Plásticos work closely with low-income neighborhoods by visiting schools and community groups to encourage them to collect various plastic waste and old tires. The collected materials are cleaned before being ground into small particles, mixed, melted, and extruded into a range of shapes – mostly

beams, blocks, and pillars – which lock together to form buildings. The company also trains communities on how to build these structures, which allows them to have ownership over their homes and empower them with skills they can take elsewhere.

Architect Oscar's plastic homes can be assembled very quickly – a 40 square meter house separated into two bedrooms, a bathroom, living room, dining room, and kitchen, which can be built by four people in only five days. The cost is also considerably lower than the traditional price of a home in rural areas – their standard house mentioned above can be built for $5,200 (Winkless, 2016). The approximate cost of a traditional 40 square meter house in Cartagena, a port city on Colombia's Caribbean coast, without the value of the land is 40,000,000 pesos or 11,608 United States Dollars. The method introduced by Conceptos Plásticos saves $6,408 per house, with the bonus of recycling plastic and providing homes to low-income families.

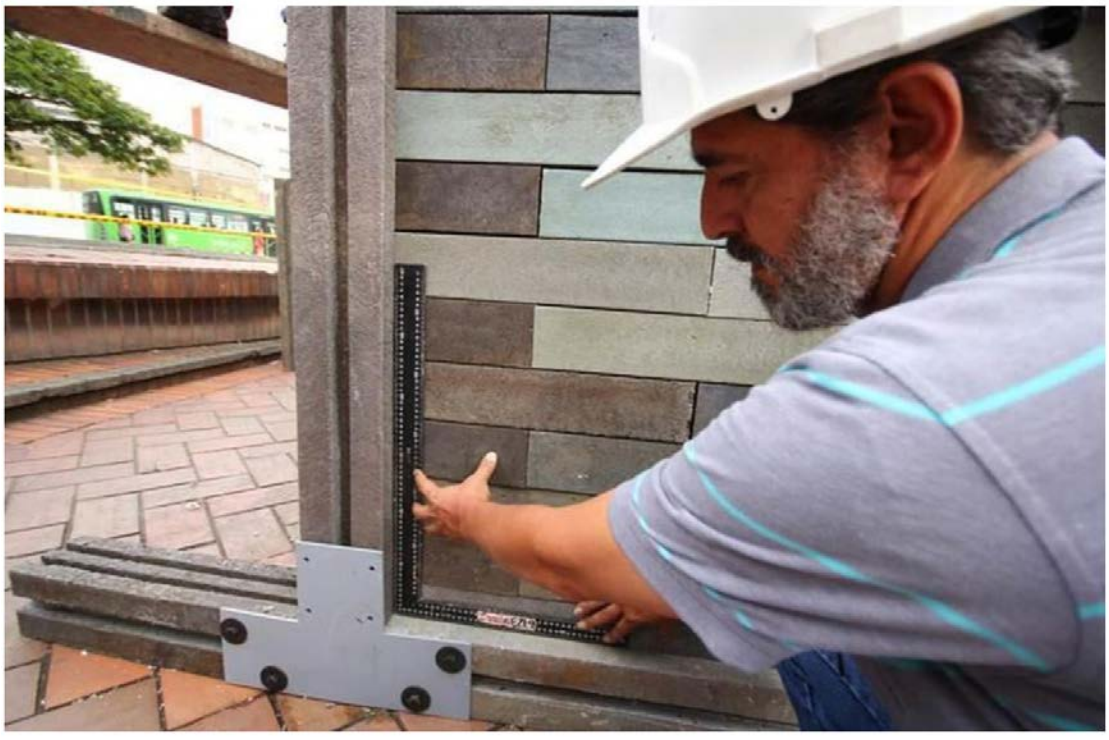

Figure 4. Building a House out of Recycled Plastic. Source: (ConceptosPlasticos, 2019)

Like LEGO blocks, these structures interlock, rendering obsolete the need for adhesive to be sturdy. These houses make a good option for mobile shelters, and since plastic need at least 500 years to biodegrade, they are guaranteed to be durable. These structures are also fireproof, earthquake-resistant, and require little maintenance. Conceptos Plásticos have built so far, a temporary shelter for 42 families displaced by violence, three smaller permanent shelters (each one measuring 1,100 square meters), and eight houses. For the future, they are planning on building 20 more homes in Cartagena.

Figure 5. House of Recycled Plastic. Source: (ConceptosPlasticos, 2019)

Figure 6. Finished Recycled Plastic House. Source: (ConceptosPlasticos, 2019)

The company is unfortunately not getting much support from the Colombian government and receives most of its funds through competitions. In 2016, Conceptos Plásticos was a finalist in "The Venture" – a competition that funds "innovative businesses that create positive change in the world." They were granted $300,000 for making it to the finals of the competition. This money allowed the organization to increase its capacity and improve its processes.

Waste management in Colombia has positively evolved over the past two decades, but there is still a lot more work to be done. The Colombian government needs to start having a more significant role in managing waste and solid waste recycling; they also need to provide higher quality solutions for smaller municipalities with less infrastructure. Lastly, since private organizations do most of the waste management, the government needs to give them a better and more sustainable way of funding through either public grants or more tax breaks (Sarmiento, 2012).

PLASTIC WASTE MANAGEMENT IN INDIA

60% of the plastic waste collected in India gets recycled back into raw materials for further processing into consumer products, while the remaining is left unutilized. This is problematic since 1 to 4 percent of India's municipal solid waste by weight is made of plastic waste. The plastic waste that is generated is collected informally, traded, and reprocessed by known methods into useful products (Upadhyay, Prasad, Srivastav, & Singh, 2005).

According to a primary survey done by the Tata Energy Research Institute (TERI) in 1996, plastics waste made up 4% to 9% of the waste across different income groups in India. In 1971, that percentage was only 0.7%. Almost all plastic wastes are sold to kabariwallahs (wealthy Indians), who form the first link in the chain of plastics recycling. For the next step, small recycling companies recycle the sold waste, creating negative environmental impacts because of their use of outdated technology, the low quality of the raw material, and the absence of government support. This method of recycling, however, offer employment and help save the vast stretches of land needed for the disposal of wastes and the detrimental effects of landfills on the environment.

In 1995, Himachal Pradesh, a state in the northern part of India, introduced the "Non-biodegradable Garbage (Control) Act." The Act's goal was to prohibit throwing or depositing of plastic articles in public places and facilitate their collection through identifiable and marked garbage receptacles for non-biodegradables, placed conveniently in public spaces. Haryana, another state in the northern part of India announced in 1997, a Bill on Non-biodegradable Garbage like that of Himachal Pradesh. Following these two states example, the government of India recommended a strategy for Plastics Waste Management that would cover the whole country. Some of these strategies included

various schemes to change the labeling of plastic products, and regulate the type of plastic that can be served with food items. The intention of these schemes, however, was not to reduce plastic waste but instead to minimize contamination, as well as the danger from the use of recycled plastic.

Like Colombia, a considerable portion of waste management in India is done informally through private support. In Delhi, plastic recycling is mainly done in a trading area called Tikri Kalan. Tikri Kalan is composed of three main areas of plastic scrap trading. These areas are composed of units organized in informal plots, where materials are stored between operations. The main operating activities are trading, sorting, dismantling and grinding of the plastic. Around 1,875 tons of plastic scraps flow daily through Tikri Kalan. 1,818 tons goes to recycling factories and 57 tons goes to brick-kilns. An overall 37% of the annual plastic waste production of Delhi is computed annually in Tikri Kalan. This activity generates 9.17 million Indian rupees daily, or around 1.4 million United States dollars. Recycling in Tikri Kalan also employs 10,000 people (Kroiss, 2016).

In India, most of the waste collection is done by the informal sector. There are two kinds of informal collectors, the Chugnewallah or scavenger, and the Kabadiwallah or itinerant buyer (Gill, 2010). Chugnewallahs take wastes from open spaces such as parks or streets, and Kabadiwallahs purchase waste from households and public or private institutions (Gill, 2010). In Tikri Kalan, there are three distinct areas of plastic trading known under the name of PVC market, Badi Tikri and Choti Tikri. Figure 6 shows their location in Tikri Kalan. The PVC market is shown in red, Badi Tikri in yellow, and Choti Tikri in green.

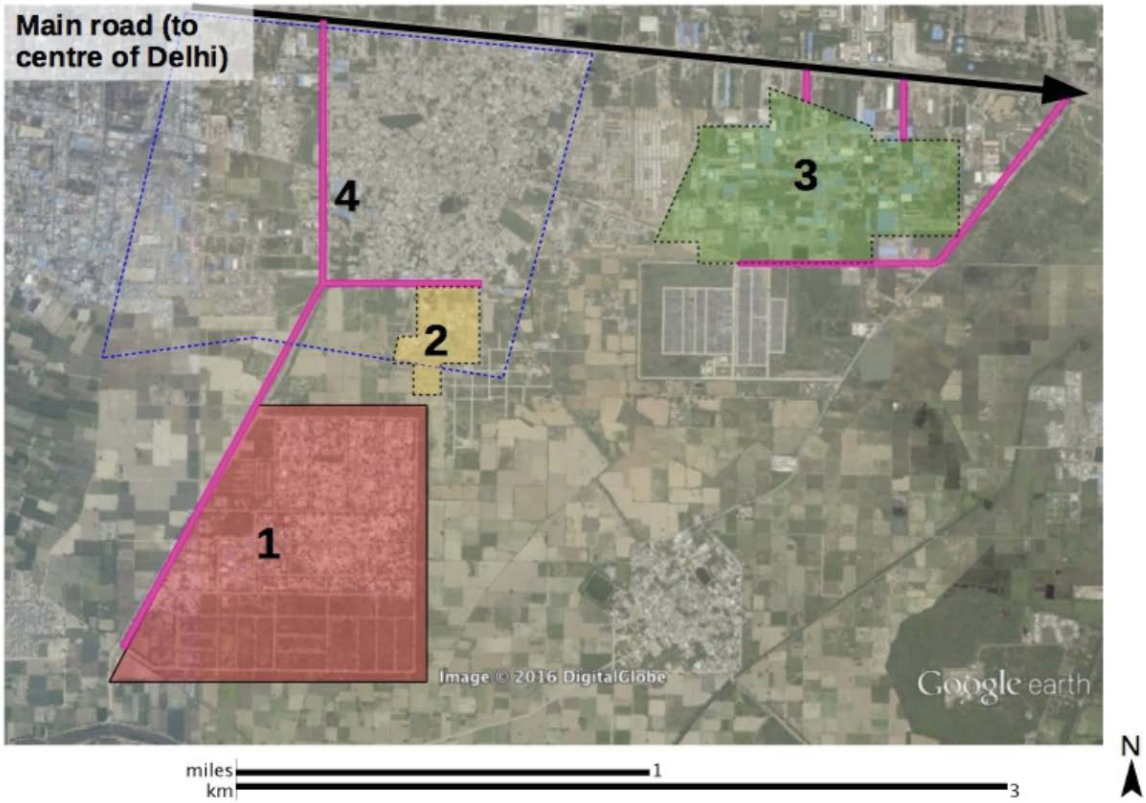

Figure 7. Location of the 3 trading areas (Kroiss, 2016)

The main players in these three areas, are traders who import plastic scraps from Kabadiwallahs, who then import them to recycling industries. PVC market is the biggest trading area (Kroiss, 2016), its name is however just a name, that has nothing to do with the type of plastic traded there. PVC market and Choti Tikri get their plastic scraps from Kabadiwallahs located inside or outside Delhi. Badi Tikri gets its plastic scraps only from PVC market (Kroiss, 2016). Plastic scraps leaving the markets are sold depending on their quality. Good quality plastic scraps are sold to plastic recycling factories, and low-quality ones go to brick-kilns. Traders can also sell their scraps to other traders of Tikri Kalan.

Overall, plastic scraps trading in Tikri Kalan is a very complex activity involving thousands of people in a relatively small area. There are still many uncertainties

regarding the recycling process in that area, due to a lack of access to trading data. It is also still unclear where many of the sorted plastic scraps are sold and how they are being recycled.

While India has detailed rules covering the disposal of Municipal Solid Waste, the implementation lags far behind. Non-recyclable waste is mostly disposed of in poorly designed and overburdened landfills (Biplob, Gaurav, & Saryu, 2015). So far, mainly the garbage collectors involved in door-to-door-collection of waste and waste pickers have managed to very efficiently sort waste and recover all items with sufficient economic value from the mixed waste stream (Biplob, Gaurav, & Saryu, 2015).

One private entity, The Plastindia Foundation, an organization dedicated to promoting responsible uses of plastics in India, created an environmental committee report for the years 2015 to 2018. This report is packed with awareness programs on plastic waste management practices, beach cleanup drives, rallies and marathons to spread awareness. The foundation initiated awareness drives at various places in India educating masses on how effectively they can separate plastic waste and use them effectively. Part of the awareness program included teaching school principals the correct ways to collect plastics to be sent for recycling. The principals were given CD's which they could show at the school, hence educating the students and the faculty on the correct ways to collect and recycle plastics. The foundation also works with municipalities. Officials in charge of small Indian towns like Vellore & Jaisalmer were taught how to separate plastics and were provided with proper tools for recycling plastics.

PLASTIC WASTE FOR HOUSING IN INDIA

Since July 2017, one village became a zero-waste village. Waste collection centers were established in the small village of Chhota Narerna in Ajmer District, which allowed the villagers to collect, manage, and recycle plastic waste sustainably (see figure 6).

Figure 8. Waste Management Process. Source: (Plastindia Foundation, 2019)

As shown in figure 6, the village used a community-run rural waste management model. Waste was directly collected from the households, then went through a separation process where organic scraps were composted, and the recyclable waste sold. The village's waste management methods also included an innovative way to store plastic waste. As shown in figure 7, plastic bottles were used to build low-income housing. The result of these ecofriendly structures shows the finished result covered in mud (Figure 8), making it look indistinguishable from any regular mud structures. This method facilitated the collection of 50,000 Plastic bottles from hotels in Jaipur (Plastindia Foundation, 2019).

Figure 9. Storage of Plastic Waste. Source: (Estil K. , 2018)

This method successfully supported 100 families and provided them with scientific and sustainable means of waste disposal. By creating dignified job opportunities, the program also helped increase worker income by 75%. Over ten months, 1000 kilos of Plastic waste was kept away from the streets and sold to recycling companies, generating a revenue of 40,000 Indian rupees, an equivalent of 565 United States dollars per family. The program also had environmental advantages for the village, it eliminated open dumping spots, reduced soil and groundwater toxicity, eliminated carcinogenic emissions due to burning of Plastics, protected the local fauna, and no waterlogging due to littered waste (Plastindia Foundation, 2019).

Figure 10. The completed Structure. Source: (Plastindia Foundation, 2019)

The foundation also found a way to create history by throwing an event open to the public, media, and environmentalists to raise public awareness of recycling. India made history on the 5th of January 2018 at the Goregaon sports club in the city of Mumbai, where the world's largest T-shirt made from 100% Recycled Plastic was unveiled. About 12 one-liter Plastic bottles can make an adult T-shirt, and six bottles can make a child T-shirt (Plastindia Foundation, 2019) . The largest T-shirt measured 96.86 m long x 69.77 m in width and is made from 100 % Recycled PET Waste. To be built, 200,000 (1 liter) drinking water bottles were recycled to create 4 tons of Fabric. After the event, the Large T-shirt was cut and converted to 10,000 child size T-shirts that were distributed amongst underprivileged children from different NGO's across India.

Figure 11. World's largest T-shirt from Plastic Waste. Source: (Plastindia Foundation, 2019)

Plastindia Foundation continues the battle against littering in India with the Versova Beach Cleanup drive. The Versova Beach Cleanup drive was labeled as the "World's Largest Beach Clean-Up Drive" as per the United Nations. On April 1st, 2018, PIF, in association with "Being Ocean Foundation," sponsored by Mr. Amitabh Bachchan, added to the beach cleaning activity by donating and maintaining a junglee excavator and tractor. Their continual goal is to create awareness among the people so that they stop littering any waste, including Plastics, into water bodies (Arora, 2017).

These foundations are planning several more initiatives for the future. They are planning to cover areas all over Gujarat, India's westernmost state for Plastic waste management, and are engaging in active discussions with big Indian companies like Aditya Birla group to construct roads using Plastic waste. They are also planning on replicating the program on the village of Chhota Narerna in many other Indians villages,

build more small collection centers for Plastics waste, and work out a better remuneration system for plastic waste recyclers.

These case studies answered **RQ2** and **RQ3** by showing the successful and unsuccessful ways that Colombia and India are managing their plastic waste and housing problems. Colombia has been successful with the emergence of private companies such as Conceptos Plasticos, taking over most of the plastic waste management in the country, and building sustainable housings for those who need it. The country has also seen some results with the ban of single-use plastic in 2017. India, similar to Colombia, has seen more success thanks to the help of private companies such as the Plastindia Foundation. The foundation has been successful in raising awareness about the importance of recycling, educating local schools and local governments, and even managed to achieve a zero-waste village by recycling plastic bottles to build housing. If private companies are to be the leading solution to plastic waste management and housing, both the governments of Colombia and India, need to start being more successful in creating more proactive policies to facilitate the recycling efforts of these companies.

CHAPTER 5: ANALYSIS AND FIELD DATA

This chapter answers **RQ1** by analyzing the scope of the plastic waste pollution and housing problems in Haiti, **RQ2,** by examining whether or not there are existing programs in Haiti with the goals of fighting waste and providing housing**.** The Field data in this chapter are all about getting the point of view and analyzing organizations that have been directly or indirectly involved in waste management and housing in Haiti. By analyzing organizations that are present and working in the country, this chapter provides an in-depth understanding of the scope of the waste management and the housing problems in Haiti, as well as potential solutions that they believe would be suitable for the country.

WASTE MANAGEMENT IN HAITI

Over the past decades, Haiti has been plagued with the relentless problem of waste management. The metropolitan region of Port-au-Prince, the capital of Haiti, produces between 1,400-1,600 metric tons of solid waste every day, with 80% coming from households, 10% from markets and 10% from industry, an estimated 75% of this waste is organic matter (food cast-offs from the street markets) (SWANA Haiti Response Team, 2010).

The waste management system in Port-au-Prince, the capital of Haiti, is organized based on an institutional or formal official order, and an informal one. The service offered by the institutional order is partial to the planned districts. More than 77% of the upper-middle-class households benefit from a waste collection service. Contrarywise, 93% of low-income families in disadvantaged communities, do not benefit from any service (Bras, Emmanuel, & Berdier, 2009).

The national authority in charge of managing waste in the country, the "Service National de Gestion de Résidus Solides (SNGRS)," is significantly under capacity and suffers from a lack of funding, ineffective maintenance of equipment, and inconsistent management. The frequent political unrest in the country also only serves to exacerbate the situation, as public services such as solid waste collection and disposal stopped functioning. In 2010, after the earthquake that devastated the country, SNGRS, then SMCRS was only able to collect 20% of the waste generated in the capital due to equipment issues (SWANA Haiti Response Team, 2010). Most households in Haiti call on private services to remove their debris. This service is rendered by individuals equipped with wheelbarrows or by companies with large vehicles. In most low-income neighborhoods, this informal system is the only form of collection service that exists.

The only recycling done in Port-au-Prince is carried out by the informal sector. Scavengers store recyclable waste for some time in their homes to then sell to waste buyers. This system is, however, not a sustainable one since scavengers typically have no formal education, training, or access to the appropriate equipment. These foragers and other recyclers in the informal sector generally sell their recovered materials to

intermediaries, who in turn sell to small and large scale processing and manufacturing industries (Bras, Emmanuel, & Berdier, 2009).

Like India and Colombia, the Haitian government's efforts alone are not enough, and the country depends a lot on the help of private companies. Impact Global International (IGI), is a US-based organization founded by Haitian national Martingly Nelson, whose goal for the past three years has been to reduce waste pollution in Haiti. On their most recent trip, IGI has been able to work alongside the Haitian community, to collect 500+ bags of waste, over 10 tons of trash, clean the river of “Montrouis,” and clean two market places (Impact Global International, 2019).

In a conversation with IGI’s founder, he explains that the country lacks the infrastructure to manage large amounts of waste, as well as the proper education on the life cycle of waste. Mr. Nelson explains how he was inspired by the “waste to energy” system that is used in the United States and is working on implementing a similar system of waste disposal in Haiti (Nelson, 2019).

Waste to energy is the method of generating energy in the form of electricity from the primary treatment of waste or the processing of waste into a fuel source (U.S Energy Information Administration, 2018). A “waste to energy” facility as a method of waste disposal could be advantageous considering that only 30% of the population in Haiti has access to electricity and that the majority of energy use in the country is combustion of wood and charcoal for cooking (Booth, Funk, & Haase, 2010). The large amounts of waste in the capital and its surrounding cities, also further validates this solution as a viable waste management method for the country.

Another organization involved in waste management in Haiti is 4ocean. 4ocean is a purpose-driven business, founded by two Florida Atlantic University alumnus Alex and Andrew, to help end the ocean plastic crisis. The company's mode of operandum is to hire boat captains and other local workers to clean the ocean and coastlines full time, and they currently have two cleanup crews in Haiti where they employ more than 70 fulltime employees. Everything they collect is brought back to their facility for sorting, where they recycle what can be recycled. At their Haiti locations, the company stores what can't be recycled until they can find a better method of disposal. 4ocean's founders were not available formore data on their disposal process .

More field data were able to be acquired from two local Haitian business owners who provided an in-depth understanding of current waste management practices in Haiti, how they are impacting local citizens, and whether or not they are working effectively. They have been in business for more than two decades, and a ccording to them, there has not been a lot of work by the government regarding waste management in Haiti. SNGRS, the national entity in charge of waste management is unreliable due to the constant political unrest in the country (Estil & Estil, 2019). To get rid of waste, they resort to dumping their waste in "Titanyen," a small village around 5 miles outside of the capital that serves as a national landfill. According tothem , lawmakers in the country are trying to change the problem of waste. There have been talks of creating policies banning single-use plastic; however, so far, they have not been able to accomplish much, and everything is pending. Haiti's constant political unrest and the many new disasters mean that the country lacks the stability that is needed for a reliable waste management program to take roots (Cook, 2016).

One of the biggest cities in the world without a central sewage system is Port-au-Prince, Haiti. The city has no sewers connecting sinks, showers and toilets to wastewater treatment plants (Hersher, 2017). Since the Haitian government cannot afford to build a sewage treatment system, the problem has attracted international donors willing to help. Since 2010, international groups have spent millions of dollars on a plan to build open-air sewage treatment plants across Haiti. In 2012, the first facility opened at Morne a Cabrit. According to government officials from an interview with NPR, funds were in place for facilities in seven other cities, however, five years later, Morne a Cabrit is still the only open-air operational sewage treatment plant in the country (see figure 12). (Hersher, 2017).

In October 2010, a proposal was made to build another sewage treatment plant near Titanyen. The initial budget was $1.9 million, then would later grow to $2.1 million to be paid by the Spanish government. Construction began immediately, however, just three months later, it stopped due to problems arising from people claiming that they owned parts of the land, and requesting compensation. The sewage treatment plant eventually opened in May 2012. The facility operated only for 18 months before a technical problem forced it to close. Since 2013, the sewage treatment plant at Titanyen has been closed (see figure 13) (Hersher, 2017).

The open-air sewage treatment plant at Morne a Cabrit is the only such facility operating in Haiti.

John W. Poole/NPR

Figure 12. Open Air Sewage Treatment Plan at Morne a Cabrit (photo by John W.Poole/NPR)

Since 2013, the $2.1 million sewage treatment plant at Titanyen has been closed. The lining of one of the disinfecting basins developed massive bubbles due to an engineering defect.

Marie Arago for NPR

Figure 13. Sewage treatment plant at Titanyen (photo by Marie Arago/NPR)

In comparison, Colombia's environmental sector have been planning some major projects. Bogota Colombia's only liquid waste processing system will be expanding a second facility, said to be constructed for 1,3 billion United States Dollar. There are also talk of other waste management projects, such as a local water supply system in the city of Cúcuta, to be built for 177 million United States Dollar, and a liquid waste processing system in the city of Pereira, to be built at 119 million United States Dollar (Global Recycling, 2019).

In India, a very constrained budget has been allotted to the solid waste sector. Funds for Solid Waste Management (SWM), are typically assigned as part of the annual municipal general budget. Municipalities receive funds from sources such as, the central government, various NGOs, and local taxes (Ghatak, 2016). In smaller Indian towns, up to 70% of municipalities total budget is spent on SWM. Metropolitan cities on the other hand, only spend around 10% of their total budget on SWM (Hanrahan, Srivastava, & Ramakrishna, 2006). Table 2 below, compare the average costs in Indian Rupees spent in SWM in different types of Indian Cities. The table compares both in cost per capita and cost per ton over the different population ranges of each type of city (Ghatak, 2016).

City with Population	Cost Rs Per capita/Year	Cost Rs Per Tonnage/Year
Metro City	150/-	1100-1200/-
Class I city	110/-	450-500/-
Class II city	70-80/-	700-800/-

Table 2. Cost Analysis of SWM for the Indian Scenario—How much does it currently cost? (Ghatak, 2016)

THE NEED FOR HOUSING IN HAITI

In Haiti, more than half of the population lives in rural areas. The majority of all rural housing consists of two-room homes that have mud walls and floors and roofs made with local grasses or palm, or coconut leaves (Estil & Estil, 2019); they may also be constructed with plastic and other materials and roofed with corrugated metal (Encyclopaedia Britannica, 2019). In the cities, housing for most people is similar to that found in rural areas. According to field data received from the local Haitian business, low-income people in Haiti, build their homes out of everything they can find, resulting in unsafe dwellings and slum creations. One of the owner of the local business , is also a builder with over 30 years of experience. He estimates that to build a sturdy house in Haiti, that will withstand hurricanes or earthquakes, one would spend anywhere between $50,000 to $300,000, an amount that most people in Haiti cannot afford (Estil & Estil, 2019). Renting in many places in Haiti is no less pricey. The cost of renting a three-bedroom house in Delmas, one of the most populated communes in the Port-au-Prince Arrondissement, is 300,000 Gourdes, or 3140 United States Dollars (Estil & Estil, 2019). Since the unemployment rate in the country is high, most Haitians are unable to afford that (Estil & Estil, 2019). Most Haitians are also unable to finance a house through bank loans. Banks in Haiti are risk-averse and reluctant to issue loans or mortgages. Without a mortgage market, developers are left to either inflate the price of housing, or deploy their capital elsewhere (Caldwell, 2018).

According to data from Conceptos Plasticos, the cost of building their standard two-bedroom plastic home is only $5,200. In Haiti, the standard cost of building materials and construction of a single-family home is $8,000, and the cost of a duplex (2 family home) is $12,000 (Double Harvest, 2019). However, according to data gathered

from the field study, building a 2 bedroom home in Haiti can go from $40,000 to $50,000 because you have to account for inflations in the cost of labor, as well as the cost of material transport (Estil & Estil, 2019). The advantages of the plastic bricks, is that, even if in the beginning it might cost more (since a recycling plant to make the plastic bricks would have to be built in Haiti), the long term advantages might outweigh the initial expense. Another advantage of building with those plastic bricks is due to their easy method of assembly that can be done by anyone. Building with them would get rid of a lot of the labor, thus lowering the cost of construction. Other advantages of adopting such a construction method in Haiti could be that even though the initial cost might outweigh regular construction methods, the long term environmental benefits have the potential to counterbalance the cost by cleaning communities.

The little number of public housing projects attempted have also not yielded fruitful results in Haiti. In 2012, the American government was involved with the construction of the Industrial park “Parc Industriel de Caracol” by financing workers' housing. Engineers from EKAM Housing heavily criticized these homes for lacking irrigation systems and being built with inferior roofing materials. These engineers also predicted that the houses had the potential of becoming a dilapidated slum, posing a threat to the health and wellness of their Haitian workers (Under Tents, 2012). Two other public housing projects, at “Morne Cabrit” (figure 10) and “Zoranje,” have suffered similar fates, with some even remaining empty (Under Tents, 2012).

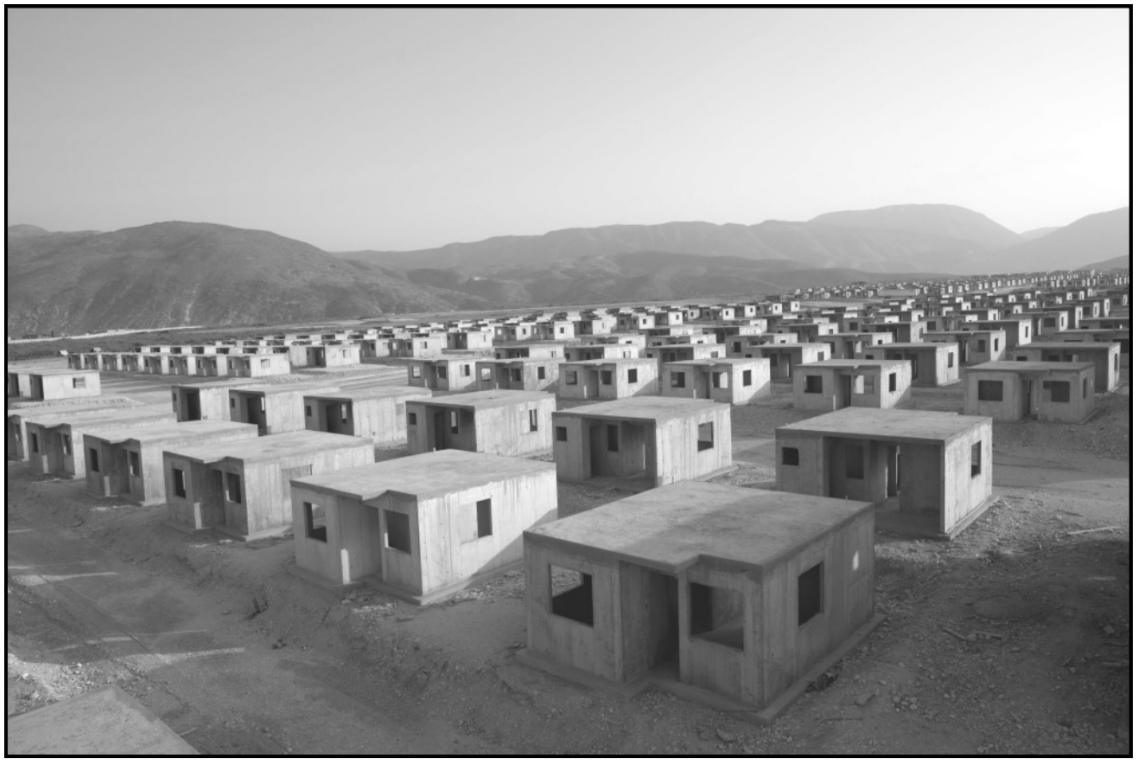

Figure 14. Public Housing Project at "Morne Cabrit" Source: (Depp, 2012)

The Housing project at Morne Cabrit was supposed to have 3, 4 and 5 story buildings in a total area of 240.000 m2 area, 172 blocks, and a total of 2748 dwellings (Tolga Architects, 2013). The project was supposed to also include an elementary and high school designed for a total of 2328 students in the Morne Cabrit area, a police station, a government building, a health care center and a market (Tolga Architects, 2013). The project, like many others before it, focused on how technology and design could improve the integrity of the structure, increase resilience, and limit the damage of future disasters. However, developing a viable housing project in Haiti is more complicated than structure and design alone, and this project did not take into account the social nature of housing delivery. While construction techniques and building technology are important aspects of housing delivery, successful housing development has to address

every facet along both the demand and supply sides of the value chain (Caldwell, 2018). The project at Morne Cabrit, although free, is inconveniently located away from employment, and with no access to infrastructure. Built on a hill far from Port-au-Prince, most of the 2748 homes built remain unoccupied today (Caldwell, 2018).

Due to its location, Haiti also has a huge need for post-disaster housing. Haiti is one of the most at-risk countries in the world to natural disasters like floods, hurricanes, earthquakes, droughts and landslides. From 1994-2013, Haiti was the third most impacted country by extreme weather events due to the many lives lost and economic damages (Global Facility for Disaster Reduction and Recovery (GFDRR), 2019). In Colombia, Conceptos Plasticos, using its method of building with recycled plastic waste, has managed to build homes that are fireproof and earthquake-resistant. So far, the company has built a temporary shelter for 42 families, three smaller permanent shelters measuring 1,100 square meters each, and eight houses (Winkless, 2016). As discussed in chapter 3, these homes built of plastic bricks are very easy to assemble and would be a good solution not only as a permanent shelter, but also as temporary shelter to quickly house displaced people after a disaster.

This chapter answered **RQ1** by showing how elitist waste management and housing is in Haiti, and **RQ2**, by showing how unsustainable and unsuccessful waste management and social housing projects have been in Haiti. Since the country has an unreliable waste management system, waste is discarded through private means that are often unsustainable and unsanitary, also, only those with the means of doing so can discard their waste to the designated landfills. The limited amount of housing projects undertaken so far has also lacked effort and has been, for the most part, unsuccessful. The

cost of constructing a home for the average Haitian is also exorbitantly high, resulting in most of them building their homes out of discarded materials. Similar to what was observed in the case studies of chapter 4, most of Haiti's waste management and housing efforts are privatized. These companies are however, not as active in Haiti as they could be due to the risks involved with investing in housing in the country. Private companies, such as IGI, as well as the Haitian government, have drafted plans on potential solutions to managing waste and providing housing; however, the constant political turmoils are a deterrent and only serve to slow down progress.

CHAPTER 6: CONCLUSIONS

The literature review of chapter 3 answered **RQ1** by showing the scope of the housing and plastic waste management problems. As shown in Figure 1, Haiti produces the least amount of plastic waste at only 328,487 tons. However, due to the size of the country in proportion to the amount produced, as well as improper management methods, the nation's waste problems are the most visible. Colombia and India also produce less plastic waste than developed countries such as the United States or Germany. Annually, Colombia produces 2.41million tons of plastic waste, and India produces 4.47 million tons of plastic waste. The combined plastic waste production of these two countries is 30.93 tons less than the 37.93 million tons of plastic waste produced in the United States alone (Our World in Data, 2019).

The lack of adequate housing is another problem that is also more visible in developing countries. The population in developing countries around the world are multiplying at a rate too rapid for them to handle, where hundreds of people live in the worst conditions. Also, interestingly, because the income rate in these nations is astronomically unproportionate to the cost of housing, the cost of living in expensive North American or European cities is affordable in comparison (see Figure 2).

Chapter 3 answers **RQ2** by providing the many ways that developing countries around the world have successfully or unsuccessfully managed their plastic waste problem. Developing countries around the world have started banning single-use plastic. Rwanda, a pioneer in this method, is now considered to be one of the cleanest nations on earth (UNEP, 2018). South Africa also had a ban on single-use plastic that was, however, not as successful as Rwanda's. In Haiti, an organization named "The Plastic Bank" attempted to provide jobs by hiring Haitian workers to pick out plastic waste for recycling. This is another initiative that so far has not been successful. This chapter also answers **RQ3** by showing the current information on the many ways that plastics are used in construction around the world. Table 1 in that chapter does an excellent job of outlining the different types of plastics and their current applications in construction.

The case studies of chapter 4 also answered **RQ2** and **RQ3** by showing how waste managers and planners in Colombia and India have managed their plastic waste. Most of the government's efforts in these two countries have only been through policies. Two private companies, however, have taken a more proactive approach to the problems of plastic waste management and housing. The Colombian company Conceptos Plasticos have managed to build homes in Cartegena made entirely out of recycled plastic waste. The Indian Foundation, Plastindia Foundation, has managed to turn the small village of Chhota Narerna into a zero-waste village, all through a community-led program. Through waste collection(see Figure 6), and a method that used plastic bottles to build low-income housing (see Figure 7&8), the village was able to recycle plastic bottles, provided employment and supplemental income to the families in the village.

The Analysis and Field Data of chapter 5 answered **RQ2** by providing insights on how Haiti is managing its plastic waste, and its need for adequate housing. According to field data gathered from the local business owners, the Haitian government has many plans on what to do to manage both problems; however, not much action has been taken. Waste management in Haiti is very informal; currently, most of the work is being done by private organizations such as 4ocean and IGI, since the governmental waste program is too unreliable.

Haiti finds itself in an unusual situation where, while the opportunities for improvement are plentiful, the constant political instability makes it difficult for even the most basic planning practices to take root. The frequent disasters are also to blame, Haiti, on average, is hit by a major hurricane every seven years, making it the Caribbean's most vulnerable nation (Pan American Development Foundation (PADF), 2019). Furthermore, the government of Haiti does not have a formal Urban Planning sector, rendering the country heavily dependent on foreign and private companies' help.

Looking at how private companies in Colombia and India have been successful, similar approaches might be possible despite the political unrest. The methods of building with plastic waste outlined in the case studies are simple enough to start as viable waste management and housing efforts in Haiti. The case study for Colombia specifically with Conceptos Plasticos, provides for dignified housing, easy enough to replicate in Haiti, and makes financial sense. If incorporated as a planning effort on a national scale, this method could be a good start for the waste management and housing efforts in the country. Colombia is also a country with a lot of political instability. According to data from The World Bank, from 1996 to 2017, when analyzing each country's political

stability index (-2.5 weak; 2.5 stable), the average value for Colombia during that period was -1.6 points. The average value for Haiti during that period was -1.05 (The World Bank, 2019). According to this index, it shows that while political instability poses a problem, it is, however, not an end-all all situation.

RECOMMENDATIONS

To tackle the plastic waste and the housing problems in Haiti, this thesis first recommends building a plastic waste recycling plant in Port-au-Prince. This factory would recycle plastic waste around the city into bricks to be used for housing. The construction of such a factory could have amazing economic development implications, such as providing new jobs, new training programs and public education programs.

In 2005, the U.S. Agency for International Development (USAID) funded a project called "The Haiti Emergency Solid Waste Collection, Landfill Rehabilitation and Jobs Creation Program". This program employed thousands of Haitians to clean up solid waste piles in Port-au-Prince over a nine-month period in 2004-2005. The result of this program was the cleanup of a number of the waste piles in Port-au-Prince. While this effort was significant, it was only temporarily effective, as a result, the waste piles returned to the streets of Port-au-Prince despite the $3 million investment by USAID (SWANA Haiti Response Team, 2010). A plastic waste recycling plant in Haiti, will have a similar effect of providing jobs to thousands of Haitians, but this time on a more permanent level.

This project will be an opportunity to educate the Haitian population on the benefits of recycling and its positive effects on the environment. Since this project is introducing a new material of construction, it will also provide education on how to build

with the bricks, as well as how they are made using plastic waste. Using Conceptos Plasticos example, the social impacts of this project could be considerable, since it will be able to empower members of the Haitian community to come together and build their own homes, using a material that can be potentially cheaper than concrete. The plastic brick allows anyone to take part in the construction process, regardless of their knowledge, abilities or financial resources.

Building such a factory will be an opportunity to make the area more prosperous by increasing revenue, developing markets and overall, help an economically underdeveloped area fight off poverty. Since one of the main goals of this factory will be to recycle plastic waste throughout the city, the environmental advantages alone of its construction will be significant. The environmental advantages of building such a recycling plant in Haiti has the potential to outweigh the housing benefits. With every new technology that has to be manufactured, there are always opportunities for monetization. This recommendation is made with the realization that, building a plastic recycling plant in Port-au-Prince might solve more of the waste management problems in Haiti than the housing problems. This thesis acknowledges that this solution might not equally solve both problems, however, its implementation is still recommended because solving the plastic waste problem in Haiti will still be a huge step in the right direction.

While building a plastic recycling plant in the country is great to address the current problems of plastic waste, a more long term goal would be to reduce the need for plastic, through investments in water infrastructure. The fact that Port-au-Prince does not have a central sewage system, has served to exacerbate further the waste problem. Raw sewage is being constantly dumped into canals that run through Port-au-Prince, causing

them to overflow when it rains, and flood poor neighborhoods (Hersher, 2017). This contaminates the water, causing Haitians to buy plastic water bottles in bulk for their potable water needs. Since an adequate recycling program is also not available, these water bottles end up in the streets and in the canals, starting all over again this vicious waste cycle. After an investment in a central sewage system for the country is made, there will be a need for programs to educate the people that municipal water is safe to drink, which will ultimately reduce the need for plastic bottles. One outcome of reducing the needs for plastic bottles, and cleaning the streets of Port-au-prince out of plastic, would be that, a recycling factory that recycles plastic into bricks for construction might become obsolete. This is a long term outcome that actually would be ideal, because it would mean that the recycling plant has achieved its ultimate environmental goal of ridding the streets of Haiti of plastic waste.

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