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Towards a Circular Economy: A Case Study of Waste Conversion into Housing Units in Cotonou, Benin

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Abstract: Cotonou is the largest city and main economic centre of the nation of Benin, Africa. Following independence, the city has experienced major population growth resulting in the extensive development of slums on flood plains and marshes causing the loss of biodiversity of these fragile ecosystems. Infrastructural development, unable to keep pace with informal settlement development, and a cumbersome municipal service system, have led to the illegal dumping of organic and plastic wastes, and extensive land pollution. In addition, due to its primary dune coastal location, Cotonou is facing sea level rise risks demonstrating the urgent need to sustainably address urban development. Through a socio-technical framework, this paper considers the use of transformed plastic wastes as new settlement building blocks to reduce solid waste, create jobs, and develop low-cost housing. This new strategy offers employment empowerment and a strategy to generate an income of US$2,380,000 per annum and the creation of 3200 permanent jobs.

Keywords: Cotonou; plastic waste; housing; job creation; circular economy; sustainability; environmental technologies

1. Introduction

Cities currently comprise 4% of land area on earth, but boast a total human population of 54% [1]. According to the Global Activity Report 2015 [2], this population number is expected to soar up towards 66% of the earth's total human population by 2050. While cities are hailed as nodes for commerce, culture, science, productivity, social, human, and economic development [2], addressing issues of quality urban planning, transport systems, water, energy, and waste management are city policy priorities lagging behind these nodal sub-aspirations, and the host city infrastructure is constantly in need of upgrading to accommodate these priorities.

Within this context, addressing waste management has been pointed to as a key indicator of the success of environmental sustainability efforts in a city. Urbanisation, coupled with population increase and economic growth, has resulted in an enormous increase in the number, volume, and mass of all kinds of wastes, including hazardous and non-hazardous garbage, biological and 'clean fill' wastes, fumes, gases, and domestic and industrial trash sourced from homes, industries, and institutions. Hoornweq and Bhada-Tata [3], from the World Bank, reported that in 2012, that approximately 3 billion urban dwellers generated over 1.3 billion tons of waste every year; this waste number was projected to reach 2.2 billion tons per year by 2025. In 2016, it was calculated that every person generated 0.74 kilograms of waste daily which translated to 2.01 billion tons of solid waste per year; this figure is projected to reach over 3.4 billion tons in 2050 [4]. Correlate this data to the fact that over 60% of the total global population lives in urban centres and you realise that the disposal (including conversion, deterioration, disintegration) and storage of waste is a key issue confronting human survival and has major collateral damage to our environments and the earth's non-human residents.

Increased purchasing power demonstrated by a majority of city dwellers, especially the 'middle class', enabled by economic growth and improved disposable income, has resulted in excessive consumption and demand for goods, housing, infrastructure, electronics, automobiles, amongst others. This consumption pattern has led to an increased generation of wastes from industries, households, offices, and the transportation sector. Additionally, increased consumption results in increased tangible wastes in the packaging of goods and services to enable conveyance and to comply with burgeoning occupational health and safety protocol regimes that are further escalating this situation despite attempts at biodegradable materials and waste conversion. The management of waste on site then becomes a major challenge. With demand for residential space increasing, waste infill sites are no longer deemed viable because there is little or no space left in cities to accommodate this waste. The issue is omnipresent especially in developing countries, which have piles of uncollected waste on almost 'every corner' [5].

Increasing waste generation exerts pressure on local municipal councils who are grappling with ways to reduce, collect, and effectively dispose of waste, with a majority, especially in developing countries, struggling with collection and the sustenance of management efforts [5,6]. This struggle emanates from insufficient waste management infrastructure, poor funding, insufficient space and venues for waste disposal, and inappropriate waste management technologies [7,8]. Mukhtar et al. [9] relate that developing cities struggle with waste management due to their adoption of uncontextualized solutions. Such have been adopted without realising the recognisable differences between contexts, policy challenges, population and waste volume temporal growth, and the underlying investments various cities require to address this issue. In the longer perspective, negative impacts like pollution, flooding, reduced supply of clean potable water, increases in health burdens, and challenges of climate change will become apparent. The consequences of these variables render waste management efforts even more daunting as monetary funds are diverted into adaptive mitigation rather than addressing proper source-based waste management strategies [10,11].

This context is very prevalent in Cotonou, one of the main cities of the African nation of Benin. With an inexorable increase in population, limited land availability coupled with scarce and inadequate waste management services, the city of Cotonou is facing an unprecedented administrative dilemma: How to reduce waste, provide human accommodation, and increase employability in a bid to enhance liveability?

This research considers this dilemma and offers a conceptual framework based upon the theory of multi-level perspective (MLP) [12] to transform plastic wastes by converting them into building bricks for accommodation lodgings. Such an endeavour could provide both work and housing for the people of Cotonou. As for all major projects, the financial side remains a major hurdle but there are possibilities for public/private partnerships and international aid in this instance to support this initiative.

2. Background

Despite Porto-Novo being the capital city of Benin, Cotonou remains the largest city and main economic centre of the nation of Benin. Cotonou hosts the Cotonou International Airport, a major port together with a population of 679,012 inhabitants (in 2013) living in a total area of 79 km^2 [13]. Despite these statistics, Dossou and Glehouenou-Dossou [14] claim that more than half of the nation's population is in Cotonou. These authors highlight the urgent need to address the issue of urban development from a sustainability perspective due to the increasing vulnerability of Cotonou to sea-level rise. One particular area that has dogged the Cotonou authorities for decades is that of waste management. Brock and Foeken [15] recognised that collection and disposal of solid waste is a highly critical issue in urban areas in Benin. The World Bank has estimated that of 154,000 tons of waste per year in Cotonou, only 7.86% is disposed of at the official landfill at Ouèssè [16]. Collection of these wastes is currently undertaken by non-government organisations (NGOs), supported previously by the Canadian International Development Agency (CIDA), but now serviced by the municipality of Cotonou.

Despite such endeavours for proper waste collection and disposal, there remains a growing mountain of solid waste and sewage emanating from households, and the Dantokpa Market, that are being constantly piled up at informal dumpsites across Cotonou. Much waste is also being discharged into the water bodies surrounding and interlacing Cotonou, including the coastal Cotonou Lagoon, a major canal, the Ouémé River, and Lake Nokoué, leading to serious ecological issues [16]. Tchakpa et al. [17] have postulated that in 2012, there were 800 tons of household waste being generated per day in Cotonou. We argue that one can observe daily solid wastes being dumped in the Lagoon that are progressively forming little 'islands' upon which slums are being informally and unregulated erected, as shown in Figure 1. Waste is even being used as infill material on the edges of the Ouémé River on which slum houses are being erected. Figure 2 depicts slum house construction in progress on the edges of the Ouémé River, and Figure 3 depicts typical housing units on wastelands.

This situation is extremely unsustainable, and prone to disease and loss of human life and biodiversity, posing a serious ecological and social threat to the population of Cotonou and to the waters of the Gulf of Guinea that water-borne wastes exit into. There is, thus, an urgent need to address more effective waste management services for Cotonou. Prasad et al. [18] have highlighted the major environmental crisis that plastic wastes pose to the world overall and have offered a potential waste management solution that involves the effective conversion of plastic wastes into plastic fibre reinforced soil blocks for use as sustainable building materials. Such an endeavour opens avenues for potential applications in Cotonou.

Figure 1. Waste dumping site near a river with slum formation.

Figure 2. Waste infill in a river serving as foundation bed for an incoming slum housing.

Figure 3. Typical housing units on wastelands in a cholera-infected area, largely due to the decomposition of organic wastes.

For too long, human waste has been viewed as an urgent problem and challenge requiring immediate action. However, despite an escalating volume of literature highlighting that waste should be viewed as a resource that can be utilised as a means to generate revenue, to innovatively serve as an alternate input in select industries and sectors and thereby as a source of permanent employment [19], little action has been effectively taken at a city or national level internationally. As collaborating evidence, Romero-Hernández and Romero [20] argue that waste management practices have the potential to reduce costs and at the same time, generate substantial revenue, qualifying the viability of this circular economy initiative.

To generate revenue, traditional methods of waste management strategies are being phased out in favour of the re-use, re-manufacturing, and recycling of different materials [21]. We argue that having a rationally planned and managed urban centre is a prerequisite for proper waste control, monitoring, and management. In such cases, it becomes possible to provide incentives to reduce waste generation, as well as to introduce 'green' taxes focusing on ensuring reduction and proper disposal of waste. Through those taxes, and application of a 'polluter pays' initiative [22], local governments are able create new revenue streams as well as to encourage waste reduction and the application of the 3Rs—reduce, reuse, and recycle [11]. In addition, besides those measures, various cities are utilising waste as a source of energy. This initiative facilitates the reduction of greenhouse gases (GHG) and provides an additional option for energy security [23,24]. The positives of these initiatives have however been disputed as having negative impacts upon the environment [20].

Through recycling, especially in cases where waste sorting is practiced, different industries are able to ensure quality raw materials that yield products such as asphalt for road paving, metal chain links, concrete blocks, and wood for diverse construction applications, amongst many other uses. For example, General Motors has related how this strategy has contributed to the diversification of their revenue sources through the sale of unwanted and unused cardboard and leftover steel. In 2016, through the sale of leftover cardboard, the company was making US$20,000 per month [25].

Waste generated from the electronics sector is an increasing challenge but there are recycling potentials present. Silicon has become an irreplaceable raw material in the production of solar panels, which are key in the renewable energy drive and have been adopted in many economies. In London, as reported by Mitchell [26], a circular economy model enabled the earning of £25.4bn in 2013, and the figure is projected to grow at a rate of 5% yearly. For this reason, Stahel [27] advocates for the re-thinking and re-designing of products to ensure a reasonable life-cycle and for transferability of use into other sectors after they have become obsolete in their primary aim. This is known as closing loops [24,27].

The increasing adoption of circular economy models not only allows for re-use and waste valorisation [28], but has been instrumental in economic growth through the creation of jobs for both skilled and un-skilled workforces [27]. In the European Union [19], it is reported that the repairing of different materials has contributed significantly in job creation with almost half of people employed under a circular economy. This has shown to encourage the creation of jobs in sectors like energy, transportation, manufacturing, and building, amongst others. The sale and re-sale of old and recycled materials in nations such as China, United States, and the European Union has also been seen to contribute significantly to job creation and ultimately in supporting the economy [24,29]. Esposito et al. [30] claim that re-manufacturing activities created over 500,000 new jobs in the United States alone in 2017 and the trend is set to expand further. Mitchell [26] reported that the adoption of circular oriented economies would inevitably equate to an increase in demand for labour; thus, helping in the local economy and societal levels.

3. Methodology

This paper considers the expanding issue of waste management in Cotonou, Benin, and proposes a new model to achieve a circular economy model for waste reuse that is coupled with addressing Cotonou's issues of housing an increasing population, and the relocation of slum dwellers into quality housing units. The approach argued is an approach that provides a theoretical foundation that ensures a coherent and inclusive implementation policy. Section 4 offers a literature review of waste management and conversion techniques currently in adoption and introduces the identified social tool; the socio-technical transition theory. Following which, a review of literature was performed to understand waste composition in Benin. Section 5 proposes a new model that is set to better respond to the local challenges, and Section 6 discusses its implementation, potential contributions to society, and the novelty of the approach.

4. Literature Review

4.1. Practices in Waste Management and Waste Conversion

Efforts to address waste has led to an increasing body of literature investigating waste management and waste conversion [5,31]. Even though it is known that waste leads to environmental degradation and increased health problems [6], it has been shown to also create revenue for local residents [29,30], create employment [29,32], and help solve building and construction challenges while providing an alternative revenue stream for local government [22], amongst others.

In the recent past, there has been numerous strategies aimed at converting waste into reusable products. In numerous municipalities, both organic and non-organic wastes are now being converted into usable fuel—often biofuels. This is resulting in a strategy that Patni et al. [33] view as an alternative to fossil energy generation. Organic wastes, such as food and garden wastes, are being converted into composts, as in Ireland [34], while in other areas, as explained by Dou et al. [35], some of these wastes are valuable in making nutritious animal feeds; especially garden wastes.

With urbanisation and population increase exerting pressure on housing and infrastructural development sectors, conversion of wastes into building materials has become a key adopted strategy for waste conversion [33,36,37]. In addition, the conversion of wastes into construction materials has also been seen as a way to address environmental degradation issues and increasing energy consumption prompted by current construction technologies [37]. A case in point is the conversion of sugar industry waste (sugarcane bagasse) into cleaner energy and construction inputs such as bricks, paver blocks, and cement [38].

Recycling of wastes, such as plastics, demolition wastes, mining wastes, and agro-wastes, have now become one way through which building and infrastructure development materials, of comparable standards to readily available market products, are being produced in different nations. Dakwale and Ralegaonkar [39] posit that wastes from the demolition of old structures can be converted into eco-bricks which are of suitable high quality and light weight for use in the construction of different housing structures. Wastes from similar sources can also be used in infrastructure development; hence, re-diverting them from landfills. Liuzzi et al. [37] explain how different agro-wastes are now being converted to produce high quality and sustainable insulation materials to replace the conventional non-renewable materials, which has been occurring for a long time in Mediterranean areas. Similarly, Apriantis [40] has explained how different waste materials like agricultural wastes, which are rich in silica, and industrial waste are being utilised in supplementing cementitious materials in concrete production. Gunnings et al. [41], have demonstrated how aggregate from different waste matters, when treated with carbon dioxide, can be converted into valuable products such as concrete, construction blocks, and substrates for green roofs; hence, benefiting the United Kingdom construction sector. They argue that production of these secondary aggregates relieves the environment from the conventional virgin aggregates extraction, and the authors note the concern to environmental issues linked to source material. Their report is supported by Tripathi [42] who shares how different wastes, including aggregates, are being valorised into building materials that meet international standards.

4.2. Theoretical Foundation

Technology use can enable a significant change in the socio-technical dimension. This conclusion is evidenced in two case studies; the socio-technical transition theory as proposed by Rip and Kemp [12], and further substantiated by Geels [43], that has been used as the theoretical foundation of this research. This theory envelops several dimensions that aim at guiding a society towards a common vision (in this case, urban sustainability) while focusing on transformative societal processes through innovations from a multi-level perspective (MLP).

The MLP postulates, on three levels, towards promoting an understanding of transitions:

- I) a macro-level that focuses on the landscape under study and includes the interconnectivity of cultural, economic, and political patterns;
- II) a meso-level that highlights the regime dimension of the city under study in terms of current practices and ongoing guidelines in a socio-technical system; and finally,
- III) a micro-dimension that involves a niche level that includes the space where radical innovations may challenge and break through the ongoing regime, as shown in Figure 4.

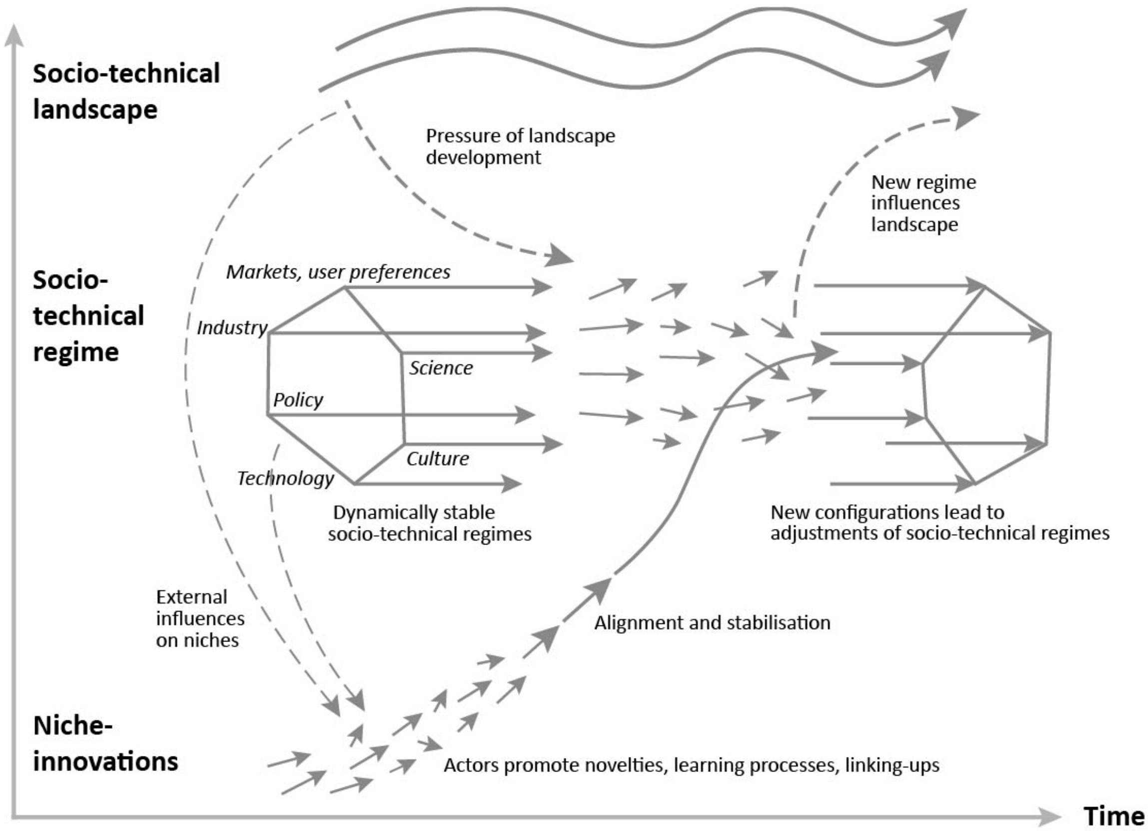

Figure 4. The multi-level perspective on transitions. Adapted from Schot and Geels [44].

Moreover, while the theoretical groundwork of the MLP offers a solid foundation to guide this research, there is a need to adopt a particular planning strategy for changing the technological systems in place for plastic waste [45]. Hoogma et al. [46] offers such a strategy that proposes "to build on the ongoing dynamics of sociotechnical change and to exert pressures so as to modulate the dynamics of sociotechnical change into desirable directions". For this study, the desired course of action is oriented towards sustainability through the smart management of plastic wastes and hence, there is need to select which level of the MLP should be pondered upon as the pressure point.

Geels [47] offers an insight on the matter of pressure points and posits that transition management through such a strategy focuses essentially on the lowest level of the MLP model, the niche. The niche is where radical innovation emerges and where the whole system can be geared into a sustainable vision.

Critiques of the MLP model have been offered by several researchers. Smith et al. [48] have highlighted the need to consider an extension of the model through a thorough focus on the central role of power in socio-technical transitions. Other criticisms argue for the need to consider an expansion of the concept of change into interpretivism and relationism, as advanced by Genus and Coles [49], while Shove and Walker [50] have identified the need to consider other theories of change in a bid to explain socio-technical changes within a society. Nonetheless, the scope of this paper is limited to the original narrative of the MLP as proposed by Shove and Walker [50] with the main drivers of change being the three planes of: (i) niche innovations; (ii) socio-technical regimes; and, (iii) socio-technical landscapes [51–54].

4.2.1. Niche Innovations

The core dimension of the MLP lies within a niche which refers to specific dimensions of a particular society. The users within a niche have specific demands and are the main proponents of change. Kemp et al. [55] and Hoogma et al. [46] have identified three major social dynamics within niches being:

- Learning processes that involve an understanding of issues pertaining to infrastructural requirements, market demands, and policy dynamics within the end users;
- The vision of innovative ideas and practices that act as the conspicuous dimension that will attract funding; and,
- Constructing new social networks geared principally at promoting new innovations.

Geels [43] posits that through social projects, the main proponents within each niche could be exposed to the innovations being proposed on a first-hand basis. This provides an impetus for promoting a general acceptance of the model of change being proposed. For example, the niche level for plastic waste transformation in Cotonou lies within the need of inhabitants having access to proper municipal services and housing. The need creates the drive for change.

4.2.2. Socio-Technical Regimes

Giddens [56] described socio-technical regimes as being the subtle rules that act as beacons in guiding and in co-ordinating end-user perceptions and actions within a particular social structure. Verbong and Geels [57] elaborated on three dimensions of the socio-technical regime as being:

(i) Material and technical elements;
(ii) Network of actors and social groups; and,
(iii) Formal, normative, and cognitive guidelines that provide responsibilities frameworks for human actors.

However, Geels [58] warns that socio-technical regimes have rigid structures that permit restricted incremental upgrading provided that they follow already established pathways and do not radically upset extant stabilising mechanisms. These mechanisms revolve around *vested interests*, *sunk investments*, and *stable beliefs* [57]. For example, transforming plastic wastes into building bricks requires specific technical inputs from various groups including the municipal services and the main proponents of change (social groups, technical experts, or co-operative societies) who will be the ones directing the transformation of plastic wastes.

4.2.3. Socio-Technical Landscapes

Above *niche innovations* and *socio-technical regimes* there prevails a larger dimension known as the socio-technical landscape. Geels [43] posits that this landscape, or context, directly influences the lower two dimensions of the MLP and includes infrastructural dimensions intricately linked within a web of specific values, beliefs, and the major economic situation. For this change, the socio-technical landscape may involve the values and guidelines pertaining to the need for sustainable development according to defined sustainable development goals. Moreover, the technical guidelines of the financing body may also be part of the landscape level.

Although these three levels are highly distinct with inherent sets of characteristics and domains, Geels [43] acknowledges that the dynamics of transition occurs subtly through interactions at all levels. For instance, once there is an introduction of an innovation at the niche innovation level, this will trigger an impetus leading to a change in the socio-technical landscape. The latter change trickles down to provide the necessary pressure to shake the established pillars of the regime and hence provide further opportunities for innovations [59]. This calls for a probing of the different pathways of change that prevail within the socio-technical transition theory from an MLP perspective.

4.2.4. Pathways of Change

These pathways, as developed by Geels and Schot [59], are:

(1) Transformation: This endeavour is dependent upon an impetus evolving from external social groups or from the landscape level. External pressure of this nature eventually leads to incremental changes causing subtle readjustment of the regimes in place. As such, the main actors of change are carried out by those at the regime level. However, Geels and Schot [59] acknowledge the failure of such changes in causing any major innovation at the niche level.

(2) Reconfiguration: Such a pathway is driven forward when there are external pressures at the landscape level and when the regime in place faces problems as well, resulting in a trickle down that shakes the established core attitudes at niche level. These kinds of situations trigger certain niche innovations within the system, like plug-and-play methods or technical changes, leading to a steady realignment of actual systems with their more pressing needs. Such realignment(s) affect not only structural components but also lead to steady changes within practices, beliefs, and principles. Moreover, in this pathway there is a well-defined line of communication between regime and niche actors in terms of development and supply logistics.

(3) Technological substitution: This pathway is characterised by a crisis(es) originating at the regime level due to landscape pressures. However, such crises offer room for innovations at the niche level. There is *niche-accumulation* whereby the new technical upgrades move on and gain ground within bigger markets and eventually replace the obsolete ones. Moreover, this pathway provides a competitive ground for niche actors competing with unavoidable actors at the regime level.

(4) De-alignment and re-alignment: Such a pathway originates when there are major changes at the landscape level. These events eventually collapse the system in place. There is de-alignment of the system to make way for a re-alignment with a new system. The new system is born out of major competitions between several niche-innovations and through trial and error during a period of intense uncertainty as regime actors no longer trust the viability of the system in place.

4.3. Waste Characterisation

In a survey carried out by Tchakpa et al. (2012) [17], it was concluded that in 2012 there were 800 tons of household waste being generated per day in Cotonou. Upon closer scrutiny, Tchakpa et al. (2012) [17] characterised the household waste under 10 sub-categories, as shown in Table 1, while waste collected from two markets were allocated into 9 sub-groups, as shown in Table 2.

Table 1. Household waste characterisation (adapted from Tchakpa et al. (2012) [17]).

Category	Percentage
1. Biodegradable materials	51.02
2. Fine sand	27.59
3. Plastics	9.06
4. Paper	3.57
5. Metal/scraps	3.01
6. Textiles	2.85
7. Glasses	1.52
8. Shoes/Leather	0.91
9. Bone and shells	0.54
10. Used batteries	0.21

Table 2. Market waste characterisation (adapted from Tchakpa et al. (2012) [17]).

Category	Percentage
1. Biodegradable materials	67.37
2. Plastics	9.12
3. Cardboards and papers	6.59
4. Fine materials	5.16
5. Shells, carapaces of crabs and pearls	4.38
6. Metals	2.78
7. Glasses	2.14
8. Textiles and foam fragments	1.83
9. Shoes and leather	0.62

From this data, an average of 9.09% of plastic waste yields about 72.7 tons of plastic waste per day, offering huge avenues for transformation into sustainable housing bricks. It should be noted though, that only 30–40% of waste is being collected and evacuated without any processing (City Hall of Cotonou, 2007 cited in Tchakpa et al. (2012) [17]). The remaining 60–70% of uncollected wastes undoubtedly remain in the larger land and water environment affecting the very core of liveability in Cotonou.

The first step towards transforming plastic waste into bricks lies within the steps of source-based waste sorting and collection. The reconfiguration pathway dictates that change originates from pressure at the landscape and regime levels in a top-down manoeuvre until innovations occur at the niche level. Such a dynamic of change already prevails at the landscape level in Cotonou. Accordingly, there is already an urgent need to address issues pertaining to waste management, unemployment, and housing. Hence, the next step is to cater for a mind-set change and to establish proper logistic framework(s) for waste collection and sorting. A new model calibrated to this particular context is required.

5. A Proposed Model

The proposed model for managing plastic waste involves a closed loop economy in which the inhabitants of Cotonou work in a bid to increase both their liveability and sustainability values within a dynamic urban structure. Since they are the main 'actors' and end users of the desired change in plastic waste management, this research proposes a reconfiguration pathway to infuse the dynamics of change within this socio-technical dimension.

Waste management and change at a niche level needs to be scrutinised at three levels:

(1) Waste collection and sorting;
(2) Transport; and
(3) Transformation.

The three levels, as stated above, have particular characteristics of serving a human population, because the human population is the primary recipient of jobs at each level. The third level, transformation, is the end result where housing units can be made, which in turn directly provides shelter for the local population; hence closing the loop and rendering a circular model. The proposed model is summarised in Figure 5.

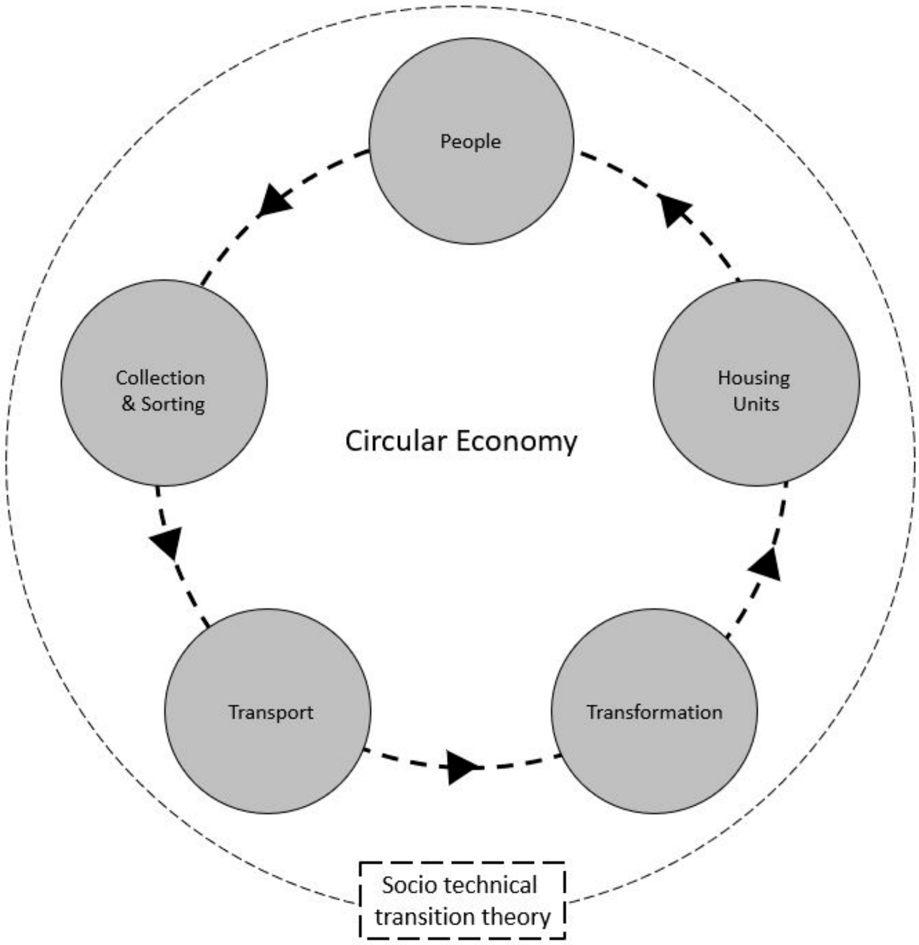

Figure 5. Proposed model for conversion of waste into housing units.

6. Discussion

There have been numerous successful cases of waste reconversion as demonstrated in the literature review. However, the case of Cotonou provides a new landscape that has been rarely covered in the literature. The proposed model offers the possibility of creating a closed loop economy where waste can be used as an asset rather than being seen as a hindrance to local municipal budgets. Because there is a lack of financial resources in most sub-Saharan nations, the issue of waste is rarely addressed as part of a larger budget. In Benin, it was observed that linear thinking would eventually lead to a leakage of municipal budget, to solve and address waste issues, but that there was still a need to relocate slums. However, no funds were allocated for the relocation of slum dwellers, nor for the construction of alternative housing for these people. The proposed model thus looks at responding to the challenges faced in Benin by initially using the funds for waste management to solve the issue of waste, but at the same time providing housing units as a by-product. The model's key dimensions are also seen as necessitating the need to evolve through the socio-technical transition theory. Adoption of this approach is the key to ensuring that the concept transcends the numerous levels of society, thus ensuring the adoption of a resilient sustainable implementation schedule upon the social fabric of the city.

6.1. Waste Collection, Sorting, and Transport

A key question is how to infuse the impetus of change within local niche actors. It comes with no surprise that it is the natural tendency of mankind to, initially, resist change no matter how important and urgent it is [60–64]. As such, even if impetus from the landscape and regime levels offer windows of opportunities at the niche level, there is a need for these innovations to be psychologically appealing. Only when the niche actors find the driver to be of a vital importance will they seriously adopt the desired change in relation to waste collection and sorting. Maslow's hierarchy of needs, as shown in Figure 6, provides a platform of the key fields that could be used by policy makers at the landscape and regime levels to positively influence the dynamics of waste sorting and eventually prompt appropriate collection methods at the niche level.

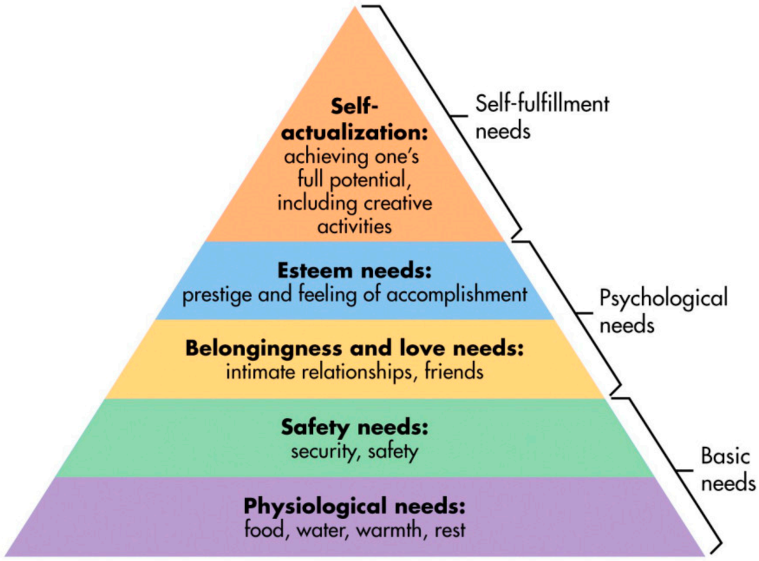

Figure 6. Maslow's hierarchy of needs (source: McLeod [65]).

A sensitisation campaign, based on the hallmarks of these hierarchy of needs, can provide the right activation energy towards initiating innovation at the niche level. However, the question still looms about who will sort and collect these wastes. Ideally, it should be the very dwellers of Cotonou whom are involved at the source points for both sorting and collection through a public–private partnership. Couth and Trois [66] evidence the feasibility of this possible solution by explaining that volunteerism is at the very core of the pillars of sustainability and should be considered in any waste management program. Couth and Trois [66] further claim that successful sustainable waste management dynamics need to focus upon small-scale solutions linked intricately to the creation of real jobs. This idea—linking economic drive through remuneration of the local population involved in waste collection—has previously been positively hailed by Tesink and Kabungo [67].

In essence, this research proposes to sensitise the population for a perception paradigm shift about waste and to proactively engage them at the same time by offering these people paid jobs implementing the actual initiative. In a more tangible sense, Couth and Trois [40] proposed two ways of sorting out plastic waste that would also ensure a source of income for a large number of inhabitants in the lower economic sector. First, through manual recovery of solid waste on an individual basis, and second, through large-scale manual and mechanical processes. However, for this endeavour to be tangible there is a need for waste recovery be part of an official policy at both regime and landscape levels [21]. This accords with the regeneration pathway of change as discussed earlier. In fact, these little innovations at the niche level will help re-align the actual system in place with the actual needs of the subject place and society.

6.2. Transformation, Jobs, and Revenue Potential

Once the logistics of sorting out plastic waste from other refuse is undertaken, and the plastic collected, it can then be transported to a transformation plant. From there, it can undergo the required processing to re-constitute it into sustainable plastic bricks. Here again, the very same niche actors need to be employed in a close economy system because they will be the driving force for 'oiling the gears' towards sustainability.

The technical aspects of plastic waste transformation into bricks has been profiled by Liu et al. [68], Hiremath et al. [69] and Prasad et al. [18]. These authors highlighted the gap in demand and supply of conventional building materials. They also discussed the relative availability of laterite quarry raw materials and the huge amount of plastic waste being generated on a daily basis. This situation offers avenues for converting plastic waste into bricks using bitumen as a binder. These re-constituted plastic bricks consist of 70% plastic, offer more compressive strength than laterite stone, and involve much less water absorption than stone. Moreover, from an economic point of view, Hiremath et al. [69] estimated the cost of plastic waste collection to transformation into bricks to be at US$25 per m^3, and that the use of these bricks to build houses is 48% cheaper than the use of laterite stone bricks. Another study, conducted by Vestergaard [70], used only plastics collected from landfills and successfully transformed these plastics into bricks that were highly resistant to compression, making them ideal as building blocks. This latter technique can cater for very low income economies because less resources are used for the conversion process compared to the method advocated by Hiremath et al. [69]. These higher performance plastic-based bricks offer a sustainable solution for plastic waste disposal in Cotonou together with offering a much cheaper alternative for low-cost housing. These bricks could be used to build low-cost housing for the people of Cotonou, hence decreasing the propensity of illegal settlements. Moreover, the economic repercussions of such an endeavour is that there are more jobs available and cheaper alternatives for low-cost housing.

Recycling offers more job prospects than waste management [71]. For instance, according to the Institute for Local Self Reliance (ILSR), the systematic removal of every 10,000 tons of solid waste only generates six jobs, while recycling for the same mass generates 36 jobs [72]. The same workforce pattern has been evident in Cotonou in a pilot recycling program called the Program for the Protection of the Environment (Pr.A.P.E) run with the Sainte Rita community in Cotonou [73]. Such an endeavour relied upon locally available labour; this labour was trained for waste collection for a total of 2700 subscribers. These subscribers included both households and organisations and comprises a catchment of a community population of 40,000. The subscribers had to pay a monthly fee of which 95% was recoverable. Moreover, such garbage collection activities generated US$140,000 per year, paving the way for the establishment of a community bank with a net worth of about US$1,400,000, while generating 200 permanent jobs out of which 85 were taken by women. Pr.A.P.E enrolled women for the collection of recyclable materials offering a daily income of US$12 per day per person [46]. These figures are for only a small community of 40,000 of Cotonou inhabitants. If these figures are extrapolated to the whole of Cotonou, there is potential for 3400 direct permanent jobs that can be created generating US$2,380,000 per year. Nonetheless, the prime issue is linked to the financial aspects of such endeavours [74,75].

6.3. Financing

Couth and Trois [66] argue that economic instruments like green taxes provide more avenues for sustainable change than direct policies. However, Matete and Trois [76] posit that economic instruments are often not successful in waste management within developing countries principally due to their fragile financial structures, lack of transparency, vested interests, corruption, and lack of human resources. Hence, in seeking to provide a sustainable framework for waste management in Cotonou, there is a need to consider all the financial aspects and economic structures within a sound policy environment. The economic downfall of this activity cannot be demeaned and needs to be sustainable and ongoing so that the system stays functionally successful within a new sustainability resilience culture. There is a need to involve community level niche actors in all sustainable waste management protocols to ensure the viability of this proposed solution for Cotonou. This argument is supported by Colon and Fawcett [77] who also proposed a triangular system involving the municipality, residents, and micro-enterprises that offered technical and commercial resources that are not easily available within and to a community. This includes transport of the waste to the industries for transformation. Moreover, Ahmed and Ali [78] posited that public private partnership (PPP) can offer a sustainable economic dimension that can maintain a sound framework for waste management in developing nations. PPP can cater for job creation for those on the lowest social strata within any given arrangement. Ahmed and Ali [78] hail the empowering capacity of PPP for the local population but warn about the need for in-depth empirical studies on projects to avoid potential loopholes. These loopholes can lead to the collapse of the structure in place. Thus, Ahmed and Ali [78] recognised the need for policy alignment with the need of the society change, hence joining in with the hallmarks of the reconfiguration pathway of change.

6.4. Novelty of the Proposed Model

While there has been new research and practices investigating waste management and conversion, several researchers that highlighted the lack of financing mechanisms [79,80] and the lack of societal structures and inclusion [81]. Yukalang et al. [82] explored the barriers to effective waste management in Thailand and concluded that although there are budget provisions, financial issues related to waste fees collection are still not well articulated. There is a perceived notion that waste has no financial value; hence, discouraging an involvement in waste management. Nafula [83] attributed the lack of sound financial mechanisms in favour of an over-reliance upon traditional financing models despite being seen as ineffective in different parts of the world. This adherence derails efforts by municipalities and governments to effectively integrate societal structures that aim at helping local communities in waste management efforts. In South Africa for instance, Madubula and Makinta [84] highlighted that there are no properly developed innovative waste management projects that would warrant job creation for the locals, service delivery improvement, and cost reduction. The budget provisions in waste management, however, do include societal contributions; hence, they fail to facilitate effective inclusion of local communities. This lack of societal inclusion in waste management and conversion contributes to the failure to adopt sustainable waste disposal methods at basic levels. This has been seen in cases like Accra, as related by Yoada et al. [85].

However, there is research that points to the benefit of adopting a circular economy to welcome a more robust economic model and to better include the society at numerous levels [22,86,87]. Beccarello and Foggia [22] argue that adopting a circular economy allows for the inclusion of the society. Adoption results in the possibility of introducing strategies aimed at helping the reduction of waste and, at the same time, promoting the re-use and recycling of waste materials. With circular economies, municipalities are able to introduce waste fees and taxes, thereby earning revenue that could be used at providing incentives geared towards waste reduction, as well as compensating citizens directly working, or involved, in waste management [20]. The adoption of circular economies are also seen as an alternative source of employment, for both skilled and non-skilled workers [26,31] active in different re-manufacturing sectors directly contributing to the economy [27,28]. Re-manufactured products thus become inputs in sectors like building and construction, infrastructure development, and flood prevention. This helps in environmental sustainability, reduction in pollution, the promotion of optimal energy and water use, but also allows for the construction of affordable residential areas. Stahel [27] further shares that it is now possible for manufacturing companies to re-design products to allow for transferability into other sector sectors thereby helping in reducing the amount of waste products being released in the environment, while increasing reusability and revenue generation across sectors.

The proposed model allows for this circular economy model from an economic standpoint, and the socio-technical transition theory ensures that there is an engagement with the local population at the various levels of engagement from the grassroots to policy level. This type of approach can thus ensures a more inclusive and long-term planning perspective.

7. Conclusions

This research undertook an exploratory case study of a potential solution to cater for plastic waste disposal and treatment, informal settlements management, and low-income job creation within the city of Cotonou, Benin. The theoretical framework proposed draws upon the socio-technical transition theory from a multi-level perspective (MLP) while the selected pathway of change resides within the hallmarks of a reconfiguration pathway. The discussion has demonstrated that by engaging actors at the niche level into waste sorting at the source, followed by subsequent collection and transformation into plastic-based construction bricks, that there is potential to help alleviate poverty, curb illegal disposal of waste, and discourage illegal settlement construction, shifting this community towards a more sustainable environment. Such an endeavour will promote liveability within the city of Cotonou. The finance part of such an endeavour should be executed through a public–private partnership due to its empowering power role upon the local population. However, there is also a need to understand all the dynamics of flow within the city of Cotonou to ensure viability and sustainability of this project. This paper aims at showcasing that waste management in Benin can generate substantial revenue, and that there is a mutualisation potential in solving the housing crisis while tackling the waste problem. This approach can be replicated in other African countries experiencing the same issue. This paper offers encouragement for policy makers to adopt similar practices.

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