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ADOPTABILITY OF BIOPLASTIC AS A SUSTAINABLE MATERIAL IN SRI LANKAN BUILDING CONSTRUCTION INDUSTRY

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ABSTRACT

The Sri Lankan construction industry is facing significant challenges in building construction projects due to the negative impacts of using traditional building materials. Consequently, there has been a surge of interest in sustainable materials, and among them, bioplastics have emerged as a promising alternative. The aim of this study is to investigate the potential of bioplastics as a sustainable building material specifically for the Sri Lankan construction industry. To achieve this, the study applied a qualitative research approach to collect data through semi-structured interviews. The research objectives are to identify alternative sustainable materials used in construction and identify how bioplastics could contribute to the construction industry as ta sustainable material. In addition to that, the study also identifies the motivators and challenges to the use of polymer building materials in Sri Lanka and subsequently develop a framework including potential strategies to use bioplastic as a sustainable construction material. The study's findings have identified significant factors that establish bioplastics as a sustainable material suitable for the Sri Lankan construction sector. Moreover, the research offers valuable recommendations to address challenges related to the adoption of polymer building materials. Furthermore, the study would contribute to the formulation of policies and regulations that promote the use of bioplastics as a sustainable building material.

Keywords: *Alternative Materials; Bioplastics; Biopolymer Building Materials; Sri Lankan Construction Industry; Sustainable Building Material.*

1. INTRODUCTION

Building is a major global user of both biological and physical natural resources, which significantly contributes to the current, unsustainable development of the global economy (Spence & Mulligant, 1995; Kulatunga et al., 2006). In addition, the construction industry is highly criticised for inefficient use of these natural resources (Kulatunga et al., 2006), According to the evidence, around 40% of the garbage generated globally comes from building development and demolition, and thus makes up a significant amount of the solid waste thrown in landfills around the world. On the other hand, waste materials are a significant environmental issue that poses a risk to the environment. It is critical to recycle and dispose of these materials (Dachowski & Kostrzewa, 2016). Since the dawn of the

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industrial revolution, the effects of the construction industry on the environment have been a major source of concern. Buildings consumed 30% of global energy in 2013 and produced 25% of total CO_2 emissions. Furthermore, the construction industry accounts for nearly 75% of global trash (Lasvaux et al., 2015). Even while bio-based polymers provide the potential for a brand-new, environmentally friendly building material that can be composted or returned to the land after construction. Bioplastics may potentially pave the way for new low-embodied-energy construction materials, enhancing energy efficiency (Ivanov & Christopher, 2016).

The construction industry faces challenges like environmental issues, material waste, and shortages, affecting productivity. To tackle these, a sustainable approach and biomaterials like bioplastics are being explored. Biopolymers offer benefits such as reduced fossil fuel use, smaller carbon footprint, and renewable resource utilisation, making them eco-friendly and waste-solving. However, there is limited research on bioplastic construction in Sri Lanka, and industry readiness is unclear. Further empirical exploration is needed. Embracing sustainability is crucial for long-term industry viability (Lamberti et al., 2020).

Developing countries like Sri Lanka face drawbacks with unsuitable building materials and long, intertwined supply chains, increasing environmental impact (Bon & Hutchinson, 2000). Without adopting alternative materials, reliance on imports and environmental impact will continue to rise (Bon & Crosthwaite, 2001). Increasing use of plastics in buildings, driven by the need for improved services, brings economic implications but also environmental and social concerns (Haque, 2019). To overcome these issues, the aim of this research project is to investigate the suitability and adoptability of bioplastic material as an alternative sustainable material for building construction in Sri Lanka. To achieve this aim, several objectives have been identified. Firstly, major and alternative sustainable materials used in the construction industry will be identified. Secondly, the potential factors for using bioplastic as a sustainable material will be identified and analysed. Thirdly, motivators and challenges to using polymer building materials in building construction in Sri Lanka will be analysed.

2. LITERATURE REVIEW

2.1 POLLUTION IN CONSTRUCTION INDUSTRY

The construction industry, a major global sector, heavily consumes natural resources. It faces challenges affecting project goals and economic growth (Wang & Adeli, 2014). Developing countries often experience material shortages due to reliance on imported conventional materials (Ofori, 1993). Construction has negative environmental impacts, depleting resources, generating greenhouse gases from fossil fuel burning (Li et al., 2010). Disposing construction waste in underground landfills harms the environment (Zhang et al., 2022). Thermoplastics are widely consumed in packaging, automotive, electrical, electronic, and building sectors (Haran et al., 2020).

Sustainable building design, also known as high-performance or green design, requires changing attitudes, paradigms, procedures, and systems to address specific challenges (Wang & Adeli, 2014). The concept of sustainable development focuses on economic, societal, and environmental advancement for future generations.

2.2 SUSTAINABLE BUILDING DEVELOPMENT

Sustainable development includes, among other things, increasing social, economic, and environmental conditions for both the present and future generations while also enhancing quality of life. In order to achieve sustainable development from the numerous environmental, social, economic, and cultural sides, the building industry has developed a new concept called sustainable construction. Traditional construction methods solely prioritise cost-cutting, performance, and quality goals, but sustainable methods additionally prioritise reducing resource depletion, environmental degradation, and improving the built environment (Jayalath & Gunawardhana, 2017).

In order to create a structure that is accessible, inexpensive, and ecologically friendly, a genuinely sustainable construction project should take economic, social, and environmental concerns into account during the design, construction, and demolition stages (Vanegas et al., 1995). Choosing materials that leave a smaller environmental imprint is one of the best ways to accomplish sustainable building. In this regard, it is advised that designers and architects pay attention to these factors from the very beginning of the design process (Mahmoudkelaye et al., 2018).

2.3 BIOPLASTIC

Bioplastics are polymers created from raw materials that are both natural and renewable, such as sugarcane, maize starch, wood, waste paper, vegetable oils, lipids, bacteria, algae, and other microorganisms. Since non-renewable petroleum is used to make the vast bulk of commercial plastics, they can have a negative impact on the environment (Sidek et al., 2019). Initial research on bioplastics dates as far back as 1962, and since then different varieties of bioplastics have been produced as depicted in Figure 1.

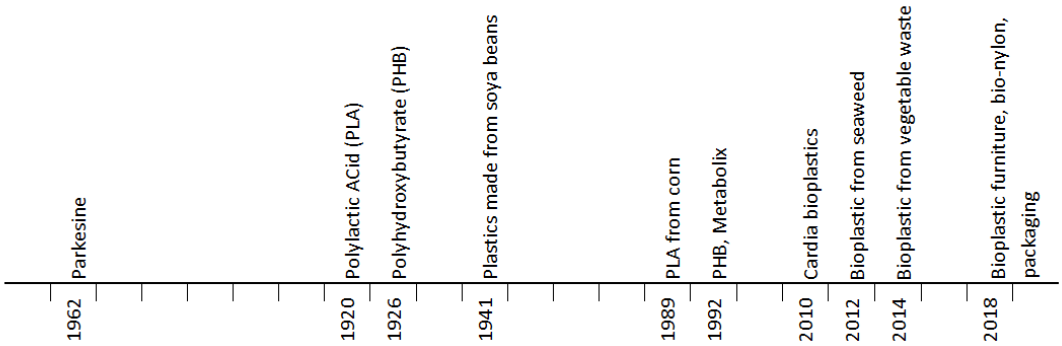

Figure 1: Bioplastic development

The chemical composition of Bioplastics is similar to traditional plastics, hence having similar characteristics (Rahman & Bhoi, 2021). The chemical composition of the bioplastic can be altered to produce non-biodegradable plastics as well as biodegradable, compostable plastics (Batori et al., 2018). While Polyethylene terephthalate (bio-PET), Polyamide (bio-PA), Polyethylene (bio-PE) display non-biodegradable properties that require special processing to initiate degradation, while polyhydroxyalkanoate (PHA), Polyvinyl alcohol (PVA), can be anaerobically degraded (Rahman & Bhoi, 2021). With the current concerns over sustainability and circular economy bioplastics presents as a viable alternative since bioplastics can be degraded avoiding any harmful residue after being used in different production cycles (Oberti & Paciello, 2022).

However, developing nations face challenges due to limited access to bioplastic production technology and material supply. Lack of knowledge and underdeveloped resources further hinder optimal utilisation (Liliani et al., 2020). Regulations regarding bio-plastics vary, often being weak in developing nations (Filiciotto & Rothenberg, 2021). Health and safety laws may also apply (Thompson et al., 2009). Affordability is a hurdle in poorer nations, but investment in infrastructure, research, and sustainable farming methods can improve accessibility while utilising waste products as raw materials (Wellenreuther et al., 2022).

Bioplastics are sustainable and renewable materials gaining attention in the construction industry, reducing greenhouse gas emissions (Reddy et al., 2008). They find applications in packaging, automotive, biomedical, and engineering fields. Biopolymers are used as concrete admixtures to enhance water retention (Oberti & Paciello, 2022). Alternative concrete formulations using enhanced cornstarch and expanded polylactic acid (EPLA) have shown promise (Sayadi, 2018). Glucan biopolymer can substitute cement in earthen construction, reducing carbon footprint (Chang & Cho, 2012). Biopolymers are also explored as filament materials in 3D printing and insulation materials (Hebel & Heisel, 2017).

Temporary structures are the most common application of bioplastics, including bio composite packing sheets, solid foam silt, and dust barriers, sealants, insulators, and non-structural components like dividing walls and partitions (Pilla, 2011). With the use of PLA, biodegradable fibres for building material reinforcement, bio composite sheets, biodegradable resins, and environmentally friendly flooring can all be produced (John & Thomas, 2008).

2.4 MOTIVATION AND CHALLENGES

Table 1 presents the enablers and challenges to the adoption of bioplastics in the construction industry. These factors have been identified from the literature.

Table 1: Enablers and challenges for adopting bioplastics identified from literature

Enablers	Challenges
The majority of landfills contains construction waste (Ariadurai, 2012)	Revolutionary technology that needs further research and development (Renee, 2017)
Reduced carbon footprint (Reddy et al., 2008)	Certain bioplastics degradation at high temperature (Misra et al., 2011)
Bioplastics do not even produce harmful waste or leak chemicals (Ivana et al., 2017)	Certain bioplastics need special treatment processes (Thakur et al., 2018)
Bioplastics have zero waste end of life (GreeenHome, 2008)	Economic factors will not be enough to propel this technology (high cost) (Iles & Martin, 2013)
Negligible impact on climate changes (Weiss et al., 2012)	Large amount of production create demand for agricultural crops (Shah et al., 2008)

3. RESEARCH METHODOLOGY

This study investigates the challenges associated with the adoption of bioplastic in the Sri Lankan construction industry using qualitative research methodology. Due to the exploratory nature of this research, qualitative research approach was employed, which investigates a phenomenon in its natural setting using non-quantifiable data (Ryan et al.,

2009). Being a technology that is most practiced in manufacturing sector in Sri Lankan context, locating experts with construction related experience was difficult. Hence, purposive sampling method was employed to select relevant respondents together with snowballing technique to locate more experts. Expert interviews were used to gather rich and detailed information from individuals with specialised knowledge and experience in the field (Kothari, 2004). The manual code-based content analysis was used to identify patterns and themes within the data (Hsieh & Shannon, 2005), providing insights into the challenges associated with the adoption of bioplastic packaging in the Sri Lankan construction industry.

4. DATA ANALYSIS AND FINDINGS

The research utilised expert interviews to collect data on the adoptability of bioplastic as a sustainable material in Sri Lankan building construction industry. Six semi-structured interviews were conducted in two phases with experts in bioplastic concepts and those working in the construction industry. The collected data was transcribed and analysed manually using code-based content analysis. The utilisation of expert interviews proved to be an effective method for gathering data, particularly in the Sri Lankan context where access to experts can be limited. The profile of the interviewees is provided in Table 2.

Table 2: Expert profiles

Name	Designation	Company Type	Years of Experience	Years of Experience in Bioplastic	Experience in Bioplastic
R01	Chairman	Production company	35	8	PhD studies relating to the bioplastic; more than 5 years in Sri Lankan Bioplastic Association
R02	Material Engineer	Production company	3	2	Participated several programs on bioplastic
R03	Assistant manager	Production company	12	3	Participated several programs on bioplastic
R04	Chartered Architect	Consultant	35	25	Participated in material selection involving bioplastic in foreign projects
R05	Material Engineer	Consultant	18	8	Conducted continuing professional development (CPD) on bioplastic in other industries
R06	University Lecturer	University	15	10	PhD studies relating to the bioplastic; conducted workshop on bioplastics in manufacturing industry

4.1 BIOPLASTICS AS CONSTRUCTION MATERIALS

The use of bioplastics in the building construction business may be a sustainable choice. R06 mentioned that "*The use of biomass sources rather of fossil fuels makes bioplastics more environmentally friendly than conventional plastics"* highlighting the positive effects on sustainability.

Regarding the use of bioplastics in construction R04 and R06 stated that *"Bioplastics could replace traditional plastic-based building materials used in packaging, insulating and non-structural finishes. They can reduce greenhouse gas emissions, decrease dependence on fossil fuels, and promote eco-friendly building techniques"*. However,

respondents also highlighted the importance of considering procurement of the raw materials on the environment and to confirm that the bioplastics are produced using sustainable and biodegradable resources.

Construction companies may become more sustainable by using bioplastics to package their products, which can minimise the amount of plastic trash they produce. it would be crucial to encourage the use of bioplastics in the building sector and create a sustainable supply chain for the raw ingredients.

According to R01, R04 and R06 "*Bioplastics made from plant-based resources can replace traditional wood-based construction materials, such as insulation, roofing, plumbing, and composites".* The respondents further elaborated that they have a smaller carbon footprint and can also be used for packaging and building components.

4.2 FACTORS CONTRIBUTING TO USE OF BIOPLASTIC AS A SUSTAINABLE MATERIAL

After recognising the potential use of bioplastic in Sri Lankan construction industry, the respondents were then inquired about the facilitators that should exist for seamless adoption of bioplastic in place of conventional material.

4.2.1 Technology

Research suggests that bioplastics in construction are still emerging but have made significant progress recently and are expected to grow further. R04, R05 and R06 held that, Sri Lanka possesses advanced technology in packaging and rubber industries but lacks in the building sector. However, the country can utilise its existing rubber industry technology to implement bioplastics in construction. Moreover, Sri Lanka has access to raw resources for bio-based polymers. Bioplastics technology is globally well-developed and accessible.

4.2.2 Availability of Raw Material

Sri Lanka, an agricultural country with abundant natural resources, possesses a large supply of raw ingredients for bioplastics. R05 and R06 mentioned that *"Agricultural waste such as rice bran, coconut shell, and coir dust are utilised for bioplastics production. Numerous R&D projects are focused on utilising these materials."* Bioplastics manufacturing makes use of underutilised agricultural areas, contributing to waste management. Additionally, bioplastic production indirectly aids in addressing Sri Lanka's waste management challenges. Furthermore, R06 mentioned that with nearly 50% of agricultural lands still unused, there is an opportunity to utilise these lands for obtaining sufficient raw materials.

4.2.3 Manufactures

Respondents acknowledged the existence of a few prominent natural rubber and plastic manufacturers in Sri Lanka who has the potential to venture into bioplastics production. R06 mention that, *"Sri Lanka is already a major producer of packaging materials and bio-based tires, which are exported globally. Sri Lanka's reputation for manufacturing high-quality products makes it an ideal location for bioplastics production in the construction sector".* The government could also actively promote the growth of the industrial sector, including the development of bioplastics, to stimulate economic

expansion and job creation. Importing bioplastics and collaborating with foreign manufacturers was also identified as a viable option.

4.2.4 Suppliers

Given the limited number of local producers capable of manufacturing bioplastic, the responded thought that importing bioplastics into Sri Lanka could be a viable option to facilitate the adoptability. R04, R05 and R06 also highlighted the additional costs like shipping and import duties should be considered. Furthermore, all respondents highlighted the importance of issuing licence to ensure that the imported bioplastics comply with Sri Lankan laws and standards. Adherence to regulations and permits is required for vendors importing bioplastics. Verification of availability, quality, and certifications is necessary to meet specific requirements.

Additionally, R04 and R06 mentioned that Private companies in Sri Lanka are actively involved in bioplastics production and development in beverage manufacturing industry could offer expertise and guidance on utilising bioplastics in the construction industry. These companies can provide valuable information to businesses interested in implementing bioplastics.

4.2.5 Research and Development

Universities in Sri Lanka with faculties of engineering, chemistry, and material science carry out bioplastics research. Government organisations that perform bioplastics research and development include the National Science Foundation (NSF) and Industrial Technology Institute (ITI). R05 emphasises that although though Sri Lanka's bioplastics business is still in its infancy, it is crucial that professionals in the area are able to create high-quality bioplastics that satisfy local building codes

4.2.6 Legal Background

Legal and regulatory barriers should be considered when utilising bioplastics in Sri Lanka's construction industry. The Sri Lanka National Building Code (NBC), Sri Lanka Standard Institution (SLSI), and organisations like NBRO and the Central Environmental Authority (CEA) oversee the usage of sustainable building materials, as highlighted by R05. The government has implemented measures to promote bioplastics, including building regulations, support for research and development, tax incentives for green buildings, public-private partnerships, and a green building rating system that encourages energy efficiency and renewable energy utilisation, as mentioned by R04, R05, and R06

4.2.7 Health and Safety

Certain base components of bioplastics pose health and safety concerns, as highlighted by R04, R05, and R06. However, these risks can be minimised by using bioplastics made from non-toxic chemicals, handling them with care, and ensuring proper disposal. R05 also points out that certain bioplastics that are not biodegradable may contribute to plastic pollution. Moreover, R06 warns that certain bioplastics contain harmful elements that can pose risks to humans and animals if ingested. Additionally, some bioplastics have a higher flammability than traditional plastics, emphasising the importance of proper handling to avoid fire hazards.

4.2.8 Production Cost

Despite higher costs in the short term, bioplastics offer sustainability benefits and could be a viable option for Sri Lanka's construction industry. R04 suggests that the use of additives can reduce the production cost of bioplastics, enhancing their affordability. Another approach is improving manufacturing efficiency through new technologies and process optimisation, leading to cost reductions. As new technologies and production techniques emerge and economies of scale are achieved, the cost of bioplastics is gradually decreasing, as mentioned by experts.

4.3 POTENTIAL OF FULL FILLING THE REQUIREMENTS

Experts agree that bioplastics can address issues associated with conventional building materials such as material scarcity, environmental concerns, and waste management as identified in the literature. Bioplastics utilise renewable resources like maize starch, sugarcane, and cassava, ensuring a sustainable supply for construction. Unlike traditional plastics made from oil, bioplastics have a lower carbon footprint and can be compostable and biodegradable, as noted by R04, R05, and R06. In certain applications, bioplastics have the potential to serve as a viable alternative to traditional building materials.

4.4 ENABLERS AND CHALLENGES TO ADOPTION OF BIOPLASTIC IN CONSTRUCTION INDUSTRY

4.4.1 Enablers

According to all experts bioplastics offer promising solutions to reduce the environmental impact of conventional materials, particularly in the context of building and demolition waste. By providing biodegradable and recyclable alternatives, they contribute to a decrease in landfill accumulation. Biodegradable bioplastics further aid in waste reduction by decomposing in the presence of microorganisms, heat, and humidity.

However, not all bioplastics are equal, and some bioplastics may not achieve a zero-waste end-of-life. R04 held that biodegradable bioplastics can significantly reduce the carbon footprint. Biodegradable bioplastics, eliminate the release of toxins during disposal and reducing the generation of toxic waste. Bio-based products, while reducing carbon emissions, may still contain hazardous substances. The potential for a zero-waste end-of-life depends on the bioplastic's recyclability. If they can be completely recycled, they can be considered zero-waste.

By minimising greenhouse gas emissions and reducing fossil fuel consumption, bioplastics help lower their manufacturing impact. This dual benefit of being biodegradable and having reduced emissions ensures that bioplastics have a positive environmental impact, leaving no detrimental traces. Additionally, their use contributes to the reduction of landfill waste, thus supporting efforts to mitigate the effects of climate change.

4.4.2 Challenges

Bioplastics are an evolving technology that requires further research to fully understand their properties and environmental impact, as stated by R04, R05, and R06. Pyrolysis, a method involving high-temperature treatment without oxygen, can be used to dispose of certain bioplastics. However, some non-biodegradable bioplastics necessitate specialised

disposal methods due to their resistance to decomposition by microorganisms, heat, and humidity.

In the Sri Lankan construction industry, the cost of bioplastics can be a limiting factor. Nevertheless, the long-term cost savings should be considered. Utilising the country's abundant unusable farmland for cultivating crops for bioplastics could provide additional income for farmers and employment opportunities in the bioplastics sector. With over half of Sri Lanka's land unsuitable for agriculture, it presents a valuable resource for sustainable bioplastics production. This utilisation of land can address material scarcity and ensure a sustainable supply of construction materials.

5. CONCLUSIONS

In Sri Lanka's building construction sector, bioplastics have the potential to replace conventional materials in a sustainable way. The study found that bioplastics' capacity to minimise waste and pollution, their renewable and biodegradable nature, and their low carbon footprint are the main potential benefits of adopting them. Environmental considerations, economic effectiveness, and the accessibility of substitute materials are some of the driving forces behind the use of polymer building materials in construction.

The study initially identified key factors contributing the adoption of bioplastic through literature and later verified the applicability of said factors to Sri Lankan context through expert interviews. The findings revealed the enablers as well as the challenges stemming from the aforementioned factors. While the availability of natural material and similar technologies in other industries were highlighted as enablers, research also drew attention to several issues that need to be resolved, such as the lack of knowledge and understanding of bioplastics, the absence of laws and standards, and the restricted availability of bioplastic goods. These findings and relationship between the key factors are further elaborated in Figure 2.

This research emphasises the potential of bioplastics to enhance sustainability in the Sri Lankan construction sector. It identifies key factors, enabling a better understanding of the challenges and opportunities of adopting bioplastics. This knowledge can guide further research and exploration of sustainable building materials in Sri Lanka and similar contexts. The study underscores the importance of education and awareness initiatives to overcome adoption barriers. Policymakers, industry professionals, and stakeholders in the construction sector can benefit from the practical insights provided by this research. Collaboration among stakeholders is crucial to address knowledge gaps and establish relevant laws and standards that promote the use of bioplastics.

Overall, the research highlights the theoretical and practical implications of integrating bioplastics into the Sri Lankan building construction sector. By identifying enablers and challenges, emphasising collaboration, knowledge dissemination, and regulatory support, this study contributes to the ongoing efforts to promote sustainable practices and environmentally friendly materials in construction. The findings serve as a stepping stone for future endeavours aimed at enhancing the sustainability and resilience of the building industry, not only in Sri Lanka but also globally.

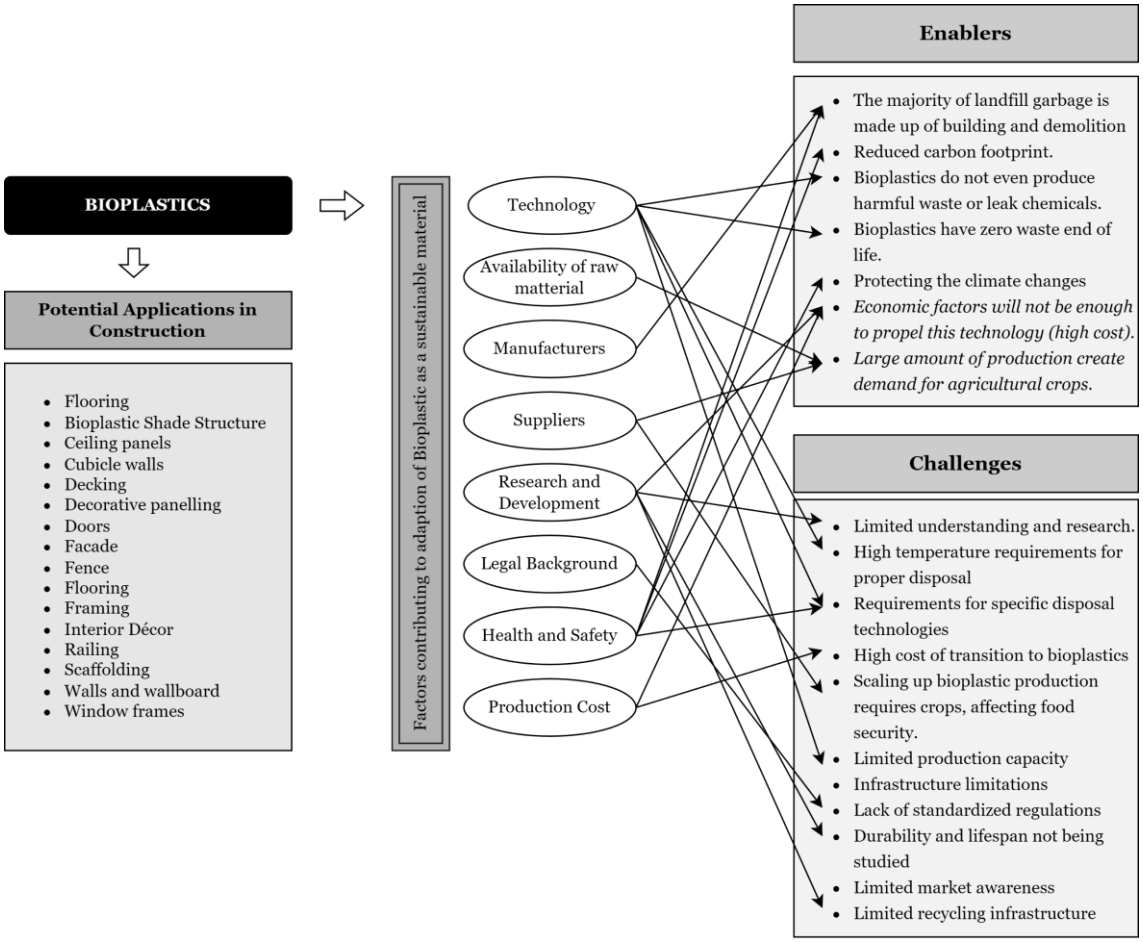

Figure 2: Relationship between the key factors

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