

**Guidelines for Craftspeople's  
Bamboo Products to meet United Nation's  
Sustainable Development Goals 2030**

*A thesis submitted in partial fulfilment of the requirements  
for the award of the degree of*

**Doctor of Philosophy**

*in*

**Design**

*by*

**Monikuntala Das**



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**DEPARTMENT OF DESIGN  
INDIAN INSTITUTE OF TECHNOLOGY GUWAHATI  
GUWAHATI - 781039, INDIA**

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**Prof. Amarendra Kumar Das**



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### **CERTIFICATE**

This is to certify that the work contained in this thesis entitled '**Guidelines For Craftspeople's Bamboo Products To Meet United Nation's Sustainable Development Goals 2030**' submitted by Ms Monikuntala Das to the Indian Institute of Technology Guwahati, Assam (India) for the award of the degree of Doctor of Philosophy has been carried out under my supervision. This work has not been submitted elsewhere for the award of any other degree or diploma.

**Prof. Amarendra Kumar Das, PhD**

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Place: Guwahati

Date: 22 July 2024



## DECLARATION

I hereby declare that the work contained in this thesis entitled '**Guidelines For Craftspeople's Bamboo Products To Meet United Nation's Sustainable Development Goals 2030**' is my work done under the supervision of Prof. Amarendra Kumar Das at the Department of Design, Indian Institute of Technology Guwahati (IITG), Assam. I hereby declare that to the best of my knowledge, it contains no materials previously published or written by another person, or a substantial proportion of material which have been accepted for the award of any other degree or diploma at IITG or any other educational institute, except where due acknowledgment is made in this thesis. Any contribution made to the research made by others, with whom I have worked at IITG or elsewhere, is explicitly acknowledged in the thesis. I also hereby declare that the intellectual content of the thesis is the product of my work, and as per general norms of the reporting research findings, due acknowledgments have been made wherever the research findings of other researchers have been cited in the thesis.

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## DEDICATION

*I would like to dedicate my thesis to the craftspeople of India.*



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**Monikuntala Das**

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## ABSTRACT

Bamboo has been constituted as a new mainstream material for the upcoming Indian market (Surfaces Reporter, 2021). Recent realization regarding the potential of bamboo as an eco-friendly material has introduced new applicability and opportunities in various fields such as building construction, automobiles, furniture and interior design. Bamboo's positive features like mechanical strength, easy process ability and availability in many tropical and subtropical areas confer it attributes to become a renewable material for product and furniture design (Boran & Cavdar, 2013). With the quality of being a non-timber product and having a short replenishment time, bamboo in furniture design could support the concern of depleting natural resources, by its identity of a non-timber, rapidly renewable and eco-friendly material.

North-East Region (NER) of India dedicates itself to commercial bamboo production which constitutes 66% of the country's growing stock (National Bamboo Mission, India, 2017). This quick-growing, versatile, non-timber forest product weaves itself effortlessly into local livelihood generation through the mode of craftsmanship. The craft sector provides livelihood and employment to 20 million people of India (Vishwanath, 2013) which constitutes 1.5% of the country's population. There are 480 units undertaking cane and bamboo works in 26 districts of Assam with an investment of Rs.371.34 lakh, employing 2212 people (Assam State Portal, 2023). With adaptation to the urban market, bamboo has immense potential for income generation and to be the breadwinning craft of the people of NER.

There have been various attempts by the stakeholders of the craftsmanship sector to upgrade the functioning, outcome and income generation of bamboo craftsmanship in the NER region, but the products have not been able to create a major rush in the market yet. The failure can be attributed to multiple factors.

1. The association of bamboo craftsmanship to a domestic background makes it a challenging sector to take towards mass manufacture.
2. Bamboo as a material has yet to be introduced to high commercialization since the products have not been ideated to serve the retail market, be it in terms of design, cost, or production.
3. There is no validated information available regarding the quality, durability and environmental friendliness of the material associated to business and marketing which could overcome stakeholder's hesitation to invest in this particular domain.

The motivation of this research is to assist the design, business and entrepreneurial decisions towards bamboo products developed by craftsmanship in NER of India through an elaborate study of all the parameters involved in the process. The research entails realtime studies of craftsmanship, entrepreneurship, manufacturing and business sectors to understand the Indian bamboo domain holistically. It also provides an updated understanding of sustainability and craft synergy along side state of the art theoretical frameworks for assessments conducted to validate bamboo products for its eco-friendliness. The assessments are analysed against bamboo craftsmanship's compatibility with the United Nation's Sustainable Development Goals 2030 (UNSDG 2030).

The analysis contains four sections :

- I. Craftsmanship and Eco-Design Principles
- II. Bamboo Entrepreneurship and Market Study
- III. Comparative Life Cycle Assessment of Competing Materials of Furniture
- IV. UN SDG 2030 in Bamboo Craftsmanship Sector

Each section delivers critical insights on the decision making process in the manufacture and business of bamboo furniture along with the socio-economic contributions to NER's bamboo craftsmanship sector.

Finally, the research delivers guidelines for businesses in bamboo through important considerations and factors of intervention in the bamboo craftsmanship sector for socio-economic upliftment of the craftspeople in the NER of India, while simultaneously encouraging material intervention for product design towards the impending climate crisis in the near future. It also throws light upon future product possibilities for eco-conscious generations through validation of bamboo material for the urban market. The results bring forward possibilities of amendments and interventions in the holistic domain of craft entrepreneurship and a new dimension towards sustainable design in business.



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## LIST OF ABBREVIATIONS

CDI	Cluster Development Initiatives
CFC	Common Facility Centre
CFT	Cubic Feet
DfE	Design for Environment
DIC	District Industries Centre
DPS	Delhi Public School
IDC	Industrial Design Centre
EC	European Commission
EPIP	Export Promotion Industrial Park
EU	European Union
IPP	Integrate Product Policy
ISO	International Organisation of Standardisation
KVIC	Khadi and Village Industries Commission
LCA	Life Cycle Assessment
LCC	Life Cycle Costing
LCI	Life Cycle Inventory
LCIA	Life Cycle Impact Assessment
LCSA	Life Cycle Sustainability Assessment
MDF	Medium Density Fibre
MPSBM	Madhya Pradesh State Bamboo Mission
MSME	Micro Small and Medium Enterprises
NABARD	National Bank For Agriculture And Rural Development
NER	North East India
OEF	Organisational Environment Footprint
PEF	Product Environment Footprint
REPA	Resource and Environment Profile Analysis
SETAC	The global Society of Environment Toxicology and Chemistry
SFURTI	Scheme of Fund for Regeneration of Traditional Industries
SLCA	Social Life Cycle Assessment
UNDP	United Nations Development Programme
UNEP	United Nations Environment Program
WBCSD	World Business Council for Sustainable Development
WCED	World Commission on Environment and Development

## CHAPTER 1 : INTRODUCTION

### 1.1 Preface

Bamboos are a diverse group of mostly evergreen perennial arborescent grasses belonging to the family *Poaceae* and are grouped under the family *Bambusoideae* (Seethalakshmi et al, 1998). Bamboos include some of the fastest-growing plants in the world (Farrelly, 1984). Certain species of bamboo can grow 91 centimetres (36 inches) within a 24-hour period, at a rate of almost 40 millimetres an hour, equivalent to 1 mm every 90 seconds (Guinness World Records, 2023). The woody ringed stems, known as culms, are hollow between the rings (nodes) and grow in branching clusters from a thick rhizome (underground stem). Bamboo culms can attain heights ranging from 10 to 15 cm (about 4 to 6 inches) in the smallest species to more than 40 metres (about 130 feet) in the largest (Britannica, 2023).

Bamboo has many indigenous as well as modern uses. Indigenous culture uses bamboo to make traditional houses with bamboo columns, walls and roofing, household utilitarian products such as furniture, baskets, fishing equipments, musical instruments, ornaments, food and biofuel. Recent realisation regarding the potential of bamboo as an eco-friendly material has introduced new applicability and opportunities in various fields such as building construction, automobiles and interior design. It is used as scaffolding, flooring, ornamental garden planting, fabric, pulp, paper, charcoal and household products.

Bamboo as a material is easily available as a backyard grass in the North East Region (NER) of India. The material contributes significantly towards bamboo craftsmanship in the region. It can be easily manipulated into various forms using simple tools through craftsmanship. Majority of the products delivered today are handmade and for traditional utilitarian purposes. The products have not yet been ideated to serve the urban retail market, be it in terms of design, cost or production. Thus, improvements are needed to bring bamboo to the fore front as a climate responsive material which also simultaneously provides a possibility for socio-economic intervention in the NER of India.

### 1.2 Motivation for the Research Work

The researcher's first introduction to Bamboo and Craftsmanship was during her Architectural Final Year Thesis, during conduction of research in a village called Mugkuchi in the Nalbari district of Assam, where the entire community of the village was engaged in making Assamese Traditional Headgears called 'Japi' with bamboo material.

The researcher found a source of interest in the skilled bamboo craftsmanship of the villagers, including women and children, and the effective distribution of work through village craftspeople to deliver the required number of Japis to the market every day [Figure 1.1]. Craftsmanship knowledge was passed on from one generation to the next within the courtyards of craftspeople houses. The final products were procured by the middlemen dealing in these products at a predetermined price and marketed by the middlemen. Also, the income of craftsmen were not commensurate with their work. Since the design of Japi is a stereotyped cultural one, there were no other products to enhance craftsman's income.



**Figure 1.1** Distribution of work amongst craftspeople for Assamese headgear 'Japi' in Mugkuchi, Nalbari  
(Source : Author)

Based on the learnings from this exposure, to enhance the income of the craftsmen and to introduce new design compatible with the stalls of the craftsmen, the researcher proposed a Research Institute within the morphology of the village called 'Adoroni' which could help assist Research and Development of the products and invite designers and other related human resources to visit the village, stay within the community in home-stays, learn and eventually contribute to product enhancement. An effort was made to not uproot the craftsmen from their household courtyards and allow them to work in their comfort, while learning Product Development and Diversification.

The researcher continued her education after graduation and during her post graduation in Industrial Design, the interest for bamboo craftsmanship was taken further. During her Masters Thesis, the objective was to understand the status of bamboo in the urban furniture market. After a market survey, it was perceived that the bamboo furniture pieces were not very well accepted in the urban market and bamboo material was not considered as a competition amongst the other materials currently used for furniture making. The quality of the furniture pieces produced in bamboo in terms of durability of raw material, treatment techniques, construction methods and design aesthetics were being compromised due to the limited knowledge of the craftsmen and hence were priced very low in the market.

An effort was made to improve the status of bamboo furniture developed by craftsmen through means of new construction techniques. To increase sophistication of the furniture pieces and to improve finesse, the researcher developed two material processing techniques for aesthetic quality improvement, as shown in Figure 1.2, they are :

- Creating 'Cavity Frames' for Torching Bamboo splits
- 'Drilling and Gun-Riveting' Bamboo splits for perfect joinery alignments

In the two techniques, the bamboo splits and cavity frames were manually prepared. The torching, drilling and riveting of the of the bamboo splits were also performed manually using torch guns and hand tools.



**Figure 1.2** Technique I - Creating 'Cavity Frames' for Torching Bamboo splits (left).  
Technique II - 'Drilling and Gun-Riveting' Bamboo splits for perfect joinery alignments (right). (Source : Author)

With the help of the two techniques, the researcher developed a set of Bamboo Lounge Chair and Ottoman [Figure 1.3], by developing uniform repetitive members for manufacturing quality. A design language for space utilisation was also incorporated in the furniture pieces by creating storage space with the help of Alternating Bamboo Members.



**Figure 1.3** Bamboo Lounge Chair & Ottoman (Source : Author)

Water treatment ensured durability for the bamboo splits and coats of resin brought lustre to the finish. After six years of manufacture, the furniture pieces retain strength to hold a minimum of 120 kgs while being weather and fungus resistant. The colour of the furniture has organically changed from a mild green to a seasoned yellow over time. The pieces of furniture have created an interest in bamboo furniture amongst a few urban dwellers. It was realized that people wished to have a piece of bamboo furniture in their households which would meet the aesthetic requirements of their dwelling spaces.

After the completion of making the Bamboo Lounge Chair and Ottoman, the researcher realized that though the furniture was made, the intention of consistent element making for furniture parts needed more revision to satisfy finesse of product. Also challenges were seen in the acceptability of the product for consumers towards the material as frequent questions were being asked about the material's strength and durability. The project needed more research on the aspect of enhancing the designs by craftsman produce to satisfy the urban market while understanding the importance of craftsmanship in terms of sustainability and its impending need of incorporation in the near future. The potential of the material had been realized but there needed further understanding in the market and business prospects towards validity of eco-friendliness, target groups and clients and assurances of durability to deliver value to the product. The deployment of the existing craftsmanship in the natural state and in the local region was also necessary for further improvement of the domain and thus, the attempt needed a holistic approach from the start till the end to change the prevailing perception.

### 1.3 Need Justification

The need for execution of this research can be justified by the following reasons.

1. Functional materials are crucial to meet today's societal challenges and needs, such as the transition towards low carbon energy production to reduce climate change, renewable energies and green economy (Hofmann et al, 2018). In recent years the requirements of different alternative products for furniture design has increased by the growing world population and improving living standards. Interventions are required in the material domain, including furniture, to combat climate crisis and reduce manufacturing load on the earth.
2. Bamboo, commonly found in the tropical and subtropical areas, is especially the most important and valuable as a non-timber forest product in India and China (Boran & Cavdar, 2013). The International Network for Bamboo and Rattan (INBAR) released a list of 'Priority Species of Bamboo and Rattan', that included 20 taxa of bamboo (species and genera) of particular economic importance in India, China and South East Asia. Selection of species for particular uses has been done by communities and producers for centuries, out of which 16 of the 20 most commercially important species are thought to have been domesticated (Rao et al, 1998). The National Bamboo Mission of India states that Bamboo covers 13.96 million hectare area holding 136 species of Bamboo in the country. North-East India dedicates itself to commercial bamboo production which constitutes 66% of the country's growing stock (National Bamboo Mission, India, 2017). Availability of bamboo in the region increases the feasibility of execution of the research.
3. The bamboo craftsmanship sector has a regional significance in North-East India due to its quick availability and robust structure for integration into the livelihoods and income generation in the region. Multiple clusters, villages and communities participate in the bamboo product and furniture design aspect to hand make and deliver products in the local as well as nearby urban regions. To improve commercialisation through the states and the country, bamboo products require design and manufacturing interventions, which could easily uplift the aesthetics, functionality and pricing, thus improving the socio economic status of the craftspeople involved in the regional process.
4. Bamboo as a material has gained a reputation of being an eco-friendly and sustainable material. It has a social and cultural connotation associated to it. But, the material has not been numerically validated to answer how much more sustainable is it when compared to the other competing materials available in the market. This discourse would allow to validate the material from a commercial point of view to instill confidence amongst stakeholders to invest in the domain.
5. There is a prevalent discussion amongst the communities of design regarding the decadence of craft and its irrelevance in the future which integrates electronic interfaces with softwares and artificial intelligence. Handicrafts are often marked as a memorabilia through history and its inability to deliver new utilitarian aspects and business directives in the market inhibits investment in this field. The domain requires a validation to develop a better perception through means of sustainability and material culture. Thus, interest must be revived towards craft by validating its attributes via the latest principles and terminologies related to sustainability in Design.

In this age of information, stakeholders seek information related to the manufacture of the product which include materials and processes used, validation of durability and impact and circumstances of the product's life. To take forward bamboo material into the near future, a validated numerical system must be available for the stakeholders to compare their investments in terms of contributions to the earth and thus, climate change.

## 1.4 Research Gap

Considerable research has been conducted regarding bamboo in terms of botany, tissue culture, material characteristics, architecture, product design, food, cuisines, manipulation of material to various forms, craft, aesthetics, ethnographic relevance and its potential towards sustainability.

- Research towards numerical validation of the material regarding sustainability when compared to other materials has not been conducted yet.
- Also, no research states the market requirement of bamboo products regarding validity for larger businesses.
- Indian craft has been understood in terms of region, people, culture and ethnography. Conducted research has also looked into the details of execution in terms of pattern, colour and material. The trouble in upholding craft to successful business ventures has led to its economic failure, thus, questioning its importance and relevance in the current state.
- Although few entrepreneurs and businessmen have realized its potential and invested early, it is still very unknown to the remaining domain of business regarding the relevance of sustainable craft systems in the near future.

This develops a requirement for a strong association with current sustainability needs to increase the volume of indigenous material systems for a climate positive future.

## 1.5 Research Questions

The following questions define the research work :

- Is Indian indigenous craftsmanship sustainable according to the latest terminologies and principles of sustainability?
- What is the current status of bamboo product design and its probable future?
- Where does bamboo stand in terms of environmental performance alongside other competing materials?
- Would enhancing bamboo product designs lead to a holistic improvement of bamboo craftsmanship sector in NER?
- What information regarding bamboo products could be provided to the market to instil confidence in customers and businessmen to invest?

## 1.6 Aim and Objectives

To create guidelines for bamboo products by craftspeople in NER of India to facilitate socio-economic interventions along United Nation's Sustainable Development Goals 2030 (UN SDG 2030).

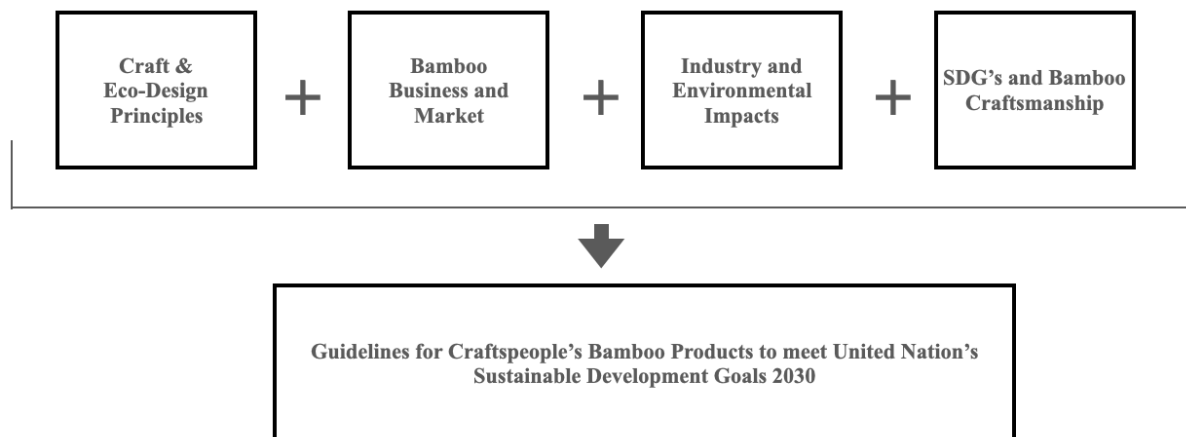
A set of Research Objectives have been identified :

- To assess aspects of indigenous craftsmanship in the context of Assam in NER, India along state of the art principles and terminologies related to sustainability in Design.
- To understand current trends and challenges in the bamboo furniture design sector in terms of design, clientele, market opportunities and business.
- To compare eco-friendliness of manufacturing process of bamboo furniture against the competing materials in the current furniture market through Life Cycle Assessment.

- To assess and deliver guidelines in terms of UN SDG 2030 for interventions in the bamboo craftsmanship sector of NER in India.

## 1.7 Research Methodology

The research integrates both qualitative and quantitative approaches to analyze data, integrate findings and draw inferences, thus directing towards a mixed method (Tashakkori & Creswell, 2007). The research has been conducted in four sections as shown in Figure 1.4 :



*Figure 1.4 Methodology of conducted research (Source : Author)*

- The first section explores the indigenous Indian craftsmanship through selected crafts of Assam. Semi structured personal interviews were conducted with multiple craftspeople and the collected data was compared with the Principles of Eco-Design.
- The second section investigates into the domain of Indian bamboo design. Semi structured interviews in person and via telephonic conversations were conducted with bamboo researchers, craft entrepreneurs and businessmen. A literature review was conducted for the position of the clientele with eco-conscious mindsets.
- The third section delivers a comparative Life Cycle Assessment of manufacture of bamboo furniture design with the competing materials in the current market namely, wood, steel and plastic. Data collection was conducted from small and medium furniture making industries in Assam through semi-structured in-depth interviews with process engineers. The collected data was analysed through OpenLCA 1.11 version software using Ecoinvent 3.8 Database for results.
- The fourth section assesses the bamboo craftsmanship sector against the UN SDG 2030 to deliver insights on the existing compatibilities. The results from the four sections are culminated to deliver guidelines for socio-economic development of the bamboo craftsmanship sector in NER of India.

## 1.8 Expected Outcome of the Research

The result of the research of the thesis can be culminated into '**Guidelines for Craftspeople's Bamboo Products**' [Figure 1.4] which would be helpful to entrepreneurs and businesspeople who are thinking of investing in the bamboo domain. It would also help eco-conscious consumers to validate their choices towards environmental and green responsibility, inform young designers about the characteristics and relative eco-friendliness of the material bamboo for future scope of implementation and also inform the

general public regarding the importance of implementing sustainable material consumption practices for a better future. It would also address United Nation's Sustainable Development Goals 2030 which are being fulfilled during application of the guidelines in the bamboo craft domain.

## 1.9 Scope and Limitations

### Scopes :

- For the validation of craftsmanship, four different crafts will be chosen according to the location of the research institute in Guwahati and availability of craft villages in the state of Assam.
- A thorough research on the state of the art principles and terminologies will be conducted to assess the aspects of craftsmanship against sustainability.
- The research shall compare four different materials and two different forms of bamboo for a life cycle assessment comparison to validate bamboo through the medium of furniture design.
- The industrial visits shall be conducted in the North Eastern Region of India.
- The softwares OpenLCA and SimaPro being available will be used in the assessment.
- The research shall deploy guidelines for the socio economic upliftment through business ventures of the bamboo craftsmanship clusters in NER of India.
- With fewer amendments, the guidelines could provide a parallel to other indigenous craftsmanship sectors in India as well.

### Limitations :

- The research will be conducted in NER and if the same research is conducted in different locations, it might deliver different results.
- No information has been considered regarding packaging design for retail.
- The research delivers the comparative status of the material when manufactured in NER and distributed pan India.
- During the industrial research, difficulties are to be identified during the streamlined collection of data.
- Minor loopholes may occur in data collection as big data were converted into smaller units for the research.

## 1.10 Thesis Structure

Chapter 1 introduces the research with the previous work done on bamboo and the aims, objectives and methodologies of the conducted research. It delivers questions to be answered through the research and the structure of the thesis.

Chapter 2 explains the Sustainability of Craftsmanship. It expands on the definition of sustainability relevant to the research defining terminologies of eco-effectiveness, eco-efficiency and the Principles of Eco-Design. It delivers the current status of sustainability and its quality in India. Further the chapter delves into the detailed historical understanding of Indian craftsmanship as an institution and the multiple aspects of craftsmanship in terms of ethnography, economy, aesthetics and consumer acceptance. It looks into four surviving craftsmanships of Assam and its aspects are compared to the principles of Eco-Design to determine the extent of sustainability approached by design of craftsmanship. A comparative analysis defines conclusions for the craft sector in term of changes and

adaptations to be incorporated for its successful interpretation of intervention in terms of relevant business.

Chapter 3 introduces Bamboo Design in India. It reflects on the work done on bamboo, its practices, patterns, products and interventions since 1975, as formal exploratory research with design considerations of bamboo material was undertaken since then. Firstly, the work done by different academic and entrepreneurial institutions have been streamlined and culminated into bamboo design's current status. Then a market study is conducted to understand the saleability of the products from the perspectives of craft entrepreneurs in the physical market domain and the website portals of the online market. To understand market further, a client is determined for the future of such products. The attitude dispensed towards eco-conscious products is registered amongst the millennials and ways to promote green consumption amongst them has been drafted.

Chapter 4 establishes a relationship between Eco-Design principles and Life Cycle Assessment (LCA) of products. An extensive research is conducted regarding the history, applications and methodology of the process of LCA which defines the Goal and Scope Definition, Life Cycle Inventory Analysis and Life Cycle Impact Assessment along with the detailed descriptions of Impact Categories assessed in LCA.

Chapter 5 is a continuation of the process to conduct a Comparative Life Cycle Assessment between the materials wood, steel, plastic and bamboo through a unit of uni-material piece of furniture. An industrial research in the quantitative format has been conducted while visiting industries in the aforementioned domain in the region of NER. The comparative LCA results have been discussed to finally validate the bamboo material for the clientele of the age of information and eco-conscious products.

Chapter 6 visits United Nation's Sustainability Development Goals 2030 and assesses the possibilities of fulfilment of the goals through effective actions in the bamboo craftsmanship sector of NER, India. The goals represent a holistic socio-economic development of the sector and provide direction to resolve guidelines for craftspeople's bamboo products for the NER region, which could be replicated in other regions of India for such similar cases of design by craft.

Chapter 7 concludes the research by delivering guidelines for execution with important considerations and interventions for the bamboo product domain developed by craftspeople. The guidelines include the complete supply chain of the craft product system from collection of raw materials to market display. The stakeholders involved in the process have been identified and every stage has been discussed under desired favourable results, methods of execution and impacts of implementation. Thus, investment in the bamboo craft domain could imprint a holistic development of the sustainable framework for craft, business and market towards a climate responsive future for the upcoming generations.

## CHAPTER 2 :

# SUSTAINABILITY OF CRAFTSMANSHIP

## 2.1 Introduction

Craftsmanship as ‘cultural materialism’ represents creative labour evolved into sustaining habits for problem finding and solving, using acquired skills. India has cradled craftsmanship since the time of ancient civilisations and has prolonged its survival well into the current times. Craftsmanship denotes a decentralised system, functioning in a holistically sustainable environment. Its parameters such as local area resources, tools and techniques, elimination of wastes, socio-economic involvement and reasonable consumer demands have characteristics of a sustaining system with minimal consequences on the natural environment.

With the evolution of the concept of sustainability in the late 1900’s, it has developed numerous contextual meanings which has delivered terminologies and goals for decades in the near future. To understand the position of craftsmanship in the current understanding, the chapter provides an updated discourse on the principles of sustainability and the institution of craftsmanship. It tries to draw parallels between the two by understanding its numerous aspects and attributes, highlighting concepts which are in sync. The study has been facilitated by a study of 5 craft villages located near Guwahati, Assam which provides a realtime understanding of the functionality of indigenous craftsmanship.

The chapter starts by seeking the definition of sustainability and the purview of Eco-Design principles and Sustainable Development Goals. The chapter then explains craftsmanship according to its numerous aspects and compares it to Eco-Design principles to redefine the status of indigenous craft towards newer dimensions of sustainability. The chapter answers the question - Is Indian indigenous craftsmanship sustainable according to the latest terminologies and principles of sustainability? Through this question the chapter establishes a relationship between craftsmanship and sustainability through the principles of Eco-Design.

## 2.2 Sustainability

Sustainable development, a concept that emerged in the context of a growing awareness of an imminent ecological crisis, seems to have been one of the driving forces of world history in the period around the end of the 20th century. The term ‘sustainability’ was first used in German forestry circles by Hans Carl von Carlowitz in *Sylvicultura Oeconomica* in 1713. Carlowitz suggested sustainable use of forest resources, which implied maintaining a balance between harvesting old trees and Sustainable development, ensuring that there were enough young trees to replace them (Du Pisani, 2006). Since then, multiple versions of the term has been introduced depending on various contexts. For the conduction of the research, a certain perspective regarding the term sustainability has been understood which has been discussed in detail in the following sections.

### **2.2.1 Defining Sustainability**

Sustainability is 'a means to secure and maintain a qualitative condition of being over time' (Fry, 2009). According to the Cradle to Cradle technique, all sustainability is local. The Hannover Principles state that 'interdependence must be recognised. The elements of human design are entwined with and depend upon the natural world, with broad and diverse implications at every scale. Thus, design considerations must be expanded to recognise distant effects'. The idea of local sustainability is not limited to materials, but it begins with them. It opens the doors to profitable local enterprise and avoids the problem of bio-invasion, when transfer of materials from one region to another inadvertently introduces invasive non-native species to fragile ecosystems (McDonough & Braungart, 2002).

### **2.2.2 Sustainability and Design**

Design names our ability to prefigure what we create before the act of creation. It is one of the fundamental characteristics that makes us human. 'Design Intelligence' is having the quality and ability to read the qualities of the form and content of the designed environment in which one exists. It involves Design activity such as what needs to be designed, act of designing, nature of the designed object, consequences of its actions in the world (immediately and over a considerable expanse of time) covering a larger frame (Fry, 2009).

Design Life specifies minimum functional duration of a product, a building, its components or elements whereas Life Cycle Assessment is the quantification of energy inputs and pollution inputs throughout the process from beginning to end. Designing in time involves examining in detail what could shape in future, positive or negative possibilities, and thereafter deciding what should and what should not be factored into design activity (Fry, 2009).

To know what needs to be eliminated, we must make a judgement between short term socio-economic gains and longer range impacts. Elimination process centres on the displacement of high impact technology with low impact technology. Elimination involves Dematerialization (removing materials) and Rematerialization (substitution of human labour by machines in a smart way) (Fry, 2009). For example, eliminating the concept of waste by design (McDonough & Braungart, 2002). Designing in time is a crucial methodological aspect of Redirective Practice. Redirection demands design but design rethought and remade. It is designing from the future to the present by future scenario building. It questions 'what potentialities beg intervention' (Fry, 2009).

### **2.2.3 Eco Effectiveness and Eco Efficiency**

Nature's services and processes are a part of a dynamic interdependence in which many different organisms and systems support one another in multiple ways. The consequences of growth - increases in insects, micro organisms, birds, water cycling, and nutrient flows - tend towards the positive kind that enrich the vitality of the whole ecosystem. We can be humbled by the complexity and intelligence of nature's activity, and we can also be inspired to some positive side effects to our own enterprises instead of focusing exclusively on a single end (McDonough & Braungart, 2002).

As long as human beings are considered as 'bad', zero is a good goal : zero waste, zero emissions and zero 'ecological footprint'. But to be less bad is to accept things as they are, to believe that poorly

designed, dishonourable destructive systems are the best humans can do. It is the ultimate failure of the 'be less bad' approach : a failure of the imagination of execution. Thus, instead of fine tuning the existing destructive framework, why don't people and industries set out to create (amongst many) : "products that, when their useful life is over, do not become useless waste but can be tossed onto the ground to decompose and become food for plants and animals and nutrients for soil, or alternately, that can return to industrial cycles to supply high quality raw materials for new products" and "a world of abundance, not one of limits, pollution and waste" (McDonough & Braungart, 2002).

Eco Effectiveness means working on the right things - on the right products and services and systems - instead of making the wrong things less bad. Once right things are being done, then doing them right with the help of efficiency among other tools makes perfect sense. There is a difference between Eco Efficiency and Eco Effectiveness as the difference between an airless, fluorescent lit grey cubicle and a sunlit area full of fresh air, natural views, and pleasant places to work, eat and converse. Thus, the 'right things' for mass manufacturers to do are those that lead to good growth - more riches, health, nourishment, diversity, intelligence and abundance - for this generation of inhabitants on the planet and for generations to come (McDonough & Braungart, 2002).

According to the Cradle to Cradle concept, here are a few ways to be Eco Effective :

- Prefer ecological intelligence
- Prefer respect for those who made the product, for the communities near where it is made, for those who handle and transport it, and ultimately for the customer
- Research states that people like the idea of buying something that makes them feel special and smart, and they recoil from products that make them feel cross and unintelligent
- Prefer delight, celebration and fun since certainly products can accomplish more than simply making the customer feel guilty or bad and can express the best of design creativity, adding pleasure and delight to life
- Creating a passive positive list by conducting a detailed inventory of the entire palette of materials used in a given product, and the substances it may give off in the course of its manufacture and use. Once screened, the substances are placed in X-List (rejected list), Gray List (needed though toxic) and P-List (positive and preferred list)
- Exert intergenerational responsibility because the Earth belongs to the living.

Eco Efficiency is doing more with less, a percept that has roots in early industrialisation. As Henry Ford said in 1926, "You must get the most out of the power, out of the material and out of the time". 'Our Common Future', a report published in 1987 by UN's World Commission on Environment and Development stated, "Mass manufacturing operations should be encouraged that are more efficient in terms of resource use, that generate less pollution and waste, that are based on renewable rather than non-renewable resources, and that minimize irreversible impacts on human health and environment" as an agenda of change. In the Business Council of Sustainable Development of 1992, one of the council founder members, Stephan Schmidheiny stated, "within a decade, it is going to be next to impossible for a business to be competitive without also being eco-efficient, which would mean adding more value to a good or a service while using fewer resources and releasing less pollution" (McDonough & Braungart, 2002).

The cyclical Cradle to Cradle biological system has nourished a planet of thriving diverse abundance for millions of years. Until very recently, it was the only system and every living being on the planet

belonged to it. Growth was good. Then came the Industry, that altered the natural equilibrium of materials on the planet. Humans took substances from Earth's crust, and concentrated, altered and synthesised them into vast quantities of material that cannot safely be returned to the soil anymore (McDonough & Braungart, 2002).

Currently, material flow can be divided into two categories, biological mass and technical, i.e, industrial mass. In order for these two metabolisms to remain healthy, valuable and successful, great care must be taken to avoid contaminating one with the other. A Biological Nutrient is a material or product that is designed to return to the biological cycle, it is literally consumed by micro organisms in the soil and by other animals; whereas a Technical Nutrient is a material or product that is designed to go back into the technical cycle, into the industrial metabolism from which it came. With the right design, all of the products and materials manufactured by industry will safely feed the biological metabolism (biosphere) and the technical metabolism (technosphere), providing nourishment for something new. If done, people would indulge in their hunger for new products as often as they wish, without guilt, and industry could encourage them to do so with impunity, knowing that both sides are supporting the metabolism in the process (McDonough & Braungart, 2002).

#### **2.2.4 Current Status of Sustainability**

It is a human condition that people who make things usually do not understand what they are making. We are trained to measure everything by a mechanical standard, which makes it difficult to see things clearly (Coomaraswamy & Moore, 1909). Designers are unable to think what design does beyond the functional, economic and restricted understandings of the symbolic, and do not care till they are commercially successful. Media reinforces perceptions of a designer as a creative capitalist nerd delivering 'sexy looking things'. Designers mostly lack the ability to talk about design in informed critical ways, they mostly articulate what they do in banalities, and above all have a very limited understanding of the consequences of what they create (Fry, 2009).

The culture founded on man made things risk continuous self harm. Men and women are seduced by sheer wonder, excitement, curiosity and so create the fiction that opening the Pandora's box is a neutral act. The generation could put numbers to the fear of self destruction, numbers so large as to numb the mind, which represent the compound of scientific blindness and bureaucratic power, where bureaucrats minded just to get the job done. One million, for instance, represents the number of years Nature took to create the amount of fossil fuel now and consumed in one single year. The planet's renewable resources are being used up 25% faster than they can be renewed. Our ecological footprint has tripled since 1961 (Fry, 2009).

Unsustainability has become part of our nature; we focus instead on its symptomatic manifestation in the natural world, leading to the erroneous hope that science and technology will 'save the planet', while allowing humanity to universally realize an even higher standard of living (Fry, 2009). We attach a disproportionate value to the productions of machinery, and as generally supposed, perhaps 60% of these productions are not labour-saving, health giving or serviceable to our general life and culture, but in fact, the reverse. Owing to the abuse of machinery, the destruction and waste it brings may not equal the gain it yields (Coomaraswamy & Moore, 1909). Cradle to Grave designs dominate modern manufacturing (McDonough & Braungart, 2002).

Design has been a significant agent of historical change. Change can generate insecurity and resistance, as it equals an abandonment of attachments to the familiar. When consequences are not altogether evident, insecurity deepens. When design is preoccupied with matter, form, function and space, the past fades into in-distinctiveness, while the future is a void. But we can learn from our past ways to cultivate the ability to identify and extract design and sustainment principles from historical materials and then transpose them into appropriate future forms. Future scenario building is not a linear evolutionary projection but establishing a view of what in the present is future determinant, then using this knowledge to elaborate a future. Through a reference work of linking the events, it could be a credible research tool as measured against the possible (Fry, 2009).

The great city of mechanical industry has come to a point when its disintegration is inevitable and there are signs that the desolution has already begun. The cry of 'back to the land', plea for a 'more reasonable life', the revival of the handicrafts, the education of the hand and eye, all these are indications of something to bring back once again into life the direct, simple, human and out of door things which the mechanical industry has deprived the working population (Coomaraswamy, 1909).

As Tony Fry says, sustainment demands the challenging abandonment of wealth generated by the current economic model, based on perpetual growth. Martin Heidegger, the philosopher, limits his place in the world to the satisfaction of simple needs like "a hut in the Black forest". This is perhaps a desire that could be kindled in anyone facing the big numbers of modern destruction (Sennett, 2008).

### **2.2.5 Sustainability and Quality**

Quality names all that adds to everything which is good. Quality folds the economic into the ethical, the singular into the collective (the common good), as things of quality that help sustain the maker, the made, the user and the world of use. Quality understood within the remit of sustainment names the performative sustaining characteristic of whatsoever is brought into being in terms of its materiality, function, symbolic meanings and its designing agency in the world over time. This is in relation to the nature of its materials, how it is made, its material ecology, the operational and symbolic use it delivers, its meaning and aesthetic as the qualities compound to form the degree of its sustaining ability (Fry, 2009).

How much should quality cost? Quality has firstly, nothing to do with luxury, but assigned to the everyday and secondly, something comes to be and what it sustains, rather than what it is; quality is what something delivers rather than a designated value of a thing. Good quality could cost more but the buyer could get more. 'Quality Economy' is the term which defines the investment in quality and the cost and return from these 'things that could be' to be grasped as ways of creating and distributing considerable wealth from a dramatically smaller material footprint (Fry, 2009).

### **2.2.6 Sustainability and Eco-Design**

Around 12,000 years ago, when human beings settled in agricultural settlements and gained food security, they started creating technologies and professions based out of needs for sustenance and lifestyle. Made of locally available natural materials, these produce initiated trade of the surplus, which eventually financed the governance of civilisations (Lloyd, 2008; Overy, 2007). As people's world

views shifted, global legacies of nature worship were remodelled and viewed nature as a resource to be harnessed through technology.

This vision actualised in rapidly evolving Europe in around 500AD. By 1300AD, Europe instigated maritime research for resource rich colonies worldwide and their conversion into production bases, which replaced the indigenous robust natural diversity to a fragile monoculture. Growing dissent between colonisers and the colonised caused numerous uprisings and Europe was unable to import labour due to bans. An alternative to this situation took to the form of Industrial Revolution. Around 1870, demands of Europe's Industrialisation created a new fetish to subjugate their colonies in Asia, Africa, Australia and America for resource extraction. Their eventual emancipation saw Europe giving away to the global civilisation age in early 1900's (Lloyd, 2008; Overy, 2007).

As Industrialisation spread, it caused rapid shift to urban, technocratic and industrialised systems, which increased population and economic growth, and laid the ground for the unsustainability we face today. While economic benefits of developed countries were boosted by globalisation, developing countries hosted the global production centres and also bore their ecological and social costs (Munasinghe, 2010).

Sustainability began to crystallise in 1970's as an ecological concept following public dissent on Industrialisation's unprecedented development over the environment (Hawken et al,1999). United Nations's Stockholm conference (1972) and Brundtland's Commission (1987) acknowledged the situation of accelerating degradation and its consequences (Mann, 2011). Brundtland's Report represented Sustainable Development as "*development that meets the needs of the present without compromising the ability of future generations to meet their own needs*" (Brundtland, 1987). UN's Earth Summit and Rio Declaration (1992), Millennium Summit (2000), Johannesburg Summit (2002) and Rio+20 delegation (2012) grounded the Sustainability Development Goals which included social and economic connotations to the primarily ecological concept (Barash & Webel, 2002). Various sustainability development models and diagrams were developed by Brundtland (1987), Barbier (1987), Munasinghe (1992), Daly (2014), SIGMA (2003), Runnalls (2008) et al and they presented various permutations of the four pillars of sustainability - ecological, social, economic and cultural dimensions (Reubens, 2016), with a future inclusion of political, temporal and ethical tenets (O'Connor, 2007).

Design as a profession also crystallised when, during the Industrial Revolution, integrated artisan based systems were divided into specialised disciplines of design, production and marketing (Walker, 1989). By the late 20th century Western culture, designers were dissociated from craftsmen and artists as there was a distinct separation between 'having ideas' and 'making objects' (Peters, 1997). The Arts and Crafts, Bauhaus, Modernist and Post Modernist movements defined evolving stages of Industrialisation. Post World War II, the depleting manufacturing power of Europe made USA the hub of production which was based on high consumption and exorbitant natural exploitation (Sheldon & Arens, 1932). In the 1970's, the spotlight onto ecological sustainability (Papanek, 1971) invited reflection on life cycle thinking through Green Design (Whitely, 1993). Eventually the social aspect surfaced among the appropriate technology practitioners worldwide. This was the driver for Design for Environment (DfE) or Eco-Design during the 1990's, which aimed to create a profitable situation by addressing both the ecology and economy (Brezet & Hemel, 1997).

Earliest concerns about resource limits and the impact of our material production on the environment are often traced back to Buckminster Fuller's teachings and work (Fuller, 1969). However, the seminal

work introducing environmental considerations into the world of designers is considered to be Victor Papanek's book 'Design for the Real World: Human Ecology and Social Change' (Papanek, 1971). Papanek provided an in-depth critique of the design profession pointing out its role in encouraging consumption and therefore contributing to ecological and social degradation. His work reflected a sophisticated response focussing not only improving the outputs of design activity but promoting transformation of the design profession. Nevertheless, the following early adoption of 'green' attitudes in the design profession had not demonstrated a similarly high desire for transformational change. The early examples of green design practice (Burall, 1991; Mackenzie, 1997) primarily focused on lowering environmental impact through redesigning individual qualities of individual products. This was usually achieved by following the waste hierarchy of reduce-reuse-recycle (e.g. reducing amount of material used in a product, reusing parts or whole products in design of new products, replacing virgin materials with recycled materials, replacing hazardous/toxic materials with non-hazardous ones). This period also saw early designs focussing on use of renewable energy such as solar street lamps (Fuad-Luke, 2002). For others, considering environment in design meant efficiency improvements in product and process engineering (e.g. Fiksel, 1996; OECD, 1998). Guidelines and toolkits advocating Design for X (X standing for any of the 'more preferable' attitudes in design from recycling to recyclability to ease of dismantling to repairability) were developed (for an overview see Chiu & Kremer, 2011). Although introducing the 'green' prefix to the lexicon of the design profession, and developing and improving the still valid 'rules of thumb' for improving environmental performance of products, green design lacked material and political depth, therefore, promoted green consumerism and did not present a significant capacity for generating environmental gain (Madge, 1997).

Used synonymously with green design when first introduced, eco-design has a main significant difference and strength over green design; i.e. a focus on the whole life-cycle of products from extraction of raw materials to final disposal (Boks & McAlloone, 2009; Pigosso, McAlloone, & Rozenfeld, 2015; Tischner & Charter, 2001). This enabled profiling the environmental impact of products across all life-cycle phases, identifying those phases with the highest environmental impact and therefore provided strategic direction for design interventions. The overall goal of eco-design is to minimise the consumption of natural resources and energy and the consequent impact on the environment while maximising benefits for customers. In eco-design, the environment is given the same status as more traditional industrial values such as profit, functionality, aesthetics, ergonomics, image and overall quality (Brezet & van Hemel, 1997; Binswanger, 2001). On a more practical side, a fairly complete set of ecodesign principles, guidelines and tools has been developed (e.g. Hemel & Cramer, 2002; Bhamra & Lofthouse, 2007; Tischner & Charter, 2001; Vezzoli & Manzini, 2008).

With adoption of the Eco-Design Directive by the European Commission (EC, 2005), which mandates life-cycle assessments to be undertaken in association with environmental management systems, eco-design has become a primary focus for most major companies, especially for those producing energy using products. Although the life-cycle focus of eco-design provides significant strengths over early practice of green design, it also has significant shortcomings. Lacking complexity, eco-design focuses solely on environmental performance (Gaziulusoy, 2015) and therefore disregards social dimensions of sustainability which cover issues around the distribution of resources and the product's social impacts related that cannot be accounted for in life-cycle assessments. Although early implementations of eco-design resulted in huge environmental gains, once the inefficiencies and 'bad design' were removed from products, the gains started to become marginal and increasingly costly, resulting in eco-design

becoming problematised. Moreover, the efficiency gains on a product basis did not resolve the impacts associated with ever increasing consumption of products which outpaced unit efficiency improvements (Ryan, 2005). In addition, although eco-design is supposed to focus on the whole life-cycle, this is mainly done from a technical perspective, with a limited attention to the human related aspects (e.g. user behaviour in the use phase) (Bhamra, Lilley, & Tang, 2011).

### **2.2.7 Eco-Design and its Principles**

Eco-Design is a product design approach to assess Sustainability through environment and economy (Karlsson & Luttrupp, 2006; Bovea & Pérez-Belis, 2012). With the help of tools and methodologies, it adopts the Life Cycle Approach, to explore and tackle all or the greatest impacts across the product's lifecycle (Short et al, 2012). The challenge for eco product developers is to fulfil a need, or to provide a benefit to the customer at the lowest environment and economic 'cost' (Luttrupp & Lagerstedt, 2006).

The 10 most frequently suggested and successful Eco-Design principles are (Hemel & Cramer, 2002) :

- Recycling of Materials,
- High Reliability/Durability,
- Recycled Materials,
- Low Energy Consumption,
- Remanufacturing,
- Less Production Waste,
- Clean Production Technique,
- Reduction in Weight,
- Clean Materials and Less,
- Clean & Reusable Packaging.

Identification of data and acquired information through identified tools, make it possible to determine new flows of information to allow Eco-Design activities for product and product families (Pochat et al, 2007). This Eco-Effectiveness or rather, the 'right things' for mass manufacturers to do are those that lead to good growth for the future generations (McDonough & Braungart, 2002).

Meanwhile, there are various obtrusive barriers for the implementation of Eco- Design practices in an enterprise such as risks involved in the translation of an existing framework, lack of a clear environment benefit, lack of understanding and awareness amongst consumers, commercial disadvantage, lack of alternative solutions etc. (Hemel & Cramer, 2002; Short et al, 2012). These barriers can be converted into promising opportunities for the application of Eco-Design in MSME's, because, unlike bigger enterprises, there is minimum risk involved in implementing changes, they are normally less bureaucratic and have quicker responses with respect to their effective internal communication channels (Hemel & Cramer, 2002; Short et al, 2012). Also, for smaller enterprises, the demand for Design for Environment (DfE) exists from customer perspective and investors or corporate stakeholders as well (Short et al, 2012). When looked into the MSME's of India, it is noticed that one-fifth section is composed of the artist and craftsmen community (India Times, 2018) and when looked into the attributes of Craftsmanship, it seems to be well in sync with most of the suggested and successful principles of Eco-Design.

### 2.2.8 United Nation's Sustainable Development Goals

The Sustainable Development Goals (SDGs) were introduced at the United Nations Conference on Sustainable Development in Rio de Janeiro in 2012. The objective was to produce a set of universal goals that meet the urgent environmental, political and economic challenges facing our world.

The SDGs replace the Millennium Development Goals (MDGs), which started a global effort in 2000 to tackle the indignity of poverty. The MDGs established measurable, universally-agreed objectives for tackling extreme poverty and hunger, preventing deadly diseases, and expanding primary education to all children, among other development priorities.

For 15 years, the MDGs drove progress in several important areas: reducing income poverty, providing much needed access to water and sanitation, driving down child mortality and drastically improving maternal health. They also kick-started a global movement for free primary education, inspiring countries to invest in their future generations. Most significantly, the MDGs made huge strides in combatting HIV/AIDS and other treatable diseases such as malaria and tuberculosis.

Key MDG achievements as per United Nations Development Programme :

- More than 1 billion people have been lifted out of extreme poverty (since 2000)
- Child mortality dropped by more than half (since 2000)
- The number of out of school children has dropped by more than half (since 2000)
- HIV/AIDS infections fell by almost 40 percent (since 2000)

The legacy and achievements of the MDGs provide us with valuable lessons and experience to begin work on the new goals.

The SDGs follow through MDG's as a commitment to finish what was started. All 17 Goals interconnect, meaning success in one affects success for others. Dealing with the threat of climate change impacts how we manage our fragile natural resources, achieving gender equality or better health helps eradicate poverty, and fostering peace and inclusive societies will reduce inequalities and help economies prosper. The United Nations has determined targets and indicators for each SDG. These allow the structured assessment of fulfilment of a goal.

The 17 Sustainability Development Goals are :

1. No Poverty
2. Zero Hunger
3. Good Health and Well-Being
4. Quality Education
5. Gender Equality
6. Clean Water and Sanitation
7. Affordable and Clean Energy
8. Decent Work and Economic Growth
9. Industry, Innovation and Infrastructure
10. Reduced Inequalities
11. Sustainable Cities and Communities
12. Responsible Consumption and Production
13. Climate Action
14. Life Below Water

15. Life on Land
16. Peace, Justice and Strong Institutions
17. Partnerships

The 2030 Agenda for Sustainable Development, adopted by all United Nations Member States in 2015, provides a shared blueprint for people and the planet, now and into the future. The 17 Sustainable Development Goals (SDGs) are an urgent call for action by all developed and developing countries in a global partnership. They recognize that ending poverty and other deprivations must go hand-in-hand with strategies that improve health and education, reduce inequality, and spur economic growth, while tackling climate change and working to preserve our natural systems (UN General Assembly, 2019).

## **2.3 Indian Craftsmanship**

### **2.3.1 Origin of Craftsmanship**

Craftsmanship is 'cultural materialism' capable of genuinely appreciating the abilities/qualities that have been realised and developed by the human animal as a working or labouring being, of evaluating them in a positive way, emphasising the concrete character of the interest in question, the sensibility that also involves a pleasure in making things that can generate 'religious, social or political views' (Sennett, 2008). India has cradled craftsmanship since the time of ancient civilisations and has prolonged its survival well into the current times. Craftsmanship denotes a functioning decentralised system in a holistically sustainable environment.

#### **2.3.1.1 The Craftsman**

Craftsman belongs to homo faber, a being wholly immersed in a dimension life where all that counts is the production of things, the execution of pre-determined tasks. The Craftsman combines a wisely trained attention to the process of making with a cultivated and formative-educative talent in relation to the learner/apprentice, as well as a sophisticated understanding of particular working techniques, and a highly developed sensibility for the social value of accomplishing the best possible and creative 'labour' or cooperation, of something skill fully produced' (Fadini, Mari and Giovannini, 2010).

Richard Sennett says, the Craftsman represents in each of us the desire to do something well, concretely, for its own sake; the special human condition of being engaged. The Craftsman explores the dimensions of skill, commitment and judgement by focusing on the intimate connection between head and hand. Every good craftsman conducts a dialogue between concrete practices and thinking, which evolves into sustaining habits, and these habits establish a rhythm between problem solving and problem finding (Sennett, 2008).

All craftsmanship is founded on skill development to a high degree. As Plato says, the aspiration for quality drives a craftsman to improve and get better rather than getting by. The emotional rewards craftsmanship holds out for attaining skill are two fold : people are anchored in tangible reality, and they can take pride in their work. Craftwork brought people out of the isolations. Personified by the cave dwellers, craft and community were indissociable. Craftsmanship may suggest a way of life which became weaker with the advent of the industrial society, but this is misleading. The Craftsman often faces conflicting objective standards of excellence, the desire to do something well for its own sake can

be impaired by competitive pressure, by frustration or by obsession. Society has often stood in the way of their emotional rewards as practical activity has been demeaned and divorced from supposedly higher pursuits. Craftsmanship is poorly understood when it is equated only with manual skill of the carpenter's sort (Sennett, 2008).

In the ancient Homeric Hymn to Hephaestus, Craftsmen have been defined by the word 'demioergos', a compound word made between public (demios) and productive (ergon). They were celebrated in the age of Homer as a social slice roughly equivalent to a middle class. The community was recognised as a 'skills society'. Skills were handed down, followers were taught to be obedient, and breathed within a communal bond. The craftsmen were identified as fellow citizens and the skills bound the ancestors to their followers. But by the Classical times, the craftsman's honour had been dimmed, and were called 'cheirotechnon' meaning simply hand worker by Aristotle. Meanwhile, in Athens, particular crafts were reserved for women which gave them respect in the public realm but no craftwork would earn Athenian women in the classical era the right to vote. The development of classical science contributed to the gendering of skill that produced the word craftsman as applying to men (Sennett, 2008).

### **2.3.1.2 Craftsmanship, Skills and Quality Work**

Ancient weavers, potters, brick makers, violin makers, architects, musicians, programmers or others, what they have in common and what defines the notion of craftsmanship are a practical sensuous engagement with objects and a continuous interplay between the practical transformation of objects and the intellectual reflection of one's practice (Kleeman, 2010). Skill is a trained practice. Skill development depends on how repetition is organised. The open relationship between problem finding and problem solving builds and expands skills. Skills opens up in this way only because the rhythm of solving and opening up occurs again and again. When looked into the Quality of Work, it can be described by either how something should be done or how to get something to work. To the absolutist in every craftsman, every imperfection is a failure, and to the practitioner, obsession with perfection seems as a prescription for failure. It might seem that the more people train and practice in developing a skill, the more practical minded they will become, focussing on the possible and the particulars (Sennett, 2008).

The difference between brute imitation of procedure and the larger understanding of how to use what one knows is a mark of all skill development. 'Autonomy' means a drive from within that impels us to work in an expressive way, by ourselves. 'Originality' traces its origins back to one Greek word 'poesis', which Plato and others used to mean "something where before there was nothing". Originality is a marker of time; it denotes the sudden appearance of something where before there was nothing, and because something suddenly comes into existence, it arouses in us emotions of wonder and awe. And, the technical name for movements in which the body anticipates and acts in advance of sense data is 'prehension'. Through this, the medieval artisan maintains the single most pressing earthly obligation of establishing a good personal reputation (Sennett, 2008).

### **2.3.2 Indian Craftsmanship and its Evolution**

What we call crafts today has historically been utilitarian products for local consumption. Craft, through its generative learning and systematic distribution of work entails a volume of non- vocalised ethics within a craftsman guild. These very utilitarian products have currently become pieces of curio in

today's living room walls and exhibition spaces. Epistemology of crafts has explicit associations to the daily livelihoods, socio-economic backgrounds, utilitarian aspects, history and anthropology of local sustenance. From the perspective of design, there is a story of creative utilitarianism which provides a deep understanding of an ethical and philosophical theory stating that 'the best action is the one that maximises utility and produces the greatest well-being of people through one's creativity' (Das & Das, 2021).

### ***2.3.2.1 History of Indian Crafts and Craftsmanship***

How long ago the craftsmen were organised into guilds, is suggested in a well known passage of Ramayana, describing the procession of citizens who went out into the forest with Bharata in the search of Rama. 'The gem cutters, potters, weavers, armorers, ivory workers, well known goldsmiths, together with many others, the foremost merchants as well as the citizens of all classes went out to search for Rama' (Coomaraswamy & Moore, 1909). Again we read in the Harivamsa, of the preparations made by the royal family and the citizens of Mathura to witness the contest between Krishna and Balarama and the king's champions. A lot of splendour depended upon these very crafts whose position was thus recognised and honoured. 'The chambers of the inhabitants of the inner apartments shone near at hand, bright with gold and painting and network of gems, they were richly decorated with precious stones, were enclosed below with costly hangings, and ornamented above with spires and banners' (Coomaraswamy & Moore, 1909).

The germ of the guild system existed at a very early time in the form of co-operative associations within the merchant community. The Royal Craftsman in the East was well established at a very early date, in the reign of Ashoka (275-231 BC). Artisans were regarded as being in a special manner devoted to the royal practice, and capital punishment was inflicted upon any person who impaired the efficiency of a craftsman by causing the loss of a hand or eye. The Mughals also maintained skilled Indian and Foreign Craftsmen at their palaces (Coomaraswamy & Moore, 1909).

### ***2.3.2.2 Crafts in the Near Indian Past***

The Craftsman is an organic element in the national life. The presence of the craftsman in the midst of a simple agricultural society made possible the self contained life of the community, so striking a feature of the Indian village. Living in a society organised on the basis of personal relations and duties, which descended in each family from generation to generation, instead of belonging to a society founded on contract and competition, their payment was provided for in various ways, of which money payment was the least important and most unusual. The payment of craftsmen was either a payment in kind, or a grant of land, besides prerequisites on special occasions; repaid during harvest time with a fixed proportion of sheaves of grain from the crop collected on the threshing floor (Coomaraswamy & Moore, 1909).

Community of interests would naturally draw together the skilled immigrants of the cities, in trade unions, the bonds of which in India, are rendered practically indissoluble by the force of caste. The trade guilds of the great poly technical cities of India, are not, however always exactly coincident with the sectarian or ethical caste of a particular caste system of artisans. Sometimes the same trade is pursued by men of different castes, and its guilds generally include every member of the trade it represents, without strict reference to caste (Coomaraswamy & Moore, 1909).

Membership in the guild is also hereditary, but new comers could be admitted into it on the payment of an entrance fee. It is not the practice to execute indentures of apprenticeship, but every boy born in a working caste of necessity learns his father's handicraft, and when he has mastered it, at once takes his place as a hereditary free man of his caste or trade guild. The guilds regulated the hours of labour, and the amount of work to be done in their workshops, by strict bye laws, enforced by the levy of fines. But this old order is passing away (Coomaraswamy & Moore, 1909).

Under British rule, which secures the freest exercise of individual energy and initiative, the authority of trade guilds in India has necessarily been relaxed, to the marked damage of those handicrafts, the perfection of which depends on hereditary processes and skill. The overwhelming imports of British manufacturers also is even more detrimental to their prosperity and influence, for it has in many ways brought wholesome ruin on the hereditary native craftsman and forced them into agriculture and even domestic service (Coomaraswamy & Moore, 1909).

But the guilds, by the stubborn resistance, further stimulated by caste prejudice, which they oppose to all innovations, still continue, in this forlorn way, to serve a beneficial end, in maintaining, for probably another generation, the traditional excellence of the sumptuary arts of India against the fierce and merciless competition of the English manufacturers (Coomaraswamy & Moore, 1909).

### **2.3.2.3 Crafts in India Now**

Society must either decide to do without art and craft as it mostly does decide at the present day, or else it must wake up its mind to pay for art and endow its craftsmen. One cannot have art and exploit it. The most striking features of the social organisation of the craftsman at this time are : the association of craftsman to villages, the hereditary character of the craft, and the importance of the Elder or Master Craftsman. The skilful and the noted craftsman was a person to be approached with gifts, and treated with respect on account of his skill and learning (Coomaraswamy & Moore, 1909).

No really great traditional art has ever been produced, except under the following conditions : freedom of the craftsman from anxiety as to his daily bread; legal protection of the standard of work; his art not exploited for profit. These are the material conditions, even more important is that spiritual conception of the serious purpose of art, which we find expressed in the work of a true craftsman of whatever age or place, but perhaps more in India than in anywhere else (Coomaraswamy & Moore, 1909).

Post industrialisation, design sees a call out to go back to one's roots to obscure local identities and revive the cultural diversities destroyed by the industrialist mindset. In the post-modern world, creative utilitarianism allows designers to be creative for themselves rather than the industry. This eventually proliferates exposure of modern design to fresh ideation. This understanding is highly required today for young upcoming designers to venture beyond form and figure explorations and infuse content into design. Integration of wholesome craft knowledge into design education will open a portal for fresh post-modern content. It shall teach the students mass customisation alongside a knowledge to work with Indigenous communities and identities (Das & Das, 2019).

### **2.3.2.4 Craftsman's Workshop**

A Workshop is a Craftsman's home. Karl Marx, Charles Fourier and Claude Saint-Simon all viewed the Workshop as a space of human labour. It is a productive space in which people deal face to face

with issues of authority. This austere definition focuses not only on who commands and who obeys in work but also on skills as a source of the legitimacy of command or the dignity of obedience. A successful Workshop will establish legitimate authority in the flesh, not in rights or duties set down on paper (Sennett, 2008).

The young craftsman is educated and brought up in the actual Workshop and is the disciple of his father. This is implicit in the expression 'hereditary craftsman'. No technical education in the world can ever hope to compensate the craftsman for the loss of these conditions. In the Workshop, technique is learnt from the beginning in relation to real things and problems, and primarily by service and personal attendance on the master. And it is not only technique learnt in the workshop, there is life itself, that gives to the pupil both life and metaphysics, more essential to art than technique itself (Coomaraswamy & Moore, 1909).

#### **2.3.2.5 Craftsmanship and Handicrafts**

'Handicrafts' are mostly defined as 'items made by hand, often with the use of simple tools, and are generally artistic and traditional in nature (Yojana & Sansad, 2006).

The Indian craftsman, who has demonstrated an uncanny understanding of materials which is combined with a mastery of the tools, techniques and processes that have evolved over the centuries through social and cultural interactions, is a tribute to the creative design abilities of the Indian village society. It is a search for the values that are uniquely Indian and will help inform current and future actions in the continuous evolution of the economy and the form that it takes in shaping the culture of the land. Today the craft continuum constitutes an enormous resource that can be harnessed for the future development of our society, particularly as the backbone of a creative economy that is enabled by the embedded knowledge in the traditional wisdom of the sector, as well as the digital technologies that help connect this ancient skill to new and future opportunities for the Craftsmen across India. The believers of the enormous potential of the Indian Craftsman, feel the need to make this enormous knowledge base accessible to planners and business platforms as well as connect these to new local and global opportunities for the skills and resources to be reinterpreted in new and imaginative ways. This shall be the foundation of the creative economy of the future in a massively web enabled network and shall have easy access to link the craftsmen to new markets across the world. This will help our craftsmen re-connect with the world markets, just as they had been doing for centuries in their own villages and in their trade route networks of the past. Hence, the world can be their new village economy, if they are enabled and empowered to change to meet these new circumstances with access to information that is both live and relevant (Ranjan, 2007).

There are two major constraints of development. Firstly, Demand Constraints which accounts for the factors for lack of demand and fall in demand in market. Secondly, Supply Constraints which account for factors that impede production such as skilled labour, raw materials, modern methods, credit facility, quality control, supply chain and infrastructure to store product (Redzuan and Alef, 2011).

### **2.3.3 Craftsmanship and the Indian Economy**

The Industries Conference of Independent India in 1947 identified the following problems which were being faced by the cottage and small scale industries including handicrafts : lack of finance, outdated

techniques of manufacturing, defective marketing, non-availability of raw materials, competition from mechanical goods whether imported or legally made. After this conference an All Indian Cottage Industries Board was set up in 1948, but as soon as the board started functioning, problems started to crop up, lack of data became a major hindrance in extending financial aid. It reached a conclusion that a single board was insufficient and the efforts taken by them were not enough and finally a sub group study was suggested as various groups of industries had diverse and peculiar problems (Jadhav, 2013).

The Minister of State for Textiles, Panabaaka Lakshmi, in a written reply to Lok Sabha stated that, as per the results made available on different parameters pertaining to the handicrafts sector based on enumeration undertaken till now, the estimated artisans in India during 2010-2011 were 6.8 million (PTI, 2013). The number of individuals to be employed with this sector by 2016-2017 is estimated to be 12.29 million (Jadhav, 2013). 78.2% production of the country comes from rural areas and 21.8% from semi-urban areas. The number of artisans is 76.5% in rural and 23.5% in semi-urban areas (Ernst & Young, 2012).

The 12th Five Year Plan highlights :

- convert artisans to self-sustained community bases entrepreneurs,
- shift from allocation based model to demand based model,
- different clusters may be at different stages of development, hence require a different set of interventions for development,
- no or limited role in the selection of the implementing agency, sanction of project, preparation of project report, identification of project interventions etc. This leads to development plans that may not necessarily be in time with the needs of the artisans, who are in fact the end beneficiaries.

The Plan's vision for the handicraft sector includes creation of globally competitive handicrafts and provision of sustainable livelihood opportunities to the artisans through innovative product designs, better product quality, and use of technology while preserving traditional art (Jadhav, 2013).

The Indian cottage industry has strengths like abundant and cheap labour, local resources, low capital investment, unique craftsmanship, increasing appreciation by international customers. But the irony is that Indian handicraft exports comprises of a meagre 1.2% of the world's market for handicraft and 1.5% of the country's overall exports. The export of handicrafts is expected to reach INR 28,368 Cr. (approx US \$6177 million) in case an average growth of 18% per annum is maintained during the 12th Year Plan (Working group report on Handicrafts for the 12th Five Year Plan, pg. no. 16-18). 40% of the production of Handicrafts is consumed by the domestic market and 60% is exported (Jadhav, 2013).

The import of cheap machine made versions of artefacts from other countries into India is killing the domestic market of the handicraft sector within the country (Jena, 2010). Though the handicraft industry is known for its exquisite craftsmanship, its inability to adapt innovative methods of production and to be creative enough to adapt to the changing needs of the consumers has become one of the limiting factors in the growth of the handicraft industry (Ghosh, 2012).

More than 52.3% of people in India are below the age of 25 currently. 41.8% will still be less than 25 by 2025. It calls for a creation of higher number of employment opportunities. Dealing with 50% young population or employable workforce will not be easy if concentration remains on building new skills. The need of the hour is to identify the existing skill sets, upgrade them and develop new skills to

complement the existing ones (Jadhav, 2013). Difficulty in preserving the art by keeping the next generation involved is the latest identified problem in the conservation of handicrafts.

### **2.3.4 Aesthetics and Consumer Acceptance**

We aesthetically prefer environmental patterns and features that are beneficial for the development of the senses' functioning and our survival in general. Thus 'Aesthetics' defines as pleasurable to the senses (Goldman, 2001). Aesthetics plays a significant role in guiding human behaviour in and outside consumer psychology. Thus it is imperative to understand the dynamics of the two to underlay the groundwork for design through craft.

#### **2.3.4.1 Defining Aesthetics**

The original Greek meaning of aesthetics refers to sensory perception and understanding. As per philosopher Baumgarten of the 18th century, aesthetics It is the gratification of the senses or the sensual delight (Goldman, 2001). An artwork experience consists of aesthetics, cognition and emotion. Aesthetic is a part of the experience (Hekkert, 2006).

Some of the general principles of taste or aesthetic pleasure are uniform in human nature. This does not automatically imply universal agreement. Aesthetic differences and responses are a result of interpretation differences, as it is said that beauty lies in the eyes of the beholder. It must be beneficial for humans to seek cues or patterns that serve our adaptive functions. We therefore, have come to derive aesthetic pleasure from patterns or features that are advantageous to these functions (Hekkert, 2006).

Hekkert says that the most prominent sensory system and the most dominant modality in our experience of the world is the visual system because we like to see things that support navigation and identification. Visual system patterns bring order in the flow of information. Similar is the importance of the other sensory systems of our body, them being ears, skin, nose and the mind.

#### **2.3.4.2 Approach to Consumer Acceptance**

To increase the aesthetic pleasure of the experience, there are a few principles which could be followed such as maximum effect for minimum means such that if we can smell, see, hear or decide something faster or with less effort, we will prefer it over the more demanding alternative. Another principle states 'unity in variety' as the perceptual tendency of grouping, of discovering relations, is reinforcing because it allows us to detect objects or meaningful wholes. An example could be symmetry, good continuation and closure stated by the Gestalt Laws of Perceptual Organisation. The third principle would be 'most advanced, yet acceptable' because it is to some extent possible to increase the novelty of a design while preserving its typicality. The fourth principle would be 'optimal match' as the ease of identification has survival value. Consistency of impressions will lead to elevated identification accuracy. The four principles can predict and explain people's aesthetic responses. When these principles are correctly applied, it is most likely, but not necessarily, that people will agree on an object's aesthetic value. Sometimes differences will arise at the group level, when the group shares the same underlying characteristics - often referred to such a group as 'culture', whereas sometimes even at the individual level (Hekkert, 2006 and Zellner, Bartoli & Eckard, 1991).

Attaching a particular theme or association to a sensory aspect is a non-aesthetic attribution process, whereas assessing whether these labels are congruent is regarded as an aesthetic event, it is pleasing to the mind to see that the themes match, it is displeasing when it finds out the labels are incongruent. Making all the sensory images congruent with the intended overall experience is therefore an important task for the designer. Aesthetic responses, like cognitive processes, are situated in the interaction between people and their environments (Smith & Semin, 2004) and subsequently obtain their social or cultural mode of expression (Hekkert, 2006).

Designing local features into products appears to be more and more important for the global market where products are losing their identity because of similarities in function and form. Cultural features are considered to be unique characteristics that can be embedded into a product both for the enhancement of its identity in the global market or for the enhancement of the individual customer experience (Handa 1999; Yair, Press & Tomes, 2001; Yair, Tomes & Press, 1999). Designers have noted this and Industrial Design has played an important role (Lin, 2007).

Consumer's perceptions of product personality can be influenced by variations in design shapes (Govers, Hekkert & Schoormans, 2003) and material choices (Kesteren, Stappers & Kandachar, 2005). Designers seem able to convert abstract personality descriptions into actual designs and that downstream, consumers are able to identify these intended product personalities (Govers, Hekkert & Schoormans, 2003). Also, consumers prefer product designs with product personalities congruent with their own (Govers & Schoormans, 2005).

### **2.3.5 Craftsmanship and Design**

When industrialisation took over the modes of production in the mid-20th century in India, handmade products fell out of preference and were extremely neglected till late 20th century (Bhat & Yadav, 2016). Crafts went from the forefront of a rising economy to a point where it required preservation. There are many reasons which led to this drastic devastation of crafts. A few of them are mentioned below (Das & Das, 2019):

- Crafts remained exclusively within the crafts community. The integrity of the teaching methods prohibited its understanding from any other group of the society. There was no appropriate propagation of their techniques and teachings outside their own community due to craftsmen humbleness. This distanced people from empathising with their crisis, post industrialisation.
- Industrialisation produced products made out of materials which could stand longer than the durability of materials used in crafts. This led to the replication of craft products in materials of mass production. This eventually led to the shifting of production houses from the original vernacular craft locations to industrial centres where the craft experienced loss of local embossing patterns and original utilitarian designs. The industrially replicated craft products were more favoured by the modern public and gradually reduced the sale of the original craft produce.
- Craft started to be seen in a manner in which its existence seemed delusional to the ever-growing industrial products. The people who adorned craft wished beauty out of it rather than utilitarian use. So, the craftsmen shifted their focus to making 'pretty' products, rather than utilitarian, which could at least be a curio, all in order to guarantee their income and their livelihoods.
- In order to enhance the demand for craft products, there was a dire need to understand design through perspectives of form, function and society. Since the craftsmen of India have very less exposure to

existing design and the needs and demands of the urban society, they were not able to create fresh ideas which could be integrated with their skills to improve their sale.

- With the loss of economic edge and income potential, the newer generation of craftsmen remained sceptical about accepting the profession as a lifelong commitment and thus learned the craft insignificantly. With the loss of techniques after passing of generations, the advocating in offspring was also weak.
- Simultaneously, Modern design with its emphasis on industrial production prevailed. A new aesthetics based on industrial processes emerged forming the base of modern industrial design. Quest for new forms based on machine production led to the discovery of machine aesthetics nurtured by movements in modern art with traits of functionality and simplicity. Craft was excluded from the aesthetic domain though it preserved its decorative character.
- Eventually, post modernism saw a call out to go back to one's roots to obscure local identities and revive the cultural diversities destroyed by the modern industrialist mindset. Disillusion with the concepts of 'Progress and better life' promised by modern industry lead to a new thinking. Designers were frustrated by the limited product expressions controlled by economy of production and distribution as well as concerns of marketing for mass consumption. A new need for post-modern design to discover and assert meaningful design is on the anvil (Rao, 2008).

The design interventions in the Indian craftsmanship sector can be very well infused into the design education system towards modern design, where students could be taught the manipulation of it by instigating them towards an interaction of design and craftsmanship (Das & Das, 2019).

### 2.3.6 Current Craftsmanship Villages in Assam

Assam has maintained a rich tradition of various traditional crafts for more than two thousand years. Presently, cane and bamboo craft, bell metal and brass craft, silk and cotton weaving, toy and mask making, pottery and terracotta work, wood craft, jewellery making, musical instruments making, etc. are remained as major traditions. Historically, Assam also excelled in making boats, traditional guns and gunpowder, colours and paints, articles of lac, traditional building materials, utilities from iron, etc.

Cane and bamboo craft provide the most commonly used utilities in daily life, ranging from household utilities, weaving accessories, fishing accessories, furniture, musical instruments to building construction materials. Traditional utilities and symbolic articles made from bell metal and brass are found in every Assamese household. Moreover, Assam possesses unique crafts of toy and mask making mostly concentrated in the Vaishnav Monasteries, pottery and terracotta work in Western Assam districts and wood craft, iron craft, jewellery, etc. in many places across the region. (Traditional Crafts of Assam, 2014)

To understand the current status of craftsmanship in Assam, the researcher visited five craft villages and tried to gather information about how the system is working. The craft villages were selected on the basis of (a) proximity from the IITG campus along NH 37 within 100 kms, (b) variety of crafts and (c) researcher's access of craftspeople in the villages for interviews. The studied villages are *Bhaluki village in Barpeta*, *Moholiapara village of Mongoldoi*, *Balikaria village in Nalbari*, who are dealing with bamboo craftsmanship and *Moriapatti village and Bharalitola town in Hajo*, who are dealing with brass metal and woodwork craftsmanship respectively. These villages are located at a 1-2 hour distance via road from each other. These places are easily accessible to Guwahati via National Highway 37.

A social entrepreneur associated with Vivekananda Kendra, Guwahati named Mr. Dipanka Mahanta helped the researcher to visit the places. Personal interviews were conducted with village craftsmen and master craftsmen along with the businessmen and entrepreneurs who were associated with the craft. The information was gathered under the heads of *Raw materials, Craftsmanship, Treatment & Tools, Transport & Commerce, Market and Government Initiatives.*

### **2.3.6.1 Bhaluki Village, Barpeta : Bamboo**

The advent of Bamboo craftsmanship started here in 1973 when Mr. Sushil Kumar Das, a resident of the Bhaluki village of Barpeta district came up with a plan to initiate an establishment of work for the unemployed citizens of the nearby villages, who had caved in to negative activities for their survival, through a workshop of Bamboo products in his house courtyard. His interest in the venture emerged when he visited Tripura after his Masters Degree in Arts in 1968 and witnessed the production of many Bamboo products in the household courtyards of the villages and wondered if the same could be replicated in his home state Assam as it also had an abundance of naturally available Bamboo. The venture started with a meeting held in his courtyard [Figure 2.1] in 1973 regarding the introduction of a Bamboo workshop with the nearby villagers asking for volunteers who would be interested in the learning and production techniques to promote Assam Bamboo products. After an initial element of surprise, 20 villagers joined him in the effort at the initial stage and within a year the count of craftsmen increased to 60-70 people and helped him grow his industry to a productive platform.



**Figure 2.1** Mr. Sushil Kumar Das's workshop courtyard in Bhaluki village, Barpeta (Source : Author)

**Raw Materials :** Bamboo at Mr Sushil's workshop is delivered from the bamboo groves of nearby villages [Figure 2.2]. Few craftsmen also have Bamboo groves in their backyard. The craftsmen majorly use Bhaluka (*Bambusa balcooa*) and Makla (*Dendrocalamus giganteus*) or Jati baah (*Bambusa tulda*) for making their products. The bamboo comes for sale in their village from nearby villages at 120-150 rupees per bamboo. The craftsmen buy raw material according to the demand of the order which they have received.



**Figure 2.2** Relay of Raw Materials in bamboo villages of Barpeta (Source : Author)

**Craftsmanship** : Mr Sushil first started experimenting on a beer mug with one of his artist friends in Barpeta. After a few iterations, the first sample was made in his courtyard in 1973. The villagers started to learn to make different kinds of bamboo products such as ash trays, table lamps, magazine holders, litter boxes, flower vases, furniture pieces, clocks etc. The initial wages which Mr. Sushil could provide to the craftsmen amounted to only 60 rupees per month. After a few years of learning, in around 1984, the craftsmen incorporated their families and took their craftsmanship to their household courtyards, thus making a better number of products for sale. This improved their household income. The system became decentralized [Figure 2.3]. Mr Sushil had identified the craftsmen's specialities and wholesomely distributed the orders accordingly. After making the products, the craftsmen submitted them to Mr Sushil's workshop and received their craftsmanship fee according to the rate in the market and the number of products made. Mr Sushil forwarded it further to the order destinations. Simultaneously, the craftsmen also identified themselves as individual retailers of the products in the local markets through which they stabilized their household income.



**Figure 2.3** Workstation of craftsmen in their respective houses in Bhaluki village, Barpeta (Source : Author)

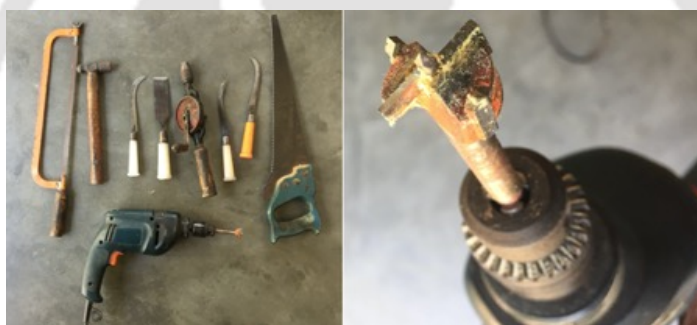
**Treatment & Tools** : There are two timeframes in which the bamboo is treated. One timeframe is when the green bamboo is procured and let to dry till it turns yellowish green so that the water in the bamboo pulp dries out. A pit is made on the ground corresponding to the size of the bamboo to be treated and a plastic sheet is placed on it. Here, a solution of insecticides like gamaxine and terminator is poured to dip the yellow bamboo for 2-3 days and then kept for drying. Another timeframe is when the products are completely made and then dipped into a tub full of the same solution added with fevicol and let to dry [Figure 2.4]. Gamaxine helps as an insecticide and fevicol helps the fibres to stick together and gain strength, avoiding cracks. The craftsmen use basic wooden tools as well as hand drilling and machine drilling tools with varied drilling bits. The hand tools include small sickle, wedge and hammer, and hack saw [Figure 2.5]. They have also been provided with a few drilling and bamboo cutting machines in the Common Facility Centre provided by KVIC.

**Transport & Commerce** : Transportation is done by tempo at around Rs.3000 per trip to Guwahati, from where it is transported further to other cities of the country. The packaging box sizes for train transport remains at 78x78x100 cm<sup>3</sup>, according to which the sizes for products or furniture pieces to be transported are defined. The cost of shipping and delivery is borne by the receiver. At the beginning of the venture, the samples of the products were first forwarded to the Assam Emporium, where the products were accepted and the sales determined the number of orders to be made in the workshop. Slowly, the products were put up in Handloom and Handicraft exhibitions of different states and with the help of Mr. Sushil's brother, Mr. Gunin, samples were forwarded to emporiums around the country. The first consignment outside Assam was sent to Kolkata in 1983 with 3 cartons filed with bamboo

products. Eventually samples were sent to Tamil Nadu (Chennai), Karnataka (Bangalore), Kerala (Wayanad), Punjab (Hoshiarpur), Delhi, Kolkata etc. The finished products were well accepted by the different states and put up for sale in the Emporiums. A few consignments were also sent abroad to Russia via Goa.



**Figure 2.4** Treatment process with fevicol water for finished products in Bhaluki village, Barpeta (Source : Author)



**Figure 2.5** Tools used by the craftsmen in Bhaluki village, Barpeta (Source : Author)

**Market :** To understand the price of the product delivered in the market, let us understand the additions with a small example. Currently the craftsmanship price of a bamboo tray is at Rs. 250/- per piece. When the craftsmen are themselves the retailers, they sell it at this price. Also when they submit their made products to Mr Shushil's workshop, they give a 10 rupees concession to him as their teacher and facilitator and sell it to him at Rs. 240/- per piece. Mr Sushil adds miscellaneous and transportation costs to Guwahati from Barpeta which amounts to approximately 60% addition to price, making it around Rs. 380/- per piece for Emporiums in Guwahati. Also when the pieces are unique, a Plus Benefit charge is added to the product which places it at a better price in the market. When the products are taken further, the transportation and miscellaneous costs are borne by the dealer involved, thus adding to the final shelf price of the products in their respective markets.

**Government Initiatives :** The Khadi and Village Industry Commission (KVIC, Guwahati) under the Scheme Fund for Regeneration of Traditional Industries (SFURTI) has taken up the cluster development initiatives (CDI) at Chakchaka block of Barpeta district during the year 2008. The KVIC with the implementing agency (IA) Anchalik Gram Unnayan Parishad (Jania), an NGO, established Common Facility Centre (CFC) at Raipur Village by covering another four villages - Bhaluki, Dhupguri, Joshihatigaon. The CFC has been provided with a workspace and machines where craftsmen do the needful and take the work back to their home courtyards. Many eminent people involved with

Bamboo in India including Prof A G Rao, has visited this facility and conducted workshops for the craftsmen. The craftsmen are registered under the Office of Development Commissioner of MSME, from where they are issued Identity cards. There are a few National Awardees of bamboo products associated with the village as well, such as Mr Abdul Majid who was awarded the National Award for best Craftsman through MSME in 2013 and also Mr Soraffudin Ali who has won the Rashtrapati Award through KVIC for his commendable craftsmanship in 2013. As a part of the SFURTI program, toolkits were delivered to the craftsman but they were of compromised quality and as per Mr Sushil and his brother, no funding has been given to their industry as such for its improvement, claiming corruption.

### **2.3.6.2 Moholiapara Village, Mongoldoi : Bamboo**

The village Moholiapara has a lot of bamboo grooves. The village streets run abundant with them and there are many varieties of bamboo available in the backyards of the households of this village. The village lies on an embankment and due to good soil humidity, the bamboo here grow stronger and taller and hence the villagers have been able to use this raw material as their source of income

**Raw Materials :** The local bamboo species found here are Jati, Bhaluka, Mokal and Bijuli bamboo. The culms of the bamboo here are 40-50 feet long and they grow very linear [Figure 2.6]. The bamboo varied in their ages and formed natural grooves. Every groove had around 50-80 bamboos and each household backyard had many such grooves. The quality of the bamboo improved as the grooves moved towards the river and embankment.



**Figure 2.6** Jati bamboo groove at Moholiapara, Mongoldoi (Source : Author)

On the day of the visit in November, harvesting of Jati bamboo was being conducted by a group of locals within the bamboo grooves of the village. The aim of the day was to fell 250 matured bamboos of the Jati species, which meant that they had to be 3-3.5 years old. The bamboos are harvested during the Krishna Paksha phase of the lunar cycle which extends between the full moon day of the month to the new moon day. As learnt from local knowledge, during this phase of the moon, there is lesser humidity in the flora kingdom. Since, the treatment of bamboo requires removal of humidity from the culms of the bamboo, this phase of lesser humidity is more favourable for harvesting bamboo.

**Craftsmanship** : There were not many craftsman in the village who were working with bamboo. The researcher happened to meet two craftsman in the nearby village who were working with bamboo weaving as their source of income. They were Tarun Deka and Mahananda Deka. Both of them are in their 60's.

Tarun Deka [Figure 2.7 (left)] has been weaving bamboo and generating an income for his livelihood through it for the last 40 years. He learnt the craft from his elder brother in his household courtyard and has honed his skills further through a self teaching method of duplicating existing products. He is followed by his son who is currently working as a fish seller in the village; who may or may not take the craftsmanship forward. Tarun makes household products for storage and utility purposes by weaving bamboo and cane and sells them in the village as well as in the market. He buys bamboo and cane at the rate of 60 rupees per piece each and out of one bamboo and one cane, he makes around 25 sieves of different kinds which he sells at around 60 rupees per piece earning him around 800 rupees from one bamboo and around 6000 rupees per month. His sales increases during rainy season during which fishing is done. He has never been very exposed and is oblivious to other bamboo products in the world but wishes to make a bamboo cycle someday.



**Figure 2.7** Craftsman Tarun Deka (left) and Mahananda Deka (right) of Moholiapara, Mongoldoi (Source : Author)

Mahananda Deka's profile is also very similar [Figure 2.7 (right)]. He was in touch with the craftsmanship since his younger days but took it up as a full time job to feed his family in his old days. He has been working with bamboo craft since the last 5-6 years and has honed himself by self-teaching. He also buys his bamboo from his village at 60 rupees each and uses plastic strips instead of cane along the rims to make similar utilitarian products. His wife helps him out with the weaving and they earn around 1000 rupees per bamboo from their sale to the middlemen. Their monthly income is around 8000 rupees. He has never experimented with any new products since new products require more invested time. He seemed very enthusiastic about learning something new about the craft if somebody gave him the instructions.

The people who harvest the bamboos are local boys of the neighbourhood who help the owners to harvest. It is a mechanical job which needs an idea of harvesting time, tools and technique.



*Figure 2.8 Jati bamboo harvesting in Moholiapara, Mongoldoi (Source : Author)*

**Treatment & Tools :** The bamboo culms were being cut at the base, keeping the roots intact. The locals used a ‘dau’ to cut the culms [Figure 2.8]. Right after cutting, the culms were kept standing on the ground for a week without destroying the leaves of the culm, since the leaves helped in digesting the glucose by photosynthesis.

Glucose within the bamboo pulp is food for various insects and termites, which if not removed, become termite colonies and eventually rupture the bamboo culms. There are various ways in which glucose can be removed from the culms, and the most prevalent organic technique is the Water Treatment Technique. The cut bamboo is placed under water in a local pond along its entire length with weight put above it and allowed to stay there for 28 days [Figure 2.9]. This process dissolves the glucose from the culm into the water and treats the bamboo against insects and termites. After withdrawing the treated bamboos from the water, they are put to dry for a week under the sun and finally sent for sale in the local market.



*Figure 2.9 Water Treatment Technique of harvested bamboo in Moholiapara, Mongoldoi (Source : Author)*



**Figure 2.10** Simple craftsman tools in Moholiapara, Mongoldoi (Source : Author)

**Transport & Commerce :** Every Wednesday and Sunday, almost a hundred pull carts go from the village to the local market with bamboo, carrying 25-30 bamboos each, both treated and untreated. They are sold at 60-80 rupees per bamboo. The sale of raw bamboo happens to be a source of income for the villagers but very less effort is being taken to rejuvenate the bamboo roots to grow more bamboo buds. Bamboo is still considered as a backyard grass rather than a crop, thus the villagers need to be informed about the potential income they can generate by selling it as a crop.

Middlemen approach the craftsman and they often sell them the goods instead of going to the market themselves. The middlemen take them in a cycle and sell them in the nearby Bongolagarh and Dimakusi markets. These markets are locally famous for domestic bamboo products. Each cycle carries products worth 10,000 rupees.

**Market :** The Mongoldoi town market sells a lot of raw bamboo for architecture and construction purposes. The raw materials is sold at a very standardised price by the craftsmen to the dealers who in turn further sell it at higher prices in nearby towns and Guwahati after including the transportation cost to it. So after addition of overhead charges, for example, a Jati bamboo which is sold at 60 rupees to the dealer, is further sold at 120 rupees in Guwahati.

**Government Initiatives :** The two interviewed craftsmen had never sought for any Government funds nor did they receive any till date. A few woke citizens of the village under the interest of village dwellers Mrityunjoy Deka and Kumud Sohoria, have taken up an initiative to improve the raw material production as they have realized that it can bring in good income to the village. They are intending to increase the water treatment area and preserving their bamboo grooves in their backyard because it is still considered as a backyard grass rather than a cash crop. Later, they intend to install a small plantation of different bamboo species with a designated numbers of bamboo grooves such that the deliverables can be increased and the bamboo sold would be treated as well.

### **2.3.6.3 Balikaria Village, Nalbari : Bamboo**

The Balikaria Village is a very well established village in Nalbari town. The villagers have well built houses and small businesses sprung everywhere. The dwellers have access to good infrastructure of paved roads, nearby schools and colleges, market, ATM's and banks, religious institutions etc. and have a scenic beauty as well. Amongst the many households of entrepreneurs of the village, the researcher visited the residence of master craftsman Raju Talukdar who works with bamboo furniture and Japi (Assamese traditional headgear) craftsman Ashwini Baishya.

**Raw Materials :** The craftsmen bought their raw material from their fellow villagers at 100 rupees for Jati bamboo and 180 rupees for Bhaluka bamboo. The Japi making craftsman also bought his additional decorative items from nearby market.

**Craftsmanship :** The village has a lot of craftsmen working individually on their produce. Though Balikaria village has many varied bamboo products made, the Balamugkuchi village nearby has around 350 craftsmen working only on Japi.

Raju Talukdar [Figure 2.11] is a 42 year old master craftsman in his village. He has been working with the material bamboo for about 15 years now. He is exposed and experienced in the bamboo product design and architecture sector and has worked in various projects pan India. Back home, he also teaches other craftsmen new techniques and currently has 15 craftsmen directly working with him. He is currently working on bamboo furniture products and on the day of visit, he was busy making a bamboo bed and a bamboo sofa set which was to be sent to Goa. He would sell them at 13-14k per sofa set, while the making cost is 1000 rupees, and he gets 3-4 such orders in a month. He had also made two pieces of engineered bamboo by cutting out a cross sectional rectangle from the pulp and sticking layers of it to make a block and a plane. The pieces have stood strong for 6 years now.



**Figure 2.11** Master Craftsman Raju Talukdar and his craftsmanship at Balikaria village, Nalbari (Source : Author)

Ashwini Baishya [Figure 2.12] is a 45 year old Japi craftsman who has been doing bamboo work since 1988. He learnt the craft from his grand father and maternal uncle in the household of his courtyard. He makes Japi for a living. He is helped by his wife in the process of making. He is followed by a son who has done a graduation in Commerce background and is trying to help his father in his craft. They make Japis of different sizes such as 18”, 14”, 12”, 8” and 4”. The prices vary from 25 rupees to 120 rupees. One bamboo can make 35 Japis and one Japi needs 3 days to complete. Making charge is 680 rupees for 35 Japi’s and selling price of the same is 2800 rupees, earning them around 2000 rupees per bamboo.

**Treatment & Tools :** Master craftsman Raju Talukdar uses a chemical in his backyard treatment place which removes insects but that renders the bamboo inorganic. He uses a hand held drilling machine and a standing cutting machine, enough tools and varnish at the end to make his furniture. Craftsman

Ashwini uses basic hand held tools for making his Japis and uses fevicol, chumkis, lace, cotton balls etc. to accessorise the Japi.



*Figure 2.12 Craftsman Ashwini Baishya and his craftsmanship at Balikaria village, Nalbari (Source : Author)*

**Transport & Commerce :** Raju's clients cover the transportation costs. They are generally taken away by Tempo's. His clients depends upon projects and so thus the transportation of the final product. Products for longer distances are made detachable such that it is easy for transportation. Ashwini's products are taken to the railway station on the stipulated day of middlemen arrival from where the produce is taken to nearby towns and cities including emporiums of Guwahati. Here too, the transportation is incurred by the middlemen and not by the craftsman. The end price is manipulated by the additional factors before final delivery.

**Market :** The craftsmen produce are precariously taken to the nearby towns for sale. The middlemen add their fare along with transportation during final delivery. The market rises during seasons. The time from Durga Puja to around February of the next year, it is a fruitful season in which the craftsmen even end up earning to a maximum of 1 lac rupees per month, since these are the months of events in which Japi is delivered as a memento in various occasions.

**Government Initiatives :** The village experiences various workshops from organisations such as DIC and NABARD. Training programs are conducted from Vivekananda Kendra and KVIC in which the craftsmen are expected to participate. When asked Mr. Ashwini about them, he mentions that the workshops keep happening but not to much effect. It keeps passing on in pen and paper but actuality would just be a day spent in the workshop with tea and biscuits and nobody turning up on the remaining days. The craftsmen are very involved in their own households and their personal income and participate in community very less.

#### **2.3.6.4 Moriapatti Village, Hajo : Bell And Brass Metal**

In the nearby Hajo town, there are two kinds of craftsmanship which are prevalent, bell metal and wood work craftsmanship. At Moriapatti Village, bell metal craftsmanship is executed and it could be a possibility for material merge with bamboo craftsmanship.



**Figure 2.13** Street of Moriapatti Village, Hajo (Source : Author)

Moriapatti is a very old Mohammedan community who have been originally from Assam [Figure 2.13]. They are a community vested in bell and brass metal craftsmanship. Bell metal is bronze, which is a composition of copper and tin, while brass metal is a composition of copper and zinc, which is malleable. Bell metal craftsmanship is particularly lesser than brass metal craftsmanship in this area. After visiting a craftsman's house who was making a brass metal container, the researcher visited the craftsman's Mahajan, Ranjib Ali, who deals with the entire process.

**Raw Material :** Ranjib Ali has been handling his cooperative business for the last 30 years. He buys his raw material in the form of raw brass of different sizes [Figure 2.15] from Fancy Bazaar in Guwahati, which comes from Kolkata. He buys it at 425 rupees per kg. They are in the form of round thick discs which can be beaten into a sheet. He also buys it in the form of a sheet.

**Craftsmanship :** Mr. Ali gives the raw material out to the craftsmen. He has around 100 craftsman working for him. The craftsmen take the material and with the help of special tools, transform it into different kinds of vessels and Xorai's of different sizes [Figure 2.14] and deliver the finished goods within 4-5 days to Mr. Ali, seeking 95-120 rupees as a craftsmanship fee against one kg, depending on the amount of skill needed for that particular 1 kg.

**Transport & Commerce :** He transports them to Hajo from Guwahati with the help of tempo at 1 rupee per kg. He generally buys a ton (1000 kg) at once and stocks it up in his shop from where he gives the raw material out to the craftsmen.

**Market :** Mr Ali adds a 10 rupees profit for himself for every 1 kg. So ultimately that particular 1 kg is sold at 530 rupees (425 + 95 + 10), transportation included. Every month Mr Ali deals with 5000 kg of brass metal and with a profit of 10 rupees, he earns 50,000 per month.

The product price ranges were explored in a nearby shop at the main town of Bharalitola in Hajo and we approached Businessman Arup Deka at Monikut Enterprises [Figure 2.16]. The products are sold in the market according to the amount of Brass Metal in the product. A smallest Xorai is sold at 600 rupees and the largest of 51" height at 30,000 rupees. The smallest Japi of 4" is sold at 100 rupees whereas the largest 32" dia Japi at 5500 rupees. The kolohs are sold according to the weight which ranges from 800-1500 rupees. Trays are at 350 rupees per piece. Their income is seasonal and their monthly income may vary from 5000 - 100000 rupees depending upon the sale.



**Figure 2.14** Brass Craftsmanship at Moriapatti Village, Hajo (Source : Author)



**Figure 2.15** Raw Material for Brass Craftsmanship at Moriapatti Village, Hajo (Source : Author)



**Figure 2.16** Brass Metal Products at Moriapatti Village, Hajo (Source : Author)

### 2.3.6.5 Bharalitola, Hajo : Woodwork

Bharalitola is the main town point near Moripatti Village. Bharalitola area has around 5-6 wood workshops where extensive furniture making is executed and delivered to various parts of Assam. Out of those workshops, The researcher visited the workshop of Khagen Das at Bharalitola who runs Liku Furniture Store [Figure 2.17].

**Raw Materials :** The raw materials come from Nalbari and Guwahati in which the middlemen set a rate of each kind of wood including their transportation costs. Bonsham comes at 1100 CFT, Titasopa at 1700 CFT, Khokhon at 850 CFT, Gomari at 750 CFT, Segun at 2700 CFT and Sal at 1800 CFT.



*Figure 2.17 Khagen Das, woodwork craftsman, Bharalitola, Hajo (Source : Author)*

**Craftsmanship :** Mr Khagen makes various kinds of wooden furniture such as sofa set, dining set, beds, dressing tables, etc. [Figure 2.19]. His making charge of a sofa set is 15000 rupees which includes material (5k) and labour cost (10k with 3 people, 7 days with 500 rupees daily wage), and the selling price is at 30000 rupees. Genrally Gomari, Bonson and Titasopa wood is used for making furniture. Dining sets are sold at 30,000-36,000 rupees, beds at 18,000-55,000 rupees, and full furniture set at 80,000-1,80,000 rupees.



*Figure 2.18 Woodwork machines of Khagen Das, Bharalitola, Hajo (Source : Author)*

**Treatment & Tools :** The raw materials come treated so there is no extra need for treatment. Mr. Khagen uses basic carpentry tools such as different kinds of wedges and hammers and uses electrical tools such as planar, cutter and drilling machine [Figure 2.18]. It makes his work easier and faster. Segun wood lasts for 60 years easily, Gomari for 6-7 years, and matured Bonsom at 15-20 years. His tools incur an extra expenditure of electricity bill which he includes in the making charge of the furniture piece or set.



**Figure 2.19** Woodwork craftsmanship samples, Bharalitola, Hajo (Source : Author)

**Transport & Commerce :** His clients come from all over Assam and he also displays his smaller wood work pieces at exhibitions for further reach. The furniture is taken by the customer at their own cost or however the deal was initially struck. It is generally transported by truck or Tempo.

**Market :** The wooden furniture pieces serve the population better at semi urban and urban societies. The acceptance of a long lasting furniture at a price is the stability customers seek out of a piece of furniture. Wood as a material serves this purpose for furniture.

#### **2.3.6.6 Loharghat Village, Kamrup : Eri Silk**

The indigenous forest communities of Assam's Loharghat Village Range produces hand spun and hand woven Eri silk fabric from silkworms. The communities practice sericulture as a source of food and yarn in their household courtyards. Despite advances in production method technologies, silk production still very much remains a labour intensive process with hard work.

**Raw Materials :** Sericulture is the term used to describe the process of gathering the silkworms and harvesting the cocoon to collect the materials. Female silk moths lay anything from around 300 – 500 eggs at any one time. The communities extract silkworm cocoons after feeding the worms on castor plant [Figure 2.20]. Unlike other silk producing methods, Eri Silk has a vegan way of making, which means that the larva is allowed to become a moth instead of boiling it within. The yarn is extracted from the abandoned cocoon of the silkworm and the short staple fibre is then hand spun like wool.

**Craftsmanship :** Spinning by hand requires a light touch that is ingrained in both muscle memory and culture. The spinners use a combination of pedal powered spinning wheels and the traditional drop spindle technique [Figure 2.21]. Mostly a skill preserved by mothers, this role provides as a source of alternative income. The entire process of the execution does not need any input from outside community. It is self-sustained from worm to weave.



**Figure 2.20** Harvested silkworm cocoons at Loharghat village, Kamrup (Source : <https://www.7weaves.com>)

**Treatment and Tools :** Dyeing as an indigenous technique is used extensively to add hues to the spun silk. More than 30 different natural dye materials are available from the local woodlands such as indigo, madder, turmeric, lac, teak etc. Once dyed, the yarn is woven into fabric using handlooms, which exist in every household [Figure 2.22 (left)].



**Figure 2.21** Traditional drop spindle and tools used for weaving Eri Silk at Loharghat village, Kamrup (Source : <https://www.7weaves.com>)

**Transport, Commerce and Market :** Woven fabrics are collected [Figure 2.22 (right)] and delivered to the nearest markets, retailers and other distributors with the help of lighter freights. The price of the produce includes sericulture related costs, transportation and the artisan's income. The weavers take considerable pride in creating these fabrics.

According to the availability and demand of clients at different locations pan India, the fabrics are distributed. The fabrics are also exported in some cases. Ensuring a strong, sustainable economic system is paramount in ensuring a future for the people, by protecting their knowledge, land and culture.



**Figure 2.22** Dyed Eri silk with Indigo (left) and Type of Eri Silk products for the market (right) (Source : <https://www.7weaves.com>)

## 2.4 Eco-Design in Indian Craftsmanship

Indian craftsmanship must be explored in a different perspective to understand its potential towards eco-friendliness in the current times. Even though there is a general consensus that craftsmanship is environmentally more sustainable, its attributes must be compared to the current principles of sustainability which are in discussion, to gather a comprehensive understanding towards the matter. This section of the research explains craftsmanship according to its numerous aspects and compares it to the principles of Eco-Design to redefine the status of craft towards the newer dimensions of eco-friendliness.

### 2.4.1 Craftsmanship and its Attributes

Craftsman belongs to homo faber, a being wholly immersed in a dimension life where all that counts are the production of things and the execution of pre-determined tasks (Fadini et al, 2010). The craftsman represents in each of us the desire to do something well. The difference between brute imitation of procedure and the larger understanding of how to use what one knows is a mark of all skill development (Sennett, 2008).

The presence of the Indian craftsman in the midst of a simple agricultural society made possible the self-contained life of the community. The craftsman guild system existed and continued in the form of co-operative associations within the merchant community. Under British rule, the authority of trade guilds was necessarily relaxed and industrialisation imposed imports to the marked damage of handicrafts (Coomaraswamy & Moore, 1909). Post industrialisation design saw a call out to go back to one's roots to obscure local identities and revive the cultural diversities destroyed by the industrialist mindset (Rao, 2008).

What remains today is a struggling institution with the repercussions of the import of cheap machine made and replicated versions of artefacts. Its inability to adopt innovative methods of production and to adapt to the changing needs of the consumers has become one of the limiting factors in the growth of the handicraft industry (Ghosh, 2012). Craft sector today provides livelihood and employment to 20 million people of India, which constitutes 1.5% of the country's population (Viswananth, 2013).

Today, craft is a family execution which has a close connection to India's caste system. It is an execution of mainly the lower classes of society. But due to the quality of the product, the craft items become the community curio in which the elite classes take pride. Craft education is transferred through generations informally. The generation next visually learns from their family members in household courtyards and eventually take part in it as they grow older. It is exceptionally a skill-based learning which focuses on muscle memory and practice via years of apprenticeship. The decentralised system allows the breakdown of the manufacturing process, and for craftsmen to find and pursue their individual expertise (Das & Das, 2019).

The market which their products cater to, fall under the category of traditional, modern, curative and functional. The craftsmen keep working on their products out of expertise, irrespective of category. They are taken forward either by middlemen, retailers and entrepreneurs for their respective markets. As time has passed and crafts have evolved, newer techniques for easier disposal have been on demand,

to bring the production numbers and quality at par with the industrial market. This has called for new material processes and technological inputs (Das & Das, 2019).

The challenge for survival of crafts today is to deliver utilitarian products which conform to the urban design and lifestyle. This requires the need for diversification of products by understanding perspectives of form, function and society. Apart from utilitarian design, elite buyers appreciate the exquisiteness in contemporary, retro, ethnic, and preservative designs. To deliver such aesthetics, an adept knowledge in the section is required. The knowledge regarding crafts, its epistemology, techniques, work, ethics, etc., stays amongst the communities as a non-vocalised comprehension. Majority of this knowledge has not been documented and remains oblivious to the corresponding design communities, thus requiring recognition for future bases (Das & Das, 2019).

#### 2.4.2 Comparison of Craftsmanship and Eco-Design Principles

To understand the sync of craftsmanship to Eco-Design, the ten most frequently suggested and successful Eco-Design principles by Hemel and Cramer (2002) are put forward for an analysis of selected four craftsmanship sectors in Assam, namely Bamboo, Wood, Brass Metal and Eri Silk below.

*Table 2.1 Analysis of craftsmanship attributes to principles of Eco-Design (Source : Author)*

Principles of Eco-Design	Bamboo	Wood	Brass Metal	Eri Muga Silk
Recycling of Materials	Organic materials degenerate into the ground	Not intentionally, but yes, at homes	Yes	Not intentionally, but yes, at homes
High Reliability/Durability	Yes	Yes	Yes	Yes
Recycled Materials	No	No	Yes	No
Low Energy Consumption	Yes	Time for growth and treatments	Thermal Process for raw material	Yes
Remanufacturing	Not yet	Not yet	Not yet	Not yet
Less Production Waste	Yes	Yes	Yes	Yes
Clean Production Technique	Yes	Not completely	Not completely	Yes
Reduction in Weight	Can be performed	Can be performed	Can be performed	Can be performed
Clean Materials	Yes	No, deforestation involved	No, excavation involved	Yes
Less, Clean and Reusable Packaging	No thought yet	No thought yet	No thought yet	No thought yet

In the table above, the colour variations indicate the segments which are existing (white), non-existing (black) and the probables (grey) of the implementation of principles of Eco-Design through the considered craftsmanships.

### **2.4.3 Inferences from comparison of Craftsmanship and Eco-Design**

The table of comparison through colour variations indicates the existing, non-existing and probables for implementation of Eco-Design principles in each craftsmanship. The 'Yes' segments indicate those principles which are being followed by the craftsmanship in their current form. The 'No' segments refer to those principles which have not received any thought for interventions, though they are highly possible through means of design thinking. The 'Intermediate' segments refer to the possibility areas for amendments in the ongoing process through technological interventions which could direct the process towards a principle, currently not being practiced as one.

The four craftsmanship display a high reliability and durability of products. Bamboo products and Eri clothes remain in a household for decades altogether. Wood and brass metal products get passed along generations in the communities. Recycling of materials is done for brass metal because of the expense of raw material. Bamboo and Eri being rapidly renewable backyard raw materials do not feel the urge for recycling. Also, like wood, many a times, they are recycled within households, for different activities, till they are exhausted. Backyard raw materials also have a cleaner extraction and technique of production.

Optimisation of raw materials is always considered to reduce labour and production waste. The energy usage for bamboo and Eri silk consumes lesser resources than wood and brass metal in terms of time of growth, treatment, and converting raw materials to workshop ready parameters. Wood and brass metal craftsmanship could benefit from amendments in the existing processing methods by switching to more environmental friendly technological interventions. The recycling and remanufacturing of the products of any of the four craftsmanship have not been taken into consideration yet but can be built by integrating a process of design thinking and execution to incorporate multiple lives of the evolving product. The ideation for packaging also has not come into effect since the products are mostly sold in local markets and long distance freights consider temporary packaging solutions before they are delivered to the clients or displayed open.

Overall, the four craftsmanships show a high compatibility with the principles of Eco-Design, and design research and technological interventions can increase the value of the craft manifold.

### **2.4.4 Implications for Practitioners**

In current times of hostility towards nature, it has become imperative for designers to understand the need of interventions in the materialistic domain and its execution ability, for the planet to persist in the ever expanding user, product and system requirements. Though the legible integration of the institutions of design and craftsmanship faces challenges of socio-economic gaps, it can be reduced by designers being genuine, using basic instincts, being clear and frank with an attitude of respect for craftsman families and communicating transparent and thorough details between the buyer and the maker, to go a long way in developing a healthy business temperament. Through the craftsmen, the businesses could also cater to mass customisation for consumers as the craftsman's execution process could include alterations according to size, need and artistic expression after the basic structure of the craft is conjured. New product systems such as 3D printing could also be incorporated in making scaled 3D models, joinery techniques, moulds and frameworks to enhance communication, quality and efficiency. Artisanal production might not have the finesse of industrial production but the final valuation can be

based on material quality, craftsman efforts, local economy generation, social migration prevention, advantage of local knowledge for the educationally deprived and decreased social disturbances. The intention must be to integrate the craftsmen community into the urban need and aesthetics without them losing their identity. Also, new identity generation helps products to sell with a new enthusiasm from consumers when delivered with a compelling story (Bheda & Kasliwal, 2020).

#### **2.4.5 Highlights of the Section**

The study suggests a high possibility of implementing Eco-Design applications and design processes in craft sectors because there is a considerable compatibility between the current attributes of craftsmanship and the principles of Eco-Design, like high reliability and durability, lower energy consumption, cleaner materials and production, possibilities for recycling, etc. The segments which have not been addressed yet, such as remanufacture and packaging, can undergo implementation through design thinking and execution. Technological interventions are required to bring amendments to the existing processing methods to drive towards principles of Eco-Design, and therefore, sustainability.

In the quest for an identity, design via craftsmanship can be effectively positioned as an Indian design identity in the upcoming modernity. The intersection can deliver an ecologically viable range of products to the Indian urban market or for the public infrastructure as well, and the Indian design community can have its indigenous efforts calibrated towards the repercussions of waste management and climate change, along with the friction against the rapidly changing environment.

#### **2.5 Conclusion**

The chapter establishes a relationship between Sustainability and Indian Craftsmanship by comparing the attributes of craftsmanship to the ten principles of Eco-Design. It infers the fact that craftsmanship in its current form is compatible to the new found principles of sustainability. Due to its status of non-industrial finesse, localised prices and building backgrounds, they are still considered items of curio adorning a space rather than a product with a utilitarian aspect and a saleable price according to industry standards. Designers and businessmen hesitate to invest in this domain due to questionable financial returns from the market. These reasons also lead to low economic sovereignty of the craftspeople, even though they hold 1.5% of the country's earning population.

The established relationship between craftsmanship and sustainability should be able to instil confidence amongst designers and entrepreneurs to invest their businesses and design thinking ventures towards the vibrant craft sector of the country. The fact that craftsmanship is in terms with the latest principles and that investing in this domain could impact climate change through material intervention and less environment harming techniques, should be able to break the inhibition towards investments for future well-being. The indeterminable status of the near future regarding sustainability brings in the need for design thinking towards a responsible future, and designers must take this at hand for a foreseeable environmentally healthier future for the generations to come.

## CHAPTER 3 :

### INDIAN BAMBOO DESIGN

#### 3.1 Introduction

The previous chapter established a relationship between sustainability and indigenous craftsmanship which univocally translated to bamboo craftsmanship as well. Bamboo craftsmanship was analysed and found to be compatible with majority of the Eco-Design principles which are being most commonly practiced in terms of sustainability. Zooming in further to understand the Indian bamboo domain, this chapter throws light upon the multiple interventions in the design, manufacture and marketing of bamboo products in the country. This chapter caters to the research question - What is the current status of Indian bamboo product design and its probable future? The answer to this question will provide the bamboo domain a direction towards design, manufacture and marketing in which it must invest in for the future.

Bamboo as a material has played a versatile role in the lifestyles of many communities in India, majorly in the North Eastern Region of the country. The easy availability of the material as a backyard grass facilitated its use in various utilitarian products in the past, which are being used in domestic households even today. Products ranging from fishing equipments, musical instruments, kitchen storage devices, spoons and ladles, local architecture and boundary walls, jewellery, household decorative pieces, temporary structures and bridges etc. amongst many, have generated an identity for the region. The integration of the material into the communities was effortless as the material required minimal processing and simple tools available in every household for making the required products.

Many researchers and entrepreneurs in India recognized the value of the material and the social construct built around it to collate information as well as to execute new designs and iterations to satiate the customers purchase and aesthetic needs. Utilitarian products through means of new designs have given way to successful ventures through bamboo to deliver furniture, luminaire, lifestyle accessories, storage units, cutleries, fabric etc. These ventures have been able to bring the bamboo material into the market forefront.

Every product requires a clientele. The later part of the research in this chapter looks into the characteristics of the newer generations and their consumer traits, along with their lifestyles and attitude towards green consumption. The future of bamboo ventures seem promising as consumerism will eventually be taken over by the newer eco-conscious generations.

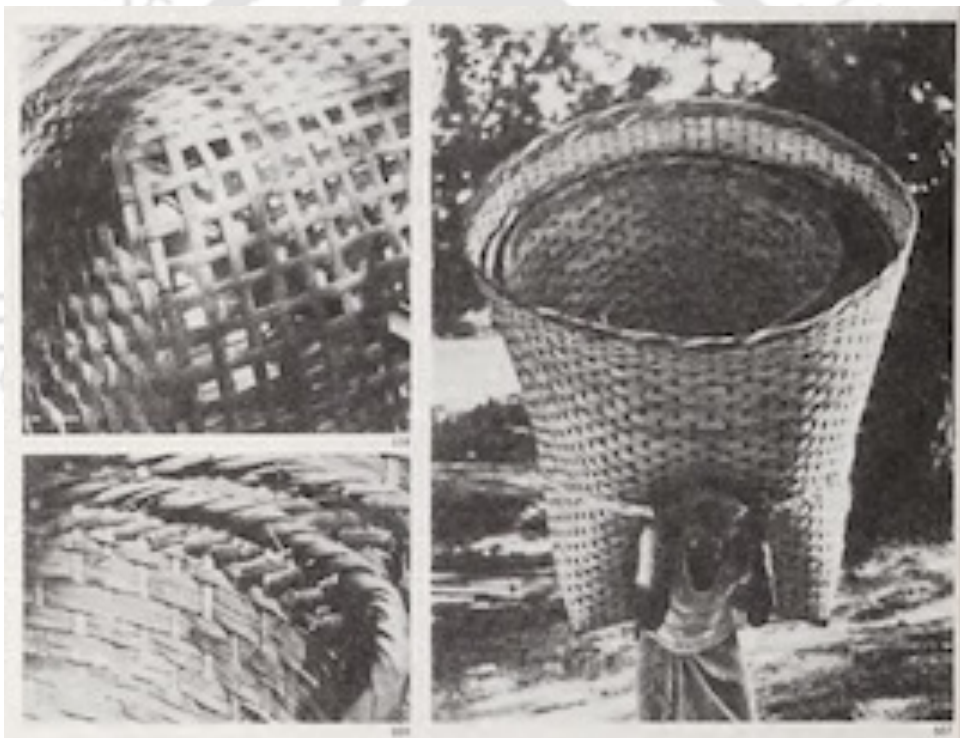
This chapter brings in a holistic understanding of bamboo design in the country. It looks into the research conducted in this domain since 1975 and the entrepreneurial ventures within the last three decades which speak about market observations and inferences. The chapter conducts multiple interviews with businesspeople and entrepreneurs involved in this domain and a comprehensive market research of the bamboo products both in the physical and online space. Eventually the chapter delivers the characteristics of the new generation consumers and throws light on their purchasing behaviours to understand the direction in which the bamboo designs could be taken forward and thus, the requirements for the market from this particular domain.

## 3.2 Research on Bamboo since 1975

Formal exploratory research on bamboo material in India started from around 1975, with interest and enthusiasm towards ethnographic relevance of the material in the North-East Indian states. Three researchers from National Institute of Design (NID) and Indian Institute of Technology (IIT) ventured into this area initially to understand the relevance and potential of the material. The researchers have been selected for their considerable contributions in academia through published papers, books and developed labs of bamboo work. This section of the chapter explores their various contributions towards bamboo and its craftsmanship.

### 3.2.1 NID Ahmedabad - M P Ranjan

Prof M. P. Ranjan did a pioneering work in study and documentation of bamboo products in the North Eastern India from 1979 to 1986 as shown in Figures 3.1, 3.2 & 3.3. His efforts culminated into an excellent publication 'Bamboo and Cane Crafts of North East India' in 2004.



*Figure 3.1 Documentation of Bamboo baskets in NER by MP Ranjan  
(Source : Bamboo and Cane Crafts of North East India, 2004)*

He has explored Bamboo as a plant and the traditional wisdom associated to the material. General properties such as physical strength, distribution, density and orientation of fibres, flexibility and surface quality of culm, response to ageing, smoking, treating with chemical and mechanical finishes and bamboo manipulation techniques were analysed and documented. He also observed the products in use and the fabrication process while these were made. Based on the uniqueness of construction, around 400 products were analysed on the bases of 60-70 attributes and a list was made of the overlapping repeated occurrences of useful properties of bamboo which could be learnt by those who could not have the privilege of being apprenticed to accomplished craftsmen (Ranjan, Iyer & Pandya, 1986).

While bamboo is one of the oldest materials exploited by man, recent developments suggest that completely new ways of using this material in an environmentally sustainable manner are possible that will put bamboo on par with the most sophisticated synthetic materials ever invented by man. There is a definite need to develop industrial entrepreneurship, to assist in the tasks of employment and income generation which are independent of direct government funding. The crafts strengths of the region offer an exiting and feasible starting point for the development of entrepreneurial attitudes essential for the overall development of the region (Ranjan, 2004).

Product diversification should be firmly rooted in the traditional wisdom expressed in these products if quality standards are to be maintained in the face of change caused by market pressure. As this craft-based industry depends on an easily renewable resource such as bamboo, cultural continuity can be maintained at the face of rapid change while ensuring the economic growth of the region (Ranjan, 2004).



**Figure 3.2** Documentation of Agricultural Bamboo Products in NER by MP Ranjan  
 (Source : Bamboo and Cane Crafts of North East India, 2004)



**Figure 3.3** Documentation of Bamboo Accessories in NER by MP Ranjan  
 (Source : Bamboo and Cane Crafts of North East India, 2004)

### 3.2.2 IDC, IIT Bombay - A G Rao

Prof. A. G. Rao understood the high potential of bamboo way back in the 1980's. He emphasised on the search for new aesthetics in Bamboo craft. He saw a promising future for the material by the adaptation of newer techniques and technology, finishes, joinery and detailing, and by incorporating modern features during redesign. He has also insisted upon the addition of design to satisfy the market profile and improve entrepreneurship. It would also encourage a new relation between the craftsman and the designer (Rao, 2008)

Rao defined two basic approaches of dealing with bamboo craft in the near future. One might be craftsman oriented, where, the designer could study the existing products, the conventional tools and techniques used by the traditional craftsmen and suggest changes, improvise and standardise the processes, increase the productivity and achieve better aesthetics to maintain the competitiveness of bamboo craft products.



*Figure 3.4 Items of Bamboo Tool Kit by AG Rao (Source : <http://www.agrao.in>)*



*Figure 3.5 Bamboo Tool Kit in closed and open position by AG Rao (Source : <http://www.agrao.in>)*

On the other hand, sensing the enormous market potential for quality products for both urban and export market, entrepreneurs could take initiative to start small scale craft based industries employing craftsmen with machines and better working facilities and projects. This would ensure employment to

both skilled and semi skilled craftsmen and also meet the market requirements of better quality and larger quantities (Rao, 2004).

For the help of the craftsmen, he developed a Tool Kit with 33 items and 4 small machines at Bambu Studio, IDC under a UNDP project on bamboo and cane [Figures 3.4 & 3.5]. When bamboo craft products reach modern markets and are compared with the standards and finishes of industrially produced goods, the need for new tools and technologies becomes obvious (Rao, 2004). Rao conducted many workshops such as Jagruti and Melghat Rakhi, along with many others related to bamboo craft training.

### 3.2.3 DoD, IIT Guwahati - Avinash Shende

A project was initiated by the Government of Meghalaya, Directorate of Industries and Commerce (DIC), by engaging the services of the Design faculty at the Department of Design, IIT Guwahati to outline a model of craft design & skill upgradation for the cane and bamboo craftsmen of their state. These craftsmen are known for their unique basket making skills.

It was believed that design Intervention in traditional Indian handicraft and handloom sector that aim to achieve economic development through inclusiveness of the craft community are faced by challenges that include social and economic considerations that far outweigh creative design inventiveness for their success. To resolve this, the project Shken.in was undertaken by a Design team led by Prof. Avinash Shende and Prof. Ravi Mokashi Punekar, Department of Design, IIT Guwahati and Prof. Mandar Rane, IDC, School of Design, IIT Bombay (Shken, 2016).



**Figure 3.6** Design interventions for bamboo weaving by Avinash Shende (Source : Author)

On the design intervention front, the project result included regularisation of the bamboo weave by using metal and FRP moulds of given dimensions and making the weaving process more comfortable for the craftsman by making a maneuverable stand with the required mould as shown in Figure 3.6.

### 3.2.4 Inferences from Research on Bamboo since 1975

The above case studies infer that the potential of bamboo material has been realised and interventions in different aspects have been conducted to improve the deliverable from the material through craftsmanship.

1. **Exploration of Bamboo Properties:** Bamboo, being an easily renewable resource, allows for cultural continuity and economic growth. Bamboo can be utilized in new environmentally sustainable ways comparable to sophisticated synthetic materials.
4. **Social Integration:** Bamboo is neatly integrated into the social fabric of NER and incorporates multiple aspects of daily livelihood, including agricultural tools, storage, accessories, architecture etc. Traditional wisdom is largely associated with the material.
5. **Product Diversification and Traditional Wisdom:** Diversification should be rooted in traditional wisdom to maintain quality standards amidst market changes. Design intervention in traditional handicrafts faces challenges beyond creative design, including social and economic considerations.
6. **Craft and Industrial Entrepreneurship:** The region's craft strengths offer a feasible starting point for entrepreneurial development. There is a definite need to develop industrial entrepreneurship, to assist in the tasks of employment and income generation which are independent of direct government funding. Modern techniques, finishes, joinery, detailing, and design must be adapted to satisfy market demands and improve entrepreneurship.
7. **Product Analysis and Documentation:** There are many craftsmen who have still not been introduced to the material. Overlapping of useful properties of bamboo have been documented that could be learned by those without traditional apprenticeship.
8. **Tool Kit Development:** Tooling techniques through hand held bamboo tools and improvement of the weaving process through manoeuvrable stands with required moulds have been developed to assist the craftspeople's comfort and efficiency.

### 3.3 Market Study

After understanding the research done towards the domain of bamboo till current times, there was a need to understand the current market status of bamboo designed furniture. The situation was perceived from a market and customer view to gain better perspectives on the demand of the market and criticality involved in the execution of business.

#### 3.3.1 The Relationship between Bamboo and Cane

It has been a general observation that bamboo and cane products have always been put under a singular category, though they are two different materials. Cane is a forest product. It requires manual labour to retrieve cane from the forest, the harvesting is seasonal and since it is a forest product, there is no plantation available. Cane has a higher price than bamboo in the market because of its lesser availability and the finesse and flexibility it provides. Hence, its comparative product pricing with similar bamboo products is higher. Cane can unilaterally produce furniture due to its strong tensile strength, comforting visual appearance and ease of use of material.

Bamboo is a backyard grass. It is available throughout the year in rural households, which, once matured, can be harvested easily according to the monthly lunar cycle. Bamboo provides lesser flexibility than cane, but gives a visual identity of strength and sturdiness. It allows multiple variations of its original form which can be manipulated to make various products. Bamboo furniture is conventionally produced with whole bamboo, wherein the joinery, surfacing and finishing of the furniture is generally done by cane slivers. Bamboo gives the strength and form while cane is used for binding and aesthetic purposes. Unlike cane, bamboo furniture seeks the assistance of cane to hide the rough edges and look more comprehensive and presentable.

Both the materials have represented the domain of furniture together. Cane furniture has been very successful with its outdoor quality and its possibility of form based aesthetics, natural texture and colour. The status of bamboo furniture has been redundant regarding designs and finesse. Due to its organic nature and relation to regional craftsmanship, it has been generally noticed that whenever customers seek furniture of the like, there is an indication towards both the materials together. Hence, it would be an incomplete research towards the market study of bamboo furniture products without simultaneously acknowledging the status of current cane furniture.

### **3.3.2 Collection of Data**

In today's information age, there is an access to two different types of business platforms - a physical market and an online market. The market analysis considered both the platforms for the research. It was analyzed in two sections - the physical market was intervened through interviews with current craft entrepreneurs invested in the bamboo and cane industry, and the online market was accessed to locate their virtual platforms and understand their digital presence online, which gave a good purview of their stories, ethics and designs. It also helped to understand the visual quality and prices of bamboo and cane furniture products in the current market.

### **3.3.3 Selection Criteria for Interviews**

The following were the criteria for the selection of craft entrepreneurs to be interviewed :

- Established in the current market of bamboo and cane furniture products
- Had a first hand experience in the ongoing industry
- Industry Experts in bamboo entrepreneurship who know the market standard and understand the ground realities.
- Successful entrepreneurs
- Have published material on bamboo and cane furniture in terms of research papers, magazine articles, books, talk shows, news clippings and online videos on reputed platforms and have received national and international recognitions.
- Their work has contributed to the existing knowledge, benefitted people and helped the bamboo cane industry.

*Special Note :*

- Avoid exclusivity of a design background to gain a broader perspective of the situation.
- Possibility of integration of other craft entrepreneurs as a special case.

### 3.3.4 Interview with Craft Entrepreneurs

To understand the status of the market of bamboo products, interviews were conducted with the current entrepreneurs of the modern craft design domain pan India who were working with comparable attributes to bamboo craftsmanship. Questions were asked regarding their enterprises and their working, along with their experiences from the market. The interview format has been attached in Appendix A. The inferences from the interviews with craft entrepreneurs have been discussed below.

#### 3.3.4.1 Sangaru Design Studio - Sandeep Sangaru

Sandeep Sangaru has specialised in Furniture Design from National Institute of Design, Ahmedabad. His design consultancy firm called Sangaru Design Studio in Yelahanka, Bangalore has been actively involved with the Craft Sector to create global products. Sangaru says that we can create unique designs for furniture pieces with simple tools and techniques which can change the preconceived perception of a particular craft or skill (Gopinathan, 2018). In 2002, when Sangaru visited Agartala's artisan workshops, he realized that the use for bamboo in the everyday lives of people in the North-East Region is so evolved, but yet the craft bazaars saw the same archaic bamboo souvenirs (The Busride, 2019). He developed an unconventional stool with the help of Agartala's artisans which he later developed into a furniture series called 'Truss Me' to change the perception of bamboo furniture design. The series included chairs, ottomans, aesthetic and functional stools, aspirational products and lamps [Figure 3.7] which were recognised on many international platforms and won him the Red Dot Design Award (TedxHyd, 2018).

He believes and follows the Rhizome approach in his work, which is an interdependent interwoven cultural system; a rich web below the surface. It is basically merging nomadically into a matrix, in the middle of it to reach an equilibrium with a choice of navigation. Its strength lies in the interconnectedness, where the nodes retain memory to which he believes to contribute (The Busride, 2019). He also talks about Minimalism as 'crafting is effective working with minimal tools' and 'good design is crafted minimalism' and 'Minimalism is Engineered Simplicity' (Creative Mornings, 2014).



**Figure 3.7** Bamboo furniture of 'Truss Me' series from Sangaru Design Studio, Bangalore, India  
(Source : <https://shop.gaatha.com/Sandeep-Sangaru>)

When asked about the current market status of bamboo products, Sandeep Sangaru says, ‘There are two ways to satisfy the market need. One way is to innovate new ways of doing things and relook at product and craft to deliver an aspirational product. Second way is to cater to market needs with an innovative thinking approach and design according to it. Innovation can be along the variables of accessibility, mass production, market segment, costs involved etc.’

On the quality of craft products he mentions that the quality of craft products is always compromised, because when customers think bamboo, they think cheap and thus expect cheaper products. If a craftsman is asked to show a basket, he will ask the customer for the price range they are looking in because he will have a basket worth 10 rupees as well as a basket of 150-200 rupees, where the difference in craftsmanship in the differently priced baskets can be visibly seen. There is more effort perceived in the higher priced basket. When customers expect cheaper products, the cost of making becomes very less and so the craftsmen do not have the liberty of making very fine products, thus delivering compromised products. Before industrialisation, artisans would provide a range of products according to different prices.

Sandeep Sangaru believes that craftsmen must be pushed to deliver better craft products to demand a better price for their efforts. When asked if crafts must achieve the standard of machine made products, he mentioned that machines can make only repetitive, pre-determined one-off products in which a certain thing is in a certain way. But handmade delivers value to the product via intangible aspects through design and craftsmanship, which the machines cannot deliver. Even though the numbers are less, every piece has personalisation performed by a craftsman, which delivers its value. For example, a single basket made in a machine will be the same throughout. But if the same basket is made by an artisan, there will be a choice of colours, different weaves, different handles etc. The customisation adds to the intangible value of the product. When asked about customer expectations, he mentions that ‘Good Quality Products treat you well. Treat customers well and you will get a better sale. If you are good at something, keep your focus, and you don’t have to sell yourself anymore. Be efficient and particular about quality.’

#### **3.3.4.2 Rhizome Design Studio - Rebecca Reubens**

Rebecca Reubens is an alumni of NID Ahmedabad and has recently completed her PhD Thesis called ‘To Craft, By Design, for Sustainability’ from TU Delft, Netherlands. She has spoken meticulously about Holistic Sustainability and her Rhizome Approach which calls for Prosumer, Glocal and Expressive Directions of Innovation (Reubens, 2016).

She also runs her independent sustainability design practice called Rhizome Design Studio, based out of Ahmedabad, which believes that renewable materials crafted into contemporary designs are the route to holistically sustainable products. Here, she is working with the materials bamboo, cork and seagrass. She uses a technique of fabric weaving integrated with bamboo furniture and has also launched a series of sustainable jewellery called Baka. A large part of her work has been for the development sector, with international bodies such as INBAR and UNIDO, in Europe, Asia and Africa.



**Figure 3.8** Bamboo furniture of Rebecca Reubens from Rhizome Design Studio, Ahmedabad, India  
(Source : <https://www.instagram.com/rhizomedesignstudio/>)

Reubens says that combining Bamboo with other materials is the middle route between using composite materials and using just bamboo. The combined materials impart the product with properties that may not be achievable with the use of a single material. She has also mentioned things to be kept in mind while combining two materials as this process increases the infrastructure required for production and directly affects the sustainability factor of the product. The other material must also be locally sourced and easily available, so the production cycle is not disrupted due to non-availability. The materials used must either complement or contrast bamboo strongly. Also, combining bamboo with high-end or luxury materials, such as leather, brocade and precious metal are interesting in terms of an increase in the perceived value of bamboo through association. The high end material when combined with bamboo, has the potential to pull bamboo up to compete in market segments where bamboo would generally not be accepted (Reubens, 2012).

While working as a Design Consultant in INBAR from 2002-2009, Rebecca Reubens sought for information regarding intervention for craftspeople and when she did not receive any answers, she decided to tie her income to the craftspeople. Through her initiative Rhizome Design Studio in Ahmedabad, she has worked extensively with craft communities to deliver market acceptable products which speak for themselves regarding design and aesthetics through a technique of fabric weaving with bamboo furniture frames as shown in Figure 3.8. When asked about the idea behind weaving, she mentioned that the weaving is done from fabric remains of textile industries. The fabric cuts down on material, reduces prices of distant transport along weight and volume, and has ecological and socio-cultural benefits as women are involved in the craft, thus considering recycling and sustainability. When asked about how have the craftspeople been benefitted, she mentioned that the Craftsmen from Tripura, who have been associated with her for the past 20 years, have made houses in Agartala and one of them is sending his child to Delhi Public School (DPS) and earns around 35,000 rupees a month, which she

considers a respectable income. She also makes sure to teach her team AutoCad, French language, Design Ideations, Colour Theory and helps them to think monetarily.

On her reach to customers she has mentioned about improving her online presence through Instagram, Facebook and other such portals to inform people of the existence, both nationally and internationally. On consumer group and expectations, she mentioned about affordable prices and a repair when damaged, which she provides as a service. Mostly her consumers belong to nuclear families and young professionals who are starting their lives. They are sensitised to sustainability and do not wish to buy big furniture, they mostly buy the furniture pieces for balcony and floors. On help from Government she mentioned that she takes no help from the Government on principle, because Government anyways has limited money and needs it for health and education, so lifestyle products can take a backseat. She prefers to be self-sustaining on principle. Regarding the future of sustainability market, she mentions that there needs to be regulatory norms for selling sustainable to avoid hogwash and the prospects for this market are bright because till unsustainability exists, sustainability will have a market.

#### **3.3.4.3 Mianzi Global - Shashank Gautam**

An alumnus of SPA Delhi and IDC Bombay, Shashank Gautam has very recently opened an initiative called Mianzi Global with exclusive bamboo products. Mianzi's vision is to revolutionize the way bamboo is seen and used by bringing India its first eco-friendly yet inventive and aesthetic bamboo-built options.

It provides a challenge of fashioning products which are not only sustainable or aesthetic but individualistically revolutionary. Though sustainability, being associated with "going without" is always belittled, Mianzi aimed to come up with products which attains both competitive edge for similar products whilst reaping benefits for the environment (Mianzi, 2018).

His goal is to cogitate bamboo as a possible semi-industrial product, so while we prototype objects with it, we always try to exploit the properties of the material in an efficient way, because the objective is not only to use it as a substitute and continue producing objects the same way, with bamboo just replacing something else, but to rethink the whole architecture of a product from the body to the details (Mianzi, 2018).

His designs have gained international reputation [Figure 3.9] and has won him the Trends Excellence Awards, 2020 Looks Good Ambiente Talents, Lexus Design Award and Elle Design Award. Mianzi is working in association with Madhya Pradesh State Bamboo Mission (MPSBM), who has provided Shashank with a workshop space in Satna, Madhya Pradesh (Mianzi, 2018).

While experimenting with the bamboo material, Shashank Gautam realized the possibility of integration of Bijarke Ingels's Hedonistic Sustainability in his ideas of modularity. In this concept, sustainability is not associated with negativity and constriction but rather, it is seen as a transformation into the youthful, dynamic and egalitarian, which is both economically profitable and environmentally sustainable, for example, a ski track on top of a garbage hill. Since, the material bamboo is already sustainable, he is working on how it can define current lifestyles without compromising style.



**Figure 3.9** Bamboo furniture of Shashank Gautam from Mianzi Global, Delhi, India  
(Source : <https://www.mianzi.in/>)

When asked about his market experience regarding his bamboo furniture pieces, he mentioned that making customers accept bamboo design is tough, unless the level of product is equal to the current available materials. It is not the time right now in India for craft and sustainable products, though the idea has been implanted. But, the next trend in 10-20 years is wabi-sabi, which, in traditional Japanese aesthetics, is a world view centered on the acceptance of transience and imperfection. Characteristics of wabi-sabi aesthetics and principles include asymmetry, roughness, simplicity, economy, austerity, modesty, intimacy, and the appreciation of both natural objects and the forces of nature. In this upcoming trend, the sale of craft related products might boom. In the US and UK, people are sensitised and try to follow a sustainable lifestyle. Since we as a country follow the West, he is hopeful about its reception in India too, but in time. He also mentions that the sale of old craft products has diminished and the market seeks for new products.

On clients and stores he mentioned that market runs on impression at first sight. He targets clients of the higher class and higher middle class. Bamboo here is sought as an aspirational product, it could even be for day to day life. He also realized that physical stores are not very important, as now slowly and steadily things and situations are changing. Also a physical store adds to the expenses and is very difficult to maintain. For the future of his work he intends to integrate technology and make amends to reduce craftsmen stress alongside maintaining a strict quality check. He intends to follow the current trend, as he has realized that even if one wishes to make something out of the box, it should not be very far away from the existing trend, to maintain a good balance between design and sales.

#### **3.3.4.4 Bamboo Jewellery Design - Neera Sarmah**

Bamboo lady Neera Sarmah is a social entrepreneur from Tezpur, Assam who teaches bamboo jewellery making in remote villages of India [Figure 3.10]. She terms the jewellery as Green Gold jewellery with a philosophy that since bamboo is a grass and can be extracted from nearby forests, it can be used to earn a purposeful living for poor people who are devoid of land. Her big idea was to help the poor and downtrodden by teaching them how to utilise forest products and earn a livelihood.



**Figure 3.10** Bamboo jewellery and Social Entrepreneurship by Neera Sarmah, Assam, India (Source : Neera Sarmah)

Since bamboo is a grass available easily in nearby forests, they can use it to create objects and make money from it. They did not have any education or training but had the knowledge of the forest and how to use it. Instead of their families running out of work in non-agricultural seasons, and indulging in drinking alcohol, domestic violence and other social evils, they should involve themselves in some productive work such as making artefacts from resources available from the nearby forests. The women of the household could bring in some income and have a purposeful livelihood of their own. She insists on learning from rural knowledge and believes that value addition must be done to gain artisans interest in making bamboo products for a living.

She was associated as a consultant to Tripura Bamboo Mission in 2000 and to Gujarat Rural Development and Tribal Area Development with Narendra Modi in 2006, and eventual associations with Madhya Pradesh, Chattisgarh and Jharkhand Bamboo Missions. She has been recognized by various women entrepreneur platforms pan India such as Hall of Fame, Women's Excellence Awards etc. along with local newspaper attention.

Regarding the demand of her jewellery in the market, she mentions about a huge demand in the market since it is an aspirational product as everybody wonders about how jewellery is being made from bamboo and since they have never seen anything like it, they wish to adorn it. She sells both nationally and internationally. She sets the price according to the market in question. In smaller town locations, an earring will be priced at 150-200 rupees but when it goes to metro cities such as Mumbai, the same piece will cost 3000-5000 rupees and when it goes to the European market, those very earrings are sold at 5\$-10\$. The market and the packaging determines the price. When asked about consumer behaviour, she mentions about two broad category of clients - the educated and high class and the middle class. The educated class of people understand the hardship of craftsmanship and value art, thus willing to pay the price, even more; whereas, the middle class people crib about the high prices and they question the authenticity of the product asking whether it is bamboo or cane. She mentions high society is the main client because they appreciate the workmanship and craft.

### 3.3.4.5 Canecraft & Allied Industries - Naveen Sood

The founder of Canecraft and Allied Industries, Naveed Sood, is a businessman from Guwahati who started the enterprise in 1993. He deals with home decor items made of cane [Figure 3.11] and has a workstation and shop in Dispur. His enterprise has been recognized by Mrinal Kumar Sarma Memorial promising entrepreneur of NE Award, 2016.



**Figure 3.11** Cane Utility Products by Naveen Sood from Canecraft & Allied Industries, Dispur, Assam  
(Source : <https://www.canecraftassam.com>)

He is concerned about the local availability of materials for production since the cane suppliers from Kaziranga, Mongoldoi, Tezpur etc. sell their produce to Siliguri and from Siliguri the prices are exorbitantly raised by 400-500% by middlemen and then delivered back to Assam. This raises the production cost of the products, and involves difficulty in receiving quality local raw material. He also faces problems of commitment from craftsmen, as they are indulged in mobile phones, which reduces workmanship hours. Even though he receives orders from abroad, he is not able to export, due to unavailability of time and labour to make huge numbers. Since they are a cottage industry, production is not in bulk and hence it stagnates commercialization.

Regarding commerce, he also mentions that 30% of the cost of furniture is in transportation, done by local logistic companies. Since the material is not wood, it cannot be screwed and hence cannot be dismantled. This increases transit volume and thus the cost. When asked about customer expectations, he mentioned about the irregularity in the pieces which are not accepted. Customers do not acknowledge the craftsmanship errors and seek extreme finesse. This makes the customers perceive the products as either very expensive or very cheap. He also mentions that if products are sellable, they do not need to be displayed; if they are not sellable then they need to be displayed.

### 3.3.4.6 Boocane - Sms Bordoloi

The owner of Boocane enterprise in Guwahati, SMS Bordoloi, has a background in science and economics and has been associated with the Indian Express for 15 years. He has always tried to be innovative towards drawing some initiative towards North East India, and with the help of his many established contacts, he has been able to make it possible through his enterprise on bamboo fabric called

‘Bambusa’ and through his cane furniture enterprise called ‘Boocane’ [Figure 3.12]. His big idea was to benefit 1 lac artisans through his initiatives.



**Figure 3.12** Furniture & Home Decor Products by SMS Bordoloi from Boocane, Guwahati, India  
(Source : <https://boocane.com>)

For Boocane, he developed machines, manufactured them in Austria and set up his Industrial Unit in Tezpur in 2015 along with a showroom in B. Barooah Road area of Guwahati, opposite Nehru Stadium, in 2019. The biggest challenge he faced was that, ‘It is very difficult to convince people that NE can produce world class products. The rest of India cannot imagine high quality product from NE. NE has an image problem, which gives it an identity of a backward area with happy go lucky people. It is very difficult to get away from this image. Another challenge was the Entrepreneur Ecosystem prevailing in NE India. The work ethics in this region is compromised, when compared to that of nodal metro cities. Here people are laid back and take work easily and hence it shows in the results.’

Before making the products, he researched on the standard of products in China, Vietnam, US and UK and did not let the product quality fall below UK standard, no compromises were made. Once the products adhered to world class standards, he received a lot of orders internationally as a curated Indian brand. He specifically mentioned that ‘if you make world class products, you don’t have to worry.’ His strongest asset was his hold on branding and marketing. He branded his initiative with compelling stories which gave the products more value and made it very attractive to companies in US and UK who are more informed about sustainability, and are looking forward to means to follow ways of life with integrate sustainability. He has developed his business abroad entirely through website branding and Facebook and Instagram pages. Compelling stories is his marketing tool.

He strongly believes that the biggest advantage of NE is that this area has very good quality of bamboo and cane and the need of the hour is owning our own technologies to handle the various species available in this region. Other countries have done so with their own species and we need to do so too. Guada and moso bamboos might not be available here, but Jati (Bambusa tulda) is the king of bamboo for all bamboo products. He finally delivers a reality check that in today’s furniture market, Online shopping has engagement but very less buying. For furniture buying, physical stores are a must. The market for sustainable products is abroad. NE might not impress others for world class products, but one should not lose heart.

#### **3.3.4.7 Canecraft - Rajiv Poddar**

Mr Rajiv Poddar is the founder of Canecraft which has its showroom in Khanapara, Guwahati. The enterprise was started in 2004 and makes three types of furnitures - cane, cane and wood, and wood. The workshop establishment of this enterprise is located in Jakhlabandha in Assam which is located 170 kms from Guwahati, with around 100 artisans from nearby villages of Karimganj and Dhekiajuli. His enterprise is in two floor building with international standard showroom quality which marks a significant landmark on the Guwahati Shillong Jorabat Road. Due to concerns of privacy, the researcher was not allowed to take pictures of his furniture pieces.

His furniture pieces are designed to satisfy elite customers in India, EU, US, Vietnam and Philippines. When asked about his market experiences he mentioned that they do not have any technique of dismantling yet, like IKEA, the reason why they always need to look into volume considerations. His biggest challenge is related to logistics pan India and transportation damage. Since there is no technique of dismantling cane furniture as of yet, he has faced damages during transportation and also faced problems to deliver through tight staircases to houses. He also mentions that no single material works, there must be an integration.

Regarding customer behaviour, he has realised that customers have a budget, but they are willing to pay more to get something better, which they do not mind. He delivers a one stop solution to the customers which include customisation. He delivers fully polished pieces, with upholstery coordinations, cushions, fabrics, all together along with services. This helps him own customer reliability and satisfaction. This gains him customer confidence. He delivers a reality check that mass customisation is an important requisite of today's furniture market. That shift of 3-4 inches must be integrated within the service of furniture design, upholding commitments and delivery schedules.

#### **3.3.4.8 7weaves - Rituraj Dewan**

Rituraj Dewan is an Assamese Entrepreneur who has been able to make a recognition through Eri Silk Fabric in the national and international market. He has an enterprise called '7weaves' in Guwahati, Assam which makes Eri silk cloth [Figure 3.13] from the indigenous forest communities of Assam's Loharghat Village Range. The village communities rear silkworms and practice sericulture as a source of food and yarn in their household courtyards. The yarn is extracted from the abandoned cocoon of the silkworm and spun with the help of drop spindles after degumification. Eri Silk is a vegan silk in which the pupae of the cocoons are not killed, rather they are let to become moths. His marketing tool is calling it a Peace Silk.

Through his venture, he has been able to collaborate with designers pan India such as Artisans of Fashion, Handwork Studio, Maku Textiles etc. and has also been able to showcase his work in fashion exhibitions of Paris, Milan and Spain. He focuses on keeping a clear and fair intention and marketing his profile effectively to the global market. He mentions strongly about the total ecological impact of a business activity. There must be thoughts for future plans throughout the lifespan of a product regarding its end, repair systems and multiple lifespans via circular economy models. He strongly believes and practices that we must be mindful of what we leave back on the earth. While addressing sustainable options in a traditional system, he includes the livelihood of the artisans around sericulture without

claiming extra land from other food crops for his business model. He maintains a self-sustaining model which does not require any input from the outside to deliver products.



**Figure 3.13** Eri Silk Products by Rituraj Dewan from 7weaves, Guwahati, India (Source : <https://www.7weaves.com>)

Regarding craftsmanship he mentions that he shares 50% of his profit with the artisans because without them the business does not run. In a small town or village, a teacher is always more respected than an artisan. Thus, through his initiative he envisions to make craft viable and at par with professions like a teacher, because craftsmanship is an art and not an unskilled labour, hence must be respected. When asked about his market experiences, he mentioned though the medium of craft, we must develop world class products which are able to receive validation from clients in the eyes of the world. These products must first set a benchmark and then must go to a market which gives the highest price. They must produce luxury rather than mass production and must sit in the same stall as Spanish and Italian designs.

#### **3.3.4.9 AKFD Studio - Ayush Kasliwal**

Ayush Kasliwal is a Furniture Design alumnus from NID Ahmedabad and is the founder of Studio AKFD based out of Jaipur. He works with understanding and preserving the tradition of Indian craftsmen. His studio delivers a wide variety of products ranging from wall decors to furniture design, with a contemporary take on traditional crafts [Figure 3.14]. His work has been recognized by many awards both nationally and internationally, a few being India MSE Award 2019, UNESCO World Crafts Council of Excellence 2018, Elle Decor India Winner 2013, India's Best Design Projects Awards 2017 and many more.

He has very strong regards towards the knowledge of the Indian craftsman and mentions that they have been making everything around us since times immemorial and history has been a proof to it. Thus, it is ethically wrong to judge a craftsman's knowledge and undervalue it by comparing it to a machine made product. The designs might have become redundant, but the knowledge sustains and strongly suggests that Indian craft be contemporised to enhance our Indian Design Identity.

On craftsmanship he also mentions that it is always favoured to work and brainstorm at the artisan's place. Better feedback is received from the artisans when they are working from the comfort of their homes. When they are brought to the studio, a power equation is set which makes them less comfortable and lesser independent to provide inputs to design. But when the discussions are held at the artisan's place, they are much more rational and rewarding. In order to maintain the balance of spaces, he develops templates in the office and the crafted objects are developed at the artisan's place. Also, since he is working with multiple craftsmanships, to avoid coordination faults and reduce chances of error, he makes sure that each one has the other piece. He also mentions that while working with artisans, the risk of making mistakes is higher, so lesser assumption is made and hence one is extra cautious.



**Figure 3.14** Contemporary Craft Products by Ayush Kasliwal from AKFD Studio, Jaipur, India  
(Source : <https://akfdstudio.com>)

Regarding the success in market, he mentions about the strict Quality Control Department of his studio. Multiple patterns are developed before finalising the product and every stage is documented and visually signed to avoid confusion. A quality sheet is maintained for every pattern to relay the acceptable window of errors in millimetres which can be committed while making a pattern. The error windows are also notified to the clients and agreed upon. Every batch of products is tagged and recorded to track mistakes and learn from them. It is not in the final stage that the quality is incorporated but rather quality is executed by a robust system in the entire process.

He mentions that quality is not in the object but rather in managing expectations of clients. He maintains the quality in communication with clients to maintain a relationship and provide a service. Along with the acceptable range of errors, he also mentions disclaimers about the usage of the product. For the future of craft market he mentions that new codes must be developed and old processes need to change for craft. Old processes must be simplified, modified and made easy for the artisans to enable quality improvement. What is done in the industry must as well be brought to the artisan's workshop.

### 3.3.5 Inferences from Interviews with Craft Entrepreneurs

The following are the inferences from the interviews conducted :

1. **Changing Perception and Trends:** There is a need to change perceptions toward bamboo products, and the upcoming trend of wabi-sabi, appreciating natural elements, may drive the demand for bamboo in the next 10-20 years. However, for now, it is essential to follow the current trend and create aspirational products for the newly sensitized consumers.
2. **Craftsmanship Development:** Craftsmanship should be pushed to learn new things and supported by machines to reduce stress and enhance performance. The aim is to develop products of international standards without compromise, setting benchmarks and selling in markets that appreciate and pay a premium for such quality.
3. **Online Presence and Marketing:** Enterprises must maintain an active online presence to inform consumers about their existence and offer sustainable choices. Telling compelling stories serves as a potent marketing tool to sensitize customers towards a sustainable lifestyle.
4. **Hedonistic Sustainability:** Hedonistic Sustainability, associating sustainability with positive qualities, should be sought for a dynamic and youthful transformation.
5. **Pricing and Customer Segmentation:** Products should be priced according to the target market. There are two distinct customer segments – the upper class appreciates craftsmanship and values art, while the middle class questions the authenticity and pricing of craft. The main clientele for sustainability-related products are the upper and upper-middle class.
6. **Challenges in Transportation:** Transportation poses a significant cost to furniture production, especially when the material is not easily dismantled. Damage during transit and challenges in home deliveries add to the complexity.
7. **Image Challenges in North East Region:** Convincing people in the North East Region (NER) to adopt high-priced bamboo furniture is challenging due to preconceived notions. The image problem in NER, lack of entrepreneur support, and compromised work ethics add to the difficulties. The current market for sustainability-related products lies abroad.
8. **Material Integration and Mass Customization:** A single material may not suffice; integration of materials is crucial. Mass customization is a key requirement in the contemporary furniture market.
9. **Customer Satisfaction through Customization:** Customer satisfaction lies in offering customization, providing integrated services at a one-stop destination, and maintaining commitments and delivery schedules.
10. **Eco-conscious Business Practices:** Enterprises should consider the complete ecological impact of their business activities. Future plans should encompass a product's end, repair systems, and multiple lifespans through circular economy models.
11. **Craft Viability and Recognition:** In rural and town settings, craft must be made viable and respected, comparable to professions like teaching, to attract the next generation to the sector.
12. **Value of Craftsman's Workshop:** Giving value to a craftsman's workshop is essential for artisan comfort and confidence, fostering a balanced power equation between designer and artisan.
13. **Strict Quality Control:** Maintaining strict quality control throughout the production process is crucial for building trust, confidence, and long-term associations with customers. Quality is not just in the final product but is executed through a robust system across all stages.

### 3.3.6 Online Market Assessment of Bamboo Furniture

An online market assessment was done to understand the visual quality and prices of bamboo and cane furniture products in the current market. The images have been shown below from Figure 3.15 to 3.20.

#### 3.3.6.1 Mianzi Global

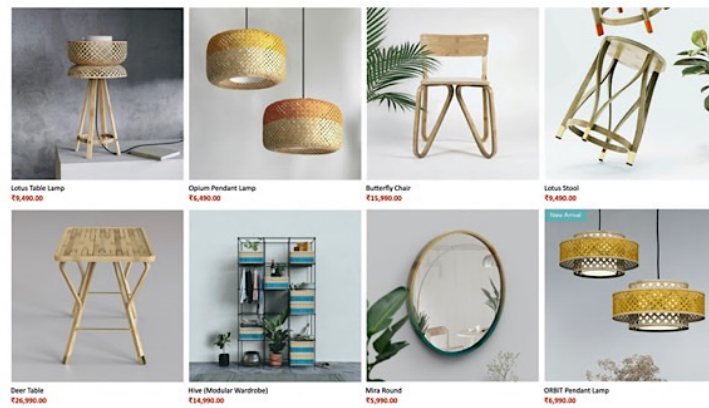


Figure 3.15 Products and prices of Mianzi Global (Source : [www.mianzi.in](http://www.mianzi.in))

#### 3.3.6.2 Boocane

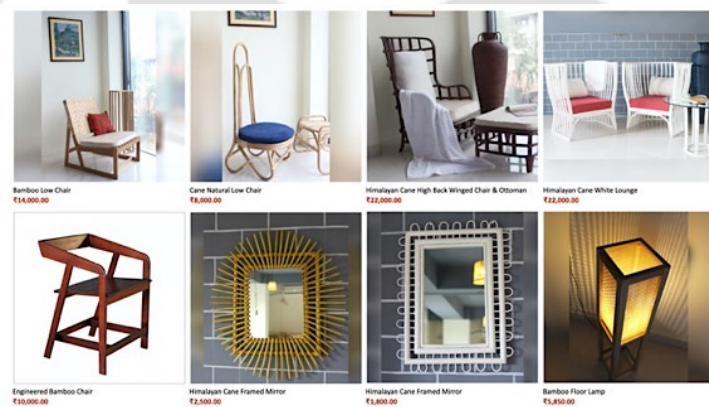


Figure 3.16 Products and prices of Boocane (Source : [www.boocane.com](http://www.boocane.com))

#### 3.3.6.3 Sangaru Design Studio

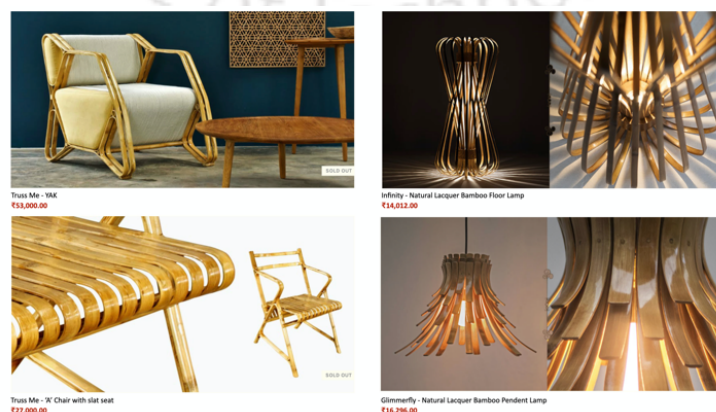


Figure 3.17 Products and prices of Sangaru Design Studio (Source : [shop.gatha.com](http://shop.gatha.com))

### 3.3.6.4 Jaypore

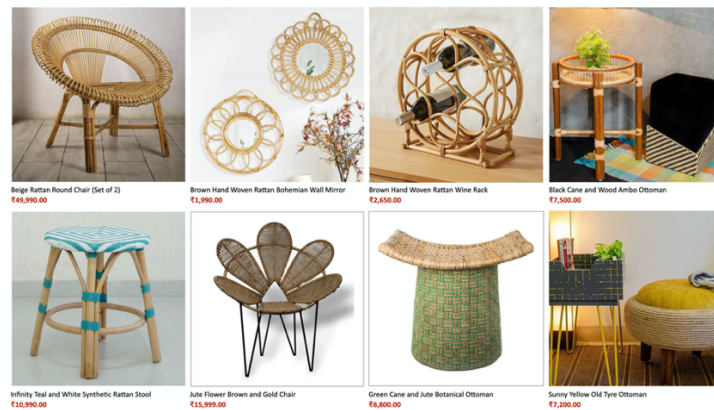


Figure 3.18 Products and prices of Jaypore (Source : [www.jaypore.com](http://www.jaypore.com))

### 3.3.6.5 Ira Furniture

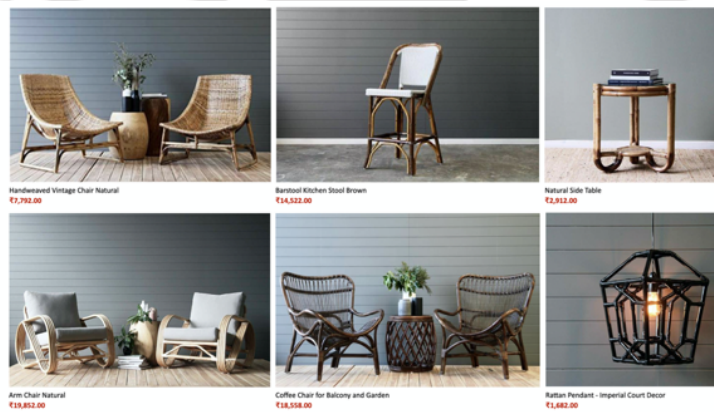


Figure 3.19 Products and prices of Ira Furniture (Source : [www.irafurniture.com](http://www.irafurniture.com))

### 3.3.6.6 Nestasia

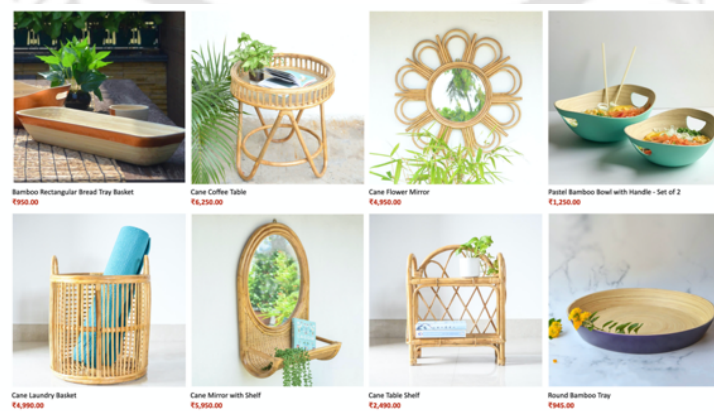


Figure 3.20 Products and prices of Nestasia (Source : [www.nestasia.in](http://www.nestasia.in))

### 3.3.7 Inferences from Online Market Assessment of Bamboo Furniture

The following are the inferences from the online market assessment of bamboo and cane furniture and related products :

#### Design and Aesthetics

1. **Modern Living Compatibility:** The furniture and products are designed for modern day living.
2. **Aesthetic Quality:** They exhibit high aesthetic quality in terms of form, finesse, and color tones.
3. **Natural Color Preservation:** The natural color tones of bamboo and cane are preserved to maintain visual association with consumers.

#### Marketing and Target Audience

4. **Visual Appeal:** Quality pictures with modern backgrounds are used on websites to appeal to customers, enhancing the aspirational quality.
5. **Target Market:** The products are priced for upper and upper-middle-class customers, with disposable incomes ranging from ₹40,000 to ₹2,50,000 (Rajora, 2023).

#### Product Characteristics and Pricing

6. **Functional Design:** The products are functional but primarily aim to make a statement with the material.
7. **Furniture Pricing:** Furniture pieces are priced between ₹7,000 and ₹25,000.
8. **Lamps and Mirrors Pricing:** Lamps and mirrors range from ₹2,000 to ₹16,000.
9. **Home Decor Pricing:** Smaller home decor items, such as bowls and baskets, are priced within ₹ 2,500, which is on the higher side for middle-class customers.

### 3.4 The Client

Since no market exists without a client, a detailed analysis was done to understand the current status of the green market and their concerns for the future clients and saleability of products under the impending crisis of global unsustainability.

#### 3.4.1 The Need for Green Products in India

Green products refer to eco-friendly products or sustainable products that do not harm the environment or deplete natural resources and can be recycled or conserved (Kim et al, 2013; Shamsadani et al, 1993). Western societies realized the need to protect natural environment early in the 1960's and 1970's. Green consumerism is catching up slowly in the developing nations due to increasing environmental damage caused by rapid industrialization, resulting in numerous health problems (Chaudhary & Bisai, 2018). Reasons why green consumerism in Indian context is important because first, India is the fastest growing major economy with a growth rate of 7.6% in 2015-16 and 2nd largest population base resulting in rapid industrialisation and hence environmental degradation; second, India is one of the most polluted countries with around 30 Indian cities figuring in the top 100 most polluted global cities across the world as per May 2016 data published by WHO (WHO, 2016); third, pollution kills 1.2 million people in India every year and India faces 3% GDP loss every year due to pollution (Times of India, 2017); and fourth, although Indian consumers have been reported to be more conscious of their

environmental impact than consumers from Brazil, Russia, Germany, Canada, Australia and America (Greendex, 2012), very limited research has focused on examining their intent and behaviour towards green behaviour and products/services (Chaudhury & Bisai, 2018).

Recent concern for the environment in the new millennium has lead firms to undertake environmental improvements in their products for a number of reasons, including a desire to be more socially responsible and a desire to cater to the needs of socially conscious consumers, particularly younger consumers, who want to purchase green products (Furlow & Knot, 2009).

The demographic composition of green consumers has changed over the last decade. This is due in part to the greater attention media has given to environmental issues and because environmental deterioration has reached the point where consumers from lower socio-economic levels are getting involved. No longer is environmental consumerism for the socially elite (Roberts, 1996). India, with the world's largest number of young consumers (400 million), who constitute more than one-third of the working population (Morgan Stanley, 2017), has become a hot market to understand for the green marketeers.

### **3.4.2 Consumer Behaviour and Generations**

The term 'generation' is used to describe differences between age groups in society and is a way of locating individuals and groups in society within current and historical periods of time with similar historical experiences (Pilcher, 1994). The tempo of social change shapes each generation's 'style' and worldview (Feuer, 1969).

The cultural context during a cohort's adolescence and young adulthood plays a critical role in shaping their characteristics, values and consumer preferences. Much can be identified from their early childhood years and their everyday common place experiences of culture (Pitta et al, 2012). Members of a generational cohort are unified because they shared the same cultural experiences during their formative years, which refer to roughly the first 20 years of their lives, which in turn, results in similarity in their values, beliefs, preferences, motivations and behaviours. Moreover, the early shaping of generational cohorts has been shown to be long lasting, with shared characteristics remaining consistent throughout their lifespan (Stewart & Healy, 1989; Schuman & Scott, 1989). Events occurring during the cohort's childhood tended to be stored unconsciously in terms of their fundamental values and expectations. In contrast, events occurring during adolescence tended to be reflected in terms of personal identity (Stewart & Healy, 1989). The emphasis on global values/expectations and personal identity reflect the developmental challenges during early childhood and adolescence respectively (Erikson, 1993).

The consistency in cohort's defining characteristics is what makes generational studies particularly relevant to marketing and business strategy (Meredith & Schewe, 2001). Understanding the key influencers of a generation means that businesses can anticipate cohort's consumer preferences before the cohort 'ages' into a 'market segment'. Knowledge of key generational influencers affords businesses with a means of anticipating millennial's future consumer preferences, which allows for adequate lead time for product production (Pitta et al, 2012).

While age data were collected in five-year intervals by the Australian Bureau of Statistics, generational terms like "Builders" (pre-1946), "Baby Boomers" (1946-1964), "Generation X" (1965-1979),

"Millennials" (1980-1994), and "Generation Z" (post-1995) are more relevant. These terms consider sociocultural, economic, and technological factors. The ABS age brackets don't align perfectly with generational categories, so they were approximated as follows: 18-29 for Generation Z, 30-44 for Millennials, 45-59 for Generation X, 60-74 for Baby Boomers, and 75+ for Builders (McCrindle & Wolfinger, 2010). Since the current young consumers of the working population are of the Millennial Generation aged 30-44, a detailed study has been conducted regarding Millennial characteristics, lifestyles and their green consumer behaviour.

### **3.4.3 Millennials and their Characteristics**

Millennials are the young adults born in the 1980's and 1990's, who became adults in the 21st century. They are also referred to as 'Generation Y' and have different lifestyles from previous generations at the same stage in life. They are mostly aged 16-35 during 2014-15 and their Date of Births range between 1981-1997 (Circella et al, 2016). They grew up in a period of rapid change and the first generation to be raised by the internet. Labeled as social, independent, proactive or sometimes even as a spoilt, bold or presumptuous, depending on circumstances, they have become an important topic for scientific and market research.

Millennials are the first generation of 'Digital Natives' who have been brought up during the age of digital technology (Milkman, 2017). This generation grew up constantly exposed to social media (Odenweller et al, 2014). Millennials are likely to be acutely affected by globalisation, communication and information technologies, economics and socialisation by very involved parents. They are likely to have different, even broader perspectives about the world marketplace, cultural diversity, performance of tasks and ways that communication and information technologies can be used to enhance performance and maximise productivity (Myers & Sadaghiani, 2010). Millennials are early adapters of new trends and technologies that later are adopted by other segments of society (Circella et al, 2016).

Millennials choose to live in more central urban locations, and have a preference for more vibrant and dense locations of the city with changes in household compositions, more committed to environmental causes and try to have healthier lifestyle. It is still unclear though, whether the impact of these motivations translate into more environmental friendly behaviours. They are reported to be less materialistic than other generations, with one exception : smartphones and mobile devices such as tabs and laptops (Circella et al, 2016).

In the 21st century, the transition from childhood to adulthood of millennials has been prolonged by the expansion of their higher education. Young adults often shuttle back and forth between post secondary education and precarious employment, a phenomenon that some commentators term 'waithood'. Aspirations rise with increased education, but they are often frustrated by chronic underemployment (Maysoun & Tannock, 2015). Thus, millennials are less likely than older generations to be 'engaged' in the workplace and they change jobs more frequently (Gallup, 2016), contributing to their biological availability at a certain place. Millennials face a stagnant labour market with far more limited options (Duke, 2016), compared to the previous generation, who came of age in a period of relatively abundant career opportunities. Those without college education fair worse, but college graduates also find it difficult to access the stable workplace based jobs, instead many settle for marginal employment as interns, temporary workers, independent contractors, freelancers and the like (Kalleberg, 2011; Krueger & Katz, 2016; Standing, 2011).

Some millennials view their early adulthood as a time to make a difference in the world and in their community. Some millennials appear to be content to volunteer or work in low paying jobs, as long as their parents are able to subsidise their standard of living (Alsop, 2008). During this time of adulthood, millennials develop better awareness of the world and exposure to cultural diversity, develop greater empathy for lower socio-economic populations, and become advocates for pressing societal issues with progressive attitudes and beliefs (Pew Research Centre, 2007). This brings in a wealth of experience and make them more accepting of people from diverse ethnicities and backgrounds and potentially more comfortable in interacting with them (Myers & Sadaghiani, 2010). Millennials value community and are civic minded and collaborative (Jacobson, 2007; Raines, 2002).

Computer Mediated Communication (CMC) is attractive to millennials for many reasons, including the way it breaks down social boundaries by reducing the limitation of physical boundaries on people's social contacts (Postmes et al, 1998). CMC muffles social context cues and hence social differences (Dubrovsky et al, 1991), thereby allowing a more egalitarian perspective for millennials. They expect open communication and frequent feedback, realise strong and meaningful commitments to individuals and are not intimidated easily (Marston, 2007). They confront persistent racial and gender disparities. They understand in the framework of 'intersectionality' which views race, gender, sexuality and class as inextricably intertwined (Milkman, 2017).

Millennials are distinctive in terms of their perspectives (Weiss, 2003), motivations (Kim et al, 2009), decision making rationales and value drivers (Boyd, 2010). They are about 3 times the size of Gen X (Palmer, 2008) and exceed all prior generational expenditure (O'Donnell, 2006) and make a large direct contribution to the economy (Jang et al, 2011). Because they also influence the majority of family purchase decisions, they have an even larger indirect economic impact (Morton, 2002; Taylor & Cosenza, 2002). Millennials are recognized as the most consumption oriented of all generations (Sullivan and Heitmeyer, 2008). With a sheer size of 1.8 billion people worldwide (United Nations, 2005), they are the most powerful consumer group in the market place (Farris et al, 2002) to have a significant current and future impact on world economics. Millennials are about to inherit massive environmental and societal problems, with overconsumption as one of the central ones. Some are developing alternatives for established consumer practices but they are far from being mainstream (Peyer et al, 2017).

#### **3.4.4 Millennials and their Lifestyle**

Analysis has revealed that millennials experienced their lifestyles as transient and there are 3 different consumer behaviour archetypes - spirited nurtured dwellers, busy frugal nomads and steady independent movers (Srivastava & Culén, 2019). The spirited nurtured dwellers are spirited teens nurtured and housed by guardians. They are mindful of opportunities and are in tune with trends. They have monthly allowances instead of income and are inclined to purchase firsthand goods with a shorter use span with a selective interest. The busy frugal nomads are fairly independent and study oriented with a financially constrained situation and a relatively self-reliant way of living with a sense of pride, responsibility and concern. They live in a temporary arrangement of shared living spaces, typically one room, shared kitchen, living and bath. They opt for cheaper second hand options for furnishings due to constrained budgets. They do not wish to own things which could not be left behind or thrown away. They live a lifestyle similar to nomads, hence moving multiple times (Srivastava & Culén, 2019).

The steady independent movers have set career goals, a full time job and a higher steady income. They have no financial dependencies on family or constraints of student life, hence no shared spaces. They have more personal spaces with close friends, partner or on their own strongly influenced choices and patterns of acquisition of things, furnishings and personal belongings. Their nomad belongings have been discarded and they have a preference for new acquisitions. Even though this group has experienced more stability in their life, the lifestyles often continue to be transient. They feel the need for renting an apartment rather than buying a new one. They wish to explore more work opportunities leading to changes in residences frequently (Srivastava & Culén, 2019). Building a career is not a primary motivator for most. Instead, work is a less significant part of their personal identities, instrumenting and supporting the lifestyle they desire (Marston, 2007). They are likely to communicate an interest in flexible career paths because their priority is work life balance (Carless & Wintle, 2007; Wey Smola & Sutton, 2002) to balance play with work. They prioritise close personal relationships over career and have diverse personal interests outside the workplace (Myers & Sadaghiani, 2010). Things they own are still not perfect but till the flux continues it is okay, but after the situation resides, they would make some changes. They prefer it trendy and are attached with their possessions (Srivastava & Culén, 2019).

### **3.4.5 Millennials and Green Consumption**

Millennials grasp the environmental consequences of their actions and have the education, motivation and social awareness to participate in the green movement. However they have not begun to fully integrate their beliefs and actions. Green consumption is strongly influenced by consumer values, norms and habits (Peattie, 2010). For millennials, being environmentally friendly is key to attracting their interest, and they seek brands they regard as having a positive effect on the environment (Rosenburg, 2015). Some suggest that millennials are more attitudinally green than behaviourally green and appear to have a lack of personal involvement in green related activities regarding recycling, reusing and using (Diamantopoulous et al, 2013; Grønhøj & Thøgersen, 2009; Johnson et al, 2004; Uyeki & Holland, 2000). Some show a divide in millennial's green consumption habits based on variable such as ecological knowledge (Kanchanapibul et al, 2014), lifestyle (Jang et al, 2011), social influence (Lee, 2008; Muralidharan & Xue, 2016), transfer of environmental attitudes from parents to children (Casaló & Escario, 2016; Meeusen, 2014) and even gender (Anvar & Venter, 2014; Lappänen et al, 2012). Environmentally concerned individuals may also influence other individual's green purchase intent through the exertion of social pressure as family, relatives, peers and friends, which in turn may enhance the sense of control by reducing the perceptions of obstacles in terms of resources, opportunity and time (Paul et al, 2016).

Millennial consumers value accessibility, affordability and quality, while green products are often associated with inconvenience, high costs and lower performance (Chen & Chai, 2010; Mainieri et al, 1997; Newman, 2014). Despite growing up during a time of technological change, globalization and economic disruption, this group continues to be most willing to pay extra for sustainable offerings. For those willing to spend more, personal values outweigh personal benefits, such as cost or convenience (Nielsen, 2015). Millennials are also more supportive of stricter environmental laws, more likely to attribute global warming to human activity, and likely to favour environmentally friendly policies such as green energy development and economic incentives for sustainability (Kohut et al, 2011).

Millennials neither select the environment over their personal comfort/convenience, nor consider themselves to be personally responsible to change their behaviour to positively impact the environment (Grønhøj & Thøgersen, 2009). The strength of pro-environment attitudes and behaviours among millennials depends on individual and personal characteristics. Selfless altruism, which is a motivational state with the goal of increasing another's welfare (Batson, 1991), has been argued to be a quality that millennials are lacking (Twenge & Campbell, 2009; Twenge & Foster, 2010). This generation has been characterized as selfish, individualist, entitled and even narcissist, leading Twenge (2006) to label it as 'Generation Me'. People are normally motivated to engage in pro-environmental behaviour because they inherently care about the environment and its human occupants. Therefore, altruism maybe a strong motive for some individuals, leading them to act environment friendly (Naderi & Steenberg, 2018). People who have satisfied their personal needs are more likely to act ecologically because they have more resources (time, money, energy) to care about bigger, less personal, social and pro-environmental issues (Kollmuss & Agyeman, 2002). This state of 'actively caring' can only occur if personality factors related to self-affirmation (i.e, self-esteem, belonging and personal control) have been satisfied (Geller, 1995). It is worth noting that millennials may lack some of these qualities, as they are still in their early stages of adulthood and independence.

Some studies claim that the increased enthusiasm for green products is partly due to consumer's perception of green as 'money saving', rather than support the environment; and this sentiment is higher among millennials (Rosenburg, 2015). Frugality (the quality of being economical with money and avoidance of waste) and economic motives are particularly critical in millennials decision making, as their financial resources are limited. Millennial's purchase habits are shaped by both strong eco-friendly ideals combined with an economizing mindset (Naderi & Steenberg, 2018). Future oriented millennials are more easily persuaded by the long term benefits of environmental interventions and would accept delays of immediate gratification to achieve longer term better goals and would be willing to invest effort and resources in current activities that have a distant payoff and would endure unpleasant current situations that have the potential for positive future outcomes (Zimbardo & Boyd, 2015).

The more individuals perceive potential risks in their environment, the more they are motivated to perform green behaviours (Seguin et al, 1999), hoping it will reduce the risk of living in a deteriorating environment in the future. While millennials are described as a risk-averse generation, this characterization does not translate into pro-environmental actions. This could be because in the context of environmental conservation, risks that may directly impact an individual are generally shorter in scope compared to those that may impact the environment. Therefore, millennials do not perceive their green consumption behaviours as endeavours that reduce the potential risk on themselves. It appears millennials tend to go green only when the benefits of themselves outweigh the costs, thus creating a disconnect between selfless altruism and their green consumption behaviours (Naderi & Steenberg, 2018).

Self oriented motives such as concern for self image, status seeking and need for admiration significantly motivate pro-environmental actions in young consumers (Griskevicius et al, 2010; Lee, 2008; Naderi & Strutton, 2015). There exists a strong belief that 'environmental change will happen only when it is in people's self interest' (Twenge & Campbell, 2009). It can be concluded that rational and self-oriented motives rather than emotional and others-oriented motives are more important in predicting millennials' commitment to act environmentally friendly (Naderi & Steenberg, 2018).

### 3.4.6 Ways to Promote Green Consumption amongst Millennials

Instead of being conceptualized as a single niche market, millennials should be treated as a collection of submarkets that differ in their levels of awareness of ethical issues, consider discrete motives when making consumption decisions, and are willing to engage in cause related purchasing to varying degrees (Bucic et al, 2012). As consumers look for tangible green product benefits, economic rationality is still a big player in this field. Green brand will have to reconcile this changing mindset with products that have historically commanded a price premium. Environmental regulators and law makers should continue their efforts to provide economic incentives to encourage pro-environmental purchases among millennials. Additionally, marketers of green products may pursue self-directed targeting strategies in promoting green products among millennials (Naderi & Steenberg, 2018).

To access frugality as an influencer, marketers must demonstrate the complete value of the product or brand to win millennials' favour. The value must not be an environmental one alone, rather playing to millennials' frugality, marketers must communicate cost savings to millennial shoppers over time. Messages with an emphasis on the importance of improving the environment for the well-being of society may not strongly influence millennials' green behaviour. An emphasis of future outcomes of acting environmentally friendly could be an effective strategy for promoting green consumption (Naderi & Steenberg, 2018).

A natural implication for green marketers and policy makers is to clearly communicate how taking small steps today leads to significant outcomes tomorrow. Using risk attached to acting irresponsibly towards the environment as the main appeal of the promotional message may not be an effective strategy in persuading this generation to behave greenly unless the direct link between the promoted product and its ecological consequences is shown and emphasized clearly (Naderi & Steenberg, 2018). Impressions and conversations with sellers are essential to shaping the attitude towards the object that millennials want to buy. Everything related to a specific transaction, starting from a way the object is presented on a platform, interactions (email, telephonic, in person meetings), all of them matter to the millennial. Thus, sustained and positive social frictions is an opportunity to scaffold trust and familiarity in relation to the service (Srivastava & Culén, 2019).

Enhancing the perceptions of ease with which the green products can be acquired and making green products easily available to consumers with minimum efforts may help marketers to expand their market (Chaudhary & Bisai, 2018). Marketers can think of broadening the green choices and improving the accessibility of green products through enhanced research and development and opening alternative channels of distribution respectively (Paul et al, 2016). This will reduce the perceived difficulty of acquiring green products and enhance consumers' perception of control.

In order for an environmental claim to have an impact on consumers, the claim should not be too strong, so that it will not be viewed as unachievable, but it should also not be too weak or it will be considered trivial, thereby making a moderate claim most effective (Manrai, 1997). For marketers wishing to promote the environmentalism of their product and organisations targeting environmental practices, they would be best served by targeting individuals that are already active in environmental causes and highly involved with environmental issues (Furlow & Knot, 2009). Enterprises who take the trouble to get to know the millennial generation can achieve very successful outcomes, and those who don't can find 'a brick wall of cynicism' to bump into (Nowak et al, 2006).

### 3.4.7 Inferences from the Client

The following are the inferences from the client assessment :

#### Changing Demographics and Market Strategies

1. **Green Consumer Demographics:** Since the demographic composition of green consumers has changed over the last decade, the stage has been set for a green revolution with green marketers.
2. **Understanding Millennials:** Understanding the millennial generation cohort and their key influences allows businesses to anticipate preferences and plan product production accordingly.

#### Characteristics of Millennials

3. **Digital Natives:** Millennials, a generation of young adults, have grown up during a period of rapid change and are highly influenced by globalization, communication, and information technologies.
4. **Waithood and Job Changes:** The apparent 'waithood' in millennials' lives makes them prone to frequent job changes, but also inclines them towards making a difference in the world and their community.
5. **Trendsetters and Environmental Commitment:** Millennials are early adopters of new trends and technologies, with broader perspectives, and are more committed to environmental causes and healthier lifestyles.

#### Economic Impact and Consumer Behavior

6. **Family Purchase Decisions:** Apart from their distinctive perspectives, millennials have a larger indirect economic impact as they are involved in family purchase decisions.
7. **Powerful Consumer Group:** With a sheer size of 1.8 billion globally, including 400 million young consumers in India, millennials constitute more than one-third of the country's working population, making them the most powerful consumer group in the marketplace.
8. **Green Attitudes vs. Behaviors:** While every millennial consumer behavior archetype grasps the environmental consequences of their actions, they are more attitudinally green rather than behaviorally green, showing a lack of personal involvement in green-related activities like recycling and reusing.

#### Willingness to Pay and Support for Environmental Policies

9. **Sustainable Offerings:** Millennials continue to be most willing to pay extra for sustainable offerings.
10. **Support for Environmental Laws:** They are more supportive of stricter environmental laws, likely to attribute global warming to human activity, and favor environmentally friendly policies.

#### Frugality and Economic Motives

11. **Decision-Making Factors:** Frugality and economic motives are critical in a millennial's decision-making process due to their limited financial resources.
12. **Future-Oriented Persuasion:** Future-oriented millennials are more easily persuaded by the long-term benefits of environmental interventions and are willing to delay immediate gratification for longer-term goals.

### **Motivations and Market Strategies**

13. **Rational vs. Emotional Motives:** Rational and self-oriented motives are more important in predicting millennials' commitment to act environmentally friendly rather than emotional and others-oriented motives.
14. **Submarket Diversity:** Millennials should be treated as a collection of submarkets that differ in their levels of awareness of ethical issues.
15. **Value Demonstration:** To access frugality as an influencer, marketers must demonstrate the complete value of the product or brand to win millennials' favor in terms of frugality, economy, and strategy of persuasion.
16. **Emphasis on Future Outcomes:** Emphasizing future outcomes of acting environmentally friendly could be an effective strategy for promoting green consumption.

Millennials can be seen as the specific client base to disseminate green consumerism through bamboo designs as they will be appreciated by their behavior. Since exploration of bamboo material in modern designs is still new, basing Millennials as clients in the initial ventures would be failsafe. The consumer dynamics amongst other generations can be analysed as well to deliver marketing strategies and products to promote bamboo designs amongst them.

In the current age of information, apart from consumer behaviour, validated information towards pro-environmentalism is sought by the consumers. It can be done by delivering the complete environmental value of the product. When considering bamboo products, the material has been very meekly discussed in numbers towards the environment. Bamboo as a material must be validated numerically against its competing materials in the market such as wood, plastic and steel, to go ahead in this pursuit of exposure and promotion amongst millennials.

In order to establish the eco-friendliness of the material, an assessment has been conducted in the following two chapters through a validated system. This will help towards the transmission of knowledge and also will proactively be useful in influencing decisions towards eco-consciousness amongst the current millennial generation.

## CHAPTER 4 :

### LIFE CYCLE ASSESSMENT

#### 4.1 Introduction

In Chapter 2, the relationship between sustainability and Indian craftsmanship has been established through Eco-Design Principles. It was established that bamboo craftsmanship is compatible to the sustainability principles, though it was not clear regarding how to translate the compatibility in numbers. Thus, this chapter introduces Life Cycle Assessment (LCA) which shall be able to analyse the sustainability of bamboo material and its craftsmanship numerically. It is one of the most well-known methods of Eco-Design implementation. The chapter explains in detail the characteristics, history and applications of LCA towards sustainability, along with philosophies, techniques and critical observations of the assessment. The information shall guide the LCA to be conducted in the research for bamboo domain.

#### 4.2 Eco-Design in Brief

Out of the many reasons for our environment problems, massive population growth and an increase in relative wealth (and thus growing consumerism) in a global level are two significant contributors to the strain on our fragile ecosystem. Our growing consumption lies directly or indirectly at the root of a great deal of pollution and depletion of resources (Commission of European Communities, 2001).

Environmental impacts are caused by every product in some way or another, from the extraction of raw materials, through their production and use, to the management and final disposal of waste (Baumann et al, 2002). It is estimated that 80% of a product's environmental performance is fixed during the early phases of development process (McAloone & Bey, 2011). It is during product development that materials, technologies and the product's lifetime are decided. The product developer has thus a great influence on the product's life cycle and therefore also on the later occurring environmental impacts and environmental performance of the product. For this reason, it is important that the product developer integrates environmental considerations carefully and systematically into the product development activity (McAloone & Bey, 2011). This integration of environmental consideration into product development is called Eco-Design.

The goal of Eco-Design is to minimize environmental impacts throughout the product's life cycle, without compromising other essential criteria such as performance, functionality, aesthetics, quality and cost (Jonahsson, 2002 and Van Weenen, 1995). Eco-Design calls on the knowledge and competencies of many disciplines in the product development process, as considerations about materials, processes, logistics, recyclability, and many more, are likely to arise as potential contributors to an improved environmental profile of the product design in hand (Brones & Carvalho, 2015). Environmental thinking in product development leads to efficient products, which are both economically viable to produce, cheaper to operate and maintain, and more robust during their lifetimes. (de Caluwe, 2004 and Eagen & Finster, 2001).

### 4.3 Life Cycle Assessment and Eco-Design

Life Cycle Assessment (LCA) is one of the most well known methods of Eco-Design implementation (Brezet et al, 1999; Cappelli & Delogu, 2006; Hunkeler & Vanakari, 2000; Munoz et al, 2006). It provides a quantification of environmental aspects and impacts across the product life cycle and supports the intermediate concepts and design options. LCA involves all successive stages of a product life cycle, ranging from extraction of raw materials through the environmental impacts of manufacturing, distribution and use of the product, all the way until its final disposal, which may include subsequent activities such as recycling of materials and components, plus other ways of treating post consumption (Azapagic & Cliff, 1999).

LCA has gained broad acceptance in industry as a trustworthy method to quantify the environmental aspects and potential impacts of the life cycle of products. The LCA methodological framework is defined by ISO 14040 and 14044 standards (ISO 2006a,b) which describe the minimum requirements for its correct use and performance. The holistic systems perspective, which is applied in LCA, enables the company to disclose the ‘problem shifting’ which occurs when solutions to environmental problems at one place in a product’s life cycle create new problems elsewhere in the life cycle (Jeswiet & Hauschild, 2005).

### 4.4 Main Characteristics of LCA

LCA takes a life cycle perspective when evaluating environmental impacts of a product or a system, while considering multiple environment issues (and sometimes social issues) when evaluating the same. The core reason for taking a life cycle perspective in LCA is that it allows identifying and preventing the burden shifting between life cycle stages or processes that happens if efforts for lowering environmental impacts in one process or life cycle stage unintentionally create (possibly larger) environmental impacts in other processes or life cycle stages (Bjørn et al, 2018).

In LCA, the comprehensive coverage of processes over the life cycle is complemented by a comprehensive coverage of environmental issues. These issues include climate change, freshwater use, land occupation and transformation, aquatic eutrophication, toxic impacts on human health, depletion of non-renewable resources and eco-toxic effects from metals and synthetic organic chemicals. LCA results are quantitative, thus can be used to compare environmental impacts of different processes and product systems. It tries to answer the question ‘How much does a product system potentially impact the environment?’.

LCA results are calculated by mapping all emissions and resource uses and if possible, the geographical locations of these, and use factors derived from mathematical cause/effect models to calculate potential impacts on the environment from these emissions and resource uses. The first step often involves thousands of emissions and resource uses. In the second step, the complexity is reduced by classifying these thousands of flows into a manageable number of environment issues, typically around 15. Quantifications generally aim for the ‘best estimate’, meaning the average values of parameters involved in the modelling are consistently chosen.

The quantification of potential impacts in LCA is rooted in natural science. Flows are generally based on measurements. The models of the relationships between emissions (or resource consumption) and

impact are based on proven casualties, or an empirically observed relationships. On top of its science core, LCA requires value judgement, which is most evident in the optional step of assigning weights to different types of environmental problems to evaluate the overall impact of a product system. LCA strives to handle value judgement consistently and transparently and in some cases, allows practitioners to make modelling choices based on their own values (Bjørn et al, 2018).

#### **4.5 Strengths and Limitations of LCA**

A main strength of LCA is its comprehensiveness in terms of its life cycle perspective and coverage of environmental issues. This allows comparison of product systems. However, the comprehensiveness is also a limitation, as it requires simplifications and generalisations in the modelling of the product system and the environmental impacts that prevent LCA from calculating actual environmental impacts. It is more accurate to say that LCA calculates ‘impact potentials’.

Another strength in the context of comparative assessments is that LCA follows ‘best estimate’ principle, which allows for unbiased comparisons as the same level of precaution is applied throughout the impact assessment modelling. A limitation to following the ‘best estimate’ principle is that LCA models are based on the average performance of the processes and do not support the consideration of risks of rare but very problematic events like marine oil spills or accidents at industrial sites.

A final limitation worth keeping in mind is that while LCA can tell what (product system) is better for the environment, it cannot tell if better is ‘good enough’. It is therefore wrong to conclude that a product is environmentally sustainable, in absolute terms, with reference to an LCA showing that the product has a lower environmental impact than another product (Bjørn et al, 2018).

#### **4.6 LCA History**

The idea of LCA was conceived in the 1960’s when environmental degradation and in particular the limited access to resources started becoming a concern. LCA had its early roots in packaging studies and focused mainly on energy use and a few emissions, spurring a largely un-coordinated method development in the US and Northern Europe. Studies were primarily done for companies, who used them internally and made little communication to stakeholders.

After a silent period in the 1970’s, the 1980’s and 1990’s saw an increase in methodological development and international collaboration and coordination in the scientific community and method development increasingly took place in universities. With the consolidation of the methodological basis, application of LCA widened to encompass a rapidly increasing range of products and systems with studies commissioned or performed by both industry and governments, and results were increasingly communicated through academic papers and industry and government reports (Bjørn et al, 2018).

To this day, methodological development has continued and increasing attention has been given to international scientific consensus building on central parts of the LCA methodology, and standardization of LCA and related approaches. Today, LCA is defined as ‘a tool to assess potential environmental impacts and resources used throughout a product’s life cycle, i.e., from raw material acquisition, via production and use stages to waste management.’ (ISO 2006b).

Life cycle oriented methods that were precursors of today's LCA were developed in the 1960's in collaboration between universities and industry. They were known as Resource and Environment Profile Analysis (REPA) (Hunt et al, 1992), or Ecobalances until the term LCA became the norm in the 1990's.

Early methods were material and energy accounting focused on inventorying energy and resource use, emissions and generation of solid waste from each industrial process in the life cycle of product systems. As inventories got more complex, the initial focus was gradually extended with a translation of the inventory results into environment impact potentials. In other words, from a list of resource uses and emissions, a set of indicator scores for an assessed product was calculated, representing contributions to a number of impact categories, such as climate change, eutrophication and resource scarcity (Bjørn et al, 2018).

Early impact assessment methods tended to represent impacts from emissions in the form of dilution volumes of air or water needed to dilute the emissions to safe levels, or below regulatory thresholds (Ahbe et al, 1990). During the 1990's many impact assessment methods evolved and the ambition since then has been to quantify all relevant environmental impacts, independent of shifting public concerns, with the goal of avoiding burden shifting. First was CML92 (Heijungs et al, 1992) developed by the Institute of Environmental Sciences at Leiden University, Netherlands, which covered a comprehensive set of midpoint impact categories. Second, Swedish EPS method (Steen, 1999a,b) focused on the damage to ecosystems and human health. Third, Dutch Eco-Indicator 99 methodology was released with a more science based approach to the damage modelling (Goedkoop & Spriensma, 2000).

The early 1990's saw the birth of a number of life cycle inventory databases maintained by different institutions and organisations covering various industrial sectors. Due to difference in data standards and quality, the resource uses and emissions of industrial processes could differ substantially. This situation was resolved with the release of the first Ecoinvent database (v1.01) covering consistent data standards for all relevant industrial sectors in 2003 (Ecoinvent 2016). A dedicated LCA software was released in 1990 called SimaPro and GaBi (Thinkstep, 2016 & PRé, 2016). EDIP2003 method (Hauschild & Potting, 2005) was released after the realisation of possibility of large differences in the sensitivity of the environment receiving the impacts. It was able to spatially differentiate non-global impacts such as eutrophication and acidification.

With the globalisation of production and an increased focus on bio-based products in LCA, methods for impact assessment of extraction related impacts have seen a lot of activity in the 2000's and 2010's. Acknowledging that sustainability also has a social dimension, a growing activity has attempted to develop methods for social LCA to quantify social impacts of product life cycles. A framework of life cycle sustainability assessment (LCSA) has emerged for performing assessments and aims to take into account an environmental, social and economic dimension of sustainability.

A 2006 survey of LCA practitioners found that LCA results were primarily used in business strategy, research and development and product or process design, but that education, policy development and labelling product declarations were also frequent uses (Smith Cooper & Fava, 2006). A similar survey from 2011 found that most practitioners made LCA studies in the agriculture (56%) & food sectors (62%), while practitioners working with other consumer goods (38%) and energy (37%) industries were somewhat less frequent (Teixeira & Pax, 2011).

The first LCA supported Nordic Ecolabel was initiated in 1989 to guide consumer towards products with the lowest environmental impacts, and the number of product categories covered by criteria grew rapidly under this and other ecolabels like the European Flower Label and the German Blaue Engel. Several European countries launched national product oriented environmental strategies with LCA as the methodological backbone presaging the European Integrated Product Policy (IPP) to be adopted at EU level in 2003 with policy instruments like the aforementioned ecolabels, environmental product declarations, green public purchase and integration of environmental aspects into standards development (Bjørn et al, 2018). The year 2008 became an important year in the history of LCA for policy support, as the European Commission initiated its Sustainable Consumption & Production and Sustainable Industry Policy (SCP/SIP) Action Plan, incorporating the previous IPP and waste and resource strategies and having LCA as the analytical backbone, but this time without the micro management regulation scope explores by the US EPA three decades earlier (Bjørn et al, 2018).

The global society of Environment Toxicology and Chemistry (SETAC) organised a workshop on 'A Technical Framework for LCA'. It was a series of workshops in 1990's, the first conducted in 1991, in Europe, Japan and North America. The work on this international fora was building on several important national and regional methodology development projects like the Nordic LCA Guideline Project (Nordic Council of Ministers, 1992 and Lindfors et al, 1995), the Dutch Handbook (Guinée et al, 2002) and the Danish EDIP Project (Wenzel et al, 1997 and Hauschild & Wenzel, 1998). In the 1990's late, SETAC reached out to the United Nations Environment Program (UNEP) to create a partnership to ensure further development in good LCA practice and global dissemination. This UNEP/SETAC Life Cycle Initiative was launched in 2002 and has increasingly focused on the dissemination of life cycle practices to the emerging economies and support with access to tools and data by delivering an authoritative status with a formalized review procedure.

Taking off after the development of the SETAC code of practice for LCA in 1993, a formal standardization process was initiated under the auspices of the International Organisation of Standardization (ISO) to develop a global standard for LCA. The standard was to meet concerns from industry who increasingly wanted to use LCA for product development and marketing of green products, but experienced that a lack of standardized methodology meant that different studies of the same product could give opposite results depending on the concrete methodological choices. The standard development resulted in the adoption and release of four standards over the next seven years, addressing the principles and framework (ISO 14040), the goal and scope definition (ISO 14041), the life cycle impact assessment (ISO 14042) and the life cycle interpretation (ISO 14043). In a 2006 revision, the later three were compiled in the ISO 14044 standard detailing the requirements and guidelines, without changing any requirements in the standards. The ISO 14040 series standards concern the LCA methodology, but in the ISO 14000 series of Environment management Standards, there are also standards and technical guidance reports on the applications of LCA, for e.g. Eco-Design (ISO 14062, ISO 14006), communication of environmental performance (ISO 14020 series on Ecolabels and ISO 14063), and greenhouse gas reporting and reduction (ISO 14064).

LCA methodology was very nascent in the 1990's, and the resulting standards are therefore not very detailed on specific methodological choices but rather focused on the framework and the fundamental principles of LCA. This is one of the reasons why the work of the UNEP/SETAC Life Cycle Initiative was needed to evaluate alternative practices and develop recommendations from a scientific point of

view. It was also the background for a process initiated by the European Commission in the mid-2000's to develop an International Life Cycle Data System (ILCD) with a database of life cycle inventory data and a series of methodological guidelines. The ISO standards left too many possibilities for ambiguities in the applied methodology and in a consultation process, the EU Commission's Joint Research Centre's Institute for Sustainability and Environment developed a comprehensive guideline in LCA (EC-JRC 2010) that builds on the ISO 14040 and 14044 standards, and over 394 pages specifies the majority of the methodological choices that are left open by the ISO standards. The collection of best practices for each impact category was compiled as the ILCD impact assessment method (EC-JRC 2011). After the release of the ILCD guidelines in 2012, the EU Commission launched the Product Environment Footprint (PEF) and Organizational Environment Footprint (OEF) Guidelines as abbreviated and slightly revised versions of the ILCD guidelines targeting different categories of products or services to be applied by companies and organisations reporting on their environmental performance (Bjørn et al, 2018).

#### **4.7 LCA Applications**

In 2001, UNEP and SETAC joined forces in the launch of a Global partnership to strengthen the dissemination and use of LCA worldwide, known as the Life Cycle Initiative (LCI). The purpose of it was 'to enable users around the world to put life cycle thinking into effective practice'. Another initiative was the European Commission's Project, the European Platform of Life Cycle Assessment, launched in 2005. Its objective was 'to promote life cycle thinking in business and in policy making' in the European Union by focussing on underlying data and methodological needs. The Integrated Product Policy (IPP) by the European Commission (EC) promotes minimizing environmental impacts of products by considering all stages of their life cycle (Mudgal, 2008). The IPP comprises various instruments and tools ranging from influencing the market to subsidies to industries, which establishes a regulatory framework for eco-design of products. This has helped to shift focus from manufacturing to the use of products and their disposal (Wenzel et al, 1997 and Azapagic & Perdan, 2000).

A major challenge to the application of LCA in these contexts is the communication of environmental performance of products. To facilitate reliable and reproducible information about the environmental performance of products and organisations, the EC has elaborated LCA based methods for PEF and OEF (Finkbeiner, 2014 and Galatola & Pant, 2014).

The application of LCA in enterprises can be classified into five main purposes (Huang & Hunkler, 1995, Bültmann, 1997, Hannsenn, 1999, Baumann, 2000, Heiskanen, 2000, Frankl & Rubik, 2000, Ekvall, 2012) :

- Decision support in product and process development
- Marketing Purposes (Eco-labelling)
- Development and selection of indicators used in monitoring of environmental performance or products or plants
- Selection of suppliers or sub-contractors
- Strategic planning

Though LCA has been traditionally developed at a products level tool, there has been an increasing interest in using LCA at the corporate level to reflect company performance or individual plants in life

cycle perspective. At product level, LCA is often used during product development and for identifying environmental hotspots of a product or process either within the organisation or in its supply chain.

As public concerns towards environment have increased and consumers have become more environmentally conscious, enterprises have also played a larger focus on quantifying their environmental performance using LCA and communicating this to the public as a way to brand their enterprise as green. Here, the major company expectations to the use of LCA are to get a competitive advantage and to increase the company image or reputation (Broberg & Christensen, 1999).

Companies may want to carry out LCA to better understand their environmental performance in an effort to implement Environmental Management System (EMS) (Lewandowska et al, 2013, 2014). EMS is a tool 'to implement a structured program of continual improvement in environment performance' and 'a tool to manage and communicate and enterprise's environmental performance to internal and outside parties' (Lombardo, 2012).

A major challenge seems to be putting the results into practice mainly due to lack of power or information of stakeholders along the product supply chain (Nakano & Hirao, 2011). SME's lack being large companies in the implementation of LCA (Johnson & Schaltegger, 2015). The major reasons are thought to be the cost of an LCA, the need for change in the workplace routines, perceived complexity in the LCA methodology and shortage of qualified personnel to carry out and LCA (Kurczewski, 2013). A downside of LCA is that it becomes too comprehensive and too complex to be easily understood, leaving an impression of a 'Black Box' (Zackrisson et al 2008). A closer collaboration with an LCA expert was found to resolve this problem in some cases (Zackrisson et al, 2008).

Johnson and Schaltegger (2015) reported the major barrier for implementation of sustainability management tools (including LCA) by SME's were lack of awareness of sustainability issues, absence of perceived benefits, lack of knowledge and expertise on sustainability issues and lack of human and financial resources, insufficient external drivers and incentives, unsuitability of formal management tools to fit the often informal and flexible SME structure and complexity of tools. While the use of LCA by SME's was considered marginal (as of 2012), it is however reported to become more and more common (Baumann et al, 2012, Schischke et al, 2012, Kurczewski, 2013). This may be due to the increased legislative focus on environmental performance, and the potential market benefits from having an environmentally friendly profile (Pamminger, 2011). SME's are eager to contribute to an LCA when a dedicated and sufficient budget is available. SME's typically find interest in identifying impact reduction opportunities, particularly those stemming from activities in the life cycle on which they themselves exert some influence.

LCA results can also serve as decision support for individuals, as citizens or consumers, mostly related to the private consumption of goods and services. Consumer decisions that maybe supported by an LCA can range from choosing a product from a range of similar products which has the lowest environmental impact over choosing the most sound way of fulfilling a function to most effectively reducing the total personal environmental impact. Also citizens might be indirectly affected by LCA results when following political decisions, such as waste management.

## 4.8 LCA and Sustainability

Most common interpretations of the Brundtland Commission's Report 1987 'Our Common Future Report' comprise of four dimensions :

- Measure of welfare
- Inter-generational Equity
- Intra-generational Equity
- Interspecies Equity

The Brundtland Report is named after its chairperson Gro Harlem Brundtland (WCED, 1987). It was a response to one, the growing disparity between the North and the South, and two, to the increased awareness that many of the natural systems on which we depend were under increasing stress. Development of the South was seen as urgently needed, but the development had to be achieved in an environmentally sound way which would allow for a continued thriving of the world's population - also in the future, in other terms, 'Sustainable' - 'development that meets the needs of the present without compromising the ability of the future generations to meet their own needs'. This depends strongly on the life support functions of the Earth, and this, is a concern for the health of the environment. LCA in many regard can be seen as stemming from the same concern of environmental protection (Moltesen & Björn, 2018).

Sustainable development is the process or journey to achieve sustainability. Researchers, especially from the economic discipline, have omitted the focus on the needs of the present and claimed that sustainability is simply about ensuring that the total utility or welfare of a society can be maintained over an infinite time horizon (Moltesen & Björn, 2018). Definitions of Sustainability are anthropocentric, and has no explicit consideration. Primary focus is inter-generational equity, because natural resources and services are seen as the foundation for society, such as crops, clean air, protection from UV rays etc. Thus, protecting environment to give future generations the same possibilities for achieving the levels of welfare that current generations are experiencing.

Protection of environmental concerns relates to intra-generational equity on similar grounds. The extent to which the environment should be protected as a condition for the inter-generational equity dimension of sustainability is, however, not clear cut. Keeping this in mind, researchers have attempted to quantify carrying capacities of ecosystems that must not be exceeded to maintain functions and other ecosystem aspects of interest.

At the global scale, planetary boundaries have been proposed and tentatively quantified. Planetary boundaries can be interpreted as carrying capacities for the entire Earth system towards various anthropogenic pressure, such as green house gases and interference with nutrient cycles. If exceeded, there is a substantial risk that the Earth system will change form from its well-known and relatively stable state that has characterised the Holocene geographical epoch in the past 12,000 years to an unknown state (Rockström, 2009 and Steffen et al, 2015a).

The planetary boundaries are :

- Climate Change
- Novel Entities
- Stratospheric Ozone Depletion

- Atmospheric Aerosol Loading
- Ocean Acidification
- Biochemical Flows (Phosphorus and Nitrogen)
- Freshwater Use
- Land-system Change
- Biosphere Integrity (Genetic and Functional Diversity)

Out of the nine planetary boundaries, for four of them, namely Climate change, Biochemical Flows, Land-system Change and Biosphere Integrity, mankind has already surpassed their respective carrying capacities beyond zone of uncertainty (Steffen et al, 2015a). Overall drivers that lead to environmental deterioration can be addressed by the IPAT equation, by Holdren & Ehrlich (1974)

$$I = P.A.T$$

where, I - Environmental Impact

P - Population

A - Per Capita Affluence

T - Technology Factor

The formula expresses that the overall impact on the environment is controlled by the number of planet people, their affluence, expressed in material affluence per person and technology's environmental intensity, expressed in environmental impact per material affluence.

While the world population has tripled from 1750 to 2010, all the indicators of affluence such as GDP, transportation and paper production, have increased at higher rates, increasing the per capita affluence 'A'. This has highered the value of 'I'. This means that technological improvements in environmental impact per material affluence 'T' have been insufficient for maintaining environmental pressures and impacts at a status quo, let alone for decreasing them.

Two of the three parameters, the number of people and their affluence, is difficult to handle. The number of people can be regulated either by increasing mortality or by reducing fertility, but in most parts of the world, this is not in the political agenda, rather the opposite, to increase people for political motives. Regarding affluence, for intra-generational equity, there is a need for increasing the affluence of the ones mostly in need. Reducing the overall affluences while increasing the affluence of the poorest inevitably calls for a decrease in the affluence of the richest part of the world population which is a difficult program for a political party striving for (re)election in a liberal democracy. Thus, what is left is the development of technology, which can allow us to regulate the environmental impact per consumed unit (T). To increase the output or functionality while keeping a constant environmental impact corresponds to increasing what is often termed eco-efficiency. According to the World Business Council of Sustainable Development, 'eco-efficiency' is achieved by the delivery of completely priced goods and services that satisfy human needs and bring quality of life while progressively reducing environment impacts of goods and resource intensity throughout the entire life cycle to a level at least in line with the Earth's estimated carrying capacity (WBCSD, 2000).

LCA shows how a specific functionality can be achieved in the most environmentally friendly way among a predefined list of alternatives, or in which parts of the life cycle it is particularly important to improve a product to reduce its environmental impacts, in other words, increase its eco-efficiency. LCA

can therefore be seen as a methodology that can guide decisions towards improving one of the three dimensions in the IPAT equation, namely the Technology ‘T’ dimension.

Moreover, it has been proposed to expand LCA into Life Cycle Sustainability Assessment (LCSA) to also encompass social and economic aspects, in addition to environmental aspects of sustainability when analysing product life cycles (Kloepffer, 2008 and Zamagni, 2012). LCSA builds on the three pillars of sustainability, environmental, social and economic from the concept of ‘Triple Bottom Line’ (Elkington, 1997). Kloepffer (2008) proposed the following scheme for LCSA :

$$\text{LCSA} = \text{LCA} + \text{LCC} + \text{SLCA}$$

where, LCC - Life Cycle Costing (aiming to quantify all costs in a life cycle)

SLCA - Social Life Cycle Assessment (goal of assessing social impacts of products over its life cycle)

LCSA conflicts with the concept of carrying capacity as it is based on the assumption that a decrease in one sustainability dimension can be compensated by an increase in another dimension. To be overall sustainable, a poor performance in LCA may be exceeding carrying capacities, which in the long term, threatens the meeting of human needs and thus social and economic sustainability. LCC’s relevance is applicable only when it is applicable to the poor for intra-generational equity.

Following the IPAT equation, and knowing the projections for the population growth and the goals for the increased in average affluence, it has been estimated that a factor of 4, or higher, increase in the eco-efficiency of technologies or products is needed just to ensure a status quo with regards to our impacts on the environment (Reijnders, 1998). For some technology and products, an increase in ‘T’ close to a factor 10 maybe required, since some planetary boundaries have already been exceeded.

While LCA can help identify the most eco-efficient solution, the actual eco-efficiency that we may achieve through redesign and technological interventions is in many cases insufficient. The increases that are gained in eco-efficiency on the product or technology can be counter balanced by increases in demand. Impacts on the environment quantified using LCA can be put into a sustainability perspective by relating them to environmental carrying capacities (Björn et al, 2015). But even when an absolute perspective is taken, LCA cannot, by itself, cover all relevant aspects of sustainability. Sustainability researchers have argued that the narrow focus on eco-efficiency will not suffice. We have to look at the necessity of services in the most eco-efficient way. There is a necessity to adjust the ‘A’ in the IPAT equation. Here, LCA falls short (Moltesen & Björn, 2018).

## 4.9 Conclusion

LCA is a standardized and pre-validated technique of ISO 14040 and ISO 14044 standards which describe the main requirements, use and performance of the assessment. The scientific models of relationship between consumption and emissions are based on measurements. LCA also requires value judgement to assign weights to environmental problems to evaluate overall impact. It is a comprehensive focus on product systems with continued methodological improvement since 1980’s. It considers both environmental and social issues while evaluating environmental impacts of a product or a system. It answers the question - ‘How much does a product system potentially impact the environment?’

As stated in the beginning of the chapter, a comprehensive knowledge about the process of LCA is gathered. Further information regarding its execution has been provided in Annexure B. The process, through its comprehensiveness, provides a clear guidance to execute assessment of sustainability in bamboo material and craftsmanship. By taking a step further, through a comparative LCA, bamboo has been compared with 5 different materials to answer the question in the following chapter - 'Where does bamboo stand in terms of environmental performance alongside other competing materials?'. The results would be used as a decision support for product and process development along with marketing purposes in the bamboo domain.



## COMPARATIVE LIFE CYCLE ASSESSMENT FOR BAMBOO FURNITURE

### 5.1 Introduction

The research has been taken forward by the conduction of a detailed Life Cycle Assessment of 5 different materials for making chair, namely bamboo craft, bamboo wood, plastic, steel and wood. The bamboo craft considered is the handmade manufacturing technique in a domestic context whereas bamboo wood entails machine manufacturing technique in an industrial context. The Life Cycle Assessment includes their Life Cycle Inventory Analyses and Life Cycle Impact Assessments. A comparative LCA has also been conducted amongst the materials to describe their relative impacts on the various indicators of environmental change.

For the conduction of the research, the researcher has visited multiple furniture making industries in Assam to collect raw data from industry sites. The data has been analysed to form frameworks and flow charts according to system boundaries. Further the data has been numerically programmed into OpenLCA 1.11 software using Ecoinvent 3.8 Database to deliver results and assessments in detail.

### 5.2 Goal Definition

#### 5.2.1 Intended Applications of the Results

- Comparing environmental impacts of bamboo craft, bamboo wood, plastic, steel and wood furniture
- Identifying the parts of a product system that contributes most to its environmental impact for all the above mentioned materials related to hotspot identification
- Evaluating improvement potentials in product design changes of bamboo furniture
- Documenting eco-costs of manufacturing processes of bamboo craft, bamboo wood, plastic, steel and wood furniture

#### 5.2.2 Limitations due to Methodological Choices

- The LCA has been conducted from Cradle to Gate which defines a system boundary from collection of raw materials to delivery in the market. The Gate to Grave phase consists of multiple user scenarios which provides less control over the results. Hence, the LCA has been conducted for the environmental impact during the manufacturing process within system boundaries, which is Cradle to Gate.
- The data collection from industrial sites has been conducted in the North East Region of India. Also, the metadata referred to in the Ecoinvent 3.8 database belong to this region. The results might reflect differently when considered a different location.
- For system modelling, a consequential approach has been considered as the attributions of each process flow is understood over a period of time. This might contain lesser datasets due to constraints on suppliers, technology and product manufacturing.

### 5.2.3 Decision Context and Reasons for Carrying out the Study

- The reason for carrying out the study is to understand the status of environmental consciousness in the product manufacture of furniture by using the five materials, i.e., bamboo craft, bamboo wood, plastic, steel and wood [Figure 5.1].
- Though bamboo has a socio-cultural context, the material has not yet been validated numerically in terms of its environmental compatibility. The study shall be to determine the same.
- The study is intended as a decision support and it is not expected to lead to any structural changes in other systems, thus a micro-level decision support.

### 5.2.4 Target Audience

- The comparative analysis is for entrepreneurs to give them confidence in investing towards bamboo as a material for furniture.
- Also to inform consumers about their decisions facilitated by their eco-sensitivity and validating their eco-conscious choices.

### 5.2.5 Comparative Studies to be disclosed to the Public

- The LCA to be performed is of comparative nature and is intended to be disclosed to the public.
- The study shall follow ISO 14040 and 14044 standards requirement on conduct and documentation of ensuring transparency and maintaining a good quality of study so that an external review process ensures that there are no potential consequences for external companies, institutions, consumers and other stakeholders.

### 5.2.6 Commissioner of the Study and Other Influential Actors

- The study is self-commissioned and financed by Indian Institute of Technology Guwahati, India for a Doctoral Research Project. No other party is involved.
- The researcher was the assimilator of the data and approaches to the industrial setups were conducted via IITG to the data provider to avoid misconduct and falsification of data, thus avoiding an unintentional bias of data collection.

## 5.3 Scope Definition

### 5.3.1 Deliverables

- The study shall be a compilation of Life Cycle Inventory (LCI) and Life Cycle Impact Assessment (LCIA) Results of the comparative LCA between bamboo craft, bamboo wood, plastic, steel and wooden chair.
- There shall be a transparency for LCI to be used as data sources for other LCA's.

### 5.3.2 Object of Assessment - A Chair

- **Functions :** A stable single person seating with a straight back and knees bent at 90 degrees (from the perspective of a user)

- **Declared Unit :** 1 unit of uni-material chair with no ornamentation and minimum material ranging from 3.5kg - 15kg, to hold a minimum of 120 kgs at residential indoor usage in India, manufactured in industrial setups in the North East Region of India.
- **Obligatory Properties :** Stable, seats one person with minimum holding capacity of 120 kgs, price cap comfortable with Millennial generation.
- **Positioning Properties :** Product aesthetics, colour and texture options, less cleaning hassle, water and termite proof
- **Reference Flow :** Varying for chairs of the different materials - bamboo craft, bamboo wood, plastic, steel and wood. It has been discussed in the Life Cycle Inventory section of this chapter.

### 5.3.3 LCI Modelling Framework & Handling Multifunctional Processes

- For system modelling, a consequential approach has been considered as the attributions of each process flow is sought to be understood over a period of time.
- In this modelling system, credits are given to reference product if the by-products are replacing the need for primary production elsewhere.
- There are constraints involved in this modelling system such as - only unconstrained suppliers are taken into consideration for the modelling and also only modern and new technologies are considered to be able to supply the market. Due to such constraints, lesser datasets are available for this modelling.
- The unit considered in the Ecoinvent 3.8 database are regionalised datasets which provides geographic specificity to the value.
- No multifunctional processes are involved in the manufacture of the chairs of different materials.

### 5.3.4 System Boundaries and Completeness Requirements

- The Cradle to Gate perspective defines the system boundary of the conducted LCA.
- An understanding of all the five categories of furniture is important, which shall be expressed in a flow chart according to Cradle to Gate. The boundaries of the system would include the requisite unit processes, and entail the elementary and waste flows.
- In the comparative study, quantitative completeness requirements shall be determined for each case of furniture.
- Also, identical processes shall be excluded from the study as it prevents the calculation of a proper hotspot analysis.

### 5.3.5 Representativeness of LCI Data

- **Geographical Representation :** The location of the background system mix shall be the state of Assam, and if required, NER region of India, to include the spatial coverage of regulation and geographical variation. The spatial extent of markets shall be considered pan India.
- **Time Related Representativeness :** The time frame of the study shall be from the year 2013 to 2023, considering a time span of 10 years, which has been considered due to the expected lifetime of furniture products from purchase to disposal and the availability of datasets.
- **Technological Representativeness :** The study shall include assessment and documentation of mechanical processes of materials delivered by heavy machinery with included softwares and low

to medium intensity hand tools without the integration of Artificial Intelligence. The technological compatibility and relativeness between the processes of the different materials shall be checked to meet quality requirements for input materials. The list of technologies shall be specified for representativeness requirements.

### 5.3.6 Preparing the Basis for the Impact Assessment

- The LCA shall be conducted by OpenLCA 1.11 version software using ReCiPe 2016 and Idemat Eco-costs 2023 methods. ReCiPe 2016 is a midpoint and an endpoint method, and is considered to calculate the environmental impacts of the different manufacturing processes. The method assesses 18 midpoint impact categories and the three areas of protection human health, ecosystem quality, and natural resources at endpoint level. Idemat Eco-costs 2023 method has 14 midpoint impact categories and is considered to calculate the eco-costs of the manufacturing process of different materials.
- OpenLCA software shall be used to model the product system and perform impact assessment and then LCIA scores shall be calculated for all the impact categories that are made available in the software as part of the ReCiPe 2016 and Idemat Eco-costs 2023 LCIA method.
- The results shall be discussed in a comprehensible manner since target audience is not an expert in LCA or its terminologies.

### 5.3.7 Special Requirements for System Comparisons

- The study shall be conducted by comparison between the same declared unit of a single person seating, and equivalent methodological considerations between the varying materials of furniture. Any differences in the conducted process shall be reported.
- Transparency and communication for comparison parameters shall be maintained. The inventory section contains details of data collection for LCA.
- The content of communication shall be checked to avoid misuse of LCA.

### 5.3.8 Need for Critical Review

- Review has been done in interactive process along intermediate stages of the LCA, such that comments can guide the study.
- The review team consists of the Doctoral Committee members, experienced LCA practitioners and also Process Engineers involved in the industrial manufacturing processes.

### 5.3.9 Units of Comparison



*Figure 5.1 Units of Comparison of chairs of 5 different materials bamboo craft, bamboo wood, plastic, steel and wood respectively for the LCA (Source : Author)*

## 5.4 Life Cycle Inventory Analysis

The data collection has been conducted from furniture making industrial setups in the NER. The manufacturing process data of the 5 units of comparison [Figure 5.1] have been collected from the following sources.

- **Bamboo Craft** - Self designed bamboo furniture
- **Bamboo Wood** - Bamboo Technology Park, Chaygaon, Assam
- **Plastic** - Supreme Plastic Industries, EPIP, Amingaon, Assam
- **Steel** - Baba Ramdev Industries, Fatasil Ambari, Guwahati, Assam and Ahura Mazda, EPIP, Amingaon, Assam
- **Wood** - Niharika Wood Furniture workshop and retail, Lankeswar Assam and Sanjay Saw Mill, Palashbari, Assam.

### 5.4.1 Bamboo Craft Chair Manufacture

The intent of the researcher's project for making bamboo chair was to deliver a uni-material furniture through innovative techniques through craftsmanship. The furniture was designed to identify with the natural look of bamboo while complementing the aesthetics of a modern household. The project was conducted at Delhi in 2017.

#### 5.4.1.1 LCI Model at System Level

Bamboo poles of 4 year old Bambusa tulda were transported through 1900 km in freight from Assam to Chattarpur in Delhi. At INR 120 per 12' bamboo pole, 25 pieces were transported from Chattarpur to ITO, Delhi by Auto-van. At the manufacturing premises, the bamboo poles were let to dry in a cool place while being sorted and marked for cutting. The bamboos were split into 5 sections and their knots and edges were cleaned manually. Bamboo husk emerged as waste which was later used to make fire. The splits underwent water treatment and were dried in the sunlight.



*Figure 5.2 Manufacturing Process of Bamboo Craft Chair (Source : Author)*

Simultaneously, a Medium Density Fibre (MDF) board was cut into a cavity frame for bamboo bending. The splits were then torched to bend within the MDF cavity frame with the help of a kerosene torch to form uniformly bent bamboo sections. These chair elements were joined together by using rivets. Electric drilling and manual riveting tools were used to deliver the chair form. In order to avoid cracks in the bamboo, the chair was coated with a solution of Fevicol SH in water, and coated with 3 layers of resin to dry in 2 days sunlight as shown in Figure 5.2. After drying, the chair was transported 25 km by auto-van for market display.

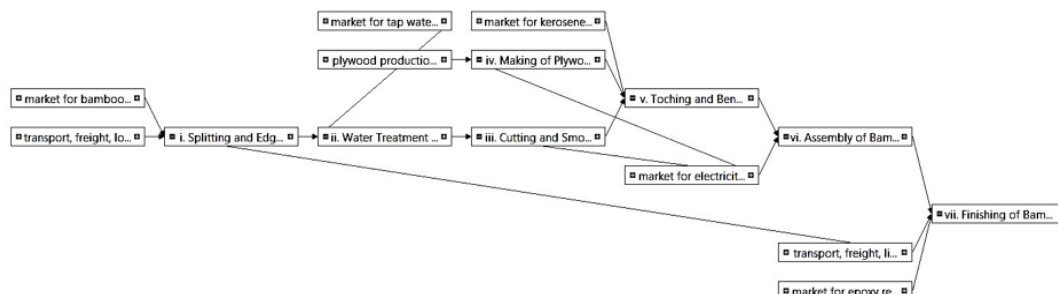
#### 5.4.1.2 Product Flows and Unit Processes for the LCI Model

**Table 5.1** Product Flows and Unit Processes of Bamboo Craft Chair Manufacture (Generated by : Author)

S.N	Product Flows	S.N	Unit Processes
i.	Bamboo Culm	i.	Splitting and Edge Cleaning of Bamboo
ii.	Bamboo Splits	ii.	Water Treatment
iii.	Treated Bamboo Splits	iii.	Cutting and Smoothing of Bamboo Splits
iv.	Smoothened Bamboo Splits	iv.	Making of MDF Cavity Frame
v.	MDF Cavity Frame	v.	Torching and Bending of Bamboo Splits
vi.	Torch Bent Bamboo Splits	vi.	Assembly of Bamboo Craft Chair
vii.	Bamboo Craft Chair	vii.	Finishing of Bamboo Craft Chair
viii.	Finished Bamboo Craft Chair		

**Assumptions :** The electricity supply to the industry is assumed to be from hydro-electric projects in the alpine region of NER.

Table 5.1 describes the product and unit flows of bamboo craft chair manufacture within the system boundaries of the LCA. Table 5.2 mentions the inputs and outputs of the system with allotted data. It includes the type, source and access of the database, along with specific description about the collected data in detail. The data was uploaded to OpenLCA 1.11 version and the database selected was Ecoinvent 3.8 as it had the latest bamboo data available in it. From the data, the software generated a LCI Model of the manufacturing process of bamboo craft chair as shown in Figure 5.3, which was a correct representation of the product system generated by the researcher [Figure 5.4] through site information.



**Figure 5.3** LCI Model of Bamboo Craft Chair Manufacture (Generated by : OpenLCA 1.11 software)

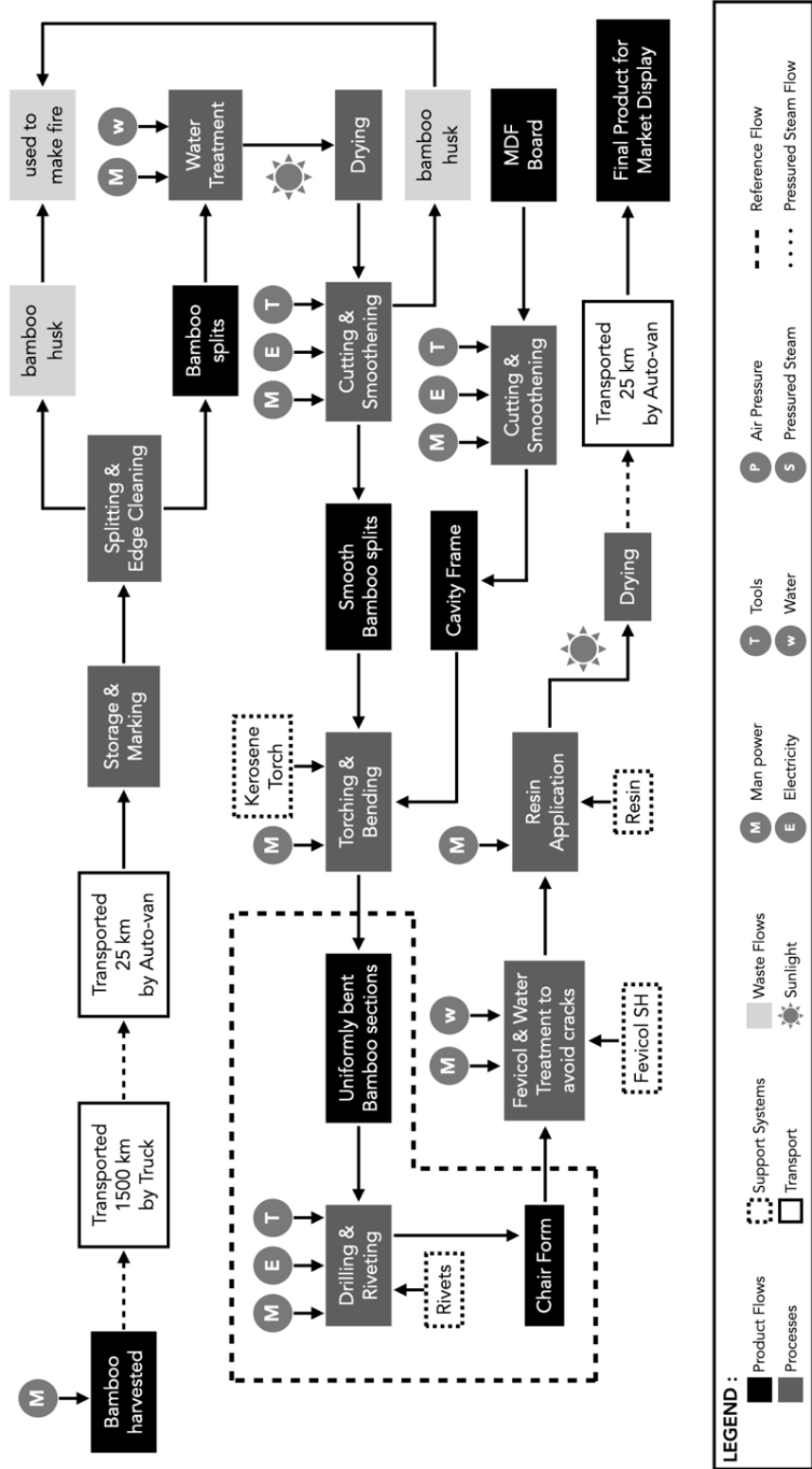


Figure 5.4 Product System within Cradle to Gate boundaries of Bamboo Craft Chair Manufacture (Source : Author)

### 5.4.1.3 Data Collection

Table 5.2 Data Collection and Specificity Analysis for Bamboo Craft Chair Manufacture (Generated by : Author)

DATA COLLECTION FOR BAMBOO CRAFT CHAIR MANUFACTURE												
SI No	Process or single data point	Quantity	Unit	Specificity					Type	Source	Access	Details and Remarks
				Very High	High	Medium	Low	Very Low				
<b>INPUTS</b>												
1	Raw material of bamboo culm species Bambusa tulda	72.0	kg	✓					Elementary Flow	Project conducted in Delhi	Direct dialogue	10ft pole of Bambusa tulda weighs 9kg. 8 poles taken to be 72 kg.
2	Tap water	50.0	kg		✓				Individual flow	Project conducted in Delhi	Direct dialogue	Bamboo drenched 5 times in water bucket with 10L
3	MDF Board	0.075	m3	✓					Individual flow	Ecoinvent	Database	8'X4' MDF Board of 25mm thickness
4	Epoxy resin	0.10	kg		✓				Individual flow	Ecoinvent	Database	100gm epoxy for one chair
<b>Electricity Use</b>												
5	Cutting and smoothening of bamboo splits	1.020	kWh		✓				Technical Parameter	Process engineer	Online search	Bosch GEX 34-150 Random Orbit Sander 340 Watt for 3 hours
6	Cutting and smoothening of MDF Board	2.010	kWh		✓				Technical Parameter	Process engineer	Online search	BOSCH GWS 600 professional Angle Grinder 670 Watts for 3 hours
7	Drilling holes to insert rivets	0.90	kWh		✓				Technical Parameter	Process engineer	Online search	Bosch Impact Drill Machine GSB 450 Watt for 2 hours
<b>Transportation</b>												
8	Bamboo from Assam to Delhi; Freight Vehicle	1900.0	km		✓				Geographic parameter	Google Maps	Online search	Bamboo transported in freight vehicle
9	Bamboo from Chattarpur to ITO, New Delhi; LMV	15.0	km		✓				Geographic parameter	Google Maps	Online search	Bamboo transported in light commercial vehicle
<b>Fuel Use</b>												
10	Kerosene	8.19	kg		✓				Individual flow	Ecoinvent	Database	1L Kerosene is 8.19kg
<b>OUTPUTS</b>												
<b>Waste</b>												
1	Bamboo waste	64.5	kg		✓				Waste flow	Project conducted in Delhi	Direct dialogue	Waste in the form of bamboo husk and dust
2	MDF Board waste	16	kg		✓				Waste flow	Project conducted in Delhi	Direct dialogue	Single cavity frame to be used for multiplicity

## 5.4.2 Bamboo Wood Chair Manufacture

The data has been collected from Bamboo Technology Park, Chaygaon, Assam in March, 2022. It is an Industrial Setup to deliver bamboo wood products such as boards, beams, briquettes, charcoal etc.

### 5.4.2.1 LCI Model at System Level

The bamboo is procured from all over Assam and delivered to the industrial plant by trucks. The bamboo poles are treated using boric-borax solution in a treatment tank. The solution is dissolved in water at 4-5% concentration for inner bamboo pulp and at 10% concentration for exterior skin. Bamboo is let to dry, preferably in the sun. Glucose in the form of bubbles oozes out from the ends. Treated bamboo is carried to the cutting section. Bamboo is cut to different lengths according to the bamboo board size by a cutting machine, splits and knots removed by splitting machine and knot removing machine, the green coat removed and sliced to a thickness of 3-5 mm by a slicing machine, then the splits are flattened out using a stranding machine. The bamboo flattened strands are dipped and boiled in Hydrogen Peroxide solution at 3-5% concentration at 100 deg C in a tank to increase the wet-ability of the strands. The dipped bamboo is dried in a drying machine through steam heat.

Next, the bamboo strands are dipped in glue containing Phenol Formalene resin and Caustic Soda water for 15-20 mins. After letting the extra glue drip out, the flattened strands are passed through a 2 layer drying machine where steam heat is passed through it at 70-80 deg C for 45 mins - 1 hour. The strands are loaded into a loader machine which takes it to the cavity machine holding a mould for the bamboo board. The machine presses the strands for 3-5 mins to make a board. The pressed bamboo board is then taken through a solidification machine which is 45 m long for a duration of 8-9 hours. It melts the resin applied to the strands and solidifies the boards. The double end cutting machine removes the flashes at the ends of the board and the trimming machine cuts through the taper in the mould. The dust collector machine is operated by suction and the collected bamboo dust is used to make briquettes. The completed boards are then passed through steam circulation to stop any bending.



*Figure 5.5 Manufacturing Process of Bamboo Wood Beam (Source : Author)*

By using cutting, shaving, sanding and drilling machines, the elements of bamboo wood chair are developed which are assembled together using glue and nails. With the help of coloured powder and resin, final processing of the chair is done. The chairs are transported 50km by freight for market display. The process has been displayed in Figure 5.5.

#### 5.4.2.2 Product Flows and Unit Processes for the LCI Model

Table 5.3 Product Flows and Unit Processes of Bamboo Wood Chair Manufacture (Generated by : Author)

S.N	Product Flows	S.N	Unit Processes
i.	Bamboo Culm	i.	Bamboo Treatment for Durability
ii.	Treated Bamboo for Durability	ii.	Cutting, Splitting, Slicing, Knot Removal and Stranding of Bamboo Culm
iii.	Flattened Strand Bamboo	iii.	Bamboo Flattened Strand Removal Treatment for Wetability
iv.	Treated Bamboo Flattened Stand for Wetability	iv.	Glue Dipping
v.	Glue Dipped Flattened Strand Bamboo	v.	Bamboo Board Making
vi.	Bamboo Board	vi.	Cutting and Trimming Bamboo Board
vii.	Bamboo Wood Chair Elements	vii.	Assembly of Bamboo Wood Chair
viii.	Bamboo Wood Chair	viii.	Finishing of Bamboo Wood Chair
ix.	Finished Bamboo Wood Chair		

**Assumptions :** The electricity supply to the industry is assumed to be from hydro electric projects in the alpine region of NER.

Table 5.3 describes the product and unit flows of bamboo wood chair manufacture within the system boundaries of the LCA. Table 5.4 mentions the inputs and outputs of the system with allotted data. It includes the type, source and access of the database, along with specific description about the collected data in detail. The data was uploaded to OpenLCA 1.11 version and the database selected was Ecoinvent 3.8 as it had the latest bamboo data available in it. From the data, the software generated a LCI Model of the manufacturing process of bamboo wood chair as shown in Figure 5.6, which was a correct representation of the product system generated by the researcher [Figure 5.7] through site information.

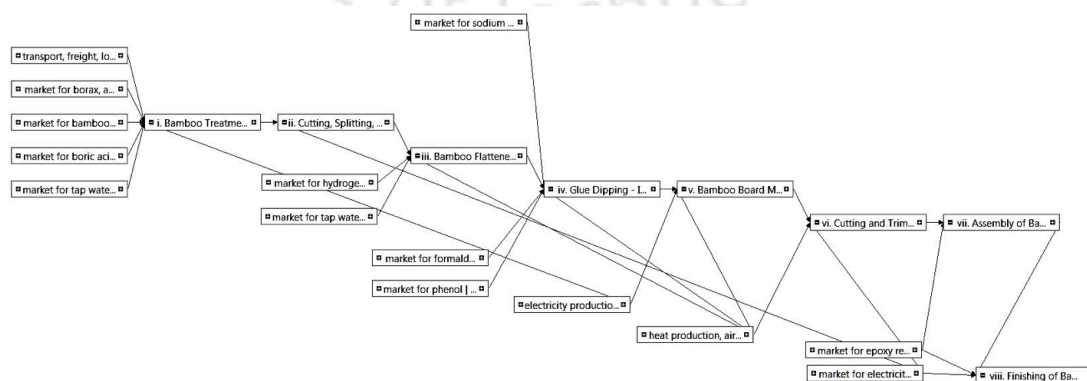


Figure 5.6 LCI Model of Bamboo Wood Chair Manufacture (Generated by : OpenLCA 1.11 software)

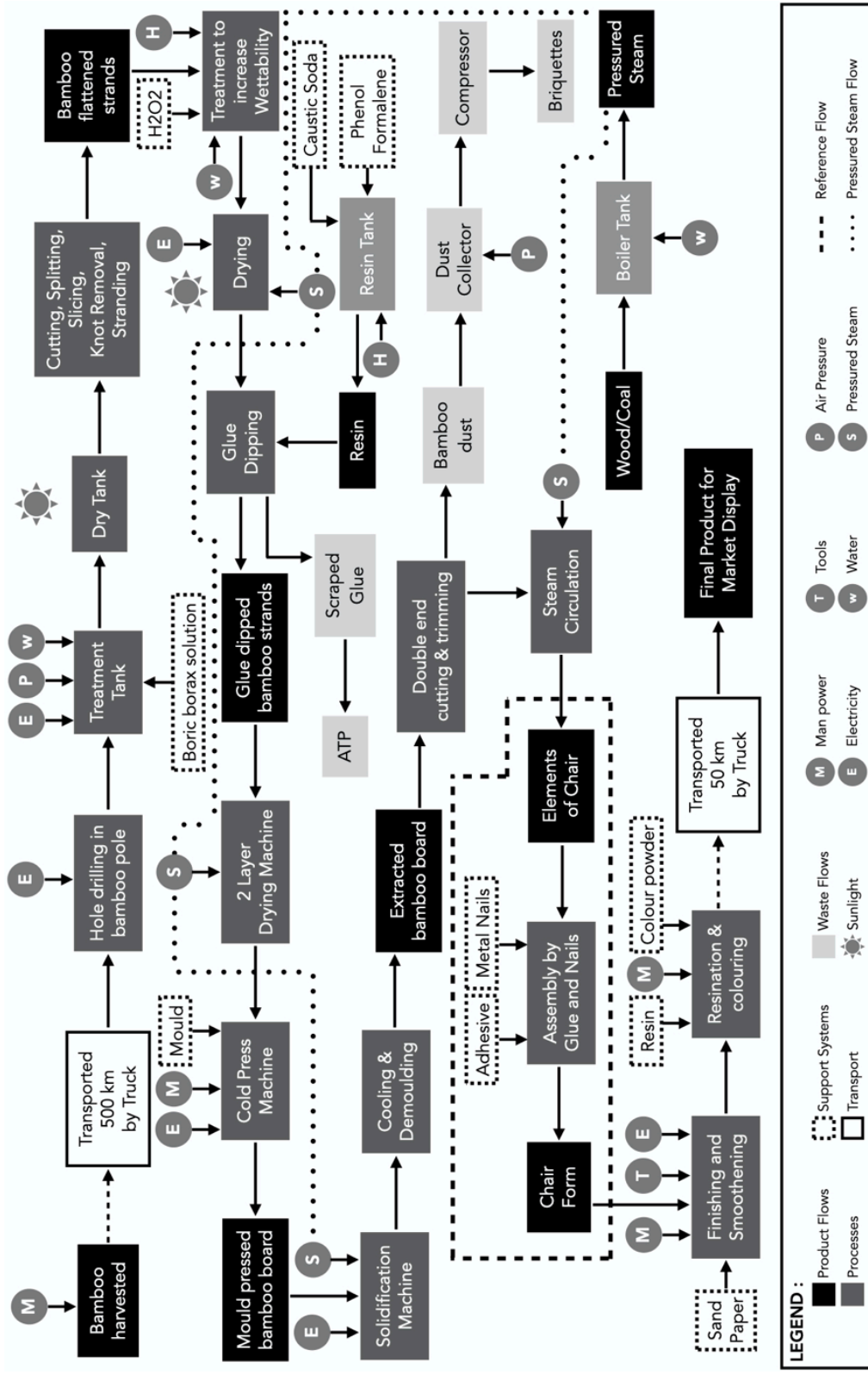


Figure 5.7 Product System within Cradle to Gate boundaries of Bamboo Wood Chair Manufacture (Source : Author)

### 5.4.2.3 Data Collection

Table 5.4 Data Collection and Specificity Analysis for Bamboo Wood Chair Manufacture (Generated by : Author)

DATA COLLECTION FOR BAMBOO WOOD CHAIR MANUFACTURE												
SI No	Process or single data point	Quantity	Unit	Specificity					Type	Source	Access	Details and Remarks
				Very High	High	Medium	Low	Very Low				
<b>INPUTS</b>												
1	Raw material of bamboo culm	88.0	kg		✓				Elementary Flow	Process engineer	Direct dialogue	Bamboo gathered from neighbouring districts of Assam
2	Boric acid for treatment	2.6	kg	✓					Concentrations	Ecoinvent	Database	Boric borax solution dissolved in water at 4.5% concentration for inner bamboo layer and 10% for exterior bamboo skin.
3	Borax for treatment	4.0	kg	✓					Concentrations	Ecoinvent	Database	
4	Tap water	74	kg	✓					Technical Parameter	Process engineer	First hand gathering	Volume to fill the cylindrical treatment tank of 6m length and 1m diameter
5	Hydrogen peroxide	0.44	kg	✓					Concentrations	Ecoinvent	Database	3-5% concentration in water
6	Formaldehyde	6.28	kg	✓					Concentrations	Ecoinvent	Database	1:2:0.5 concentration proportion for phenol, formaldehyde and caustic soda
7	Phenol	3.14	kg	✓					Concentrations	Ecoinvent	Database	
8	Caustic soda	1.57	kg	✓					Concentrations	Ecoinvent	Database	
9	Epoxy resin	0.35	kg	✓					Individual flow	Ecoinvent	Database	100gm epoxy for one chair
<b>Electricity Use</b>												
10	Treatment process	2.2	kWh		✓				Technical Parameter	Process engineer	Direct dialogue	11kW for a month, 10 times a month for 2 hours
11	Manipulating bamboo form to flattened strand bamboo	81.0	kWh		✓				Technical Parameter	Process engineer	Direct dialogue	135kW for month, 10 times a month for 6 hours
12	Bamboo board making	400.0	kWh		✓				Technical Parameter	Process engineer	Direct dialogue	400kW for month, 10 times a month for 10 hours
13	Manipulating bamboo board to required forms	3.03	kWh		✓				Technical Parameter	Process engineer	Direct dialogue	340W sanding machine for 3 hours and 670W cutting machine for 3 hours
14	Finishing chair	1.02	kWh		✓				Technical Parameter	Process engineer	Direct dialogue	340W sanding machine for 3 hours
<b>Transportation</b>												
15	Bamboo from nearby districts to Chaygaon	500.0	km		✓				Geographic parameter	Google Maps	Online search	Bamboo transported in freight vehicle
<b>Heat Use</b>												
16	Heat through steam	22.58	MJ		✓				Technical Parameter	Process engineer	Online search	For heating 10t.8kg water from 20degC to 100degC
<b>OUTPUTS</b>												
<b>Waste</b>												
1	Bamboo waste	75.85	kg		✓				Waste flow	Process engineer	Direct dialogue	Waste in the form of bamboo husk and dust

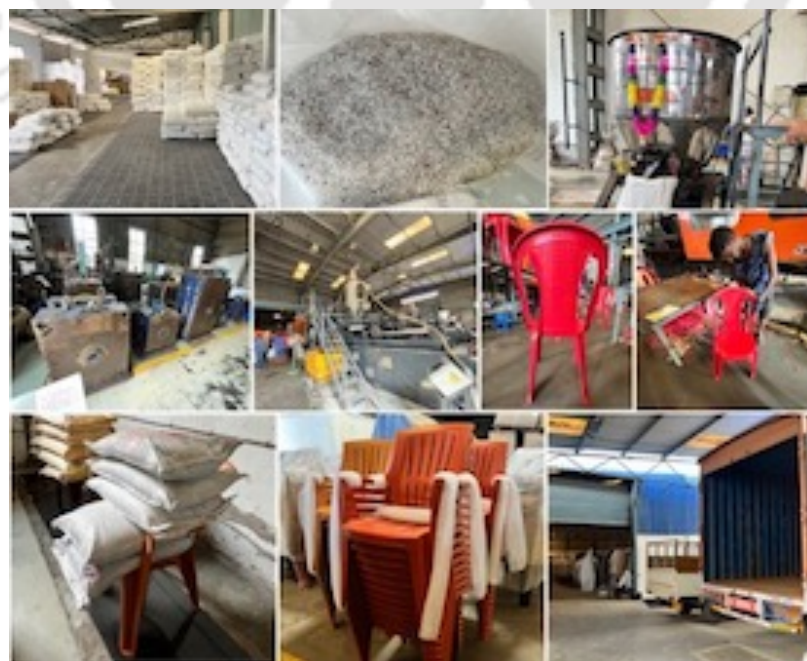
### 5.4.3 Plastic Chair Manufacture

Supreme Plastic Industries at EPIP (Export Promotion Industrial Park), Amingaon, Assam provided data for LCA in October, 2022. The industry, which has been operating since 2004, develops 23 different variants of plastic chairs in different colours.

#### 5.4.3.1 LCI Model at System Level

As shown in Figure 5.8, the industry gathers Plastic Pellets from Brahmaputra Cracker and Polymer Limited (BCPL) in Dibrugarh, Assam through freight of 500 km. The raw material is polypropylene (PP) in the form of homopolymer (66%), copolymer (16%), a filler agent (16%) and a master batch (1-2%). The proportions are variable as per product. Homopolymer helps with the shape, copolymer with the strength, filler agent adds weight and master batch adds colour to the product. The industry uses a 850 tonnage injection moulding machine from Windsor India. The plastic pellets are mixed in a roller at 150 kg per batch. Then they are carried to the hopper of the injection moulding machine. It goes through a shaft and inserts into an injection point in melted state which is carried forward to a die of a chair. The injection point is at the base of the seat of the chair. The melted PP translates into a chair, which is then released within 46 seconds to the ground. 40 pieces of 3 kg chair can be produced in a single batch of 150 kg PP.

The chair is let to cool and while cooling the flashes are cut manually. They are subsequently taken for load testing of 125 kgs by placing bags of pellets on them. Then they are dropped about 5 times from a height of 10 ft for drop test, after 24 hours of production. The chairs are stacked in numbers of 12,15 and 20 as per size of the chair and packaged with bubble wrap. For packaging, card boxes, poly bag and sticker prints are mostly procured from local vendors. The waste is mostly flashes, which is collected, ground and reused into the chairs. In a batch of 150 kg, 11 kg is reused plastic which is used with the main batch of PP. The chairs are transported to dealers in NER by freight.



**Figure 5.8** Manufacturing Process of Plastic Chair (Source : Author)

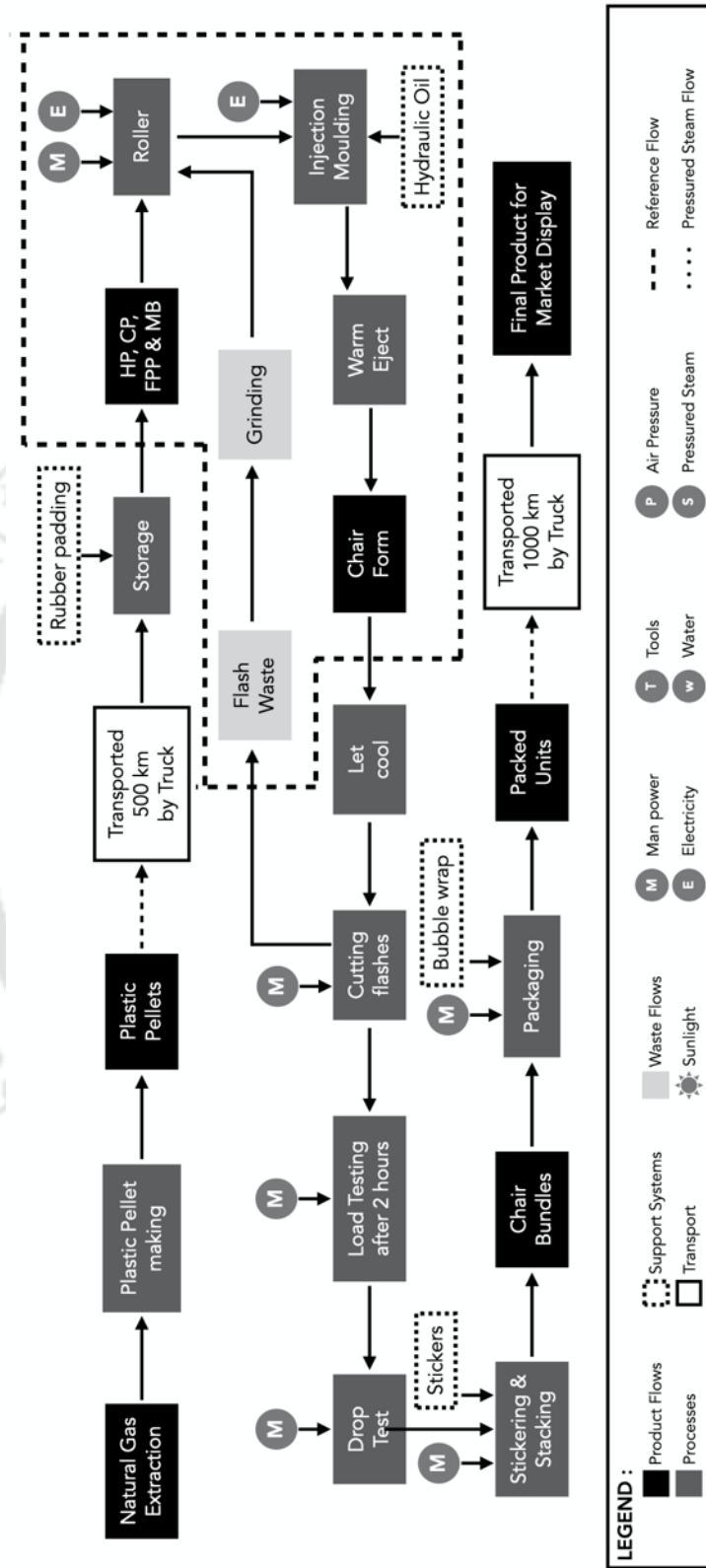


Figure 5.9 Product System within Cradle to Gate boundaries of Plastic Chair Manufacture (Source : Author)

### 5.4.3.2 Data Collection

Table 5.5 Data Collection and Specificity Analysis for Plastic Chair Manufacture (Generated by : Author)

DATA COLLECTION FOR PLASTIC CHAIR MANUFACTURE											
SI No	Process or single data point	Quantity	Unit	Specificity				Type	Source	Access	Details and Remarks
				Very High	High	Medium	Low				
<b>INPUTS</b>											
1	Polypropylene granulates	150.0	kg	✓				Individual flow	Process engineer	Direct dialogue	Weight considered according to one batch of production
2	Synthetic rubber padding for storage	3.0	kg	✓				Individual flow	Ecoinvent	Database	1kg per soft of rubber padding to hold one sack carrying 50kg of granulates
3	Plastic sheet roll for packaging	625.0	g		✓			Individual flow	Ecoinvent	Database	2m/10 chairs for 50 chairs of 3kg, 22 micron plastic sheet - 0.94g/cm <sup>3</sup> density and 3m height
<b>Electricity Use</b>											
4	Run the pellet mixture	0.75	kWh	✓				Technical Parameter	Process engineer	Direct dialogue	750W pellet mixing machine for 1 hour
5	Injection Moulding	150.0	kg		✓			Complete unit process	Ecoinvent	Database	Weight considered according to one batch of production
<b>Transportation</b>											
6	Transport of pellets from Dibrugarh to Guwahati	500.0	km	✓				Geographic parameter	Google Maps	Online search	Granulates transported in freight vehicle
<b>Fuel Use</b>											
7	Hydraulic oil	20.0	kg		✓			Individual flow	Ecoinvent	Database	100L per month, calculated for 1 day with 4 batches
<b>OUTPUTS</b>											
<b>Waste</b>											
1	Plastic waste	5.0	kg		✓			Waste flow	Process engineer	Direct dialogue	Waste in the form of plastic flashes

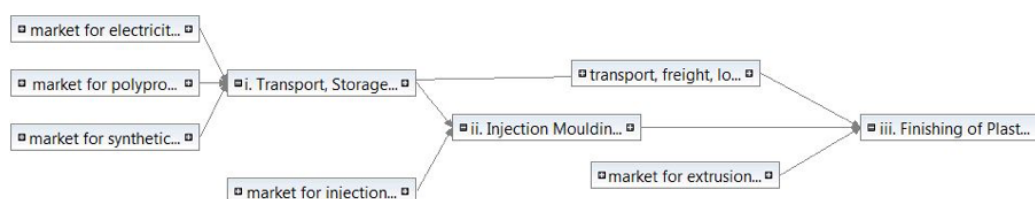
### 5.4.3.3 Product Flows and Unit Processes for the LCI Model

**Table 5.6** Product Flows and Unit Processes of Plastic Chair Manufacture (Generated by : Author)

S.N	Product Flows	S.N	Unit Processes
i.	Mixed Plastic Pellets	i.	Transport, Storage and Mixing of Plastic Pellets
ii.	Plastic Chair	ii.	Injection Moulding
iii.	Finished Plastic Chair	iii.	Finishing of Plastic Chair

**Assumptions :** The electricity supply to the industry is assumed to be from hydro-electric projects in the alpine region of NER.

Table 5.6 describes the product and unit flows of plastic chair manufacture within the system boundaries of the LCA. Table 5.5 mentions the inputs and outputs of the system with allotted data. It includes the type, source and access of the database, along with specific description about the collected data in detail. The data was uploaded to OpenLCA 1.11 version and the database selected was Ecoinvent 3.8 as it had the latest bamboo data available in it. From the data, the software generated a LCI Model of the manufacturing process of plastic chair as shown in Figure 5.10, which was a correct representation of the product system generated by the researcher [Figure 5.9] through site information.



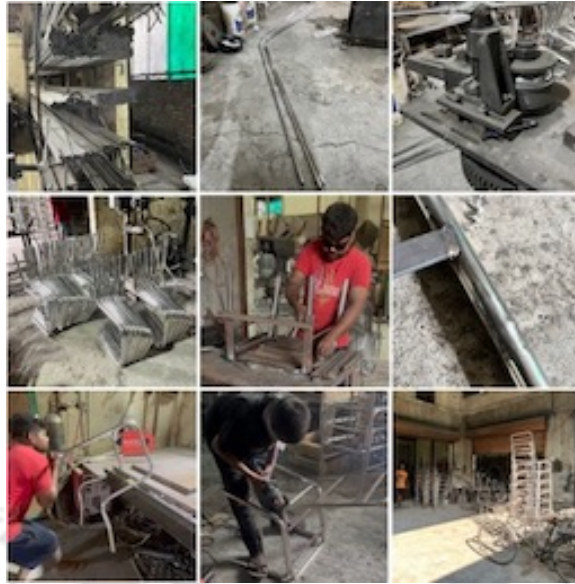
**Figure 5.10** LCI Model of Plastic Chair Manufacture (Generated by : OpenLCA 1.11 software)

### 5.4.4 Steel Chair Manufacture

The data has been collected from two sources namely Baba Ramdev Industries, Fatasil Ambari, Guwahati and Ahura Mazda, EPIP Amingaon visited in October 2022. The former manufactures with steel pipes whereas the later manufactures with sheet metal. The steel pipes were bent using dies for the chair frame and welded together with sheet metal parts to deliver the chair form.

#### 5.4.4.1 LCI Model at System Level

Baba Ramdev Industries, the industrial setup gathers raw material in the form of steel pipes of varying sections, weights and lengths from nearby sources, within the range of 5 km. The making process starts with sourcing steel pipes (Jindal Steel ISI SS202) which are already cut into required lengths of 14', 13', 11.5' and 4' as per the furniture design. Some cutting into required lengths is also done inside the workshop with an electric cutting machine. The cut pieces are bent into required shapes as per elements of furniture by using dies. The dies are installed in electric machines which are handled manually, which are pipe bending machines. The dies are procured from Chandigarh and Delhi. The forms developed by bent pipes are put in a mould with the help of which the elements are placed at the right points and welded together by using a mig-welding machine. The welded surfaces are smoothed by an electric disc sanding machine, which involves using an extra power flat disc no. 60. The steel frame is shined by a buffing machine which has a soft brush to shine the chair within 10 mins [Figure 5.11].



**Figure 5.11** Manufacturing Process of Steel Chair (Source : Author)

The later industrial setup called Ahura Mazda procures its raw materials in the form of galvanised iron sheet rolls of 1 ton from Sagar Steel, Tata Steel and Bhushan Steel from Kolkata and Orissa, considering a freight of 1000 km. The thickness of the sheet is 1 mm, 0.9 mm, 0.8 mm, 0.7 mm and 0.6 mm. After downloading, the metal sheet goes through CTLL horizontal shearing machine and CNC shearing machine to be cut according to the size of the base and back of chair. The pieces of sheet metal are passed through press brake machine for creating notches, die cutting and folding edges.

Meanwhile, the steel frames are transported from Baba Ramdev Industries to the premises of Ahura Mazda using freight. Spot-welding and mig-welding is done for assembly with the steel frames. Spot-welding is for surfaces where undulations must not be seen and mig-welding is done for the rough and hidden corners and edges. The welded edges are sanded through a metal grade sanding blade, and then buffed through a hand held buffing machine. The discarded pieces are put to trash, or else refurbished from whatever can be scoured from the damage which are taken away by the local scrappers for recycling. The final assembled products are taken through quality check by checking welding marks and alignment. They are labelled, stickered and stacked, put in bubble wrap, covered in cardboard boxes with corrugated corners for protection, and taken for truck loading. The chairs are delivered to distributors pan India through freight.

#### 5.4.4.2 Product Flows and Unit Processes for the LCI Model

**Table 5.7** Product Flows and Unit Processes of Steel Chair Manufacture (Generated by : Author)

S.N	Product Flows	S.N	Unit Processes
i.	Bent Steel Pipes	i.	Cutting, Marking and Bending of Steel Pipes
ii.	Steel Chair Base	ii.	Shearing and Cutting of Steel Sheet Roll
iii.	Nut and Bolts	iii.	Assembly of Steel Chair
iv.	Steel Chair	iv.	Smoothing and Buffing of Steel Chair
v.	Finished Steel Chair	v.	Packaging of Steel Chair
vi.	Packaged Steel Chair		

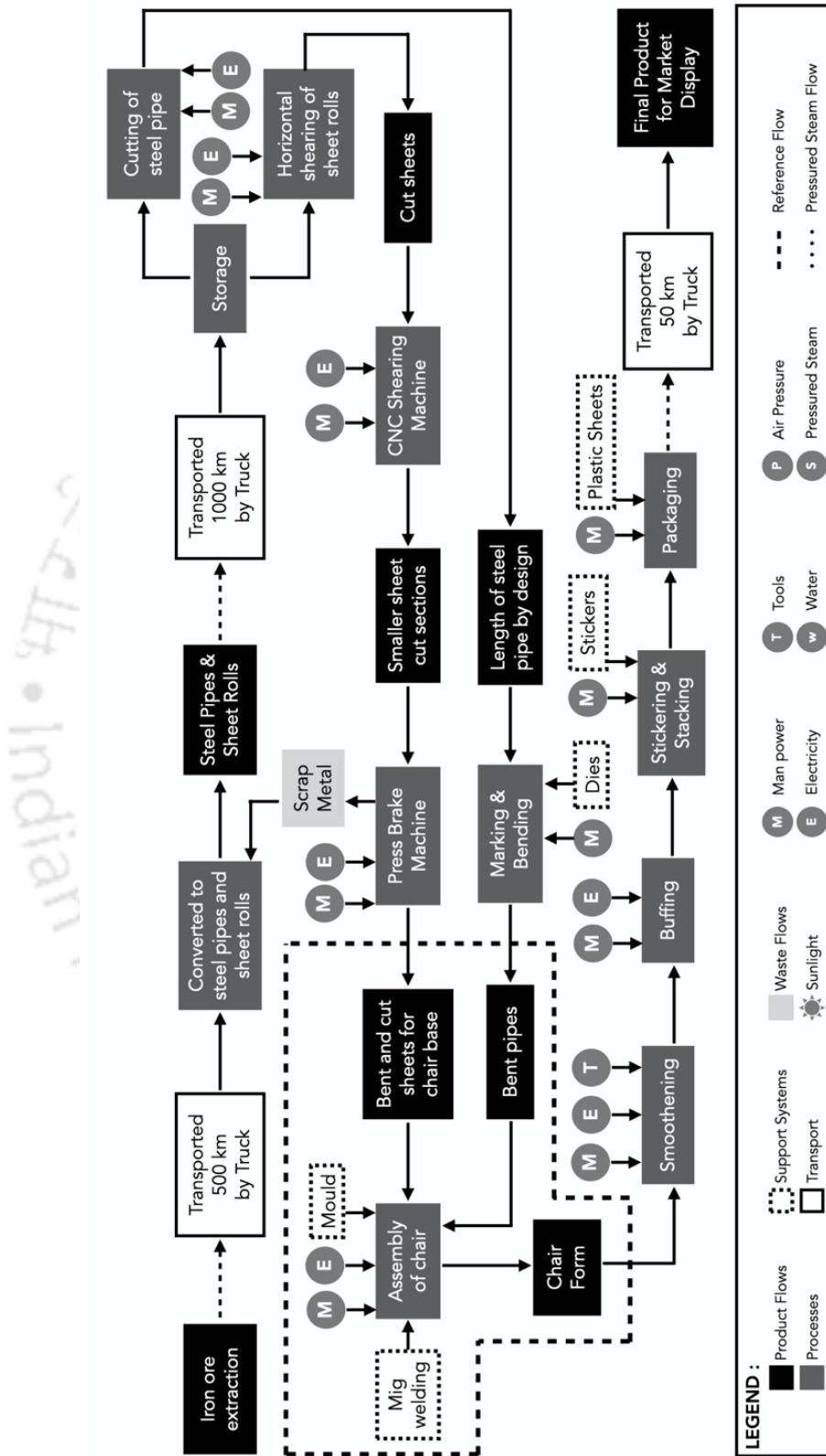


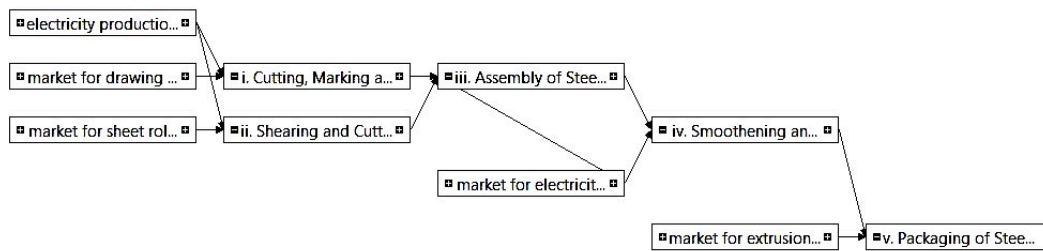
Figure 5.12 Product System within Cradle to Gate boundaries of Steel Chair Manufacture (Source : Author)

### 5.4.4.3 Data Collection

Table 5.8 Data Collection and Specificity Analysis for Steel Chair Manufacture (Generated by : Author)

DATA COLLECTION FOR STEEL CHAIR MANUFACTURE											
SI No	Process or single data point	Quantity	Unit	Specificity				Type	Source	Access	Details and Remarks
				Very High	High	Medium	Low				
<b>INPUTS</b>											
1	Steel pipe	437.5	kg	✓				Individual flow	Ecoinvent	Database	Weight considered for a batch of 50 chairs, unit weight 8.75kg
2	Steel sheet roll	67.5	kg	✓				Individual flow	Ecoinvent	Database	Weight considered for a batch of 50 chairs unit weight 1.35kg
3	Nut and bolts	10	kg	✓				Individual flow	Process engineer	Direct dialogue	0.2kg for each chair
4	Plastic sheet roll for packaging	31.25	kg		✓			Individual flow	Ecoinvent	Database	2m/10 chairs for 50 chairs of 8.2kg, 22 micron plastic sheet - 0.94g/cm <sup>3</sup> density and 3m height
<b>Electricity Use</b>											
5	Bending steel pipe	4.2	kWh		✓			Technical Parameter	Process engineer	Direct dialogue	2HP = 1.4kW motor steel bending machine used for 3 hours
6	Shearing and cutting steel sheet	55.5	kWh		✓			Technical Parameter	Process engineer	Direct dialogue	18.5kW 3 machines used for 1 hour each
7	Welding parts together	1.125	kWh		✓			Technical Parameter	Process engineer	Direct dialogue	250W mig welding machine used for 4.5 hours
8	Finishing steel chair	1.125	kWh		✓			Technical Parameter	Process engineer	Direct dialogue	250W buffing machine used for 4.5 hours
<b>OUTPUTS</b>											
<b>Waste</b>											
1	Scrap steel	105.0	kg		✓			Waste flow	Process engineer	Direct dialogue	Waste of 2.1kg steel per chair for 50 chairs

**Assumptions :** The electricity supply to the industry is assumed to be from hydro electric projects in the alpine region of NER.



**Figure 5.13** LCI Model of Steel Chair Manufacture (Generated by : OpenLCA 1.11 software)

Table 5.7 describes the product and unit flows of steel chair manufacture within the system boundaries of the LCA. Table 5.8 mentions the inputs and outputs of the system with allotted data. It includes the type, source and access of the database, along with specific description about the collected data in detail. The data was uploaded to OpenLCA 1.11 version and the database selected was Ecoinvent 3.8 as it had the latest bamboo data available in it. From the data, the software generated a LCI Model of the manufacturing process of steel chair as shown in Figure 5.13, which was a correct representation of the product system generated by the researcher [Figure 5.12] through site information.

#### 5.4.5 Wood Chair Manufacture

The data has been collected from Sanjay Saw Mill, Palashbari, Guwahati and Niharika Wooden Furniture Store, Lankeswar, Guwahati, visited in February, 2022. The former deals with timber harvesting and the later develops wooden furniture for retail. Timber is harvested and transported for 500 km and manipulated using heavy machinery to form rectangular planks of wood. Using carpentry tools and techniques, the wooden planks are converted into chairs. Sanding and resin application finishes the manufacturing process for retail.

##### 5.4.5.1 LCI Model at System Level

Sanjay Saw Mill deals in different hardwoods available in NER such as Teak, Indian Rosewood, Indian Siris, Beechwood and Salwood. The material is extracted from nearby plantations in Assam such as Rani, Boko, Sonapur, Kaziranga, Kokrajhar and Sibsagar plantations. It is extracted in log form when they are 12 meter high, 15-20 cm in diameter and 20-25 years old and carried through freight of 500 km. For timber harvesting, a survey of Joint Verification by Circle Office is conducted for permissions. The Forest Department uses GPS to locate land and the number of trees to be felled. A maximum of 50-55 trees are permitted to be harvested at a time. The saw mill people go with trucks and portable saw machines to execute harvesting and pay INR 8000-9000 as a minimum price to the owner of the land. Punjab body trucks are used for harvesting, while the saw machines run on petrol requiring 6-7L of petrol to fell 4-5 big trees. Per day, 4-5 big trees are felled, depending on the volume, length and location of the tree. In one truck, the safety amount is 200-250 CFT (1CFT = 0.028 cubic meter) for volume. Basic cost of per CFT of wood ranges from INR 1600-1700. This is the Selling Price after adding taxes.

The logs are brought to the mill where they are made into squares or rectangles from circles with the help of trolley machine. The sides are cut off with bark and maximum of the wooden log is extracted,

the rest become firewood. The sharpening machine for the trolley is also used for 1 hour daily. Then the bench machine cuts the rectangular wooden blocks into wooden planks, again to be delivered in CFT to clients. Both trolley and bench machines are operated for 6 hours every day culminating to INR 6000-7000 per month electricity bill. Saw dust collected is used as chicken feed in farms and used in dhabas for their source of heat in the tandoor. The wooden planks are distributed all over the city, NE Region and nearby states by tempo or truck.



**Figure 5.14** Manufacturing Process of Wooden Chair (Source : Author)

Sanjay Saw Mill also delivers wooden planks to the workshop of Niharika store in Gomora which is 5 km away. With the help of a tempo, a volume of 5-10 CFT is delivered. The weight varies according to the type of wood. Approximately 1 KB of wood is required to make a single chair. The wooden planks are bought and dried for a month in sunlight. The plank undergoes cutting, shaving, sanding and drilling as per the design of the chair. The tools involved are hammer, chisel, saw, shaver, drilling machine, shaving tool, curve cutting machine, measurement tape, electric cutter and sand paper. About 20% of the material is discarded due to damaged growth, the region is demarcated by the change in colour. Wooden nails are made out of waste wooden chips discarded from chair elements. Iron nails in multiple sizes are used for joining the elements. Nail lengths range from 1.5-15 cm. The adhesive used for joining is Kanger Aqua+ 10L. The extra waste wooden chips are burnt everyday which amounts to 5-10 kg. For basic finishing the chair form, Electric and Hand Shaver machines are used along with finer grades of sand paper. A plywood board is added to the chair base which amounts to 5% of the material in weight. The workshop unit has a monthly electricity consumption of INR 14,000-15,000.

The half-done pieces of furniture are transported in Tempo to Niharika's retail outlet which is 5 km away. For finishing the final chair at the retail store in Lankeswar, sanding is done along with resin application of 50 ml for a chair. The resin is applied by a paint brush. The edges of the furniture are spray painted with tones of brown with PU clear base. 250 ml spray paint is required for 1 chair. The paint powder used is from Berger Paints. The retail unit has a monthly electricity consumption of INR 20,000 [Figure 5.14].



### 5.4.5.2 Data Collection

Table 5.9 Data Collection and Specificity Analysis for Wood Chair Manufacture (Generated by : Author)

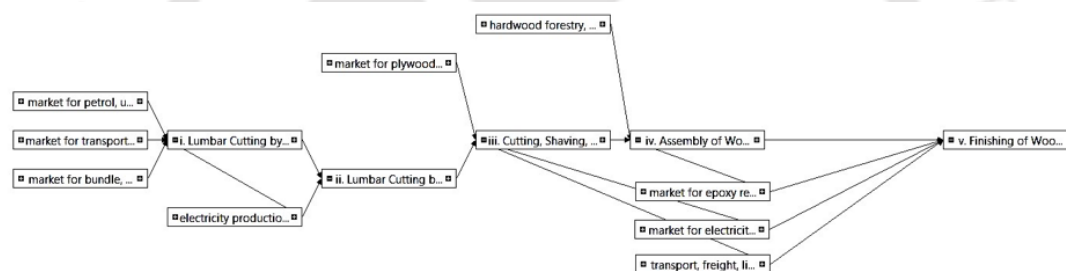
DATA COLLECTION FOR WOOD CHAIR MANUFACTURE											
SI No	Process or single data point	Quantity	Unit	Specificity				Type	Source	Access	Details and Remarks
				Very High	High	Medium	Low				
<b>INPUTS</b>											
1	Harvested wood	5.0	ton		✓			Elementary Flow	Process engineer	Direct dialogue	Hardwood gathered from neighbouring districts of Assam, permissible weight in a freight vehicle
2	Plywood	0.03	m <sup>3</sup>	✓				Individual flow	Ecoinvent	Database	Data considered for 6 wooden chairs
3	Epoxy resin	3.6	kg	✓				Individual flow	Ecoinvent	Database	600gm epoxy for one chair
<b>Electricity Use</b>											
4	Trolley machine	66	kWh	✓				Technical Parameter	Process engineer	Direct dialogue	11kW trolley machine used for 6 hours
5	Bench machine	5.4	kWh		✓			Technical Parameter	Process engineer	Direct dialogue	1.8kW trolley machine used for 3 hours
6	Manipulating wood planks to chair forms	60	kWh		✓			Technical Parameter	Process engineer	Direct dialogue	1560 kWh for 26 days, data considered for 24 hours
7	Finishing wooden chair	78	kWh	✓				Technical Parameter	Process engineer	Direct dialogue	2050 kWh for 26 days, data considered for 24 hours
<b>Transportation</b>											
8	Timber from nearby districts to Guwahati	500.0	km		✓			Geographic parameter	Google Maps	Online search	Wood transported in freight vehicle
9	Wood planks from Palashbari to Gomora	5	km	✓				Geographic parameter	Google Maps	Online search	Wood planks transported in light commercial vehicle
10	Wood planks from Gomora to Lankeswar	5	km	✓				Geographic parameter	Google Maps	Online search	Wood planks transported in light commercial vehicle
<b>Fuel Use</b>											
11	Petrol consumption for harvesting	165	MJ	✓				Technical Parameter	Process engineer	Online search	33MJ for 1L petrol, 5L
<b>OUTPUTS</b>											
<b>Waste</b>											
1	Wood waste	459.8	kg		✓			Waste flow	Process engineer	Direct dialogue	Waste in the form of wooden barks, 10% waste
2	Sawdust	446	kg		✓			Waste flow	Process engineer	Direct dialogue	Waste in the form of sawdust, 10% waste

### 5.4.5.3 Product Flows and Unit Processes for the LCI Model

Table 5.10 describes the product and unit flows of wood chair manufacture within the system boundaries of the LCA. Table 5.9 mentions the inputs and outputs of the system with allotted data. It includes the type, source and access of the database, along with specific description about the collected data in detail. The data was uploaded to OpenLCA 1.11 version and the database selected was Ecoinvent 3.8 as it had the latest bamboo data available in it. From the data, the software generated a LCI Model of the manufacturing process of wood chair as shown in Figure 5.16, which was a correct representation of the product system generated by the researcher [Figure 5.15] through site information.

**Table 5.10** Product Flows and Unit Processes of Wood Chair Manufacture (Generated by : Author)

S.N	Product Flows	S.N	Unit Processes
i.	Rectangular Wood Blocks	i.	Timber Cutting by Trolley Machine
ii.	Wood Planks	ii.	Timber Cutting by Bench Machine
iii.	Wood Chair Elements	iii.	Cutting, Shaving, Sanding and Drilling of Wood Planks
iv.	Chair Base	iv.	Assembly of Wood Chair
v.	Wood Chair	v.	Finishing of Wood Chair
vi.	Finished Wood Chair		



**Figure 5.16** LCI Model of Wood Chair Manufacture (Generated by : OpenLCA 1.11 software)

**Assumptions :** The electricity supply to the industry is assumed to be from hydro-electric projects in the alpine region of NER.

## 5.5 Life Cycle Impact Assessment

### 5.5.1 Comparative Analysis of Impacts by ReCiPe 2016 Assessment Method

The Life Cycle Inventory results collated in the previous section were put to comparison in the OpenLCA 1.11 version to interpret their contributions to the 18 mid point indicators of the ReCiPe 2016 method. The LCIA method with its indicators and the five systems for comparison were delivered to the OpenLCA software for comparison. Ecoinvent 3.8 Database has been selected because of the availability of latest bamboo data in the database. ReCiPe 2016 is a midpoint and an endpoint method. The method assesses 18 midpoint impact categories and 3 endpoint impact categories.

The following are the impact categories that were considered for the comparison :

1. Agricultural Land Occupation
2. Climate Change
3. Fossil Depletion
10. Metal Depletion
11. Natural Land Transformation
12. Ozone Depletion

- |                              |                                     |
|------------------------------|-------------------------------------|
| 4. Freshwater Ecotoxicity    | 13. Particulate Matter Formation    |
| 5. Freshwater Eutrophication | 14. Photochemical Oxidant Formation |
| 6. Human Toxicity            | 15. Terrestrial Acidification       |
| 7. Ionizing Radiation        | 16. Terrestrial Ecotoxicity         |
| 8. Marine Ecotoxicity        | 17. Urban Land Occupation           |
| 9. Marine Eutrophication     | 18. Water Depletion                 |

Calculation of results along these indicators will give a holistic result of the environmental performance of the five materials for furniture - bamboo craft, bamboo wood, plastic, steel and wood. It shall also deliver the individual contributions to the various impact factors to determine the hotspot of environmental impacts. Table 5.11 below delivers the results of the impact assessment.

**Table 5.11** Comparative Life Cycle Impact Assessment of 5 chairs  
(Generated by : ReCiPe 2016 method in OpenLCA 1.11 software)

SN	Impact category	Reference unit	Bamboo Craft Chair	Bamboo Wood Chair	Plastic Chair	Steel Chair	Wood Chair
1	agricultural land occupation - ALOP	m <sup>2</sup> a	99.79143	51.38168	37.75063	-404.00800	103.86810
2	climate change - GWP20	kg CO <sub>2</sub> -Eq	22.37755	162.40590	1526.55400	1541.50100	56.68877
3	fossil depletion - FDP	kg oil-Eq	9.74362	54.26940	1028.46100	325.17390	17.54137
4	freshwater ecotoxicity - FETP100	kg 1,4-DCB-Eq	0.14956	1.60037	4.59469	42.29582	0.53491
5	freshwater eutrophication - FEP	kg P-Eq	0.00420	0.08455	0.12929	0.11829	0.03160
6	human toxicity - HTP100	kg 1,4-DCB-Eq	6.74486	4.31085	33.18706	-60.96380	3.91946
7	ionising radiation - IRP <sub>I</sub>	kg U <sub>235</sub> -Eq	0.92520	2.10010	17.47849	37.55232	1.72845
8	marine ecotoxicity - METP100	kg 1,4-DCB-Eq	0.11350	1.22657	3.88978	38.53046	0.42180
9	marine eutrophication - MEP	kg N-Eq	0.04399	0.15639	0.96802	0.72565	0.07014
10	metal depletion - MDP	kg Fe-Eq	1.27164	4.78255	46.97558	502.83210	1.18734
11	natural land transformation - NLTP	m <sup>2</sup>	-1.83474	-1.68028	0.10540	0.82892	0.01105
12	ozone depletion - ODP <sub>inf</sub>	kg CFC-11-Eq	0.00000	0.00001	0.00004	0.00015	0.00000
13	particulate matter formation - PMFP	kg PM10-Eq	0.05379	0.37512	1.63199	1.72198	0.13735
14	photochemical oxidant formation - POFP	kg NMVOC	0.14175	0.43825	4.29122	3.83910	0.20843
15	terrestrial acidification - TAP20	kg SO <sub>2</sub> -Eq	0.09925	0.50348	3.33765	2.78150	0.18987
16	terrestrial ecotoxicity - TETP100	kg 1,4-DCB-Eq	0.01010	0.07903	0.53164	6.70972	0.00665
17	urban land occupation - ULOP	m <sup>2</sup> a	1.49149	2.40331	11.94662	5.25909	1.69204
18	water depletion - WDP	m <sup>3</sup>	0.02840	0.22237	0.40493	1.48439	0.08025

Due to variation in the life span of different materials, the overall environmental impacts of the chairs are different as their inputs get divided over the life span of the chair. Secondary research has been conducted to determine the lifespan of each material, preferably in chair form. Low, 2023 states that, regarding the life span of bamboo products, measures such as protecting the bamboo from rain and water by keeping it indoors, elevated and covered must be taken. If these measures are successfully combined, bamboo can have a lifespan of 30+ years.

Bamboo ply woods have a longer life span than traditional hardwood. Bamboo is one of the toughest natural materials. After proper treatment in hot boric acid solution it resists dust and insects. They are resistant to moisture and oblivious to dents and scratches. Bamboo does not warp over time and can ideally last a lifetime. They can easily last from 15 to 20 years with minimal maintenance. Furthermore bamboo can be refinished 2-3 times thus increasing its lifespan (Bothbest Bamboo Flooring, 2023).

Plastic furniture is destined to have a service life of 3-5years in general. If under the premise of quality assurance, normal use plus proper maintenance, then the service life of plastic furniture will reach more than 10 years (Maka, 2021)

The average lifespan of stainless steel pipes and sheets can vary depending on several factors, including the quality of the stainless steel used, the environment in which it is installed, and the maintenance and care they receive. However, as a general estimate, stainless steel pipes and sheets can have a lifespan of 50 to 100 years or more. This is due to the inherent corrosion resistance of stainless steel, which helps to protect from rust and other forms of degradation. Additionally, stainless steel pipes are known for their durability and strength, allowing them to withstand high temperatures, pressure, and other harsh conditions (Hance Construction, 2020).

Solid wood furniture made from oak, Segun, maple, mahogany, teak, and other hardwoods will typically last over 100 years with care. Even cheaper wood furniture made from pine, poplar, and other softwoods can survive 15-30 years if maintained properly. Wooden furniture tends to last long, with wooden chairs going 10-15 years and dining tables 15-20 years or more with proper care. Solid wood chairs can potentially last decades (Rahaman, 2023).

Considering the above statements, the life spans of the chairs have been considered as : Bamboo craft - 30 years, Bamboowood - 15 years, Steel - 100 Years, Plastic - 10 Years and Wood - 50 Years. The assessment results have been divided by the lifespans of the chairs to provide a more accurate understanding as the impacts get distributed over lifespan years. The following table delivers the impact assessment results after being divided by lifespans.

### **5.5.2 Interpretations from ReCiPe 2016 Assessment Method**

In order to realise the actual impact on the environment by the five different materials, the Impact Assessment Results of Table 5.11 were divided by the average life spans of the respective chairs. A new table was generated in which Relative Marking was done by colour coding the results in an ascending order of the materials' environmental performance in a particular impact category. The results were provided colour coding of green, light green, yellow, orange and red to denote the comparison of lowest to highest environmental impacts of different materials respectively. The final environmental performance result of the chairs has been shown in the Table 5.12 below.

**Table 5.12** Comparative Life Cycle Impact Assessment of 5 chairs after considering their lifespans  
(Generated by Author using OpenLCA 1.11 software)

SN	Impact category	Reference unit	Bamboo Craft Chair	Bamboo-wood Chair	Plastic Chair	Steel Chair	Wood Chair
1	agricultural land occupation - ALOP	m <sup>2</sup> a	3.32638	3.42545	3.77506	-4.04008	2.07736
2	climate change - GWP20	kg CO <sub>2</sub> -Eq	0.74592	10.82706	152.65540	15.41501	1.13378
3	fossil depletion - FDP	kg oil-Eq	0.32479	3.61796	102.84610	3.25174	0.35083
4	freshwater ecotoxicity - FETP100	kg 1,4-DCB-Eq	0.00499	0.10669	0.45947	0.42296	0.01070
5	freshwater eutrophication - FEP	kg P-Eq	0.00014	0.00564	0.01293	0.00118	0.00063
6	human toxicity - HTP100	kg 1,4-DCB-Eq	0.22483	0.28739	3.31871	-0.60964	0.07839
7	ionising radiation - IRP 1	kg U <sub>235</sub> -Eq	0.03084	0.14001	1.74785	0.37552	0.03457
8	marine ecotoxicity - METP100	kg 1,4-DCB-Eq	0.00378	0.08177	0.38898	0.38530	0.00844
9	marine eutrophication - MEP	kg N-Eq	0.00147	0.01043	0.09680	0.00726	0.00140
10	metal depletion - MDP	kg Fe-Eq	0.04239	0.31884	4.69756	5.02832	0.02375
11	natural land transformation - NLTP	m <sup>2</sup>	-0.06116	-0.11202	0.01054	0.00829	0.00022
12	ozone depletion - ODPinf	kg CFC-11-Eq	0.00000	0.00000	0.00000	0.00000	0.00000
13	particulate matter formation - PMFP	kg PM10-Eq	0.00179	0.02501	0.16320	0.01722	0.00275
14	photochemical oxidant formation - POFP	kg NMVOC	0.00473	0.02922	0.42912	0.03839	0.00417
15	terrestrial acidification - TAP20	kg SO <sub>2</sub> -Eq	0.00331	0.03357	0.33377	0.02782	0.00380
16	terrestrial ecotoxicity - TETP100	kg 1,4-DCB-Eq	0.00034	0.00527	0.05316	0.06710	0.00013
17	urban land occupation - ULOP	m <sup>2</sup> a	0.04972	0.00000	1.19466	0.05259	0.03384
18	water depletion - WDP	m <sup>3</sup>	0.00095	0.01482	0.04049	0.01484	0.00161

As per the results, Bamboo craft chair manufacture delivers the least impact into the environment, followed closely by wood. Steel chair and bamboo wood chair manufacture compete closely following wood. Plastic chair delivers the maximum impact into the environment due to its shorter life span. Looking further into the data, the OpenLCA software also provides information on which processes in the individual furniture system contributed most to the impact categories. Looking into the data, the material process which would require iteration for a better environmental performance can be individually recognized.

**Bamboo Craft Chair Manufacture :**

The process yields moderately towards Agricultural Land Occupation due to the introduction of plywood in the manufacturing process. It also contributes moderately towards Human Toxicity due to the bamboo and wood dust waste and application of resin. Ozone Layer Depletion and Terrestrial Ecotoxicity is affected by the petroleum consumption which would foster from the transportation of materials. The process contributes positively towards majority of the impacts, specifically towards Natural Land Transformation due to sustainable forest management via bamboo forestry.

**Bamboo Wood Chair Manufacture :**

This process has a medium level contribution to every impact category. The chemicals, electricity, intense heat and pressure add to the impacts. The chemicals such as phenol, formaldehyde, sodium hydroxide amongst others add to Freshwater Eutrophication. It also contributes moderately to Particulate Matter Formation due to bamboo dust from the industrial premises. It adds positively towards Natural Land Transformation by sustainable forest management through bamboo forestry.

**Plastic Chair Manufacture :**

The process contributes significantly towards a majority of the impact factors. Since polypropylene is a petroleum product, the extraction of this process contributes heavily towards Fossil Depletion, Climate Change, Terrestrial Acidification and Photochemical Oxidant Formation. The residual material landfill from mining and conversion of alloys related to this process contributes heavily towards Freshwater and Marine Eutrophication. Contributions from transport of products and material also add to the impacts. This process does not have a positive report on environmental performance.

**Steel Chair Manufacture :**

The process involves manipulating iron ores to steel sheets and pipes. Iron ore mining leads to Metal Depletion. The pig iron production contributes significantly towards Climate Change. The coal mining and natural gas production involved in the process adds to Fossil Depletion. The treatment of sludge during steel rolling affects Freshwater and Marine Ecotoxicity. The alkali electrolytes used in the process contribute to Ozone Depletion. Though the process contributes significantly mildly towards Agricultural Land Occupation, this process too does not have a positive report on environmental performance.

**Wood Chair Manufacture :**

This process contributes moderately towards majority of the impact categories but contributes significantly towards Agricultural Land Occupation due to hardwood forestry. This very reason also affects the Natural Land Transformation. Petroleum production, electricity and freight adds to Ozone Depletion and Climate Change. Wood dust adds to Particulate Matter Formation but overall this process has satisfactory results regarding its environmental performance.

The results provide for a comprehensive analysis of the five different material chairs and their environmental impacts in every stage of manufacturing. A relative understanding of the environmental impacts of the materials has been put forward by the assessment. Bamboo craft and wood chair perform well towards environmental performance due to its different qualities. Though bamboo wood has the material bamboo in it, but the industrialisation process releases environmental wastes and consumes considerable energy, thus increasing its impact. Steel and plastic, due to its extraction process and shorter life span respectively, do not perform very well on the environmental impacts.

To analyze further regarding eco-costs of the manufacturing processes, another assessment was conducted using the Idemat Eco-costs 2023 method, which has been discussed in detailed in the following section.

### 5.5.3 Eco-cost Generation by Idemat Eco-costs 2023 Assessment Method

Eco-costs are a measure to express the amount of environmental burden of a product on the basis of prevention of that burden. They are the marginal costs which should be made to reduce the environmental pollution and materials depletion to a level which is in line with the carrying capacity of the earth (Delft University of Technology, 2024). These costs can be generated by using the Idemat Eco-costs 2023 method as it has the relevant data for the purpose.

The Life Cycle Inventory results collated in the previous section were put to comparison in the OpenLCA 1.11 version to interpret their contributions to the 14 mid point indicators of the Idemat Eco-costs 2023 method. The LCIA method with its indicators and the five systems for comparison were delivered to the OpenLCA software for comparison. Ecoinvent 3.8 Database has been selected because of the availability of latest bamboo data in the database.

The Idemat Eco-costs 2023 assessment method has 14 midpoint impact categories which deliver results in different units as relevant to the impact categories. Out of the 14, only 3 impact categories deliver the results in Euro's [Table 5.13]. These 3 impact category results have been considered to calculate the Eco-costs of the manufacturing processes of chairs of different materials. The following table delivers the results of the Impact Assessment by Idemat Eco-costs 2023 method.

**Table 5.13** Comparative Life Cycle Impact Assessment of Eco-costs of 5 chairs  
(Generated by : Idemat Eco-costs 2023 V1.0 method in OpenLCA 1.11 software)

SN	Indicator	Unit	Bamboo Craft	Bamboo Wood	Plastic	Steel	Wood
1	Acidification	mol H+ eq	0.05150	0.41900	0.02970	0.00526	0.13600
2	Baseline Water Stress	m <sup>3</sup> eq	0.09320	1.33000	0.01350	0.01790	0.06560
3	Climate change	kg CO <sub>2</sub> eq	20.50000	153.00000	14.70000	3.80000	54.20000
4	Ecotoxicity, freshwater	CTUe	578.00000	1060.00000	29.30000	4.60000	118.00000
5	Eutrophication	kg PO <sub>4</sub> eq	0.15600	0.73200	0.04120	0.00776	0.32100
6	Human toxicity, cancer	CTUh	0.00000	0.00000	0.00000	0.00000	0.00000
7	Human toxicity, non-cancer	CTUh	0.00000	0.00000	0.00000	0.00000	0.00000
8	Land use (biodiversity change)	bio factor	0.04690	0.02520	0.00042	-0.00031	0.04900
9	Landfill	euro	0.00000	0.00000	0.00000	0.00000	0.00000
10	Metals scarcity	euro	0.16600	0.64400	0.22000	0.10400	0.15200
11	Particulate matter	kg PM <sub>2.5</sub>	0.01290	0.04340	0.00345	0.00092	0.01680
12	Photochemical ozone formation	kg NMVOC eq	0.13400	0.42000	0.04280	0.00889	0.19700
13	Use fossil based plastics and fossil based transport fuels	kg oil eq	0.00000	0.00000	0.00000	0.00000	0.00000
14	Use uranium	euro	0.12600	0.31500	0.07380	0.01580	0.25100

Table 5.14 Eco-costs, Market Costs and Division Quotient of 5 chairs (Generated by Author)

Bamboo Craft		Eco-cost	
SN	Impact Factor	Euro	INR (Euro X 90.30)
i.	Landfill	0.00	0.00
ii.	Metal Scarcity	0.166	14.99
iii.	Use Uranium	0.125	11.29
<b>Total Ecocost</b>		<b>0.291</b>	<b>26.28</b>
<b>Market Cost</b>		<b>38.76</b>	<b>3500</b>
<b>Quotient = Market Cost / Eco-cost</b>		<b>133.18</b>	
Bamboo Wood		Eco-cost	
SN	Impact Factor	Euro	INR (Euro X 90.30)
i.	Landfill	0.00	0.00
ii.	Metal Scarcity	0.644	58.15
iii.	Use Uranium	0.315	28.44
<b>Total Ecocost</b>		<b>0.959</b>	<b>86.72</b>
<b>Market Cost</b>		<b>46.51</b>	<b>4200</b>
<b>Quotient = Market Cost / Eco-cost</b>		<b>48.43</b>	
Plastic		Eco-cost	
SN	Impact Factor	Euro	INR (Euro X 90.30)
i.	Landfill	0.00	0.00
ii.	Metal Scarcity	0.220	19.87
iii.	Use Uranium	0.073	6.59
<b>Total Ecocost</b>		<b>0.293</b>	<b>26.46</b>
<b>Market Cost</b>		<b>6.37</b>	<b>575</b>
<b>Quotient = Market Cost / Eco-cost</b>		<b>21.73</b>	
Steel		Eco-cost	
SN	Impact Factor	Euro	INR (Euro X 90.30)
i.	Landfill	0.00	0.00
ii.	Metal Scarcity	0.103	9.30
iii.	Use Uranium	0.015	1.35
<b>Total Ecocost</b>		<b>0.118</b>	<b>10.66</b>
<b>Market Cost</b>		<b>24.36</b>	<b>2200</b>
<b>Quotient = Market Cost / Eco-cost</b>		<b>206.37</b>	
Wood		Eco-cost	
SN	Impact Factor	Euro	INR (Euro X 90.30)
i.	Landfill	0.00	0.00
ii.	Metal Scarcity	0.152	13.73
iii.	Use Uranium	0.251	22.67
<b>Total Ecocost</b>		<b>0.403</b>	<b>36.39</b>
<b>Market Cost</b>		<b>55.37</b>	<b>5000</b>
<b>Quotient = Market Cost / Eco-cost</b>		<b>137.4</b>	

The 3 impact factors namely, Landfill, Metal Scarcity and Use Uranium deliver results in Euro which were added and converted to INR for convenience of analysis of Eco-cost. The Market Cost of the chairs of different materials were also gathered from the company catalogues of the products as shown in Table 5.14.

#### **5.5.4 Interpretations from Idemat Eco-costs 2023 Assessment Method**

The market cost was divided by the Eco-cost value to get the division quotient. The quotient could determine the relative amount of eco-costs as compared to the market costs of the products. The higher the quotient, the lesser is the relative eco-cost. Thus, the furniture of the material would be more environmentally friendly.

Multiple factors affect the market costs and they cannot be compared to the actual manufacturing cost. The analysis suggests that, steel chair delivered the highest quotient and least eco-cost. This was followed by wood with both high eco-cost and quotient. Bamboo craft chair delivered lower eco-cost than Wood chair, but similar eco-cost to Plastic chair and comparable quotient as Wood chair. Bamboo wood and Plastic chairs delivered low quotients, with Bamboo wood chair delivering the highest eco-costs.

#### **5.5.5 Conclusion and Recommendations**

Considering both the Impact Assessments by ReCipe 2016 and Eco-costs 2023, the discussions suggest that Bamboo Craft and Wood chairs have the least and comparable environmental impacts. This could be attributed to bamboo's contribution to natural land transformation and wood's elongated lifespan which distributes its impacts over the years. Bamboo wood and Plastic chairs on the other hand have the maximum environmental impacts. This could be attributed to the usage of multiple chemicals in the manufacturing process of bamboo wood and the shortest lifespan of plastic. Steel has delivered lowest eco-costs and considerable environmental impacts. The position of steel could be analysed further from availability of data.

From the above assessment, it can be concluded that Bamboo Craft Chair Manufacture is an environmentally sustainable process and should be taken forward for entrepreneurship and effective manufacture. It has the best performance when compared to its competitive materials, i.e., wood, steel, plastic and even bamboo wood. The relative ranking should be able to deliver a new information to the eco-conscious consumers to validate their decision towards sustainable consumption. The result must be taken forward to businessmen, craftspeople, consumers as well as general public domain to imbibe a new possibility towards a sustainable future.

## CHAPTER 6 :

# **SUSTAINABLE DEVELOPMENT GOALS IN BAMBOO CRAFTSMANSHIP SECTOR**

## **6.1 Introduction**

This section of the research looks further into the Sustainable Development Goals and if Bamboo Craftsmanship can contribute to the SDG's targets for 2030. To validate the material and the technique for usability in the future, insights have been generated for the possible implementation of efforts and workforce towards fulfilling the targets of SDG's via Bamboo Craftsmanship.

## **6.2 Current SDG's in Brief**

United Nations Headquarters in New York from 25-27 September 2015 decided on the new global Sustainable Development Goals. The 17 Sustainable Development Goals with 169 associated targets are integrated and indivisible. The new Goals and targets came into effect on 1 January 2016 and will guide the decisions taken over the next fifteen years called Agenda by 2030.

The outcomes of all major UN conferences and summits have laid a solid foundation for sustainable development and have helped to shape the new Agenda. These include the Rio Declaration on Environment and Development; the World Summit on Sustainable Development; the World Summit for Social Development; the Programme of Action of the International Conference on Population and Development, the Beijing Platform for Action; and the United Nations Conference on Sustainable Development ("Rio+ 20"). The UN also affirms the follow-up to these conferences, including the outcomes of the Fourth United Nations Conference on the Least Developed Countries, the Third International Conference on Small Island Developing States; the Second United Nations Conference on Landlocked Developing Countries; and the Third UN World Conference on Disaster Risk Reduction.

The Millennium Development Goals were agreed in 2000. These provided an important framework for development but the progress was uneven and some MDG's went off track. The new Agenda builds on the Millennium Development Goals and seeks to complete what these did not achieve, particularly in reaching the most vulnerable.

UN's new agenda includes Universal Declaration of Human Rights, gender equality and the empowerment of women and girls, sustained, inclusive and sustainable economic growth, regional economic integration and interconnectivity in sustainable development, eradicating extreme poverty by 2030, providing inclusive & equitable quality education at all levels, promote physical and mental health and well-being, address threat posed by climate change and environmental degradation, sustainable management of our planet's natural resources, minimize the impact of cities on the global climate system, build peaceful, just and inclusive societies that provide equal access to justice and that are based on respect for human rights, foster inter-cultural understanding, tolerance, mutual respect and an ethic of global citizenship and shared responsibility, contribution of sport to the realization of development and peace and respect the territorial integrity and political independence of States.

### 6.3 SDG Targets compatible with Bamboo Craftsmanship

The targets of the individual SDG's were placed against the sector of Bamboo Craftsmanship in NER and the targets which could be contributed to by the process of manufacture were identified. The ways through which the SDG target could be met by bamboo craftsmanship sector were also identified. References were taken from the inferences of the previous sections about craftsmanship, eco-design, entrepreneurship and market study and life cycle assessment conducted in this research.

From a holistic perspective of business, market and environmental performance, the ways to fulfil SDG targets via bamboo craftsmanship were articulated and calibrated to be discussed in Table 6.1 below.

**Table 6.1** Ways to fulfil UN SDG 2030 Target via Bamboo Craftsmanship in NER (Generated by : Author)

SN	SDG AND ITS TARGET	WAYS TO FULFIL SDG TARGET VIA BAMBOO CRAFTSMANSHIP IN NER
<b>G.1</b>	<b>End poverty in all its forms everywhere</b>	
1.a	Ensure significant mobilization of resources from a variety of sources, including through enhanced development cooperation, in order to provide adequate and predictable means for developing countries, in particular least developed countries, to implement programmes and policies to end poverty in all its dimensions	For a quality controlled craft product, resources shall be required from various stakeholders within the perimeters of the craft location. Mobilisation of resources would bring better business opportunities for the economy of developing countries.
<b>G.5</b>	<b>Achieve gender equality and empower all women and girls</b>	
5.a	Undertake reforms to give women equal rights to economic resources, as well as access to ownership and control over land and other forms of property, financial services, inheritance and natural resources, appropriate new technology and financial services, including micro finance in accordance with national laws	Bamboo craftsmanship sector incorporates both men and women. Their workshops are their household courtyards where every member of the family including women help in the different processes. Decentralisation of work for product manufacture will facilitate women with equal rights to economic resources through micro finance.
<b>G.6</b>	<b>Ensure availability and sustainable management of water and sanitation for all</b>	
6.3	By 2030, improve water quality by reducing pollution, eliminating dumping and minimizing release of hazardous chemicals and materials, halving the proportion of untreated wastewater and substantially increasing recycling and safe reuse globally	Since the process includes minimal resins and chemicals, it minimizes the dumping of hazardous chemicals and materials into water through runoff. This keeps the water constituents non-toxic for terrestrial and aquatic life.
<b>G.8</b>	<b>Promote sustained, inclusive and sustainable economic growth, full and productive employment and decent work for all</b>	
8.2	Achieve higher levels of economic productivity through diversification, technological upgrading and innovation, including through a focus on high-value added and labour-intensive sectors	The sector includes a process of decentralisation of bamboo tools in their local area sheds. The raised quantity of products through technological intervention could bring economic productivity
8.3	Promote development-oriented policies that support productive activities, decent job creation, entrepreneurship, creativity and innovation, and encourage the formalization and growth of micro, small & medium-sized enterprises, including through access to financial services	The sector can provide decent job creation, entrepreneurship, creativity and innovation as they are financed by local NGO's and formalisation could be encouraged further for MSME's to receive better financial opportunities and outreach.

8.4	Improve progressively, through 2030, global resource efficiency in consumption and production and endeavour to decouple economic growth from environmental degradation, in accordance with the 10-year framework of programmes on sustainable consumption and production, with developed countries taking the lead	Bamboo material allows decoupling economic growth from environmental degradation as it adds positively to natural land transformation due to sustainable forestry management and pace of regrowth. Economic growth through sustainable production and consumption allows progressive improvement.
8.5	By 2030, achieve full and productive employment and decent work for all women and men, including for young people and persons with disabilities, and equal pay for work of equal value	Craftspeople are paid according to the number of artefacts prepared. Both men and women participate in the manufacturing process, with smaller business. Equal pay for equal no of artefacts could be maintained to achieve full and productive employment.
8.6	By 2020, substantially reduce the proportion of youth not in employment, education or training	Youth could be trained with new mechanical tools in their local sheds, also involve themselves in product diversification from their internet exposure as a new challenge for market.
<b>G.9</b>	<b>Build resilient infrastructure, promote inclusive and sustainable industrialization and foster innovation</b>	
9.b	Support domestic technology development, research and innovation in developing countries, by ensuring a conducive policy environment for industrial diversification and value addition to commodities	Industrial tools are derived from craft actions, to decrease effort and increase quantities of production. The tools have been installed in common areas for accessibility which allows industrial diversification in a local context.
9.4	By 2030, upgrade infrastructure and retrofit industries to make them sustainable, with increased resource-use efficiency and greater adoption of clean and environmentally sound technologies and industrial processes, with all countries taking action in accordance with their respective capabilities	Since the process is still in the evolutionary phase, and businesses are still to be developed, changes for sustainability can be incorporated in the initial phase, to avoid conflict and financial loss to change thereafter. This would include adoption of clean and environmentally sound technologies and industrial processes.
9.5	Enhance scientific research, upgrade the technological capabilities of industrial sectors in all countries, in particular developing countries, including, by 2030, encouraging innovation and substantially increasing the number of research and development workers per 1 million people and public and private research and development spending	Institutions with designers and engineers must be involved in the infrastructure upgradation along with management for business propagation. A scientific POV would be able to give inputs on the system for effectiveness and efficiency. This would also encourage institutions to deliver specialisations in the domain of RnD.
<b>G.11</b>	<b>Make cities and human settlements inclusive, safe, resilient and sustainable</b>	
11.a	Support positive economic, social and environmental links between urban, peri-urban and rural areas by strengthening national and regional development planning	The craft villages are around Guwahati at a range of 60-150kms. Transportation is reliable and the locations are potential nodes of business outside the city limits. Manufacturing units in the villages and market in the city could strengthen development and planning.
<b>G.12</b>	<b>Ensure sustainable consumption and production patterns</b>	
12.2	By 2030, achieve the sustainable management and efficient use of natural resources	Bamboo is a rapidly renewable material with mechanical strengths and properties compatible with multiple uses in the utilitarian domain. It is high on carbon sequestration and controls waste. Grows as a

		backyard grass for local economies with clean production techniques.
12.4	By 2020, achieve the environmentally sound management of chemicals and all wastes throughout their life cycle, in accordance with agreed international frameworks, and significantly reduce their release to air, water and soil in order to minimize their adverse impacts on human health and the environment	The process includes minimum energy in terms of electricity, heat and pressure, chemical usage is less than 1% and the wastes are biodegradable. There are no adverse impacts on human health and the environment due to its production.
12.5	By 2030, substantially reduce waste generation through prevention, reduction, recycling and reuse	The wastes created are in the form of bamboo dust which can be converted to briquettes for slow burning, or incorporated into the incense stick factory.
12.8	By 2030, ensure that people everywhere have the relevant information and awareness for sustainable development and lifestyles in harmony with nature	Increased interest towards this domain will make people aware of sustainability and its importance for the future. The act of being a stakeholder in any part of the process will evoke the satisfaction from awareness.
12.a	Support developing countries to strengthen their scientific and technological capacity to move towards more sustainable patterns of consumption and production	Educational institutes in India keep a scope for grass-root innovations. This inspires entrepreneurs to look forward towards a scientific and technological capacity for sustainable production and consumption.
12.b	Develop and implement tools to monitor sustainable development impacts for sustainable tourism that creates jobs and promotes local culture and products	Product diversification can improve the quality of markets for tourism which are installed at various tourist destinations in NER. This could improve the cultural representation as well as contribute to tourism and economy.
<b>G.15</b>	<b>Protect, restore and promote sustainable use of terrestrial ecosystems, sustainably manage forests, combat desertification, and halt and reverse land degradation &amp; halt biodiversity loss</b>	
15.3	By 2030, combat desertification, restore degraded land and soil, including land affected by desertification, drought and floods, and strive to achieve a land degradation-neutral world	Bamboo can easily restore degraded land and soil as it requires very little maintenance and develops a rhizome through the ground. The groove stays intact through floods stabilising desertification.
15.b	Mobilize significant resources from all sources and at all levels to finance sustainable forest management and provide adequate incentives to developing countries to advance such management, including for conservation and reforestation	National Bamboo Missions in the country are established at various locations. Financial resources could provide adequate incentives to advance for management, including conservation and reforestation of bamboo grooves.

## 6.4 Conclusion

As interpreted from the above analysis, it can be concluded that 8 out of the 17 Sustainable Development Goals can be contributed towards through bamboo craftsmanship enterprises. The targets of the goals, namely, Ending Poverty, Gender Equality, Clean Water & Sanitation, Decent Work and Economic Growth, Sustainable Industrialisation and Innovation, Safe and Resilient Cities, Responsible Production and Consumption and Responsibility towards Life on Land and Life under Water can be contributed towards by various aspects of the bamboo craftsmanship sector in NER of India. As mentioned above, references were taken from the inferences of the previous sections about craftsmanship, eco-design, entrepreneurship and market study and life cycle assessment conducted in the thesis. Also, references were taken from the material status of bamboo, the realtime interpretations of craft businesses and the involvement of the Indian government through missions for bamboo. Investing in bamboo craft enterprises will imprint a holistic development of the sustainable framework for craft, business and market towards a stable future for the upcoming generations.



## CHAPTER 7 :

### CONTRIBUTION OF THE RESEARCH

#### 7.1 Guidelines for Craftspeople's Bamboo Products to meet UNSDG 2030

This section of the research looks further into the Sustainable Development Goals and if Bamboo Craftsmanship can contribute to the SDG's targets for 2030. To validate the material and the technique for usability in the future, insights have been generated for the possible implementation of efforts and workforce towards fulfilling the targets of SDG's via Bamboo Craftsmanship.

The thesis researched upon four broad sections towards bamboo craftsmanship - craftsmanship and compatibility with eco-design principles, current entrepreneurial and market research, life cycle assessment comparing bamboo to other materials and the possible contributions to Sustainable Development Goals. The aim of the research was to validate indigenous Indian craftsmanship in terms of sustainability and bamboo furniture design in terms of eco-friendliness to create guidelines for socio-economic interventions along Sustainability Development Goals (SDG's) in the bamboo craftsmanship sector of North East Region (NER) of India. Thus, the entire thesis can be culminated to the following guidelines for execution which could be helpful to entrepreneurs who are thinking of investing in bamboo, eco-conscious consumers to validate their choices towards environmental and green responsibility, young designers about the characteristics and relative eco-friendliness of the material bamboo for future scope of implementation and also for the general public to understand the importance of implementing sustainable material consumption practices for a better future. The guidelines of implementation has been explained through factors desired, parameters & actionable points and impacts of implementation, and thus can be brought under the following 8 points of action [Table 7.1].

*Table 7.1 Guidelines for Craftspeople's Bamboo Products to meet United Nation's Sustainable Development Goals 2030 (Generated by : Author)*

<b>A</b>	<b>Raw Material Procurement in NER India</b>
<b>A.1</b>	<b>Factors Desired</b>
I.	Healthy bamboo poles belonging to a good taxa of species.
II.	Well-grown bamboos in a conducive environment for the growth of the grass.
III.	Matured bamboo poles aged 3-4 years.
<b>A.2</b>	<b>Parameters and Actionable Points</b>
I.	Bamboo poles must be procured from local resources. It must be encouraged to grow bamboo as a backyard grass for local economies of the NER region.
II.	Selection of bamboo species must be done from The International Network for bamboo and Rattan's (INBAR) released list of 'Priority Species of Bamboo and Rattan', that include 20 taxa of bamboo (species and genera) of particular economic importance in India, China and South East Asia (Rao et al, 1998).
<b>A.3</b>	<b>Impacts of Implementation</b>

I.	The Eco-Design Principles of cleaner extraction and techniques of production can be achieved by growing bamboo material as a backyard grass in craft settlements.
II.	Natural Land Transformation impact of LCA is contributed in a positive manner by sustainable forest management through bamboo forestry and pace of regrowth.
III.	Economic growth through bamboo as sustainable material production and consumption allows progressive improvement. It allows decoupling economic growth from environmental degradation, thus improving resource efficiency and satisfying UN SDG 2030 Goal 8.4.
IV.	Impacts on Ozone Layer Depletion and Terrestrial Eco-toxicity of LCA is reduced by procurement of bamboo from local sources as it decreases cost of transportation and petroleum consumption
V.	Degraded land and soil can be easily restored by bamboo as it requires low maintenance and develops a rhizome through the ground. The grooves stay intact through floods which are very prevalent in NER, stabilising desertification and thus satisfying UN SDG 2030 Goal 15.3.
VI.	Bamboo is a rapidly renewable material with mechanical strengths and properties compatible with multiple uses in the utilitarian domain. It is high on carbon sequestration and controls waste, thus satisfying UN SDG 2030 Goal 12.2 to achieve the sustainable management and efficient use of natural resources.
<b>B Treatment of Bamboo in NER</b>	
<b>B.1 Factors Desired</b>	
I.	Bamboo with durability for validity of product for consumers.
II.	Longer shelf life of bamboo products.
III.	Techniques of treatment with lesser impact on the environment.
<b>B.2 Parameters and Actionable Points</b>	
I.	Treatment of bamboo must be conducted using chemicals and resins with the least environmental impact.
II.	Simple cost effective traditional methods must be used for bamboo treatment that do not require complex supporting equipment.
III.	Traditional methods of bamboo treatment are - water leaching treatment, smoke treatment, lime washing treatment. Chemical methods are - pressure treatments (Bouchiere process, vacuum pressure treatment), boil treatment (hot and cold treatment, vertical soak diffusion method), dip-diffusion process and inter-nodal injection (Manjunath, 2022)
IV.	Chemicals used for bamboo treatment are - Coal tar creosote, Copper Chrome Arsenic (CCA) solution, Copper Chrome Boron (CCB) solution, Acid Cupric Chromate solution, Boric-Borax solution (Manjunath, 2022)
V.	Currently, Boric-Borax solution, water leaching treatment and smoke treatment are found to be the least impactful regarding environment degradation (Manjunath, 2022).
<b>B.3 Impacts of Implementation</b>	
I.	Treated bamboo will last for about 15 years in ground contact and 50 years for building components and products with non-ground contact. There shall be no fungus or termite attacks (Manjunath, 2022)
II.	Treated bamboo shall deliver a validated number for durability in years for product marketing towards customers.
III.	Treatment of bamboo shall increase the number of years towards life span of bamboo products, which shall further reduce its impact on the environment.

<b>C</b>	<b>Product Design with Bamboo</b>
<b>C.1</b>	<b>Factors Desired</b>
I.	Products designed to satisfy the aesthetic appeal and requirements of the current consumers.
II.	Incorporation of new product design languages and product diversification.
III.	Products catering to utility and functionality while accessorising via tourism and cultural representation.
<b>C.2</b>	<b>Parameters and Actionable Points</b>
I.	Bamboo products must have a high aesthetic quality in terms of form, finesse and colours to meet market requirements. The natural hues of bamboo must be retained to build visual association of the material with the consumers.
II.	Bamboo products must be designed to suit modern day living. The products must be functional but must lean more towards creating an impression by the material.
III.	Integration of different materials with bamboo must be encouraged. The flaws of one particular material could be supported by another material's strengths to improve the overall aesthetic and structural integrity of the product (Reubens, 2016)
IV.	Hedonistic Sustainability must be sought which would mean not associating sustainability with negativity but rather with youthful, dynamic and egalitarian transformation (Mianzi, 2018)
V.	Design thinking in the domain of transportation volumes must be encouraged as approximately 70% of the product cost arises from transportation. This happens as the products are difficult to dismantle and cause damages during transit and home deliveries through tight staircases and doors. Design thinking in this domain could improve cost effectiveness and dynamics of sale (A. Shende, personal communication, 10 Jan, 2017).
VI.	Ideas of recycling, repurposing and remanufacturing must be incorporated through design thinking for multiple lives of the evolving product.
VII.	Design thinking for mass customisation must be encouraged to satisfy consumers. It allows them the option for customisation according to their needs, thus increasing sale factor.
VIII.	In order to convince people in the NER to adapt to high priced bamboo products, the products must first get validated internationally and then re-approached NER for sale. This will remove the perception of bamboo as a cheap, background material and the high standard of design will create aspiration amongst customers. The designer must not lower the standard of design or accept a compromise below the high standards of US and UK markets (SMS Bordoloi, personal communication, 12 Oct, 2020).
<b>C.3</b>	<b>Impacts of Implementation</b>
I.	The change in the perception of bamboo will take another 10-20 years. Till then, the current trend must be followed and one should not fall very much out of the box. The upcoming trend of wabi-sabi, which allows asymmetry, modesty and appreciation of natural elements, might see a boom of bamboo products in the next 10-20 years
II.	Product diversification will improve the quality of markets for tourism which are installed at various tourist destinations in NER. This will improve the cultural representation as well as contribute to tourism and economy, thus satisfying UN SDG Goal 12.b.
III.	Validation of the products through national and international portals will create aspiration amongst consumers, thus improving the image of bamboo products.
<b>D</b>	<b>Consumerism and Target Group</b>
<b>D.1</b>	<b>Factors Desired</b>

I.	Bamboo products must adhere to the current nuances, belief systems and behaviour traits of the present generations.
II.	The target group must be well defined to direct the design development of products for a particular consumer base.
<b>D.2 Parameters and Actionable Points</b>	
I.	Stage for green revolution by green marketeers has been set over the last decade. There is a change in the demographic composition of green consumers. Bamboo products must profit from the opportunity.
II.	The new demographic of green consumers include Millennials, who are the young adults born in the 1980's and 1990's, transitioning to adulthood in the 21st century. They have grown up in a period of rapid change and are the first generation to be raised by the internet (Circella et al, 2016). Due to the attention and exposure of media to environmental issues, green consumption in this demographic has become prevalent in all the socio-economic levels (Roberts, 1996). Bamboo products must be designed and marketed to fulfil the needs of this targeted group.
IV.	Millennials are early adaptors of new trends and technologies that are later adopted by other segments of the society (Circella et al, 2016). They are more committed to environmental causes and try to have a healthier lifestyle. They view their early adulthood as a time to make a difference in their world and in their community. During this time, millennials develop better awareness of the world and exposure to cultural diversity, develop greater empathy for lower socio-economic populations, and become advocates for pressing societal issues with progressive attitudes and beliefs (Pew Research Centre, 2007). They are also civic minded and collaborative (Jacobson, 2007 & Raines, 2002). These considerations must be acted upon by design led opportunities.
V.	Millennials grasp the environmental consequences of their actions and have the education, motivation and social awareness to participate in the green movement. However, they have not fully begun to integrate their beliefs and actions. They are more attitudinally green rather than behaviourally green and appear to have a lack of personal involvement in green related activities regarding recycling, reusing and using (Diamantopoulous et al, 2013). Thus personalisation of products to accentuate personal choices displays must be incorporated to improve the interest of the cohort towards green consumerism.
<b>D.3 Impacts of Implementation</b>	
I.	Catering green products to the right category of people through proper incentives will help in the acceptance of the material through products.
II.	Design development through behavioural traits of targeted consumers will improve the scale of consumerism. Insights through designs will facilitate a clearer road map for future investments and returns.
III.	Understanding the Millennial generation cohort and their key influences will mean development of strategies through anticipation of preferences, allowing lead time for product manufacturing.
<b>E Design Implementation through Craftsmanship</b>	
<b>E.1 Factors Desired</b>	
I.	Indian craftsmanship must be recognised and utilised in the design process.
II.	Collaborative efforts between designers, businessmen and craftspeople for quality and effective disposition of products.
III.	Interventions in the craftsmanship sector for better quality and consumer related products.
IV.	To integrate craftsmanship community into urban needs and aesthetics without letting them loose their identity.
V.	A new Indian design identity with current aesthetic and functional requirements to be delivered via Indian craftsmanhip

VI.	Improvement in the socio-economic front for future prospects of the craftspeople generation.
<b>E.2</b>	<b>Parameters and Actionable Points</b>
I.	The Eco-Design Principles of high reliability and durability, lower energy consumption and cleaner materials for production can be achieved by products developed by Indian crafts in their current form
II.	The socio-economic gaps between designers and craftspeople must be reduced by designers using basic instincts and by being genuine, clear and frank with an attitude of respect towards craftsman families. A craftsman's workshop must be given considerable value in an enterprise to allow comfort and confidence of an artisan and to set a balanced power equation between designer and craftsman. If done right, the decisions are more rational and the efforts more rewarding (Kasliwal, 2020).
III.	There must be clear and transparent communication of thorough details between the designer and the craftsman, through mediums comprehensible to both parties. 3D models and 2D drawings with clear dimensions must be introduced in this aspect. 3D printing of scaled models must be introduced to explain joinery techniques and develop easy moulds for product diversification, and also for mindful and iterative discussions over design. This could contribute towards enhanced communication, efficiency and quality of the products for the business involved (Kasliwal, 2020 and Bheda, 2020).
IV.	There must be a healthy business temperament between the designer, craftspeople and businessmen.
V.	Craftsmanship must be pushed to learn new things and supported with machines to reduce stress and perform better. Through this, mass-customisation must be amplified amongst the craftspeople as they will be able to cater better to the consumers needs without over complication of work.
VI.	In rural and town settings, crafts must be made viable and at par with professions like a teacher. This allows a possibility of respectful integration of the next generation in the bamboo sector.
VII.	Craft through design must develop products of international standards without compromise. The products must receive validation from national and international platforms, set a benchmark to be able to sell it in a market which gives it the highest price and value. It must be able to deliver luxury customisation rather than mass production and be at par with Spanish and Italian designs (SMS Bordoloi, personal communication, 12 Oct, 2020).
<b>E.3</b>	<b>Impacts of Implementation</b>
I.	Craft community will be appreciated for their non-vocalised comprehension of material knowledge through their workshops, when acknowledged by designers and businesspeople.
II.	In the current modern times, the idealised conception of crafts as simply the counterpart of modernity, is standing in the way of a deep reflection on how craftsmanship could provide the ground for new thinking and production of work. By implementation of the above, crafts get a chance to grow through design, thus improving their scope of economic improvement.
III.	Decadence of crafts will be neutralised by providing a new direction to the knowledge of the crafts community.
IV.	Indian design will develop a unique identity within the globalised market, which is otherwise much dominated by the western culture and aesthetics.
V.	By sharing a common space with craftspeople, Indian designers will better understand the roots of indigenous materialism and integrate them tactfully into future designs. This will facilitate a revival of Indian craftsmanship through means of design in the Indian business scenario.
<b>F</b>	<b>Industrialisation of Bamboo Products</b>
<b>F.1</b>	<b>Factors Desired</b>
I.	Mindful steps taken towards environmental performance of industrial products.
II.	Incorporation and retainment of craftsmanship sector in the industrial manufacturing process.

F.2	Parameters and Actionable Points
I.	The 10 Eco-Design Principles, namely Recycling of Materials, High Reliability and Durability, Recycled Materials, Low Energy Consumption, Remanufacturing, Less Production Waste, Clean Production Technique, Reduction in Weight, Clean Materials and Less, Clean & Reusable Packaging (Hemel & Cramer, 2002) must be practiced in a holistic manner towards industrial product development. These principles act as a gateway towards developing eco-friendly products which are healthy for the environment.
II.	It has been proven through LCA that bamboo craft and industrial manufacturing process has the least environmental impact generated when compared with the materials plastic, steel and wood for manufacturing products including furniture. Thus manufacturing through bamboo must be encouraged for positive impacts towards the environment.
III.	Since the process of manufacturing using bamboo is still in the evolutionary phase, and businesses are still to be developed, changes towards sustainability must be incorporated in the initial stage to avoid conflict and financial loss to change thereafter. This would include adoption of clean and environmentally sound technologies and industrial processes, thus satisfying UN SDG 2030 Goal 9.4.
IV.	Institutions with designers and engineers must be involved in the infrastructure upgradation along with management for business propagation. A scientific POV would be able to give inputs on the system for effectiveness and efficiency. This would also encourage institutions to deliver specialisations in the domain of RnD, thus satisfying UN SDG 2030 Goal 9.5.
V.	For singular or integrated craft ventures, craft villages within a distance limit of 50-150 kms must be selected, such that the transportation is reliable and the locations are potential nodes of business outside city limits. Development of manufacturing units in the villages and markets in the city could strengthen development & planning, thus satisfying UN SDG 2030 Goal 11.a.
VI.	The industrial tools derived from craft actions must be installed in common areas of craftsmanship sectors for accessibility, which allows industrial diversification in a local context, thus satisfying UN SDG 2030 Goal 9.b.
VII.	The bamboo product manufacturing process in the current state includes minimum energy in terms of electricity, heat and pressure, chemical usage is less than 1% and the wastes are biodegradable. There are no adverse impacts on human health and the environment due to its production, thus satisfying UN SDG 2030 Goal 12.4. Any additional processes incorporated must use lesser amount of energy in terms of electricity, heat and air pressure.
VIII.	Minimal resins and chemicals must be used in the industrialisation process as it minimises the dumping of hazardous chemicals and materials into water through runoff. This keeps the water constituents non-toxic for terrestrial and aquatic life, thus satisfying UN SDG 2030 Goal 6.3.
IX.	Wastes created are in the form of bamboo dust which must be converted to alternate products such as briquettes for slow burning or incorporated into the incense stick factory. Treatment of wastes must be taken care of mindfully as it is the major source of adulteration of natural land and water ecosystems. Indigenous efforts must be calibrated towards repercussions of waste and its effective management, thus satisfying UN SDG 2030 Goal 12.5.
X.	Transportation of raw materials and finished products must be kept to a minimum to decrease the consumption of petroleum products and eventually the environmental impact of the produce.
XI.	For a quality controlled craft product, resources must be acquired from various stakeholders within the perimeters of the craft location. Mobilisation of resources will bring better business opportunities, which would cater towards ending poverty in all its dimensions, thus satisfying UN SDG 2030 Goal 1.a.
XII.	Industrialisation in this sector must include the process of decentralisation within the craftsmanship community via introduction to bamboo tools in their local area sheds. The raised quantity of products through technological intervention could bring economic productivity, thus satisfying UN SDG 2030 Goal 8.2.

XIII.	An enterprise must always consider the complete ecological impact of their business activity. There must be thoughts of future plans throughout the lifespan of a product regarding its end, repair systems and multiple lifespans via circular economy models.
<b>F.3 Impacts of Implementation</b>	
I.	A holistic approach towards sustainable and environmentally responsive industrial techniques will deliver a steady growth of the domain towards a climate positive future.
II.	Mindful industrial processes will translate to positive marketing of the product towards targeted consumers without green-washing. It will also add value to the image of bamboo as an eco-friendly material.
III.	Small and medium industrialisation ventures through craft and regional resources will improve economic prospects for the sector, which is already in tandem with the principles of Eco-Design.
IV.	Researched and pre-determined industrial processes with the help of sustainability researchers, designers and engineers will create a strong base for sustainable methods of industrial implementation via circular economy methods.
<b>G Marketing of Bamboo Products</b>	
<b>G.1 Factors Desired</b>	
I.	Effective marketing strategies for the domain of bamboo products to cater to targeted eco-conscious consumers.
I.	Successful and mindful business marketing strategies by understanding consumer behaviour and their buying practices.
<b>G.2 Parameters and Actionable Points</b>	
I.	New identity generation through product diversification help products to sell with a new enthusiasm from consumers. Compelling stories must be used as a marketing tool to sensitive customers towards a lifestyle of sustainability.
II.	Packaging solutions for unboxing, market display and sale must be incorporated to improve interest towards products, which are also befitting towards the principles of Eco-Design.
III.	The products must be priced according to the market being addressed. There are two distinct type of customers in the market - one is the upper class, who appreciate the hardship of craftsmanship and value art, thus willing to pay the price; and the other is the middle class who question the authenticity of craft and its price. The main clientele of sustainability related products are the upper and upper middle class.
IV.	Enterprises must maintain an active online presence to inform consumers of their existence and provide them an option at sustainable purchase decisions. The websites must display quality pictures with modern backgrounds to relate to the customer, which adds to the quality of aspiration. The websites must not mention any particular genre of customers but must price their products according to the affordability of upper and upper middle class customers.
V.	The bamboo furniture pieces must range from ₹7,000 - ₹25,000; lamps and mirrors must range from ₹2,000 - ₹16,000 and other smaller home decor items such as bowls and baskets must range within ₹2,500, thus being on the higher side of price range for middle class people. The disposable income of middle class families for the current market range from ₹40,000 - ₹2,50,000. (Rajora, 2023)
VI.	The final valuation of the industrial craft produce must be based upon material quality, craftsman efforts, local economy generation, social migration prevention, advantage of local knowledge for the educationally deprived and decreased social disturbances.

VII.	Regarding millennial generation, they have a larger economic impact as they are involved in family purchase decisions. With 34% (440 million) of country's total population, India has one of the largest millennial populations (BFSI Economic Times, 2023). It makes them the most powerful consumer group in the market place. This fact must be considered while making economic decisions for product development.
VIII.	Millennials continue to be most willing to pay extra for sustainable offerings. They are also more supportive of stricter environmental laws, more likely to attribute global warming to human activity, and likely to favour environmentally friendly policies (Nielsen, 2015). Such product information must be used in product marketing for millennials.
IX.	Frugality and economic motives are particularly critical in millennials decision making, as their financial resources are limited. Marketing tactics towards long term benefits of environmental interventions must be implemented for future oriented millennials as they would accept delays of immediate gratification to achieve better goals long term.
X.	Rational and self oriented motives rather than emotional and others-oriented motives must be implemented in predicting millennials' commitment to act environmentally friendly (Naderi & Steenberg, 2018).
XI.	Millennials must be treated as a collection of submarkets that differ in their levels of awareness of ethical issues. Discrete motives must be considered when making consumption decisions to engage in cause related purchasing to varying degrees (Bucic et al, 2012).
XII.	To access frugality as an influencer, marketers must demonstrate the complete value of the product or brand to win millennials' favour in terms of frugality, economy and strategy of persuasion. An emphasis of future outcomes of acting environmentally friendly could be an effective strategy for promoting green consumption (Naderi & Steenberg, 2018).
XIII.	Strict Quality Control must be maintained in the products to gather trust, confidence and long time associations with the customers. Quality must not be just in the final stage but rather quality must be executed by a robust system through the entire process. Quality lies not in the object but in managing expectations of the clients, with a transparency of acceptable range of errors and disclaimers of product usage (Kasliwal, 2020)
<b>G.3</b>	<b>Impacts of Implementation</b>
I.	Strategies involved to increase interest towards bamboo products will enhance people's sustainability awareness and its future importance. Being a stakeholder in any determined part of the process will evoke satisfaction from execution, thus satisfying UN SDG 2030 Goal 12.8.
II.	Bamboo products delivered by industrialised craftsmanship will reach the right section of consumers through appropriate channels and relatable content.
<b>H</b>	<b>Socio-Economic Impacts and Outreach of Bamboo Sector</b>
<b>H.1</b>	<b>Factors Desired</b>
I.	Socio-economic upliftment of the bamboo craftsmanship sector in NER according to UN SDG 2030.
II.	Maximising financial, research and industrial support for the bamboo sector in NER.
<b>H.2</b>	<b>Parameters and Actionable Points</b>
I.	Bamboo craftsmanship sector incorporates both men and women. Their workshops are their household courtyards where every member of the family including women and children help in the different processes. Decentralisation of work must be incorporated in the product manufacture process to facilitate women with equal rights to economic resources through micro finance, thus achieving gender equality for UN SDG 2030 Goal 5.a.

II.	The sector must provide decent job creation, entrepreneurship, creativity and innovation by being financed by local NGO's. Formalisation of the sector must be encouraged for MSME's to receive better financial opportunities and outreach, thus satisfying UN SDG 2030 Goal 8.3.
III.	Craftspeople are paid according to the number of artefacts prepared. Both men and women participate in the manufacturing process, with smaller business. Equal pay for equal number of artefacts must be maintained to achieve full and productive employment.
IV.	Youth must be trained with new mechanical tools in their local sheds, also involve themselves in product diversification from their internet exposure as a new challenge for market.
V.	Educational institutes in India must keep a scope for grass-root innovations. This will inspire entrepreneurs to look forward in a scientific and technological capacity towards sustainable production and consumption.
VI.	National Bamboo Missions in the country are established at various locations. Financial resources through them must provide adequate incentives to advance for management, including conservation and reforestation of bamboo grooves.
<b>H.3</b>	<b>Impacts of Implementation</b>
I.	Decent work for all women and men, including for young people, and equal pay for work of equal value will be achieved by incorporating pay by number of artefacts created, thus satisfying UN SDG 2030 Goal 8.5.
II.	By employing youth in getting trained with new mechanical tools, proportion of youth not in employment, education or training will be substantially reduced, thus satisfying UN SDG 2030 Goal 8.6.
III.	Involvement of Indian educational institutions will strengthen their scientific and technological capacity to move towards more sustainable patterns of consumption and production, thus satisfying UN SDG 2030 Goal 12.a.
IV.	Mobilising significant resources from National Bamboo Missions at all levels will finance sustainable forest management and provide adequate incentives to advance management and satisfy UN SDG 2030 Goal 15.b.

## 7.2 Limitations of the Research

The conducted research has the following limitations :

- For assessment of craft attributes against the Principles of Eco-Design, only four different crafts in the state of Assam were considered due to geographical proximity, whereas there are a multitude of variety of crafts in the India.
- For entrepreneurs in bamboo, only Indian entrepreneurs were selected for interviews as the assessment was conducted in the context of India.
- Though there are multiple materials through which furniture is developed in India for the urban market, only five different materials were considered for the Comparative Life Cycle Assessment.
- Most of the data collected is from the North East Region of India due to the geographical proximity of the industries and craft settlements. The results of the research might differ if placed in a different context.
- The timeline considered for the research is within the last decade. The results of the research might differ if placed in a different time context.

### 7.3 Conclusion

Finally, the research delivers Guidelines through important considerations and factors of intervention in the bamboo craftsmanship sector for socio-economic upliftment of the craftspeople in the NER of India, while simultaneously encouraging material intervention for product design towards the impending climate crisis in the near future. It also throws light upon future product possibilities for eco-conscious generations through validation of bamboo material for the urban market. The results bring forward possibilities of amendments and interventions in the holistic domain of craft entrepreneurship and a new dimension towards sustainable design in business.

The guidelines shall be useful for all the stakeholders who are involved in the process and propagation of bamboo craft produce in NER of India. It shall help in the holistic development of the sector for the people in NER, acknowledging their indigenous knowledge which has been passed down over generations. Every knowledge has to evolve over time according to the new terms of the world. Inability to keep up might lose the strength of propagation amongst the consumer masses. Hence, through this thesis an attempt has been made to bring a structure to the ideation and contemplation of bamboo craft produce which can adjust well to the shifting norms of the current world, by acknowledging the potential of the material and manipulating it to be a fit produce for the upcoming generations of the near future.



## REFERENCES

- Ahbe, S., Braunschweig, A., & Müller-Wenk, R. (1990). Methodology for ecobalances based on ecological optimization. *Bern: Buwal (Safel). (Environment Series, 133)*.
- Alsop, R. (2008). The trophy kids grow up: How the millennial generation is shaking up the workplace. *John Wiley & Sons*.
- Anvar, M., & Venter, M. (2014). Attitudes and purchase behaviour of green products among generation Y consumers in South Africa. *Mediterranean Journal of Social Sciences, 5*(21), 183.
- Argyris, C. (1983). Action Science and Intervention. *Journal of Applied Behavioural Science* 19(2): 115-140.
- Assam State Portal. (2022, August 20). *Cane and Bamboo*. <https://assam.gov.in/citizen/428>
- Azapagic, A., Clift, R.: Life cycle assessment as a tool for improving process performance: a case study on boron products. *Int. J. Life Cycle Assess.* 4, 133–142 (1999)
- Azapagic, A., Perdan, S.: Indicators of sustainable development for industry: a general framework. *Trans. IChemE* 78, 243–261 (2000). doi:10.1205/095758200530763
- Barash, D.P., & Webel, C.P. (2002). Peace and conflict studies. *Sage Publications, London*.
- Barbier, E.B (1987). The concept of sustainable economic development. *Environmental Conservation* 14:101–110.
- Batson, C.D. (1991). The Altruism Question: Toward A Social-psychological Answer. *Erlbaum, Hillsdale, NJ*.
- Baumann, H., Boons, F., & Bragd, A. (2002). Mapping the green product development field: engineering, policy and business perspectives. *Journal of cleaner production, 10*(5), 409-425.
- Baumann, H. (2000). Introduction and organisation of LCA activities in industry: description and analysis of two LCA projects in Swedish companies. *The International Journal of Life Cycle Assessment, 5*, 363-368.
- Baumann, M., Held, M., Herrmann, C., Saraev, A., Riese, O., & Steininger, H. (2012, September). Ecodesign tool for SMEs in the electronics sector. In *2012 Electronics Goes Green 2012+* (pp. 1-8). IEEE.
- Bhamra, T., & Lofthouse, V. (2016). Design for sustainability: a practical approach. Routledge.
- Bhamra, T., Lilley, D., & Tang, T. (2011). Design for sustainable behaviour: Using products to change consumer behaviour. *The Design Journal, 14*(4), 427-445.
- Bhat, J. A., & Yadav, P. (2016). The sector of handicrafts and its share in Indian economy. *Arabian Journal of Business and Management Review* 5, 3.
- Bheda, C., & Kasliwal, A. (2020, June 28). Design Strategy and Business Thinking. *Instagram live of @designstrategistwud, World University of Design, Sonipat*.
- Binswanger, M. (2001). Technological progress and sustainable development: what about the rebound effect?. *Ecological economics, 36*(1), 119-132.
- Bjørn, A., Diamond, M., Owsianiak, M., Verzat, B., & Hauschild, M. Z. (2015). Strengthening the link between life cycle assessment and indicators for absolute sustainability to support development within planetary boundaries. Chicago
- Bjørn, A., Owsianiak, M., Molin, C., & Laurent, A. (2018). Life Cycle Assessment Theory and Practice: Main Characteristics of LCA. Springer International Publishing, 9-17. doi 10.1007/978-3-319-56475-3
- Boks, C., & McAlone, T. C. (2009). Transitions in sustainable product design research. *International Journal of Product Development, 9*(4), 429-449.
- Boran, S., & Cavdar, A. D. (2013). Evaluation of bamboo as furniture material and its furniture designs. *Prologno, 9*(February), 811–819. Retrieved from <https://www.researchgate.net/publication/295401511>
- Bothbest Bamboo Flooring. (2023). *Benefits of Bamboo Plywood*. Retrieved Jan 15, 2024 from <https://www.bambooindustry.com/blog/benefits-of-bamboo-plywood.html#:~:text=They%20are%20resistant%20to%20moisture,times%20thus%20increasing%20its%20lifespan.> Accessed on 15 Jan, 2024.
- Boulay, A. M., Bare, J., Benini, L., Berger, M., Lathuillière, M. J., Manzardo, A., & Pfister, S. (2018). The WULCA consensus characterization model for water scarcity footprints: assessing impacts of water consumption based on available water remaining (AWARE). *The International Journal of Life Cycle Assessment, 23*, 368-378.
- Bovea, M.D., & Pérez-Belis, V. (2012). A taxonomy of ecodesign tools for integrating environmental requirements into the product design process. *Journal of Cleaner Production* 20(1), 61–71.

- Boyd, D. (2010). Ethical determinants for generations X and Y. *Journal of Business Ethics*, 93(3), 465-469.
- Brezet, H., & van Hemel, C. (1997). Ecodesign: A promising approach to sustainable production and consumption. *United Nations Environment Programme, Industry and Environment, Paris*.
- Brezet, H., Stevels, A., & Rombouts, J. (1999, February). LCA for ecodesign: the Dutch experience. In Proceedings First International Symposium on Environmentally Conscious Design and Inverse Manufacturing (pp. 36-40). IEEE.
- Britannica. (2023, May 22). *Bamboo*. <https://www.britannica.com/plant/bamboo>
- Broberg, O., & Christensen, P. (1999). LCA experiences in Danish industry: results of a survey. *The International Journal of Life Cycle Assessment*, 4, 257-262.
- Brones, F., & de Carvalho, M. M. (2015). From 50 to 1: Integrating literature toward a systemic ecodesign model. *Journal of Cleaner Production*, 96, 44-57.
- Brundtland, G.H. (1987). Our common future. *Oxford University Press, Oxford*.
- Bucic, T., Harris, J., & Arli, D. (2012). Ethical consumers among the millennials: A cross-national study. *Journal of Business Ethics*, 110(1), 113-131.
- Bültmann, A. (1997). Produktökobilanzen und ihre Anwendung in deutschen Unternehmen. *Schriftenreihe des IÖW*, 112, 97.
- Burall, P. (1991). Green design. *London : Design Council*.
- Cappelli, F., Delogu, M., & Pierini, M. (2006). Integration of LCA and EcoDesign guideline in a virtual cad framework. *Proceedings of LCE, 2006*, 185-188.
- Carless, S. A., & Wintle, J. (2007). Applicant attraction: The role of recruiter function, work-life balance policies and career salience. *International Journal of Selection and Assessment*, 15(4), 394-404.
- Casaló, L. V., & Escario, J. J. (2016). Intergenerational association of environmental concern: Evidence of parents' and children's concern. *Journal of Environmental Psychology*, 48, 65-74.
- Chaudhary, R., & Bisai, S. (2018). Factors influencing green purchase behavior of millennials in India. *Management of Environmental Quality: An International Journal*.
- Chen, T. B., & Chai, L. T. (2010). Attitude towards the environment and green products: Consumers' perspective. *Management science and engineering*, 4(2), 27-39.
- Chiu, M. C., & Kremer, G. E. O. (2011). Investigation of the applicability of Design for X tools during design concept evolution: a literature review. *International Journal of Product Development*, 13(2), 132-167.
- Circella, G., Tiedeman, K., Handy, S., Alemi, F., & Mokhtarian, P. (2016). What affects Millennials' mobility? Part I: investigating the environmental concerns, lifestyles, mobility-related attitudes and adoption of technology of young adults in California.
- Commission of the European Communities. (2001). General Report on the Activities of the European Union. European Commission.
- Coomaraswamy, A. K., & Moore, A. C. (1909). *The Indian Craftsman* (Vol. 6). London: Probsthain.
- Creative Mornings (2014, January 8). *Sandeep Sangaru : Minimal*. Retrieved from <https://www.youtube.com/watch?v=f5WrnEz0iHA>
- Daly, H. E. (2014). *Beyond growth: the economics of sustainable development*. Beacon Press.Chicago
- Das, M., & Das, A. K. (2019). Craft Education In Design. *DS 95: Proceedings of the 21st International Conference on Engineering and Product Design Education (E&PDE 2019)*, University of Strathclyde, Glasgow.
- Das, M., & Das, A. K. (2021). Eco-Design, Craftsmanship and Sustainability. In *Design for Tomorrow—Volume 1: Proceedings of ICoRD 2021* (pp. 889-899). Springer Singapore.
- De Caluwe, N. (2004, January). Business benefits from applied EcoDesign. In 2004 International IEEE Conference on the Asian Green Electronics (AGEC). Proceedings of (pp. 200-205). IEEE.
- Delft University of Technology. (2024). *The concept, structure, and midpoint tables of the eco-costs for LCA*. Sustainability Impact Metrics. <https://www.ecocostsvalue.com/ecocosts/eco-costs-concept/>.
- Den Hartog, F. & van Sluijs, E. (1995). *Onderzoek in organisaties: een methodologische reisgids*. PhD thesis, Delft University of Technology, Delft, the Netherlands.

- Diamantopoulos, A., Schlegelmilch, B. B., Sinkovics, R. R., & Bohlen, G. M. (2003). Can socio-demographics still play a role in profiling green consumers? A review of the evidence and an empirical investigation. *Journal of Business research*, 56(6), 465-480.
- Du Pisani, J. A. (2006). Sustainable development—historical roots of the concept. *Environmental sciences*, 3(2), 83-96.
- Dubrovsky, V. J., Kiesler, S., & Sethna, B. N. (1991). The equalization phenomenon: Status effects in computer-mediated and face-to-face decision-making groups. *Human-computer interaction*, 6(2), 119-146.
- Duke, B. V. (2016). When I was your age. *Washington, DC: Center for American Progress*. Retrieved from <https://www.americanprogress.org/issues/economy/report/2016/03/03/131627/when-i-was-your-age/>.
- Eagan, P., Finster, M., & Hussey, D. (2001, December). Creating business value by linking industrial ecology with business strategy and product design. In *Proceedings Second International Symposium on Environmentally Conscious Design and Inverse Manufacturing* (pp. 842-847). IEEE.
- EC (2005). Directive 2005/32/EC of the European parliament and of the council of 6 July 2005 establishing a framework for the setting of ecodesign requirements for energy-using products. *Official Journal of the European Union*, 191, 29-58.
- EC-JRC: Environmental Footprint—Update of Life Cycle Impact Assessment Methods; DRAFT for TAB (Status: May 2, 2016) Resources, Water, Land. Ispra, Italy (2016)
- EC-JRC.: European Commission—Joint Research Centre—Institute for Environment and Sustainability: International Reference Life Cycle Data System (ILCD) Handbook—General Guide for Life Cycle Assessment—Detailed Guidance. First edition March 2010. EUR 24708 EN. Publications Office of the European Union, Luxembourg (2010)
- Ekvall, T. (2012). Life cycle assessment. Ahmed K (ed) Getting to green: a sourcebook of pollution management policy tools for growth and competitiveness. World Bank, Washington, DC. <http://documents.worldbank.org/curated/en/560021468330349857/Getting-to-green-a-sourcebook-of-pollution-management-policy-tools-for-growth-and-competitiveness>
- Elkington, J., & Rowlands, I. H. (1999). Cannibals with forks: The triple bottom line of 21st century business. *Alternatives Journal*, 25(4), 42.
- Erikson, E. H. (1993). Childhood and society. *WW Norton & Company*.
- Ernst&Young. (2012). Competitive study on Handicrafts Sector in China. Retrieved from website of Exports Council of India.
- Fadini, U., Mari, G., & Giovannini, P. (2010, October). on Richard Sennett's The Craftsman. In *Iris* (Vol. 2, No. 4, pp. 507-521).
- Fantke, P., Jolliet, O., Evans, J. S., Apte, J. S., Cohen, A. J., Hänninen, O. O., ... & McKone, T. E. (2015). Health effects of fine particulate matter in life cycle impact assessment: findings from the Basel Guidance Workshop. *The International Journal of Life Cycle Assessment*, 20, 276-288.
- Farrelly, D. (1984). The Book of Bamboo, Sierra Club Books. *San Francisco, California*. National Bamboo Mission, India
- Farris, R., Chong, F., & Danning, D. (2002). Generation Y: Purchasing power and implications for marketing. *Academy of Marketing Studies Journal*, 6(1-2), 89.
- Feuer, L. S. (1969). The Conflict of Generations. *New York and London*.
- Fiksel, J. 1996, Design for Environment: Creating Eco-Efficient Products and Processes. McGraw-Hill, New York.
- Finkbeiner, M. (2014). Product environmental footprint—breakthrough or breakdown for policy implementation of life cycle assessment?. *The International Journal of Life Cycle Assessment*, 19, 266-271.
- Foshay, A. W. (1998, June). Action research in the nineties. In *The Educational Forum* (Vol. 62, No. 2, pp. 108-112). Taylor & Francis Group.
- Fry, T. (2009). Design futuring. University of New South Wales Press, Sydney, 71-77.
- Fuad-Luke, A. (2002). EcoDesign: the sourcebook. Chronicle Books.
- Fuller, R. B. (2008). Operating manual for spaceship earth. Estate of R. Buckminster Fuller.
- Furlow, N. E., & Knott, C. (2009). Who's reading the label? Millennials' use of environmental product labels. *The journal of applied business and economics*, 10(3), 1.
- Galatola, M., & Pant, R. (2014). Reply to the editorial “Product environmental footprint—breakthrough or breakdown for policy implementation of life cycle assessment?” written by Prof. Finkbeiner (Int J Life Cycle Assess 19 (2): 266–271). *The International Journal of Life Cycle Assessment*, 19, 1356-1360.

- Gallup, I. (2016). *How millennials want to work and live*. Retrieved from <http://www.gallup.com/reports/189830/millennials-work-live.aspx>.
- Gaziulusoy, A. I. (2015). A critical review of approaches available for design and innovation teams through the perspective of sustainability science and system innovation theories. *Journal of cleaner production*, 107, 366-377.
- Geller, E. S. (1995). Actively caring for the environment: An integration of behaviorism and humanism. *Environment and Behavior*, 27(2), 184-195.
- Ghosh, A. (2012). Triggering innovation and creativity in traditional handicraft sectors : An Indian perspective (ISSN 0973-936X). *Management Insight* , VIII (1), 2-5.
- Goedkoop, M.J., Spriensma, R. (2000). Eco-indicator 99, a damage oriented method for lifecycle impact assessment, methodology report (update April 2000)
- Goldman, A. (2001). The Aesthetic. In B. Gaut and D. McIver Lopes (Eds.), *The Routledge companion to aesthetics* (pp. 181-192). London: Routledge.
- Gopinathan, V. (2018, January). Form. Function. Furniture. Craftsmen at Christie's. Retrieved from [http://www.insiteindia.in/2018/jan/Insite%20Story\\_Furniture%20Design.pdf](http://www.insiteindia.in/2018/jan/Insite%20Story_Furniture%20Design.pdf)
- Govers, P. C., & Schoormans, J. P. (2005). Product personality and its influence on consumer preference. *Journal of Consumer Marketing*, 22(4), 189-197.
- Govers, P., Hekkert, P., & Schoormans, J. P. (2003, October). Happy, cute and tough: Can designers create a product personality that consumers understand. In *Design and emotion* (pp. 345-349). CRC Press.
- Greendex (2012). *Consumer choice and the environment – a worldwide tracking survey*. Retrieved from [http://images.nationalgeographic.com/wpf/media-content/file/NGS\\_2012\\_Final\\_Global\\_report\\_Jul20-cb1343059672.pdf](http://images.nationalgeographic.com/wpf/media-content/file/NGS_2012_Final_Global_report_Jul20-cb1343059672.pdf)
- Griskevicius, V., Tybur, J. M., & Van den Bergh, B. (2010). Going green to be seen: status, reputation, and conspicuous conservation. *Journal of personality and social psychology*, 98(3), 392.
- Grønhoj, A., & Thøgersen, J. (2009). Like father, like son? Intergenerational transmission of values, attitudes, and behaviours in the environmental domain. *Journal of Environmental Psychology*, 29(4), 414-421.
- Guinée, J.B., Gorée, M., Heijungs, R., Huppes, G., Kleijn, R., de Koning, A., van Oers, L., Wegener Sleswijk, A., Suh, S., Udo de Haes, H.A., de Bruijn, J.A., van Duin, R., Huijbregts, M.A.J. (eds.). (2002). *Handbook on Life Cycle Assessment: Operational Guide to the ISO Standards*. Series: Eco-efficiency in industry and science. Kluwer Academic Publishers, Dordrecht. Hardbound, ISBN 1-4020-0228-9; Paperback, ISBN 1-4020-0557-1
- Guinness World Records. (2022, September 25). *Fastest Growing Plant*. <https://www.guinnessworldrecords.com/world-records/fastest-growing-plant/>
- Hance Construction. (2020, July). *Butler Building Renovation and Durability of Steel*. <https://www.hanceconstruction.com/news/blog/butler-building-renovation-and-durability-of-steel#:~:text=How%20long%20do%20steel%20buildings,from%2050%20to%20100%20years>. Accessed on 15 Jan, 2024.
- Handa, R. (1999). Against arbitrariness: Architectural signification in the age of globalization. *Design Studies*, 20(4), 363-380
- Hanssen, O. J. (1999). Status of Life Cycle Assessment (LCA) activities in the Nordic region. *The International Journal of Life Cycle Assessment*, 4, 315-320.
- Hauschild, M. Z., & Huijbregts, M. A. (2015). *Introducing life cycle impact assessment* (pp. 1-16). Springer Netherlands.
- Hauschild, M., & Potting, J. (2005). Spatial differentiation in Life Cycle impact assessment-The EDIP2003 methodology. *Environmental news*, 80, 1-195.
- Hauschild, M., & Wenzel, H. (1998). Environmental assessment of products. Volume 2: Scientific background. *Chapman&Hall, UK*, 316-329.
- Hauschild, M.Z. (2018). Life Cycle Assessment Theory and Practice: LCA Methodology. *Springer International Publishing*. 59-66. doi 10.1007/978-3-319-56475-3
- Hawken, P., Lovins, A., & Lovins L.H. (1999). *Natural capitalism: Creating the next industrial revolution*. Little Brown, Boston.
- Heijungs, R., Guinée, J.B., Huppes, G., Lankreijer, R.M., Udo de Haes, H.A., Wegener Sleswijk, A., Ansems, A.M.M., Eggels, P.G., van Duin, R., de Goede, H.P. (1992). *Environmental Life Cycle Assessment of products. Guide and Backgrounds*. Centre of Environmental Science (CML), Leiden University, Leiden

- Heiskanen, E. (2000). Managers' interpretations of LCA: enlightenment and responsibility or confusion and denial? *Bus. Strateg. Environ.* 9, 239–254. doi:10.1002/1099-0836(200007/08)9: 4<239:AID-BSE250>3.0.CO;2-6
- Hekkert, P. (2006). Design aesthetics: principles of pleasure in design. *Psychology science*, 48(2), 157.
- Hemel, C., & Cramer, J. (2002). Barriers and stimuli for ecodesign in SMEs. *Journal of Cleaner Production* 10, 439–453.
- Hofmann, M., Hofmann, H., Hagelüken, C., & Hool, A. (2018). Critical raw materials: A perspective from the materials science community. *Sustainable Materials and Technologies*, 17, e00074.
- Holdren, J.P., Ehrlich, P.R. (1974). Human population and the global environment. *Am. Sci.* 62, 282–292
- Huang, E., Hunkeler, D. (1995). Life cycle analysis: summary of a fortune 500 survey and a Japanese comparison. Vanderbilt Univ. US–Japan Cent
- Hunkeler, D., Vanakari, E. (2000) EcoDesign and LCA: Survey of current uses of environmental attributes in product and process development. *Int. J. Life Cycle Assess.* 5, 145–151
- Hunt, R.G., Sellers, J.D., Franklin, W.E. (1992). Resource and environmental profile analysis: a life cycle environmental assessment for products and procedures. *Environ. Impact Assess. Rev.* 12(12), 245–269
- India Times (2018). *MSME's most attractive segment in commercial credit with fastest growth, Low NPAs*. Retrieved from <https://economictimes.indiatimes.com/small-biz/sme-sector/sidbi-and-transunion-cibil-launch-msme-pulse/articleshow/63269240.cms?from=mdr>.
- ISO.: Environmental Management—Life Cycle Assessment—Principles and Framework (ISO 14040). ISO, the International Organization for Standardization, Geneva (2006a)
- ISO.: Environmental Management—Life Cycle Assessment—Requirements and Guidelines (ISO 14044). ISO, the International Organization for Standardization, Geneva (2006b)
- Jacobson, W. S. (2007). Two's company, three's a crowd, and four's a lot to manage: Supervising in today's intergenerational workplace. *Popular Government, Fall*, 18-23.
- Jadhav, S. (2013). Indian handicrafts: Growing or depleting. *IOSR Journal of Business and Management*, 2(15), 7-13.
- Jang, Y. J., Kim, W. G., & Bonn, M. A. (2011). Generation Y consumers' selection attributes and behavioral intentions concerning green restaurants. *International Journal of Hospitality Management*, 30(4), 803-811.
- Jena, P. K. (2010). Indian Handicrafts in Globalization Times: An Analysis of Global - Local Dynamics (ISSN 1334-4676). *INDECS*, 8 (2), 119-137.
- Jeswiet, J., Hauschild, M. (2005). EcoDesign and future environmental impacts. *Mater. Des.* 26, 629–634. doi:10.1016/j.matdes.2004.08.016
- Johansson, G. (2002) Success factors for integration of ecodesign in product development: a review of state of the art. *Environ. Manag. Health* 13, 98–107. doi:10.1108/09566160210417868
- Johnson, C. Y., Bowker, J. M., & Cordell, H. K. (2004). Ethnic variation in environmental belief and behavior: An examination of the new ecological paradigm in a social psychological context. *Environment and behavior*, 36(2), 157-186.
- Johnson, M.P., Schaltegger, S. (2015) Two decades of sustainability management tools for SMEs: how far have we come? *J. Small Bus. Manag.* doi:10.1111/jsbm.12154
- Kalleberg, A. L. (2011). Good jobs, bad jobs: The rise of polarized and precarious employment systems in the United States, 1970s-2000s. *Russell Sage Foundation*.
- Kanchanapibul, M., Lacka, E., Wang, X., & Chan, H. K. (2014). An empirical investigation of green purchase behaviour among the young generation. *Journal of Cleaner Production*, 66, 528-536.
- Karlsson, R., & Luttrupp, C. (2006). EcoDesign: what's happening? An overview of the subject area of EcoDesign and of the papers in this special issue. *Journal of Cleaner Production* 14 (15- 16), 1291-1298.
- Kesteren, V. I., Stappers, P. J., & Kandachar, P. (2005). Representing product personality in relation to materials in a product design problem. *Nordes*, (1).
- Kim, H., Knight, D. K., & Crutsinger, C. (2009). Generation Y employees' retail work experience: The mediating effect of job characteristics. *Journal of Business Research*, 62(5), 548-556.
- Kim, Y. J., Njite, D., & Hancer, M. (2013). Anticipated emotion in consumers' intentions to select eco-friendly restaurants: Augmenting the theory of planned behavior. *International Journal of Hospitality Management*, 34, 255-262.
- Kleemann, F. (2010). *Book Reviews of the Craftsman by Richard Sennett*. London: Penguin Books. ISBN, 9780141022093.

- Kloepffer, W. (2008). Life cycle sustainability assessment of products. *Int. J. Life Cycle Assess.* 13, 89–95. doi:10.1065/lca2008.02.376
- Kohut, A., Taylor, P., Keeter, S., Doherty, C., Dimock, M., & Parker, K. (2011). The generation gap and the 2012 election. *Washington, DC: Pew Research Center.*
- Kollmuss, A., & Agyeman, J. (2002). Mind the gap: why do people act environmentally and what are the barriers to pro-environmental behavior?. *Environmental education research*, 8(3), 239-260.
- Krueger, A. B., & Katz, L. F. (2016). *The Rise and Nature of Alternative Work Arrangements in the United States, 1995-2015.*
- Kurczewski, P. (2013) Life cycle thinking in small and medium enterprises: the results of research on the implementation of life cycle tools in Polish SMEs-part 1: background and framework. *Int. J. Life Cycle Assess.* doi:10.1007/s11367-013-0675-0
- Lee, K. (2008), “Opportunities for green marketing: young consumers”, *Marketing Intelligence & Planning*, Vol. 26 No. 6, pp. 573-586.
- Leppänen, J. M., Haahla, A. E., Lensu, A. M., & Kuitunen, M. T. (2012). Parent-child similarity in environmental attitudes: A pairwise comparison. *The Journal of Environmental Education*, 43(3), 162-176.
- Lewandowska, A., Kurczewski, P., Kulczycka, J., Joachimiak, K., Matuszak-Flejszman, A., Baumann, H., Ciroth, A. (2013). LCA as an element in environmental management systems— comparison of conditions in selected organisations in Poland, Sweden and Germany: part 1: background and initial assumptions. *Int. J. Life Cycle Assess.* 18, 472–480. doi:10.1007/s11367-012-0480-1
- Lin, R. T. (2007). Transforming Taiwan aboriginal cultural features into modern product design: A case study of a cross-cultural product design model. *International Journal of Design*, 1(2).
- Lindfors, L.-G., Christiansen, K., Hoffman, L., Virtanen, Y., Juntilla, V., Hanssen, O.-J., Rønning, A., Ekvall, T., Finnveden, G. (1995). *Nordic Guidelines on Life-Cycle Assessment.* Nord1995:20, Nordic Council of Ministers, Copenhagen
- Lloyd, C. (2008). *What on earth happened...in brief.* Bloomsbury, London.
- Lombardo, P. (2012). Environmental management systems. In: Ahmed, K. *Getting to Green: A Sourcebook of Pollution Management Policy Tools for Growth and Competitiveness.* World Bank, Washington, DC. <http://documents.worldbank.org/curated/en/560021468330349857/Getting-to-green-a-sourcebook-of-pollution-management-policy-tools-for-growth-and-competitiveness>
- Low, E.J. (2023, Aug). How Long Can Bamboo Last. *Better Bamboo Buildings.* <https://www.betterbamboobuildings.com/home/how-long-does-bamboo-last#:~:text=Combined%20with%20regular%20inspection%2C%20maintenance,last%20more%20than%2030%20years.> Accessed on 10 Jan, 2024
- Luttrupp, C., & Lagerstedt, J. (2006). Eco-Design and the Ten Golden Rules. *Journal of Cleaner Production* 14, 1396-1408.
- Mackenzie, D. (1997). *Green design: Design for the Environment.* Hong Kong : Lawrence King.
- Madge, P. (1997). Ecological Design: A New Critique. *The Design Culture Reader* (pp. 50-60). Routledge.
- Mainieri, T., Barnett, E. G., Valdero, T. R., Unipan, J. B., & Oskamp, S. (1997). Green buying: The influence of environmental concern on consumer behavior. *The Journal of social psychology*, 137(2), 189-204.
- Maka. (2021, Nov). *How long is the lifetime of plastic furniture.* <https://www.linkedin.com/pulse/how-long-lifetime-plastic-furniture-> Accessed on 16 Jan, 2024.
- Manjunath 2022
- Mann, S. (2011). *Sustainable lens: A visual guide.* NewSplash Studio, Dunedin.
- Manrai, L. A., Manrai, A. K., Lascu, D. N., & Ryans Jr, J. K. (1997). How green-claim strength and country disposition affect product evaluation and company image. *Psychology & Marketing*, 14(5), 511-537.
- Marston, C. (2007). *Motivating the “What’s in it For Me?” Generation Workforce.*
- Mayssoun, S., & Tannock, S. (2015). *Youth Rising. The Politics of Youth in the Global Economy* Routledge: New York and London.

- Mcaloone, T.C., Bey, N. (2011). Environmental improvement through product development—a guide, 1st edn. Denmark, Copenhagen
- McCrinkle, M., & Wolfinger, E. (2010). Generations defined. *Ethos*, 18(1), 8-13.
- McDonough, W., & Braungart, M. (2002). Remaking the way we make things: Cradle to cradle. New York: North Point Press. ISBN, 1224942886, 104.
- McNiff, J., Lomax, P., & Whitehead, J. (1996). You and Your Action Research Project, Routledge & Hyde Publications.
- Meeusen, C. (2014). The intergenerational transmission of environmental concern: The influence of parents and communication patterns within the family. *The Journal of Environmental Education*, 45(2), 77-90.
- Meredith, G. E., Schewe, C. D., & Karlovich, J. (2001). Defining Markets Defining Moments, New York: Hungry Minds.
- MIANZI. (2018, July 25). Retrieved from <https://mianzi.in/>
- Milkman, R. (2017). A new political generation: Millennials and the post-2008 wave of protest. *American Sociological Review*, 82(1), 1-31.
- Millenium Ecosystem Assessment: Ecosystems and human well-being: biodiversity Synthesis. World Resources Institute, Washington, DC (2005)
- Moltesen, A., Bjørn, A. (2018). Life Cycle Assessment Theory and Practice: LCA and Sustainability. Springer International Publishing, 43-58. doi 10.1007/978-3-319-56475-3
- Morgan Stanley (2017). *India's millennials to recast economy in own tech savvy image*. Retrieved from [www.morganstanley.com/ideas/india-millennials-makeover-disruption-growth](http://www.morganstanley.com/ideas/india-millennials-makeover-disruption-growth).
- Morton, L. P. (2002). Targeting generation Y. *Public Relations Quarterly*, 47(2), 46.
- Mudgal, S. (2008). Reporting on the Implementation of Integrated Product Policy (IPP). European Commission, DG Environment. Service Contract 0703307/2007/481297/G.4. [http://ec.europa.eu/environment/ipp/pdf/bio\\_ipp.pdf](http://ec.europa.eu/environment/ipp/pdf/bio_ipp.pdf). Accessed 11 August 2017
- Munasinghe, M. (2010). Making development more sustainable: Sustainomics framework and practical applications. *Munasinghe Institute for Development (MIND), Colombo*.
- Munoz, I., Rieradevall, J., Domenech, X., Gazulla, C. (2006). Using LCA to assess eco-design in the automotive sector—Case study of a polyolefinic door panel. *Int. J. Life Cycle Assess.* 11, 323–334. doi:10.1065/lca.2005.05.207
- Muralidharan, S., & Xue, F. (2016). Personal networks as a precursor to a green future: a study of “green” consumer socialization among young millennials from India and China. *Young Consumers*.
- Myers, K. K., & Sadaghiani, K. (2010). Millennials in the workplace: A communication perspective on millennials’ organizational relationships and performance. *Journal of business and psychology*, 25(2), 225-238.
- Naderi, I., & Strutton, D. (2015). I support sustainability but only when doing so reflects fabulously on me: can green narcissists be cultivated?. *Journal of Macromarketing*, 35(1), 70-83.
- Naderi, I., & Van Steenburg, E. (2018). Me first, then the environment: young millennials as green consumers. *Young Consumers*.
- Nakano, K., Hirao, M. (2011). Collaborative activity with business partners for improvement of product environmental performance using LCA. *J. Clean. Prod.* 19, 1189–1197. doi:10.1016/j.jclepro.2011.03.007
- National Bamboo Mission, India (2017, August 20). <https://nbm.nic.in/Home>
- Newman, G. E., Gorlin, M., & Dhar, R. (2014). When going green backfires: How firm intentions shape the evaluation of socially beneficial product enhancements. *Journal of Consumer Research*, 41(3), 823-839.
- Nielsen (2015). *The sustainability imperative*. Retrieved on 18 January 2016.
- Nordic Council of Ministers: Product Life Cycle Assessment—Principles and Methodology. Nord 1992:9, Nordic Council of Ministers, Copenhagen (1992)
- Nowak, L., Thach, L., & Olsen, J. E. (2006). Wowing the millennials: creating brand equity in the wine industry. *Journal of Product & Brand Management*.
- O’Connor, M. (2006). The Four Spheres framework for sustainability. *Ecological Complexity* 3: 285–292 (2007).
- O’Donnell, J. (2006). Gen Y sits on top of consumer food chain; they’re savvy shoppers with money and influence. *USA Today*, 11(2), 322-358.

- Odenweller, K. G., Booth-Butterfield, M., & Weber, K. (2014). Investigating helicopter parenting, family environments, and relational outcomes for millennials. *Communication Studies*, 65(4), 407-425.
- OECD. (1998). Eco-efficiency. *Paris : OECD (The Organization for Economic Cooperation and Development)*
- Overy, R. (2007). Complete history of the world. *Times Books, London*. OECD. (1998). Eco-efficiency. *Paris : OECD*
- Palmer, D. (2008). *Cracking the Gen Y culinary code*. *Australian Food News*. Retrieved from <http://www.ausfoodnews.com.au/2008/11/05/cracking-the-gen-y-culinary-code.html#>.
- Pamminger, R. (2011). Technical report on needs and demands of SMEs. Deliverable D1.1 LCA to go project within the European Commission's Seventh Framework Programme. <http://www.LCA2go.eu>. Accessed 11 August 2017
- Papanek, V. (1971). Design for the real world: Human ecology and social change. *Pantheon Books, New York*.
- Paul, J., Modi, A., & Patel, J. (2016). Predicting green product consumption using theory of planned behavior and reasoned action. *Journal of retailing and consumer services*, 29, 123-134.
- Peattie, K. (2010). Green consumption: behavior and norms. *Annual review of environment and resources*, 35.
- Peters, A. (1997). The status of craft. In P. Dormer (Ed.). *The culture of craft* (pp. 17-20). *Manchester University Press, Manchester*.
- Pew Research Centre (2007). *Lives, How Young People View Their Futures and Politics: A Portrait of Generation Next*. Retrieved from <http://people-press.org/report/300/a-portrait-of-generation-next>.
- Peyer, M., Balderjahn, I., Seegebarth, B., & Klemm, A. (2017). The role of sustainability in profiling voluntary simplifiers. *Journal of Business Research*, 70, 37-43.
- Pigosso, D. C., Rozenfeld, H., & McAloone, T. C. (2013). Ecodesign maturity model: a management framework to support eco-design implementation into manufacturing companies. *Journal of Cleaner Production*, 59, 160-173.
- Pilcher, J. (1994). Mannheim's sociology of generations: an undervalued legacy. *British Journal of Sociology*, 481-495.
- Pitta, D., Young, A. M., & Hinesly, M. D. (2012). Identifying Millennials' key influencers from early childhood: insights into current consumer preferences. *Journal of Consumer Marketing*.
- Pochat, S., Bertoluci, G., & Froelich, D. (2007) Integrating eco-design by conducting changes in SMEs. *Journal of Cleaner Production* 15(7), 671-680.
- Postmes, T., Spears, R., & Lea, M. (1998). Breaching or building social boundaries? SIDE-effects of computer-mediated communication. *Communication research*, 25(6), 689-715.
- PTI. (2013, April 29). News by Industry. Retrieved July 16, 2013, from <http://articles.economicstimes.indiatimes.com>.
- Rahaman, K.A. (2023, Aug). *Furniture Durability: How Long Good Quality Furniture Actually Last?* Hatil Lifestyle, Dhaka, Bangladesh. <https://hatil.com/blog/en/furniture-durability-how-long-good-quality-furniture-actually-last/>. Accessed 18 Jan, 2024.
- Raines, C. (2002). Managing Millennials. *Connecting Generations: The Sourcebook*.
- Rajora, S. (2023, Jul 5). Indian middle class will nearly double to 61% by 2046-47: PRICE Report. *Business Standard*. [https://www.business-standard.com/economy/news/indian-middle-class-will-nearly-double-to-61-by-2046-47-price-report-123070500864\\_1.html](https://www.business-standard.com/economy/news/indian-middle-class-will-nearly-double-to-61-by-2046-47-price-report-123070500864_1.html)
- Ranjan, A., & Ranjan, M. P. (Eds.). (2007). *Handmade in India*. Council of handicraft development corporations, Office of the development commissioner handicrafts, Ministry of textiles.
- Ranjan, M. P. (2004). Bamboo and Rural Prosperity: Leveraging the Seedlings of Wealth. In World Bamboo Congress.
- Ranjan, M. P., Iyer, N., & Pandya, G. (1986). *Bamboo and cane crafts of northeast India*. Development Commissioner of Handicrafts, Govt. of India.
- Rao, A. G. (2004). Tools, Small Technologies and Design for Bamboo Craft: Indian experience. In 2004 World Bamboo Congress. Delhi.
- Rao, A. G. (2008). Craft as a Post-Modern Venture: Experience in Bamboo Craft. In PD2008 8th Brazilian International Conference.
- Rao, A. N., Ramanatha Rao, V., & Williams, J. T. (1998). *Priority species of bamboo and rattan*.
- Redzuan, M., & Aref, F. (2011). Constraints and potentials of handicraft industry in underdeveloped region of Malaysia. *African Journal of Business Management*, 5(2), 256-260.

- Rees, W.E. (1992). Ecological footprints and appropriated carrying capacity: what urban economics leaves out. *Environ. Urban* 4, 121–130. doi:10.1177/095624789200400212
- Reijnders, L. (1998). The factor X debate: setting targets for eco-efficiency. *J. Ind. Ecol.* 2, 13–22
- Reubens, R. (2012). *Bamboo - From Green Design to Sustainable Design*. Rainbow Publishers
- Reubens, R. (2016). *To Craft, by Design, for Sustainability*. Delft University of Technology, Delft.
- Rio Declaration on Environment and Development, in Report of the United Nations Conference on Environment and Development, UN Doc. A/CONF.151/26 (Vol. I), 12 August 1992, Annex I.
- Roberts, J. A. (1996). Green consumers in the 1990s: Profile and Implications for Advertising. *Journal of business research*, 36, 217-231.
- Rockström, J. (2009). Planetary Boundaries: Exploring the Safe Operating Space for Humanity. *Ecology and Society*. 14(2), art. 32
- Rosenburg, J. (2015). Millennials green up American consumerism. *Retrieved*, 17(11), 2019.
- Runnalls, D. (2008). Our common inaction: Meeting the call for institutional change. *Environment: Science and Policy for Sustainable Development*, 50(6), 18-29.
- Ryan, C. (2005). Learning from a Decade (or so) of Eco-design experience, Part II. *Journal of Industrial Ecology*, 8(3).
- Schischke, K., Nissen, N.F., Sherry, J. et al. (2012). Life cycle thinking in small and medium sized enterprises—status quo and strategic needs in the electronics sector. In: *Electronics Go Green 2012*
- Schuman, H., & Scott, J. (1989). Generations and collective memories. *American sociological review*, 359-381.
- Seethalakshmi, K. K., Kumar, M. M., Pillai, K. S., & Sarojam, N. (1998). *Bamboos of India: A compendium* (Vol. 17). Brill.
- Seguin, C., Pelletier, L.G. and Hunsley, J. (1999). Predicting environmental behaviors: the influence of self-determined motivation and information about perceived environmental health risks. *Journal of Applied Social Psychology*, Vol. 29 No. 8, pp. 1582-1604.
- Sennett, R. (2008). *The craftsman*. Yale University Press, New Haven & London.
- Shamdasani, P., Chon-Lin, G. O., & Richmond, D. (1993). Exploring green consumers in an oriental culture: Role of personal and marketing mix factors. *ACR North American Advances*.
- Sheldon, R., & Arens, E. (1932). *Consumer engineering: A new technique for prosperity*. Harper and Brothers, New York.
- Shken.in. (2016, August 20). Retrieved from <https://shken.in/>
- Short, T., Lee-Mortimer, A., Luttrupp, C., & Johansson, G. (2012). Manufacturing, sustainability, ecodesign and risk: lessons learned from a study of Swedish and English companies. *Journal of Cleaner Production* 37, 342-352.
- Shukla, N. (2014, September 11). Truss me, it's bamboo. Retrieved from <http://www.craftingluxurylifestyle.com/truss-me-its-bamboo/>
- SIGMA (2003). *The SIGMA guidelines—An Overview. Putting Sustainable Development into Practice—A Guide for Organisations* (London: British Standards Institute). Retrieved from <http://www.projectsigma.com> (accessed April 2019).
- Smith Cooper, J., Fava, J.A. (2006). Life-cycle assessment practitioner survey—summary of results. *J. Ind. Ecol.* 10(4), 12–14
- Smith, E. R. & Semin, G. R. (2004). Socially situated cognition in its social context. *Advances in Experimental Social Psychology*, 36, 53-117.
- Srivastava, S., & Culén, A. L. (2019). Implications for Transitions to Sustainable Consumption: Finding Millennials' Behaviour Archetypes.
- Standing, G. (2011). *The precariat: the new dangerous class*, Bloomsbury Academic. London, New York.
- Steen, B. (1999a) *A Systematic Approach to Environmental Priority Strategies in Product Development (EPS)*. Version 2000-general system characteristics; CPM report 1999:4, Chalmers University of Technology, Gothenburg, Sweden
- Steen, B. (1999b). *A Systematic Approach to Environmental Priority Strategies in Product Development (EPS)*. Version 2000-Models and data of the default method; CPM report 1999:5, Chalmers University of Technology, Gothenburg, Sweden

- Steen, B.A. (2006). Abiotic resource depletion different perceptions of the problem with mineral deposits. *Int. J. Life Cycle Assess.* 11, 49–54. doi:10.1065/lca2006.04.011
- Steffen, W., Richardson, K., Rockström, J., et al. (2015a) Planetary boundaries: Guiding human development on a changing planet. *Science*. doi:10.1126/science.1259855
- Stewart, A. J., & Healy, J. M. (1989). Linking individual development and social changes. *American Psychologist*, 44(1), 30.
- Stockholm Declaration on the Human Environment, in Report of the United Nations Conference on the Human Environment, UN Doc.A/CONF.48/14, at 2 and Corr.1 (1972).
- Sullivan, P., & Heitmeyer, J. (2008). Looking at Gen Y shopping preferences and intentions: exploring the role of experience and apparel involvement. *International Journal of Consumer Studies*, 32(3), 285-295.
- Taylor, S. L., & Cosenza, R. M. (2002). Profiling later aged female teens: mall shopping behavior and clothing choice. *Journal of consumer marketing*.
- TEDxHyd (2018, August 14). The Social Impact of Design Sandeep Sangaru. Retrieved from <https://www.youtube.com/watch?v=zFg10Tn029o>
- Teixeira, R., Pax, S. (2011). A survey of life cycle assessment practitioners with a focus on the agri-food sector. *J. Ind. Ecol.* 15, 817–820. doi:10.1111/j.1530-9290.2011.00421.x
- The Busride. (2019, May 18). The Rhizome and Sandeep Sangaru. Retrieved from [https://issuu.com/thebusride/docs/the\\_rhizome\\_and\\_sandeep\\_sangaru](https://issuu.com/thebusride/docs/the_rhizome_and_sandeep_sangaru)
- Thinkstep: A brief history of Life Cycle Assessment (LCA). <http://www.gabi-software.com/news/news-detail/article/a-brief-history-of-life-cycle-assessment-lca/>. (2016). Accessed 16 June 2016
- Times of India (2017, January 11). *Air pollution causes 1.2 million deaths in India annually; Delhi most polluted: Greenpeace report*. Retrieved from <https://timesofindia.indiatimes.com/india/air-pollution-causes-12-lakh-deaths-in-india-annually-delhi-most-polluted-greenpeace-report/articleshow/56478622.cms>.
- Tischner, U., & Charter, M. (2017). Sustainable product design. In *Sustainable Solutions* (pp. 118-138). Routledge.
- Traditional Crafts of Assam. (2014, March 5). Retrieved March 25, 2015, from Wikipedia: [http://en.wikipedia.org/wiki/Traditional\\_crafts\\_of\\_Assam](http://en.wikipedia.org/wiki/Traditional_crafts_of_Assam)
- Twenge, J. M. (2006). The age of anxiety (and depression and loneliness): Generation stressed. *Generation Me: Why Today's Young Americans are More Confident, Assertive, Entitled—and More Miserable than Ever Before*.
- Twenge, J. M., & Campbell, W. K. (2009). *The narcissism epidemic: Living in the age of entitlement*. Simon and Schuster.
- Twenge, J. M., & Foster, J. D. (2010). Birth cohort increases in narcissistic personality traits among American college students, 1982–2009. *Social Psychological and Personality Science*, 1(1), 99-106.
- Udo de Haes, H.A., Joliet, O., Finnveden, G., Hauschild, M., Krewitt, W., Mueller-Wenk, R. (1999). Best available practice regarding impact categories and category indicators in life cycle impact assessment. Part 1. *Int. J. Life Cycle Assess.* 4, 167–174. doi:10.1007/BF02979453
- United Nations Department of Economic, Social Affairs, Programme on Youth (2005). World youth report 2005. Young people today, and in 2015. *New York. United Nations*.
- UN General Assembly, *Transforming our world : the 2030 Agenda for Sustainable Development*, 21 October 2015, A/RES/70/1. Retrieved from <https://www.refworld.org/docid/57b6e3e44.html>. Accessed 19 December 2019
- Uyeki, E. S., & Holland, L. J. (2000). Diffusion of pro-environment attitudes?. *American Behavioral Scientist*, 43(4), 646-662.
- Van der Lugt, P. (2008). Design interventions for stimulating bamboo commercialization-Dutch Design meets bamboo as a replicable model.
- van der Vall, M. (1980). De structuur van ongestructureerde problemen: Een rationele methode tot effectuering van beleid (in Dutch). Academisch boekencentrum, De Lier, the Netherlands.
- Van Weenen, J. C. (1995). Towards sustainable product development. *Journal of Cleaner Production*, 3(1-2), 95-100.
- Vezzoli, C., & Manzini, E. (2008). *Design for environmental sustainability* (p. 4). London: Springer. Chicago
- Viswanath B. (2013). Enumeration of Crafts Persons in India. *Madras School of Economics*, 19-42.
- Walker, J. (1989). Design history and the history of design. *Pluto Press, Winchester*.

WBCSD World Business Council for Sustainable Development Corporate Social Responsibility: Making Good Business Sense. Geneva: WBCSD, 2000.

WCED, S. W. S. (1987). World commission on environment and development. *Our common future*, 17(1), 1-91.

Weiss, M. J. (2003). To Be About-To-Be When Americans hit age 21, it's not just time for a celebratory drink. Today's crop of 21-year-olds already antes up about \$187 billion a year on consumer goods and services—from concert tickets, to clothing, to music and tech gadgetry. *American demographics*, 25(7), 28-36.

Wenzel, H., Hauschild, M.Z., Alting, L. (1997). Environmental assessment of products. In: Vol. 1— Methodology, Tools and Case Studies in Product Development. Kluwer Academic Publishers, Hingham, p. 544. ISBN 0 412 80800 5

Wey Smola, K., & Sutton, C. D. (2002). Generational differences: Revisiting generational work values for the new millennium. *Journal of Organizational Behavior: The International Journal of Industrial, Occupational and Organizational Psychology and Behavior*, 23(4), 363-382.

Whitely, N. (1993). Design for society. *Reaktion Books Ltd, London*.

World Health Organization (2016). *Ambient air pollution: A global assessment of exposure and burden of disease*. Retrieved from <http://apps.who.int/iris/bitstream/10665/250141/1/9789241511353-eng.pdf?ua=1>.

Yair, K., Press, M., & Tomes A. (2001). Crafting competitive advantage: Crafts knowledge as a strategic resource. *Design Studies*, 22(4), 377-394.

Yair, K., Tomes, A., & Press, M. (1999). Design through marking: Crafts knowledge as facilitator to collaborative new product development. *Design Studies*, 20(6), 495-515.

Yojana, B., & Sansad, M. (2006). Status Study of Tribal Handicraft-An Option for Livelihood of Tribal Community in the States of Arunachal Pradesh Rajasthan. Uttaranchal and Chhattisgarh.

Zackrisson, M., Rocha, C., Christiansen, K., Jarnehammar, A. (2008). Stepwise environmental product declarations: ten SME case studies. *J. Clean. Prod.* 16, 1872–1886. doi:10.1016/j.jclepro.2008.01.001

Zamagni, A. (2012). Life cycle sustainability assessment. *The International Journal of Life Cycle Assessment*, 17, 373-376.

Zellner, D. A., Bartoli, A. M., & Eckard, R. (1991). Influence of color on odor identification and liking ratings. *American Journal of Psychology*, 104, 547-561.

Zimbardo, P. G., & Boyd, J. N. (2015). Putting time in perspective: A valid, reliable individual-differences metric. In *Time perspective theory: review, research and application* (pp. 17-55). Springer, Cham.

## LIST OF PUBLICATIONS

1. Das, M., & Das, A. K. (2019). Craft education in design. In *DS 95: Proceedings of the 21st International Conference on Engineering and Product Design Education (E&PDE 2019)*, University of Strathclyde, Glasgow. 12th-13th September 2019.
2. Das, M., & Das, A. K. (2021). Eco-Design, Craftsmanship and Sustainability. In *Design for Tomorrow—Volume 1: Proceedings of ICoRD 2021* (pp. 889-899). Springer Singapore.
3. Das, M., Das, A.K. (2023). Factors Affecting Success and Failure of Bamboo Products in North-East Region of India. In *1st Design Conference - Insights, Inclusions and Innovations (I3)*, National Institute of Design Madhya Pradesh. 15th-16th December 2023.
4. Das, M., Choudhury, R., Bhaskar, A.K., Das, A.K. (2023). Bamboo in Toy Design. In *Next Generation Bamboo : Solution, Innovation and Design*, World Bamboo Organisation. 18<sup>th</sup>-22<sup>nd</sup> April, 2024.
5. Das, M., Banerjee, S., Das, A.K. (2023). Comparative Life Cycle Assessment of Bamboo Chair Manufacture with Competing Materials. In *International Journal of Life Cycle Assessment (in review)*
6. Das, M., Das, A.K. (2023). Businesses in Bamboo and their Considerations for a Sustainable Venture. In *Design Commit 2024, 1st International Conference on Design and Industry 2024*. 20-22<sup>nd</sup> May, 2024.

## ANNEXURES

### ANNEXURE A - Questionnaire Format for Interview with Craft Entrepreneurs

Interview Format and Questionnaire for Craft Entrepreneurs

#### A. About the Enterprise :

1. Raw Materials : what are the raw materials  
where are they procured from  
how much quantity in how much time  
rate of any other purchased materials
2. Craftsmanship : how and when did the original craftsmanship start  
how did it take pace - craftsmen involved, work,  
process, produce  
what is its status now
3. Treatment : details of any treatment done
4. Tools : tools used by the artisans  
hand tools and electric machines
5. Storage : condition required for storage  
location of storage
6. Transport : means of transport  
packaging materials  
money invested in transport  
shorter and longer distance freights
7. Market : demands  
prices  
destinations  
retailers and distributors
8. Commerce : profit shares  
designer's fee  
craftsmanship fee
9. Recycling : extra produce  
use of recycled material  
consideration of recycling  
multiple lives of final product  
considerations in design
10. Govt Help : Any Govt help sought or taken  
Any existing initiative in the village

## **B. Experiences about the Initiative :**

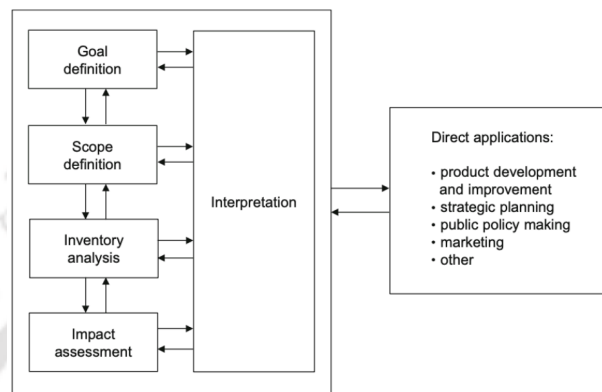
1. Brainchild - Big Idea
2. Initial Journey, Installation and Collaboration
3. Big Challenges
4. Initial Compromises
5. Strongest Asset
6. Biggest Advantage
7. Marketing Tool
8. Has this enterprise brought any changes for artisans? If so, how?
9. Experiences from Marketing?
10. Consumer Expectations and Behaviour
11. Reality Check - Advice for new Entrepreneurs



## ANNEXURE B - Methodology of Life Cycle Assessment

The LCA framework operates with four separate phases (ISO 14040) as shown in Figure B.1 :

- Goal and Scope Definition
- Inventory Analysis
- Impact Assessment
- Interpretation



*Figure B.1 Framework of LCA modified from the ISO 14040 standard (Source : Life Cycle Assessment, Hauschild 2018)*

### Goal and Scope Definition

LCA starts with a well considered and deliberate definition of the goal of the study. It requires the defining of a functional unit, which is the quantitative description of the function or service for which the assessment is performed, and the basis of determining the reference flow of product that scales the data collection in the next LCA phase, the inventory analysis.

Scoping the product system includes deciding which activities and processes belong to the life cycle of the product that is studied. It involves selecting the assessment parameters, the geographical and temporal boundaries and setting of the study, and the technology that is relevant for the processes in the product system. It decides the relevant perspective to apply in the study of whether it should be a consequential study assessing the impacts that can be expected as a consequence of choosing one alternative over another, or should it be an attributional study assessing the impacts that are associated with the studied activity. It further identifies the need to perform critical review, in particular if the study is a comparative assertion intended to be disclosed to the public.

The goal and scope definition involves choices that determine the collection of data and the way in which the system is modelled and assessed. They therefore have a strong influence on the validity of the conclusions and recommendations that are based on the results of the LCA (Hauschild, 2018).

## **Inventory Analysis**

Following the definition of goal and scope, the inventory analysis collects information about the physical flows in terms of resources, materials, semi-products and products, and the output of emissions, waste and valuable products for the product system. The analysis studies all the processes that were identified as belonging to the product system, and the flows are scaled in accordance with the reference flow of the product that is determined from the functional unit. The outcome of the inventory analysis is the Life Cycle Inventory, a list of quantified physical elementary flows for the product system that is associated with the provision of the service or function described by the functional unit (Hauschild, 2018).

## **Impact Assessment**

Taking the life cycle inventory as a starting point, the impact assessment translates the physical flows and interventions of the product system into impacts on the environment using knowledge and models from environment science. The impact assessment consists of five elements of which the first three are mandatory according to the ISO 14040 standard.

- Selection of impact categories representative of the assessment parameters that were chosen as part of the scope definition. For each impact category, a representative indicator is chosen along with an environmental model to quantify the impact of elementary flows on the indicator.
- Classification of elementary flows from the inventory by assigning them to impact categories according to their ability to contribute by impacting the chosen indicator.
- Characterisation using environmental models for the impact category to quantify the ability of each of the assigned elementary flows to impact the indicator of the category. The resulting characterised impact scores are expressed in a common metric for the impact category. This allows aggregations of all contributions into one score, representing the total impact that the product system has for that category. The collection of aggregated indicator scores for the different impact categories (each expressed in its own metric) constitutes the characterised impact profile of the product system.
- Normalisation is used to inform about the relative magnitude of each of the characterised scores for the different impact categories by expressing the relative to a common set of reference impacts - one reference impact per impact category. The result of the normalisation is the normalised impact profile of the product system in which all category indicator scores are expressed in the same metric.
- Grouping or Weighting supports comparison across the impact categories by grouping and possibly ranking them according to their perceived severity or by weighting them using weighting factors that for each impact category gives a quantitative expression of how severe it is relative to the other impact categories. Quantitative weighting allows aggregation of all the impact scores into one overall environment impact score for the product system, which may be useful when the results of the LCA are used in decision support together with other condensed information like the economic costs of the alternatives.

In the above 'Framework of LCA' figure, a number of arrows indicate that rather than a linearly proceeding process, LCA involves many feedback loops between LCA's different phases. Insights from the impact assessment are used in refining the inventory analysis and insights from both of these phases may feed back to the scope definition. Sensitivity and uncertainty analysis are thus not just performed in the interpretation

at the end but throughout the study as part of both inventory analysis and impact assessment in order to identify the key figures or key assumptions of the study and the data that are associated with the largest uncertainties. In practice, the first iteration will often be a screening that covers the full life cycle, but in terms of inventory data largely is based on easily accessible data from available databases. Following the impact assessment, the parts of the product system that contribute most strongly to the total results can be identified, and the chosen boundaries of the product system could be tested. As a consequence the scoping might have to be redefined. The large iterations should be the target of the next iteration to get more recent or representative data. Based on the revised inventory, a new impact assessment is performed, and the sensitivity analysis is performed once more to see which are now key figures and key assumptions. Large uncertainties may also accompany the factors applied in the characterisation of some of the inventory flows in the impact assessment, and if the sensitivity analysis indicates that such uncertainties may have a decisive influence on the results, these factors will also be a target of a consecutive iteration. If the goal of an LCA is to identify which among several alternatives has the lowest environmental impacts, the number of needed iterations may be low if the alternatives show large differences in their impact, while a higher number of iterations will be needed if the alternatives are more similar. An LCA performed to support an environmental product declaration with a general requirement to the uncertainty of the impact scores can require a high number of iterations before all impact scores are determined within the stipulated level of uncertainty (Hauschild, 2018).

## **B.1 Goal Definition**

There are six aspects of Goal Definition, based on ILCD guidelines (EC-JRC in European Commission—Joint Research Centre—Institute for Environment and Sustainability: International Reference Life Cycle Data System (ILCD) Handbook—General Guide for Life Cycle Assessment —Detailed Guidance. Publications Office of the European Union, Luxembourg 2010) :

1. Intended applications of the results
2. Limitations due to methodological choices
3. Decision context and reasons for carrying out study
4. Target audience
5. Comparative studies to be disclosed to the public
6. Commission of the study and other influential factors

Aspects 1 and 3 are central for doing an LCA because they have pervasive influence on decisions made in later LCA phases. On the other hand, aspects 2, 4, 5 & 6 mainly relate to communicating the results of an LCA.

### **B.1.1 Intended Applications of the Results**

It is important to determine intended applications of the LCA results at the onset, because it influences later phases of an LCA, such as the drawing of system boundaries, sourcing of inventory data and interpretation of results.

All LCA's involve studying one or more product systems and this can be used in several applications such as –

- Comparing environmental impacts of specific goods and services
- Identifying the parts of the product system that contribute most to the environmental impact
- Evaluating improvement potentials from changes in product designs
- Documenting the environmental performance of products
- Developing criteria for an eco-label
- Developing policies that consider environmental aspects

### **B.1.2 Limitations due to Methodological Choices**

This aspect is a critical reflection of what an LCA can and cannot be used for. If a study only refers to climate change (often referred to as 'carbon footprint study'), it cannot be used to claim general environmental superiority of a studied product. Similarly, if a comparative study disregards one or more life cycle stages, it is important to stress how that limits the interpretation of results. Limitations stated here should only relate to the choices made in the goal and scope phases of LCA. Choices made during the impact assessment and inventory phases of an LCA relate to unforeseen constraints and assumptions and must be documented at a later point in an LCA report.

### **B.1.3 Decision Context and Reasons for Carrying out the Study**

This is important because it strongly influences the appropriate elaboration of a lifecycle inventory. The identification of decision support depends on -

- whether the study is intended as decision support
- whether structural changes in interacting systems are expected from a decision supported by the study
- whether it is chosen to model interactions with other systems as part of the product system model or to handle them partially through allocation.

### **B.1.4 Target Audience**

This states to whom the results of the study are intended to be communicated. They maybe consumers, consumer organisations, companies, government, NGO's etc. The target audience greatly influences the extent to which details of the study should be documented, the technical level of reporting, and the interpretation of results. If the audience is unfamiliar with LCA, the content of the report must be presented pedagogically by explaining technical terms that the readers could not be expected to be familiar with, thus would be appropriate to provide brief background information about LCA.

### **B.1.5 Comparative Studies to be disclosed to the Public**

Goal definition must explicitly state whether the LCA study is of a comparative nature and if it is intended to be disclosed to the public. If this is the case, the ISO standard specifies a number of requirements on the

conduct and documentation of the study and an external review process, due to the potential consequences that the communication of the results of the study may have for external companies, institutions, consumers and other stakeholders.

### **B.1.6 Commissioner of the Study and Other Influential Actors**

Goal definition should explicitly state who commissioned the study, who financed it and other organisations who have influence on the study. It is to highlight potential conflicts of interest to readers of the study. Such a conflict of interest might occur if a key provider of data has an economic interest in the particular LCA results and interpretations. In comparative studies, it may also lead to unintentional bias of data collection.

## **B.2 Scope Definition**

Scope definition determines what product systems are to be assessed and how this assessment should take place. Nine items taking up scope definition are :

1. Deliverables
2. Object of Assessment
3. LCI modelling framework and handling of multifunctional processes
4. System boundaries and completeness requirements
5. Representativeness of LCI data
6. Preparing the basis for the impact assessment
7. Special requirements for system comparisons
8. Critical review needs
9. Planning reporting of results

Together with the goal definition, the scope definition serves as a firm guide for how the ensuing LCA phases should be performed and how the LCA should be reported. An overarching aim of the scope definition is to ensure and document the consistency of methods, assumptions of data and strengthen the reproducibility of the study. The items 2 - 6 incline towards pervasive influence on decisions made in later LCA phases and items 1, 7, 8, 9 mainly relate to reporting and communicating an LCA study (Björn et al, 2018).

### ***Terminology and Key Concepts***

#### **Unit Processes and Flows :**

The smallest element considered in a life cycle inventory model for which input and output data are quantified. They are the building blocks of a life cycle inventory model that are glued together by input and output data. There are six categories of physical flows :

- Input : i) Energy ii) Materials iii) Resources  
Output : iv) Products v) Waste to Treatment vi) Emissions  
Summation of Input = Summation of Output

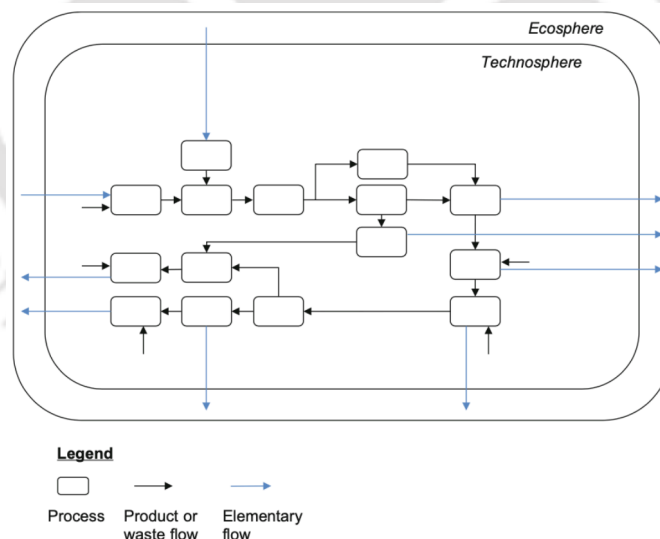
Output flows belonging to the ‘product’ or ‘waste to treatment’ categories from one unit process can act as input flows belonging to the categories ‘materials’ and ‘energy’ for other unit processes and this is how unit processes are linked in a life cycle inventory model. By comparison, ‘resources’ and ‘emission flows’ are not exchanged between unit processes. They are referred as ‘elementary flows’ and defined by ILCD as ‘single substance or energy entering the system being studied that has been drawn from the ecosphere without previous human transformation or single substance or energy leaving the system being studied that is released into the ecosphere without subsequent human transformation’. Resource flows are not outputs from other unit processes, similarly, emissions are not inputs to other unit processes.

**The Technosphere and the Ecosphere :**

Technosphere is everything that is intentionally ‘manmade’; including processes that are naturally origin, but manipulated by humans, such as photosynthesis in an agricultural system. Ecosphere is the environment or nature, it is everything that is not intentionally manmade. In the ecosphere resides those qualities that LCA has been designed to protect, i.e, ecosystems, human health and resource availability. These qualities are called Areas of Protection or damage categories in the field of LCA [Figure B.2].

Changes to the ecosphere can be considered unintentional ‘manmade’ consequences of activities in the technosphere. Note that the ecosphere also undergoes natural changes, with makes it difficult to choose an appropriate natural state against which human impacts should be measured. Elementary flows potentially impact Area of Protections.

There is no clear cut spatial separation between technosphere and ecosphere; they are largely intermingled and therefore quite abstract and a often debated matter in the LCA community.



**Figure B.2** Division between ecosphere and technosphere for a generic product system. Elementary flows are represented by blue arrows, while flows within the technosphere are in black (Source : Life Cycle Assessment, Hauschild 2018)

### **Foreground and Background System :**

Foreground system is commonly defined as those processes of a product system that are specific to it. It is largely modelled using primary data. Processes in this system can be changed by the decision maker commissioning the study.

Background system is commonly defined as those processes of a product system that are not specific to it. It is typically modelled using LCA databases with average industry data from different regions. Processes in the background system cannot be typically changed structurally by the decision maker.

### **Life Cycle Inventory Model and Results :**

LCI Model links all unit processes required to deliver the studied product in an LCA. LCI Result is an inventory of the aggregates quantities of elementary flows, separated into resources and emissions, from all the unit processes in the system boundary. It must be correctly scaled.

### **Life Cycle Impact Assessment :**

LCIA comprises of selection of impact categories, classification and characterisation, normalisation and weighting.

#### **B.2.1 Deliverables**

The types of deliverables should directly affect the intended application of results, as goal definition. Life Cycle Assessment is a compilation of Life Cycle Inventory (LCI) and Life Cycle Impact Assessment (LCIA) Results. There must be transparency for LCI to used as data sources for other LCA's.

#### **B.2.2 Object of Assessment**

- **Functions :** LCA is the environmental assessment of needs fulfilment focusing in functions first and then on the products needed to provide these functions. Functions must be defined according to the perspective of the user. Function must be the same for a meaningful comparison.
- **Functional Unit :** It defines the qualitative aspects and quantifies the quantitative aspects of the function, which generally involves answering the question what? how much? for how long/how many times? where? and how well? Obligatory properties are features that a product must possess, may include legally required features. Positioning properties are optional features of a product, to position it as more attractive to the consumer, in competition with other similar products. Positioning properties often vary from consumer to consumer as opposed to obligatory properties.
- **Reference Flows :** It is the amount of product that is needed to realise the functional unit. It is typically different quantitatively and qualitatively for different products compared on the basis of functional unit due to differences in product properties and characteristics. Reference flow is the starting point of LCI analysis of an LCA.

### **B.2.3 LCI Modelling Framework & Handling Multifunctional Processes**

- Secondary Functions and Multifunctional Processes : Secondary functions have no relevance to users of product, unlike primary functions with obligatory or positioning properties. Instead, they are relevant to other systems of the technosphere that the studied product system interacts with, making the process multifunctional.
- The ISO 14040 Hierarchy to solving Multifunctionality : First, the production of the product is divided from the co-product. If this fails, the system is expanded. If expansion is not feasible, then division is carried out between the inputs and outputs of the multifunctional process or system between the different products. This is called allocation, based on deductive reasoning, through a causal physical relationship, based on parameters representing a common function. If no parameters are found, then allocate an economic relationship, determined by a long term average market prices.
- LCI Modelling Framework - Attributional and Consequential LCA : Attributional LCI Modelling aims to represent a product system in isolation from the rest of the technosphere or economy. It answers ‘what environmental impact can be attributed to product X or what environmental impact is X responsible for?’ But product systems do not exist in isolation. Thus, attributional LCI has an element of subjectivity, of making choices. Consequential LCA modelling was developed to eliminate the weakness inherent in the attributional LCA modelling framework due to the attempt to artificially separate a product from the rest of the economy. Its overall aim is to describe the changes to the economy caused by the introduction of the studied product system. It answers ‘what are the environmental consequences of consuming X?’
- Recommended Modelling Choices for the Identified Decision Context : Situation A concerns a micro-level decision support and the consequence of a decision. Situation B concerns meso-level decision support. Situation C relates to accounting, meaning the studies are not to be used to directly support decisions and are of purely descriptive manner. Situation C1 considers interactions with other systems whereas Situation C2 disregards interaction with other systems.

### **B.2.4 System Boundaries and Completeness Requirements**

System Boundaries demarcate the boundaries between the studied product system and the surrounding economy (technosphere) and the environment (ecosphere). Completeness Requirements is a related concept that can be used to determine what processes should be included within the system boundaries to reach the degree of completeness in the product system modelling that is needed to be in agreement with the goal of the study.

### **B.2.5 Representativeness of LCI Data**

It is the aim of LCA to reflect physical activity. This means that the model should represent what actually happens or has happened to the extent possible, and the unit processes applied to model the product system must be representative of the actual processes. Representativeness of LCI data must be understood in three inter related dimensions : geographical, time-related and technological (Björn et al, 2018).

- **Geographical Representativeness** : This reflects how well the inventory data represents the actual process regarding location specific parameters. It is important to consider because two processes delivering the same product output, but taking place in two different locations can be quite different in terms of the other flows such as elementary flows, energy, material and waste flows. Differences between unit processes can be caused by geographical differences, such as local climate and proximity to natural resources, regulatory differences, such as emission threshold and energy taxes. The LCA practitioner must define the geographical scope of the process in the scope definition. The starting point should be the foreground system, where the locations of processes are typically known with high certainty, and further proceed to defining the geographical scope of upstream and downstream processes that typically are more certain. The appropriate resolution of the geographical scopes depends on factors such as the spatial coverage of regulation, geographical variations and the spatial extent of markets.
- **Time-Related Representativeness** : As above, two processes delivering the same product output can be different if they occur at different times. This is due to technological innovation and development, which often leads to more efficient processes over time, meaning less input and sometimes also less unwanted by-products. Technological innovation is fast in some sectors than others. Therefore, a unit process that reflects the situation 10 years prior to the occurrence of the process in the product system can have a high time-related representativeness if it belongs to a mature sector with little technological innovation but it can have a low representativeness if it is part of a sector with rapid technological development. LCA practitioners must define time-related representativeness in different stages of life cycle in the scope definition. These times are largely influenced by the expected lifetime of the studied products. In comparative studies it is important to investigate whether there is a risk that differences in time-related representativeness for the compared alternatives can lead to a bias that favours one product system over the others.
- **Technological Representativeness** : Two identical products can be produced using two different technologies and thereby be associated with different sets of unit processes and related flows. technological representativeness reflects how well the inventory data represents the actual technologies involved in the studied product system. It is interlinked with geographical and temporal representativeness. It is important to ensure that the unit processes modelled in the system are in fact internally technologically compatible, meaning that the product output of one process should meet the quality requirements for input materials of the next process in the system. The scope definition should therefore contain a list of technologies that are known to be involved in the foreground and background system for which such knowledge exists, specifying representativeness requirements. This list should be partly based on the outcome of the geographical scope and time frames in terms of where and when processes are taking place.

## B.2.6 Preparing the Basis for the Impact Assessment

The planning of the impact assessment in the scope definition has two main purposes :

- ensure that it is done in accordance with the goal definition
- prepare for the inventory analysis where the elementary flows that should be included depend on the impact categories to be covered in the LCIA.

Planning how to perform the LCIA prior to the life cycle inventory analysis helps ensuring that the right data is being collected in the cycle inventory analysis.

- **Selection of Impact Coverage :** According to the ISO 14044 standard for LCA, the selection of impact categories to be covered by an LCA ‘shall reflect a comprehensive set of environmental issues related to the product system being studied, taking the goal and scope into consideration.’ This means that all environmental impacts where the product system has relevant contributions must included in the impact assessment, unless the goal definition explicitly states otherwise. Transparency in the selection of impact categories is essential to avoid an ‘interest driven’ selection of impact categories, due to disfavoursing the commissioner.
- **Selection of LCIA Methods :** To support the choice between alternative LCIA methods that can be used to calculate an indicator score for the same impact category, ILCD has developed six criteria for evaluating, namely i) Completeness of Scope, ii) Environmental Relevance, iii) Scientific Robustness and Certainty, iv) Documentation, Transparency and Reproducibility, v) Applicability and vi) Stakeholder’s Acceptance.

An LCIA Method is a collection of impact categories that aims to have a broad coverage of environmental issues, and is typically developed by a research group. For some LCA studies, no LCIA method may cover an environmental impact that is considered relevant. In such cases, the LCA practitioner can choose to develop an LCIA method on their own and this development should be guided by the six criteria above. The potentially relevant environmental impacts that are not covered by the impact assessment should be highlighted in the scope definition and considered qualitatively in the interpretation of results.

An important aspect related to compatibility between collected elementary flow of the life cycle inventory analysis and the ensuing LCA is the degree spatial differentiation of the LCA study. Spatial differentiation essentially means taking into account where an elementary flow occurs. This information is relevant for many impact categories because the sensitivity of the environment towards 1 unit of elementary flow differs from place to place. This requires the collection of spatial information for the elementary flows in the life cycle inventory analysis that is compatible with these methods.

Normalisation and Weighting are optional steps under ISO14040/14044:2006. Normalisation is usually beneficial to aid the understanding of results if the target audience are not experts, and Weighting is required if an aggregation of impact scores across the environmental impact categories is intended.

### **B.2.7 Special Requirements for System Comparisons**

ISO 14044 states that ‘Systems shall be compared using the same functional unit and equivalent methodological considerations, such as performance, system boundary, data quality, allocation procedures, decision rules on evaluating inputs and outputs and impact assessment. Any differences between systems regarding these parameters shall be identified and reported.’

When a comparative study is intended to conclude on the superiority or equivalence of the compared alternatives in terms of their environmental performance and to make these conclusions publicly available, the standard identifies it as ‘a comparative assertion intended to be disclosed to the public’. Thus the standard requires that these points shall be evaluated in a critical review performed by a panel of invested parties. This is done to prevent the misuse of LCA in comparative market competition. ILCD guidelines furthermore require that the uncertainties involved must be evaluated and communicated when one product system appears to have a lower environmental impact for one or more impact categories than the other. In the case where the goal definition prescribes a comparison based on a single indicator, the LCA study must highlight that the comparison is not suitable to identify environmental preferable alternatives, as it covers only the considered impact.

### **B.2.8 Need for Critical Review**

A critical review is performed by experts not involved in making a study. It is sometimes required, but even if not, a critical review is useful for improving the quality and credibility of a study. It should be determined in scope definition to specify the form of review. It also must be decided if review is required in the final draft of LCA or in intermediate stages, through interactive processes throughout the study such that comments can guide the study.

### **B.2.9 Planning the Reporting of Results**

To reduce the risk of erroneous and misleading use of the LCA, it is essential that the report is clear and transparent with a clear indication of what has and has not been included in the study and which conclusions and recommendations the outcome supports. The reporting of an LCA study should target the audience as it is specified in the goal definition. Depending on whether the study is comparative and public, the ILCD guidelines identify 3 reporting levels :

- Internal use by the commissioner of study
- External use by a third party, i.e., a limited well-defined list of recipients with at least one organisation that has not participated in the study
- Comparative studies to be disclosed to the public

Due to the sensitive nature of comparative assertions based on LCA, there are a number of additional reporting requirements for Level 3 studies. No formal requirements apply to Level 1, but it is recommended to follow the requirements for Level 2.

## **B.3 Life Cycle Inventory Analysis**

It is the most time consuming part of an LCA. It is guided by the goal and scope definition and its core activity is the collection and compilation of data on elementary flows from all processes in the studied product system(s) drawing on a combination of different scenarios. The output is a compiled inventory of elementary flows that is used as basis for the subsequent life cycle assessment phase. LCIA has six stages :

- Identifying processes for the LCI model of the product system
- Planning and collecting data
- Constructing and quality checking unit processes
- Constructing LCI model and calculating LCI results
- Preparing the basis for uncertainty management and sensitivity analysis
- Reporting

Insights that the LCA practitioner gains when conducting the LCI analysis are also commonly used to adjust the requirements of the scope definition. It is rarely practically possible to collect the highest quality of data for all processes of the LCI due to the unreasonable high cost that would be involved. Fortunately, it is also rarely needed to complete goals. Therefore, the inventory analysis requires a structured approach to ensure that time is being spent on collection of data for those parts of the product's life cycle that are most important for the overall impacts from the product system.

An LCI constructed using the knowledge about the industrial processes taking part in the life cycle and the physical flows connecting them is called a process based (or bottom-up) approach to inventory modelling. A complementary approach is to model the LCI from a macro scale perspective by drawing on a combination of i) information on elementary flows associated with one unit of economic activity in different sectors and ii) national statistics on the trade of products and services between sectors. This is called environmentally extended input-output analysis (EEIO) and is a top-down approach. The strength of EEIO is that it has a completeness of 100% in theory as no processes need to be cut off due to missing data or budget constraints. The weakness of EEIO is that the coverage of elementary flows is rather limited, compared to process based approach and the resolution of many products and services is quite low due to heterogeneous nature of many sectors.

### **B.3.1 Identifying Processes for the LCI Model**

The first step of the LCI details the coarse initial system diagram made under the scope item System Boundaries and draws upon the related Completeness Requirements. The outcome of the step is a detailed depiction of the foreground system and the processes of the background system neighbouring the foreground system. For all decision contexts A, B, C1 and C2, the approach to identifying processes is to start with the reference flow and construct the entire foreground system process by process.

- 0. The unit processes having the reference flow as product output, should first be identified. This is termed as Level '0' process (for eg. assembly).
- 1. The processes required to deliver flows that will be physically embodied in the reference flow should then be identified. These are termed as Level '1' processes (for eg. production of assembly materials).
- 2. The processes required to deliver flows that perform a supporting function to the Level '0' process (i.e. not becoming physically embodied in its output) should then be identified. These are termed Level '2' processes (for eg. electricity and transportation).
- 3. The processes required to deliver services to the Level 0 processes should then be identified. These are termed Level '3' processes (for eg. administration and marketing).

- 4. The processes required to produce and maintain the infrastructure that enables the Level 0 process should then be identified. These are termed Level ‘4’ processes (for eg. replacing and repairing).

After having identified Level 1, 2, 3, 4 processes belonging to the level 0 process (the reference flow), Step 1-4 is then repeated for each of these processes. The procedure is, in principle, repeated until the foreground system is completed and can be linked to LCI database processes of the background system. While carrying out, the LCA practitioner must identify all the multifunctional processes. In practice, many processes belonging to Level 3 and 4 will end up being entirely omitted from an LCI model, because their individual contribution to the indicator score is expected to be insignificant and because data can be hard to find, at least when using the bottom-up approach to constructing inventories. In such cases, the environmental impacts of product systems are systematically underestimated by various degrees. It is an important task of the inventory analysis and consecutive impact assessment to ensure that this underestimation does not violate the completeness requirements of the study.

### B.3.2 Planning and Collection of Data

This planning has the purpose to balance the effort of data collection by the relevance of the respective data and information. As starting point for data collection, practitioners are encouraged to create a table that outlines a plan for the data collection for each process or single data point [Figure B.3]. The table can be adapted according to revisions after early iterations of LCIA phase. The initial planning should be based on the requirements to data representativeness from the scope definition, as well as on the efforts that are expected in order to obtain data for a given quality.

The data type to be prioritised is always complete unit processes, because this form the basis of the LCI results. However, for very high and high data specificity, complete site-specific unit processes often do not exist and therefore must be constructed by the practitioner from single data points. Ideally elementary flow data should be gathered in the physical unit matching the characterisation factors to be applied in LCIA (usually ‘kg’) per specific reference flow of the unit process (usually the primary product output). The units must be scaled.

Process or single data point	Specificity					Type	Source	Access
	Very high	High	Medium	Low	Very low			
X	X					Concentration	Process engineer	Questionnaire
Y		X				Kg/year	Academic paper	Online search
Z				X		Unit process	ecoinvent	Database search

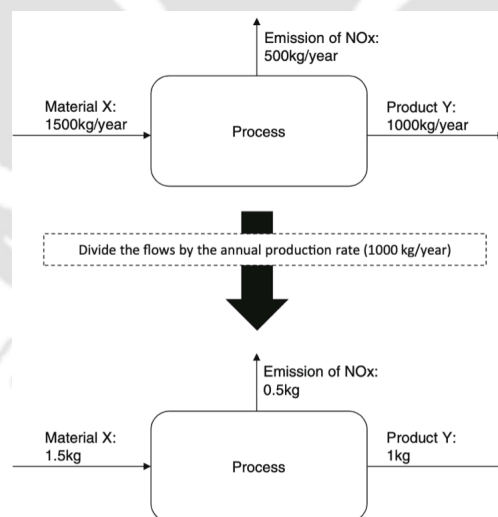
**Figure B.3** Template for planning and collection of data based on Wenzel et al, 1997

If unit process data is not available (due to cost of measuring), flows can be modelled from other site specific data such as concentration of pollutant in effluents. Another approach is to calculate flows using mass balance. Mass of input is equal to mass of output [Figure B.4]. Data should be time specific and site specific, other data specificity is lower.

List of process based LCI Databases :

- **Ecoinvent** (Swiss database; [www.ecoinvent.org](http://www.ecoinvent.org))
- **ELCD** (Database of the JRC of the European Commission; [eplca.jrc.ec.europa.eu/ELCD3/index.xhtml](http://eplca.jrc.ec.europa.eu/ELCD3/index.xhtml))
- **Agri-Footprint** (Feed, food and biomass database; [www.agri-footprint.com](http://www.agri-footprint.com))
- **LCA Food** (Danish database; [www.lcafood.dk](http://www.lcafood.dk))
- **Swedish National LCA Database** (SPINE format; [cpmdatabase.cpm.chalmers.se](http://cpmdatabase.cpm.chalmers.se))
- **GaBi Databases** (Preferable in India; [www.gabi-software.com/international/databases/gabi-databases](http://www.gabi-software.com/international/databases/gabi-databases))
- **LC-inventories** (Extension of Ecoinvent V2.2; [www.lc-inventories.ch](http://www.lc-inventories.ch))
- **NEEDS** (European Research Project; [www.needs-project.org/needswebdb/index.php](http://www.needs-project.org/needswebdb/index.php))
- **NREL** (US-American database; [www.nrel.gov/lci](http://www.nrel.gov/lci))
- **ProBas** (German database; [www.probas.umweltbundesamt.de/php/index.php](http://www.probas.umweltbundesamt.de/php/index.php))
- **LCA Commons** (US database; [www.lcacommons.gov](http://www.lcacommons.gov))
- **Ökobaudat** (German database; [www.oekobaudat.de/en.html](http://www.oekobaudat.de/en.html))

When data is sourced from online searches, or LCI databases, it is important to pay attention to the available metadata describing the characteristics and conditions of the process to evaluate how representative the data is for the actual data needed. Relevant metadata for the foreground processes should be reported by the LCA practitioner and furthermore considered in the later sensitivity analysis and uncertainty management. If efforts to obtain data have been fruitless, one may rely on expert judgement, from experts in the technical domain of similar LCA practitioners. If that fails, a last resort is to use a ‘reasonable worst case’ for the calculation of the first iteration of the LCA results. It can be derived from correlation or from calculation of other processes.



**Figure B.4** Example of the scaling of three annual flows to one unit (kg) or reference flow (product Y)  
(Source : Life Cycle Assessment, Hauschild 2018)

### B.3.3 Constructing and Quality Checking Unit Processes

The data that is collected should represent full operation cycle of the process, including preparation activities like heating, calibration (with loss of materials and products as scrap), operation, idling, cleaning and maintenance, also consider typical scrap rates during operation. Data collection must happen over a longer period of time, ideally covering several production cycles, perhaps one year's production. Impacts from manufacturing and end-of-life stage of production equipment are important and they should be included in data collection. When the data has been collected, it is time to construct the unit processes in the right format. To reiterate, all data must be in the form of flows scaled to the unit of the reference flow of the unit process.

There are 3 complementary approaches for validating the completeness of flows :

- Knowledge of similar processes can help identifying potentially missing flows
- Knowledge of the nature of a physical transformation in a process can hint what emissions or waste flows to treatment may be missing
- A qualitative comparison of input and output flows can show if there is disagreement between the elements entering a process and the elements leaving the process.

A unit process must contain the right flows as well as the right quantities. A number of validation techniques exist to check flow quantities :

- A mass balance is a universal approach because the sum of flows entering a process should amount to the same number as the sum of flows leaving a process since no accumulation occurs inside the process. A mass balance can also be applied at the level of individual elements, but one should be aware of 'hidden' elements in heterogenous flows.
- Energy balances can in principle be used as a validation approach, but this would require calculations of the chemical energy stored in inputs and outputs and quantification of heat lost to the environment, which is often not reported as an emission in a unit process.
- Following validation based on mass balance, a complementary validation based on stoichiometry can be carried out if the process to be validated involves one or more chemical reactions. This serves to check if the ratio between inputs and outputs involved in a chemical reaction is correct.
- Another validation approach relies on comparisons to external information. This could be information for similar processes that are expected to contain flows of similar magnitudes as the process to be validated. The external information could also be legal limits.
- Finally, another validation approach relies on the first iteration of LCIA results, to identify erroneously high flow quantities.

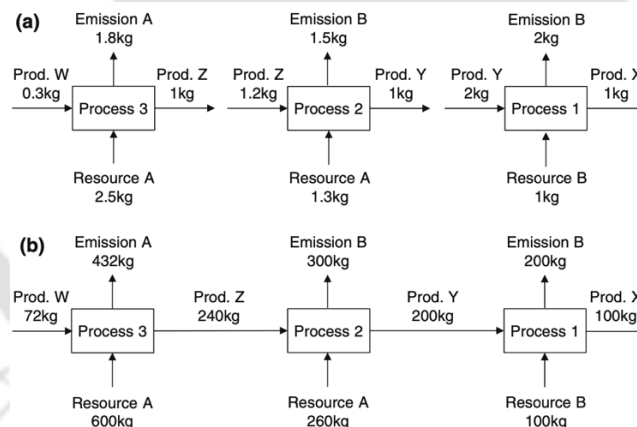
To prepare a unit process for use in an LCI model, it is important that the LCA software used 'understands' the identity of the flows of the unit processes. If not, a flow cannot be linked correctly to other processes or characterisation factors (in the case of elementary flows). LCA practitioner should always check the flow nomenclature of the software used and follow this when naming the flows of constructed unit processes.

LCA practitioners may face a situation where an LCA software has no name for a given elementary flow or the CAS number (Chemical Abstract System number - a unique identifier for a chemical) of an emitted chemical does not exist in the list of flow names in a software. In this case, the LCA practitioner should check if there is a Characterisation Factor (CF) for the chemical in the LCIA method to be applied in the ensuing LCIA step and create a new flow in the LCA software.

### B.3.4 Constructing the LCI Model and Calculating LCI Results

When all unit process have been constructed or collected from LCI databases, the LCA practitioner can construct the LCI model. Each unit process can be seen as a building block in the LCI model, the ‘size’ of which is ultimately decided by the study’s reference flow derived from the functional unit in the scope definition. Each unit process must be scaled to fit the LCI model [Figure B.5].

In practice, inventory modelling is normally performed using a dedicated software which supports both the building of the product system model, connecting the relevant unit processes, the linking to available unit process databases and storing of own processes, and the linking of elementary flows in the inventory results to the relevant characterisation factors for the life cycle impact assessment. Processes from LCI databases exist in disaggregated and aggregated versions, the difference being that the latter scales all processes upstream and downstream according to the reference flow of the process and aggregates their elementary flows, so that the only output of the aggregated process (or input, in the case of waste treatment processes) that is not an elementary flow is its reference flow.



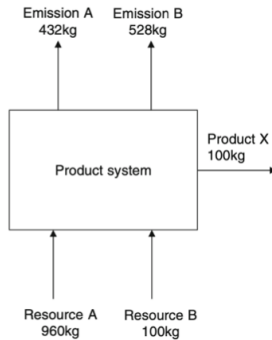
**Figure B.5** Three simplified unit processes unconnected (a) and connected (b) based on a study reference flow of 100 kg of product X (the reference flow of process 1) (Source : Life Cycle Assessment, Hauschild 2018)

Few widely used software for performing LCA are as follows :

- **SimaPro** (Pré Consultants, [www.pre-sustainability.com/simapro](http://www.pre-sustainability.com/simapro))
- **GaBi** (Thinkstep; [www.gabi-software.com/international/index](http://www.gabi-software.com/international/index))
- **OpenLCA** (GreenDelta, open access; [www.openlca.org](http://www.openlca.org))
- **Umberto** (Ifu Hamberg; [www.ifu.com/en/umberto](http://www.ifu.com/en/umberto))

### B.3.5 Calculation of LCI Results

The LCI results are the compilation of elementary flows over all the processes that are part of the LCI model (scaled to reference flow of the functional unit). The results would simply be the sum of each of the resources and emissions across all the processes, describing final LCI results as shown in Figure B.6.



**Figure B.6** LCI results for the product system in Fig 5. The aggregated elementary flows of product W (72 kg), that are not shown in Fig 5, are 100 kg of resource A and 28 kg of emission B (Source : Life Cycle Assessment, Hauschild 2018)

### B.3.6 Data Needs for Uncertainty and Sensitivity Analysis

Uncertainty and Sensitivity Analysis informs the LCA practitioner on how robust the conclusions of the study are and where future studies should focus on to make results even more robust. Uncertainty analysis allows for the quantification of uncertainties of the final result, as a consequence of the uncertainty of each parameter in the LCI model. To enable an uncertainty analysis, the practitioner must, for quantitative parameters in the foreground system, collect information on their statistical distribution (e.g. normal, log-normal or uniform) and corresponding statistical parameter values (e.g. mean and standard deviation for normally distributed parameters). Sensitivity analysis allows for systematic identification of the parameters that have the highest influence on the LCIA results. The influence of parameters on results is calculated by changing them, one by one, and observing the changes in results. These changes in parameters should reflect uncertainties about the actual product system modelled. For quantitative parameters in the foreground system, the practitioner should aim to collect minimum and maximum values, or a low and a high percentile (e.g. 2.5th and 97.5th) when a parameter's statistical distribution is known, in addition to the default value that is used in the LCI model.

It often takes more time to collect sensitivity and uncertainty data for some parameters in the foreground system than for others and it may not be necessary to collect data for all processes, depending on the outcome of the first iteration of the analysis. For the background system, many LCI databases include uncertainty information on processes, which can feed into uncertainty and sensitivity analysis in LCA software. The practitioner therefore needs not to bother about such data in the inventory analysis.

### B.3.7 Reporting

- **Documentation of LCI model at system level :** It is proposed to use a flowchart that contains all the linked processes in the fore- ground system for each studied product system and shows their links to processes in the background system. Each process should be named and, depending on the size of the

foreground system, flow names and quantities may also be given. Flow chart should be reported in the main part of an LCA report. Only the unit processes of the background system that are linked to the foreground system needs to be included in the flow chart. From this information, the reader may reconstruct the remaining background system on their own by using aggregated versions of the reported 'neighbouring' background processes from the relevant LCI databases.

- **Documentation of Each Unit Process :** It is recommended to create a table for each unit process in the foreground system that contains its name (identical to the one used in the flow chart of the first reporting element) and the names and quantities of all flows. It is also advocated to provide the source of a process or flow, a reference to the section of a report where details of calculation are provided, and finally reference to other unit process tables that are input or output to the process of interest.
- **Documentation of Metadata :** It is recommended to report metadata according to specificity, type, source and access using the specificity table. For easy overview, the rows of the table should be grouped into life cycle stages. The data specificity classification for each data point should be transparent. The documentation of metadata should be consistent with the documentation of unit processes, and cross references between the two should be made. It is advocated to report metadata in the main part of the LCA report.
- **Documentation of LCI Results :** The LCI results should simply be documented as a list of quantified elementary flows, divided into resources and emissions. This typically consists of an extensive table, which can be documented as an appendix for readability of the LCA report.
- **Assumptions for Each Life Cycle Stage :** Due to lack of information and budget constraints, it is common to make several assumptions when constructing an LCI model. All assumptions made during the construction of the LCI model should be transparently documented preferably directly into the table containing the metadata. It is also recommended that a list of all assumptions, minor or major, be placed in an Appendix.
- **Documentation of Data Collected for Uncertainty and Sensitivity Analysis :** For sensitivity analyses, the LCA report must state which parameters are analysed and whether this is done by calculating normalised sensitivity coefficients (for parameters of a continuous nature) or by the construction of sensitivity scenarios (for parameters of a discrete nature). In the former case, the perturbed values for each parameter must be documented and the basis of these explained. In the latter case, the sensitivity scenarios should be documented and references to the assumptions they are based on made. For uncertainty analyses, the best practice is to use statistical distributions of parameter values as input to Monte Carlo analysis, in which case the distributions (e.g. uniform, normal or log-normal) and statistical parameters (e.g. standard deviation) must be documented for each parameter value covered in the uncertainty analysis. If, due to lack of such data, the Pedigree approach is taken, the underlying uncertainty factors and calculated geometric standard deviation for process must be documented.

## B.4 Life Cycle Impact Assessment

LCIA is the third phase of an LCA study, where the life cycle inventory's information on elementary flows is translated into environmental impact scores. LCIA is, in practice, largely automated by LCA software, but the underlying principles, models and factors should still be well understood by practitioners to ensure the insight that is needed for a qualified interpretation of the results.

LCIA is a phase of LCA aiming to assess the magnitude of contribution of each elementary flow. Its objective is to examine the product system from an environmental perspective using impact categories and category indicators in conjunction with the result of the inventory analysis. This will provide information useful in the interpretation process.

An environmental impact is a set of defined changes, positive or negative, due to an anthropogenic intervention. Such impacts are studied and assessed using a wide range of quantitative and qualitative tools, all with specific aims and goals to inform or enable more sustainable decisions. This is an important phase in LCA as it transforms an elementary flow from the inventory into its potential impacts on the environment. This is important since elementary flows are just quantities emitted or used but not directly comparable to each other in terms of the importance of their impact.

LCIA characterisation methods essentially model the environmental mechanism that underlies each of the impact categories as a cause-effect chain starting from the environmental intervention all the way to its impact. However, the results of the LCIA should neither be interpreted as predicted actual environmental effects nor as predicted exceedance of thresholds or safety margins nor as risks to the environment or human health. The results of this LCA phase are scores that represent potential impacts.

The ISO 14040/14044 standards (ISO 2006 a,b) distinguish mandatory and optional steps for the LCIA phase. The mandatory steps are :

- Selection of Impact Categories, Category Indicators and Characterisation Models (in practice typically done by choosing an already existing LCIA method)
- Classification (assigning LCI results to impact categories according to their known potential effects; in practice automatically done by LCI databases and LCA software)
- Characterisation (calculating category indicator results quantifying contributions from the inventory flows to the different impact categories; typically done automatically by the LCA software).

The optional steps are :

- Normalisation (expressing LCIA results relative to those of a reference system)
- Weighting (prioritising or assigning weights to each impact category)
- Grouping (aggregating several impact indicator results into a group)

Assessed impacts in the LCIA phase should be interpreted as impact potentials and not as actual impacts or exceeding thresholds or risks because they are :

- Relative expressions of potential impacts associated with the life cycle of a reference flow needed to support a unit of function

- Based on inventory data that are integrated over space and time, and thus often occurring at different locations and over different time horizons
- Based on impact assessment data which lack information about the specific conditions of the exposed environment.

### ***Terminology and Key Concepts***

#### **Area of Protection :**

A cluster of category endpoints of recognisable value to society (for eg - human health, natural resources, natural environment) (Hauschild & Huijbregts, 2015)

#### **Category Indicator :**

Quantifiable representation of an impact category (ISO 2006b)

#### **Category Endpoint :**

Attribute or aspect of natural environment, human health or resources, identifying an environmental issue giving cause for concern (ISO 2006b).

#### **Characterisation Model :**

Reflect the environmental mechanism by describing the relationship between the LCI results, category indicators and, in some cases, category endpoint(s). The characterisation model is used to derive the characterisation factors (ISO 2006b)

#### **Characterisation Factor :**

Factor derived from a characterisation model which is applied to convert an assigned life cycle inventory analysis result to the common unit of the category indicator (ISO 2006b)

#### **Elementary Flow :**

Material or energy entering the system being studied that has been drawn from the environment without previous human transformation, or material or energy leaving the system being studied that is released into the environment without subsequent human transformation (ISO 2006b)

#### **Environmental Impact :**

Potential impact on the natural environment, human health or the depletion of natural resources, caused by the interventions between the technosphere and the ecosphere as covered by LCA (e.g. emissions, resource extraction, land use) (EC-JRC 2010a)

#### **Environmental Mechanism :**

System of physical, chemical and biological processes for a given impact category, linking the life cycle inventory analysis results to category indicators and to category endpoints (ISO 2006b)

**Environmental Relevance :**

Degree of linkage between category indicator result and category endpoints (ISO 2006b)

**Impact Category :**

Class representing environmental issues of concern to which life cycle inventory analysis results may be assigned (ISO 2006b)

**Impact Pathway :**

Cause–effect chain of an environmental mechanism

**LCIA Method :**

Collection of individual characterisation models (each addressing their separate impact category)

**Midpoint Indicator :**

Impact category indicator located somewhere along the impact pathway between emission and category endpoint (Hauschild & Huijbregts, 2015)

**Potential Impact :**

Relative performance indicators which can be the basis of comparisons and optimisation of the system or product (Hauschild & Huijbregts, 2015)

**Mandatory Steps According to ISO 14040/14044 :****B.4.1 Selection of Impact Categories, Category Indicators and Characterisation Models**

The objective of the above is to find the most useful and needed ones for a given goal. The selection of impact categories must be in accordance with the goal of the study and is done in the scope definition phase prior to the collection of inventory data to ensure that the latter is targeted towards what is to be assessed in the end.

ISO 14044 (2006b) states that the choice of impact categories needs to assure they :

- are not redundant and do not lead to double counting
- do not disguise significant impacts
- are complete
- allow traceability

Their obligatory criteria includes being :

- consistent with the goal and scope of the study
- justified in the study report
- comprehensive regarding environmental issues related to the product system under study
- well documented with all information and sources being referenced

ISO 14044 (2006b) recommendations :

- International acceptance
- Minimisation of value choices and assumptions
- Scientific and technical validity of the characterisation model
- Being based upon a distinct, identifiable environmental mechanism and reproducible empirical observation
- Environmental relevance of category indicators

External factors include :

- Requirements following from the defined goal and specified in the scope definition of the LCA
- Requirements by the commissioner of an LCA
- Fixed requirements (rules and schemes)

Practical constraints include :

- Availability, completeness and quality of LCI results required for a specific impact category
- Availability, completeness and quality of characterisation models and factors for a specific impact category, including the need to consider specific rare or new impact categories such as noise
- If normalisation is required, availability, completeness and quality of normalisation factors for a specific impact category or LCIA method.

If practical constraints prevent the practitioner from including what has been identified as relevant impact categories, this needs to be made clear in the discussion and interpretation of the LCA results and comments need to be made on whether it may change the conclusions.

#### **B.4.2 Classification**

In this step the elementary flows of the LCI are assigned to the impact categories to which they contribute. This is handled automatically by the LCA software.

#### **B.4.3 Characterisation**

To this end, all elementary flows  $E_i$ , classified within a specific impact category  $c$  (representing an environmental issue of concern), are multiplied by their respective characterisation factor  $CF_i$  and summed over all relevant interventions  $i$  (emissions or resource extractions) resulting in an impact score  $IS_c$  for the environmental impact category (expressed in a specific unit equal for all elementary flows within the same impact category)

$$IS_c = \sum_i (CF_i \cdot E_i)$$

**i. Characterisation Factor** represents the contribution per quantity of an elementary flow to a specific environmental impact (category). The unit of a  $CF$  is the same for all elementary flows within an impact category. It is defined by the characterisation model developers and may express the impacts directly in

absolute terms (e.g. number of disease cases/unit toxic emission) or indirectly through relating them to the impact of a reference elementary flow (e.g. CO<sub>2</sub>-equivalents/unit emission of greenhouse gases).

- The first step when establishing an impact category is the observation of an adverse effect of concern in the environment. Once accepted as an effect of concern, the focus will be on how to characterise (quantify) the observed effect in the framework of LCA.
- The basis and starting point of any characterisation model is always the establishment of a model for the environmental mechanism represented by a cause–effect chain, essentially distinguishing two types based on the direction of the relevant elementary flows between technosphere and ecosphere - a) an emission into the atmosphere and b) a resource extraction from the environment.

For **a) an emission into the environment**, the principle cause-effect chain may be divided into the following :

- **Emission** : into air, water or soil (groundwater, indoor air etc.)
- **Fate** : environmental processes causing transport, distribution and transformation of the emitted substance in the environment, by wind or flowing water undergoing degradation and transformation
- **Exposure** : contact of the substance from the environment to a sensitive target like animals and plants, entire ecosystems by inhalation, ingestion of food, dermal contact etc
- **Effects** : observed effects of adverse form in the sensitive target after exposure to the substance, for eg. increase in disease cases (reversible/irreversible) per unit intake in a human population or number of species effected (disease, behaviour, immobility, reproduction, death etc.) after exposure of an ecosystem
- **Damage** : distinguishing severity by quantifying the fraction of species' death, also for humans including irreversible/reversible problems (mobility, dysfunctional organs, skin rash, headache etc.)

For **b) a resource extracted from the environment**, the principle cause-effect chain may comprise some or all of the following :

- **Extraction or use** : of minerals, crude oil, water, soil etc.
- **Fate** : physical changes in local conditions of the environment, for eg. soil organic carbon content, soil permeability, carbon released, ground water level, soil albedo
- **Exposure** : change in available quantity, quality and functionality of a resource and potential competition among several users, such as humans or ecosystems with different degrees of adaptation and compensation, for eg. habitat loss, dehydration stress, soil biotic productivity etc.
- **Effects** : advert effects on people and users that are unable to adapt or compensate (for eg. diseases, migration, death, malnutrition etc.) and contribution to other impact pathways (for eg. global warming due to changed soil albedo, released soil carbon etc.)
- **Damage** : distinguishing severity of observed effects by quantifying reduction in diversity, affected human health and social effects such as war on water.

Four main Principles for all Extraction related Impact Categories :

- **Land Use** (affecting biotic productivity, aquifer recharge, carbon sequestration, albedo, erosion, mechanical and chemical filtration capacity, biodiversity, etc.)
- **Water use** (affecting human health, aquatic ecosystems, terrestrial ecosystems)
- **Abiotic resource use** (fossil and mineral) affecting the future availability of the non-renewable abiotic resources
- **Biotic resource use** (e.g. fishing or wood logging) affecting the future availability of the renewable biotic resources and the ecosystems from which they are harvested.

**ii. Impact Indicator** represents the contribution from an elementary flow in an LCI flow which is measured by the ability to affect an indicator for the selected impact category along its cause-effect chain. This selection of indicator should be guided by the environmental relevance of the indicator. In general, the further down the cause-effect chain an indicator is chosen, the more environmental relevance (and meaning) it will have. To select the impact indicator, developers must therefore strike a compromise between choosing an indicator of impact :

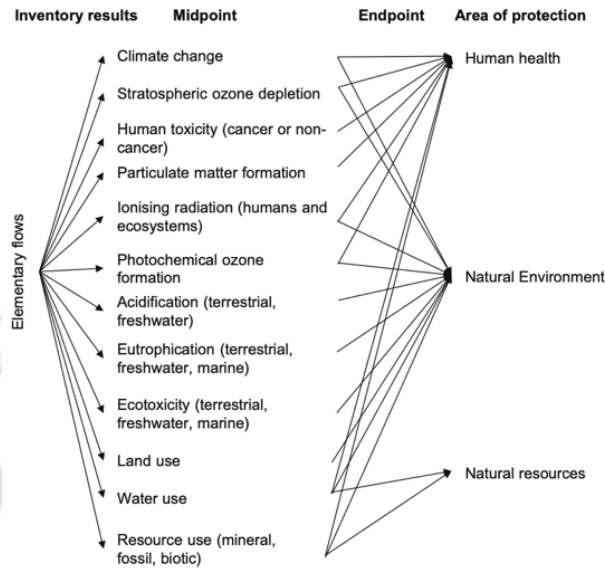
- Early in the environmental mechanism, giving a more measurable result but with less environmental relevance and more remote from the concerns directly observable in the environment, versus
- Downstream in the environment mechanism, giving more relevant but hardly verifiable information

This has led to two different impact categories, applying indicators on two different levels of the environment mechanism : a) Mid-point impact indicators and b) End-point impact indicators.

**a) Mid-Point Impact Indicators :** Here, the classification gathers the inventory results into groups of substance flows that have the ability to contribute to the same environmental effect. Typical mid-point categories (including respective sub-categories/impact pathways) are [Figure B.7]:

- Climate Change
- Stratosphere Ozone Depletion
- Acidification (terrestrial, freshwater)
- Eutrophication (terrestrial, freshwater, marine)
- Photochemical ozone formation
- Ecotoxicity (terrestrial, freshwater, marine)
- Human toxicity (cancer, non-cancer)
- Particulate matter formation
- Ionising Radiation (human health, aquatic and terrestrial ecosystems)
- Land Use
- Water Use
- Abiotic Resource Use
- Biotic Resource Use
- Noise
- Pathogens

The characterisation at midpoint level of the elementary flows in the LCI results in a collection of midpoint impact indicator scores, jointly referred to as the characterised impact profile of the product system at midpoint level. This profile may be reported as the result of the LCIA, and it may also serve as preparation for the characterisation of impacts at endpoint level.



**Figure B.7** Framework of the ILCD characterisation linking elementary flows from the inventory results to indicator results at midpoint level and endpoint level for 15 midpoint impact categories and 3 areas of protection [adapted from EC-JRC (2010b)]

**b) End-point Impact Indicators :** Midpoint indicators are expanded or linked to one or more end-post indicators on the basis of damage and severity. They represent ‘Areas of Protection’ or AoP that ‘defend’ out interests as a society with regard to human health, ecosystems or planetary life support functions including ecosystem services and resources. They are chosen at the very endpoint of chains. Typical end-point indicators are [Figure B.7] :

- Human Health
- Ecosystem Quality or Natural Environment
- Natural Resources or Ecosystem Services

All endpoint indicators for the same AoP have a common unit and can be summed up to an aggregated impact score per AoP. On midpoint level, aggregation and contribution analysis of multiple impact categories are only possible after applying normalisation and weighting.

To go from midpoint to endpoint scores, additional midpoint to endpoint characterisation factors, also known as severity or damage characterisation factors, are needed to express endpoint indicator. In contrast to the midpoint characterisation factors which reflect the properties of the elementary flow and hence are elementary flow specific, the midpoint to endpoint characterisation factors reflect the properties of the midpoint indicator and there is hence only one per midpoint impact category. The units of CF’s for midpoint impact categories is specific for each category and LCIA method chosen. Endpoint CF’s are typically expresses in absolute units which are relatively common across LCIA methods. They are :

- Human Health (years) expressed as DALY (Disability Adjusted Life Years) concept proposed by Murray & Lopez, 1996
- Ecosystem Quality or Natural Environment (sqmyear or cumyear) expressed as Potentially Disappeared Fraction (PDF) of species in an ecosystem
- Resource Depletion and Ecosystem Services which has different consensus forming on different approaches.

**iii. Uncertainties** is important in LCIA and it contributes sustainability to overall uncertainty of an LCA result. A large uncertainty is by no means a valid reason to exclude an impact category from the assessment. This would violate the goal of LCA to avoid problem shifting from one impact category to another.

#### **iv. Main Assumptions of LCIA methods in context of LCA**

- **Steady state** : LCIA models are usually not dynamic, but represent the environment as a system in steady state; all parameters which define its behaviour are not changing over time.
- **Linearity** : Steady state conditions in LCIA implies a linear relationship between the increase in an elementary flow and the consequent increase in its potential environment impact.
- **Marginal v/s Average Modelling** : Marginal Impact Modelling Approach represents the additional impact per additional unit emission/resource extraction caused by the product system on top of the existing background impact. This allows considering non-linearity of impacts depending on local conditions. An Average Impact Modelling Approach is strictly linear and represents an average impact independent from existing background impacts, which is similar to dividing the overall impact by the overall emissions.
- **Potential Impacts** : LCIA results are not actual or predicted impacts, nor excellence of thresholds or safety margins, or risk. They are relative expressions of impacts associated with the life cycle of a reference unit of function (functional unit), based on inventory data which are integrated over space and time, representing different locations and time horizons and based on impact assessment data which lack information about the specific conditions of the exposed environment.
- **Mass/Energy Conservation and Balance** : Mass/energy cannot be created or disappear, it can only be transferred. This principle must be followed in all transformations to maintain the balance at all times.
- **Parsimony** : To follow basic modelling principle of ‘as simple as possible and as couples as necessary’ to the entire LCA approach.
- **Relativity** : LCA results are relative expressions of impacts that relate to a functional unit and can be compared between different alternatives providing the same function. An absolute interpretation of LCA results (A is sustainable, B is not) is not advisable as it requires a lot of additional assumptions.
- **Best Estimate** : A fundamental value choice in LCA is not to be conservative, precautionary or protective, but to focus on avoiding any bias between compared scenarios by assuming average conditions, also referred to as Best Estimate. LCA is a comparative assessment methodology. Direct adoption of conservative regulatory methodology and data is often not appropriate, and should be avoided in LCIA in order not to bias comparison between impact categories where different levels of precaution may be applied.

## Optional Steps According to ISO 14040/14044 :

### B.4.4 Normalisation

It makes it feasible to relate indicator scores of different impact categories to each other, and decide their impact size. Hence, by comparing the potential impacts to a reference system like a country, world or industrial sector, they can be expressed in common units and determine impact size. Normalisation can be used for :

- Providing an impression of the relative magnitudes of the environmental impact potentials
- Presenting the results in a form suitable for a subsequent weighting
- Controlling consistency and reliability
- Communicating results

Typical references are total impacts per category per :

- Geographical zone (global to local)
- Inhabitant of a geographical zone (space/person)
- Industrial sector of a geographical zone (environment space)
- Baseline reference scenario (another product system)

Normalisation Factors are essentially calculated per impact category by conducting an LCI and LCIA on the reference system, i.e. quantifying all environmental interventions  $E$  for all elementary flows  $i$  for the reference system and applying the characterisation factors  $CF$  per elementary flow  $i$ , respectively, for each impact category  $c$ . Although not obligatory, the normalisation reference is typically divided by the population  $P$  of the reference region  $r$ , in order to express the NF per average inhabitant of the reference region (per capita impacts or “person equivalents”). This way, a total impact of the reference system per impact category is calculated, resulting in one NF per impact category  $c$ :

$$NF_c = \left( \frac{\sum_i (CF_i \cdot E_i)}{P_r} \right)^{-1}$$

Ensuring consistency, the LCI data used to calculate a NF need to represent a common reference year and duration of activity (typically one year, being the reference year) for all impact categories. This results in NF having a unit expressing an impact per person and year, also referred to as person equivalent. A normalised impact score NS for a product system is calculated by multiplying the calculated impact score IS for the product system by the relevant NF per impact category  $c$ :

$$NS_c = IS_c \cdot NF_c$$

### B.4.5 Weighting and Aggregation

Weighting can be used to determine which impacts are most important and how important they are. This step can only be applied after the normalisation step and allows the prioritisation of impact categories by applying different or equal weights to each category indicator. Weighting can be used for :

- Aggregating impact scores into several or one single indicator (note that according to ISO 14040/14044 there is no scientific basis on which to reduce the results of an LCA to a single result or score because of the underlying ethical value-choices)
- Comparing across impact categories
- Communicating results applying on underlying prioritisation of ethical values

Transparency must be maintained regarding weighting factors. Must be in accordance to goal and scope definition, considering target group preferences and supporting the study. Shared values are crucial for the acceptance of LCA results, as they have multiple stakeholders - shareholders, customers, employees, retailers, authorities, insurance, politics etc. If one set of weighting factors are not accepted by all, then stakeholders will be prioritised or different sets used, which are more science based rather than value based. Principles applied to derive weighting factors are :

- Social assessment of damages (financial, will to pay, healthcare)
- Prevention costs (higher costs mean higher weighting)
- Energy consumption (prevention by technical means)
- Expert panel or stakeholder assessment
- Distance to target (politically or scientifically defined)
- Social science based perspectives (combining groups to internally consistent profiles)

#### **B.4.6 Grouping**

It can be done by :

- Sorting and clustering midpoint impact categories on a nominal basis
- Ranking impact categories into set hierarchy (subjective)

#### **B.5 Footprints v/s LCA**

Its appearance in the environmental field can be tracked back to 1992 when William Rees published the first academic article on the thus-termed “ecological footprint” (Rees 1992), which was further developed by him and Mathis Wackernagel in the following years. Its aim is to quantify the mark left by human activities on natural environment. Prominent examples are :

- Ecological footprint (land use) [www.footprintnetwork.org](http://www.footprintnetwork.org)
- Cumulative Energy Demand (CED) (non-renewable energy)
- Material Input per Unit of Service (MIPS) (material use)
- Water footprinting (volumetric accounting) [waterfootprint.org](http://waterfootprint.org)
- Water footprinting based on pollution (ISO 14046)
- Carbon footprinting (climate change) (ISO 14046, ISO/TS 14067, WRI/WBCSD GHG protocol)
- Chemical footprinting (toxicity impacts)
- Phosphorus depletion footprint

All footprints are fundamentally based on the lifecycle perspective and most of them focus on one environmental issue or area of concern. Their strengths are :

- Easily accessible, intuitive
- Easy to communicate
- Availability of data
- Easy to perform
- Wide range of targets

Their limitations are :

- Focus on one issue; does not inform about burden shifting; not suitable to support decisions regarding environmental sustainability; assesses only quantities, not impacts
- Do not reflect damages; cannot be combined to show overall results because system boundaries are not aligned.

Footprints are life cycle-based, narrow-scoped, environmental metrics focusing on an area of concern. They are widely and easily applicable, as well as easily understood by non-environmental experts and therefore straightforward to communicate. They are particularly useful for communication of environmental problems or achieved improvements, as long as their use is restrained to their coverage of environmental concerns and care is taken when interpreting them (burden-shifting), particularly when results are disclosed to non-expert audiences (e.g. public opinion). A footprint's life cycle perspective can be an inspiring first contact with the concept of life cycle thinking for the general public, and for policy and decision-makers it often serves as an entry-door into the concept and methodology of LCA. Footprints have the ability to raise environmental awareness and therefore are springboards towards the use of more-encompassing assessment tools such as LCA. They can constitute a first step for organisations or companies, who can already implement procedures as a preparation for full environmental assessments. However, due to a footprint's narrow scope and limited representativeness for a comprehensive set of environmental indicators, they are not suitable for decision-support of any kind including product labels, eco-design, policy-support and the like.

## **B.6 Detailed Description of Impact Categories Assessed in LCA**

### **B.6.1 Climate Change**

The greenhouse effect of our atmosphere, discovered and explored from the early 19<sup>th</sup> century, is vital to life on our planet and has always existed since the dawn of life on Earth. Without it the global average temperature of our atmosphere near the ground would be  $-18\text{ }^{\circ}\text{C}$  instead of currently  $15\text{ }^{\circ}\text{C}$ . Hence, there are natural drivers and sources keeping it in balance (with periodical imbalances leading to natural events such as ice ages). In addition to those, anthropogenic activities also contribute to this effect increasing its intensity and creating global warming, which refers to the phenomenon of rising surface temperature across the planet averaged over longer periods of time. The Intergovernmental Panel on Climate Change (IPCC) defines climate change as 'a change in the state of the climate that can be identified (e.g. using statistical tests) by changes in the mean and/or the variability of its properties, and that persists for an extended period, typically decades or longer.' IPCC observed acceleration in temperature rises in the last 5-6 decades at

northern latitudes of the Arctic and ocean temperatures 3000m below. Although debated by a few sceptics, most scientists agree on the presence of this effect with anthropogenic activities as the main cause.

Global warming potentials are calculated for each Green House Gas according to :

$$GWP_i = \frac{\int_0^T a_i \cdot C_i(t) dt}{\int_0^T a_{CO_2} \cdot C_{CO_2}(t) dt}$$

where,

$a_i$  : thermal radiation absorption (instant radiative forcing) following an increase of one unit in the concentration of gas  $i$

$C_i(t)$  : Concentration of gas  $i$  remaining at time  $t$  after emission

$T$  : number of years for which the integration is carried out (20-100 years)

Main contributors to natural greenhouse effect are :

- Water vapour (55%)
- Carbon dioxide  $CO_2$  (39%)
- Ozone  $O_3$  (2%)
- Methane  $CH_4$  (2%)
- Nitrous oxide  $N_2O$  (2%)

### B.6.2 Stratospheric Ozone Depletion

Ozone ( $O_3$ ) is a highly reactive and unstable molecule, forming a bluish gas and somewhat sharp odour at normal ambient temperature. Tropospheric ground level ozone is considered a pollutant due to its many harmful effects to plants, animals and materials, whereas stratospheric ozone is vital to life on Earth due to its capacity to absorb energy rich UV radiation.

Dobson Units express the whole of ozone in a column from the ground passing through the atmosphere. Ozone concentration is considered as critically low when the value of the integrated ozone column falls below 220 Dobson units (a normal value being about 300 Dobson units). Impacts of stratospheric ozone depletion are essentially linked to reduced absorption of solar radiation in the stratosphere leading to increased UV radiation intensities at the planet surface, of which three broad (wavelength) classes are distinguished: UV-C, UV-B and UV-A. The impact of UV radiation on living organisms depends on its wavelength, the shorter the more dangerous. UV-C is the most dangerous wavelength range, but almost completely filtered by the ozone layer. UV-B (wavelengths 280–315 nm) is of the most concern due to ozone layer depletion, while UV-A is not absorbed by ozone.

The exposure impacts of UV-B includes skin cancer, cataracts, sun burn, skin cell ageing, immune system diseases, headaches, burning eyes, irritation to respiratory passages, epidermal damages of animals, reduced photosynthesis, loss of phytoplankton, accelerates generation of photochemical smog, thereby stimulating the production of tropospheric ozone, which is a harmful pollutant. Chlorine and Bromine compounds are important contributors to ozone-depletion, half of which stem from human activities (CFC's). One Chlorine atom can destroy very high number of ozone molecules, thus known as 'active' ozone depleting substances

(ODS) with fast reactions. Ozone Depletion Potential (ODP) evaluates potential of a chemical to destroy the ozone layer based on a model from the World Meteorological Organisation (WMO 2014). ODP essentially expresses the global reduction in stratospheric O<sub>3</sub> concentrations CO<sub>3</sub> due to an ozone depleting substance i relative to the global reduction of stratospheric O<sub>3</sub> concentration CO<sub>3</sub> due to 1 kg of CFC-11 (CFC1<sub>3</sub>), and is hence expressed in CFC-11 equivalents :

$$\text{ODP}_i = \frac{\Delta C_{O_3}(i)}{\Delta C_{O_3}(\text{CFC} - 11)}$$

Groups of anthropogenic ODS are: bromochloromethanes (BCM), CFCs, carbon tetrachloride, hydro-bromofluorocarbons (HBFCs), hydrochlorofluorocarbons (HCFCs), tetra-chloromethane, 1,1,1-trichloromethane, methyl bromide, methyl chloride and halons. The main uses of ODS during the last century were: fire extinguishing systems (halon), plastic foams, propellant gas in spray cans, fumigate and pesticides (methyl bromide), metered-dose inhalers (MDIs), refrigeration and air-conditioning and solvent degreasing.

### B.6.3 Acidification

Acidification of soil or aquatic ecosystems can be defined as an impact which leads to a fall in the system's acid neutralising capacity (ANC), i.e., a reduction in the quantity of substances in the system which are able to neutralise hydrogen ions added to the system. Acidification happens naturally over time but it is greatly increased by manmade input of hydrogen ions to soil and vegetation. The most important acidifying manmade compounds are Sulphur oxides, Nitrogen oxides, Ammonia and Strong Acids.

Acidifying compounds affect vital plant organs, may lower pH of soil, decrease pH of water in lakes by exposure of acidified soil water. Calcareous and clayey soil are resistant to acidification, while sandy soil are more sensitive. The security of an ecosystem can be described by its 'critical load' - 'a quantitative estimate of an exposure to one or more pollutants below which significant harmful effects on specified sensitive elements of the environment do not occur according to present knowledge.' Carbon dioxide is the only important contributor to oceanic acidification, by its dissolution which decreases pH as a consequence of increasing concentrations of carbon dioxide in the atmosphere, by producing carbonic acid.

Today, the main sources of both SO<sub>x</sub> and NO<sub>x</sub> are combustion processes in thermal power plants, combustion engines, waste incinerators and decentralised furnaces. Regulation now ensures that sulphur content is removed from the fuels, that important combustion activities like thermal power plants and waste incinerators have an efficient neutralisation of the flue gases before they are released, and that combustion engines have catalysers lowering the NO<sub>x</sub> content of the exhaust gases. Ammonia relates to agricultural fertiliser and emissions from animal husbandry.

The acidification potential depends both on the potency of the emitted gas and the soil and ecosystem sensitivity of the location expressed by their critical load. Thus, Characterisation Factors must be determined by emitted substances as well as emission location.

#### **B.6.4 Eutrophication**

Eutrophication essentially describes the enrichment of the aquatic environment with nutrient salts leading to an increased biomass production of planktonic algae, gelatinous zoo-plankton and higher aquatic plants, which results in the degradation of water quality (eg. appearance, colour, smell, taste) and an altered species composition of the ecosystem, reduction of oxygen and biodiversity loss, eventually over a long period of time, turning a lake into a swamp. Substances which contain nitrogen or phosphorus in a biologically available form are classified as potential contributors of nutrient enrichment.

Eutrophication is considered a local to regional impact category. The calculation of characterisation factors for a nutrient enriching substance consists of an assessment of the number of moles of Nitrogen or Phosphorus which can be released into the environment from one mole of the substance emitted. Agriculture is a significant source of Phosphorus and Nitrogen emission in the form of phosphates and nitrates, respectively, affecting groundwater via percolation and surface water via runoff and poaching processes, and of ammonia emitted to air and deposited on land nearby.

#### **B.6.5 Photochemical Ozone Formation**

Also known as tropospheric ozone formation, photochemical ozone formation or creation, photo oxidant formation, photo smog or summer smog. With minor differences, they all address the impacts from ozone and other reactive oxygen compounds formed as secondary contaminants in the troposphere by the oxidation of the primary contaminants volatile organic compounds (VOC), or carbon monoxide in the presence of nitrogen oxides ( $\text{NO}_x$ ) under the influence of light. VOCs are here defined as organic compounds with a boiling point below 250 °C (WHO 1989).

Ozone is reactive and unstable in nature and oxidises organic molecules in exposed surfaces. Problems arise when inhaled, it damages tissue of the respiratory tract, attack surfaces of plants and animals, and destroy photosynthetic organs, damage manmade materials on oxidation. The ozone formation requires the reaction between a hydroxyl radical and a bond between carbon and hydrogen or another carbon atom in a VOC molecule. The higher the number of such bonds, higher the relative strength of VOC to form ozone.

#### **B.6.6 Ecotoxicity**

Today's toxicology science agrees to Paracelsus's statement made 500 years ago that 'All substances are poisons, there is none which is not a poison. The right dose differentiates a poison from a remedy'. It also adheres to the principle that any substance emitted may lead to toxic impacts depending on :

- emitted quantity
- mobility
- persistence
- exposure patterns and bioavailability
- toxicity

Ecotoxicity Characterisation Factor can be expressed as :

$$CF_{eco} = FF \times XF_{eco} \times EF_{eco} \times SF_{eco}$$

where,

FF is the fate factor

$XF_{eco}$  is the ecosystem exposure factor

$EF_{eco}$  is the eco-toxicity effect factor (midpoint effects), and

$SF_{eco}$  is the eco-system severity factor (endpoint effects).

Chemical emissions into the environment will affect terrestrial, freshwater, marine and aerial ecosystems depending upon time and place of emission and characteristics of the substance emitted. It affects natural organisms in many different ways, causing increased mortality, reduced mobility, reduced growth or reproduction rate, mutations, behavioural changes, changes in biomass or photosynthesis activity etc.

### **B.6.7 Human Toxicity**

Human toxicity in LCA is based on essentially the same driving factors as ecotoxicity. Chemical exposure of humans can result from emissions into the environment which will affect the whole population, but also from the many chemical ingredients in products released during their production, use or end-of-life treatment and thus affecting workers or consumers. The cause-effect chain linking emissions and impacts can be expressed as :

$$CF_{hh} = FF \times XF_{hh} \times EF_{hh} \times SF_{hh}$$

where,

FF is the fate factor

$XF_{hh}$  is the human exposure factor

$EF_{hh}$  is the human toxicity effect factor (midpoint effects), and

$SF_{hh}$  is the human health severity factor (endpoint effects).

The midpoint human toxicity CF (number of cases per kg emitted) expresses the toxic impact on the global human population per mass unit emitted into the environment and can be interpreted as the increase in population risk of disease cases due to an emission into a specific environmental compartment. The endpoint human health CF quantifies the impact factor on human health in the global population in Disability Adjusted Life Years (DALY) per mass unit emitted into the environment.

### **B.6.8 Particulate Matter Formation**

This is known as different names in different LCIA methods, (for eg. 'particulate matter/respiratory inorganics' in ILCD, 'respiratory effects' in IMPACT 2002+, 'human health criteria pollutants' in TRACI, or 'particulate matter formation' in ReCiPe). Exposure to particulate matter (PM) is associated in epidemiological and toxicological studies with various adverse health effects and reduction in life expectancy including chronic and acute respiratory and cardiovascular diseases, chronic and acute mortality, lung cancer, diabetes, and adverse birth outcomes (Fantke et al, 2015).

Particulate Matter (PM) can be distinguished according to formation type (primary and secondary) and according to aerodynamic diameter (respirable, coarse, fine and ultra fine). Primary PM refers to particles that are directly emitted, for eg. road transport, power plants or farming activities. Secondary PM refers to organic and inorganic particles formed through reactions of precursor substances including Nitrogen and Sulphur oxides, Ammonia, semi volatile and volatile organic compounds (VOC). Secondary particles include sulphate, nitrate and organic carbonaceous materials and can make upto 50% of ambient PM concentrations.

Respirable particles (PM<sub>10</sub>) have an aerodynamic diameter less than 10 µm, coarse particles (PM<sub>10-2.5</sub>) between 2.5 and 10 µm, fine particles (PM<sub>2.5</sub>) less than 2.5 µm, and ultrafine particles (UFP) less than 100 nm (WHO 2006). PM<sub>2.5</sub> is often referred to as the indicator that best describes the component of PM responsible for adverse human health effects (Lim et al. 2012; Brauer et al. 2016). For toxicity impact categories, combining all factors from emission to health impacts or damages yields the characterisation factor for particulate matter formation (CF) with units (disease cases/kg emitted) at midpoint level and (DALY/kg emitted) at endpoint level.

$$CF = FF \times XF \times EF \times SF$$

where, CF is the characterisation factor for particulate matter formation

FF is the fate factor with unit kg in air integrated over one day per kg emitted

XF is the exposure factor at unit kg PM inhaled per kg PM in air integrated in 1 day

SF is the severity factor with unit DALY per disease case (endpoint effects)

Apart from the modelling setup, population density, activity patterns, background disease and severity rate, emission location and height also play a part.

### **B.6.9 Land Use**

Land use refers to anthropogenic activities in a given soil area, for eg. agricultural, forestry production, urban settlement, mineral extraction. There is a direct link between land use and land cover, which is used to analyse land use dynamics and landscape use patterns. Soil loss actually occur quantitatively with the average soil formation rate being extremely low compared to the soil depletion rate. It also affects qualitative soil attributes, because degrading takes place via unsustainable management practices for the highest quality soils.

Land use activities (including land conversion and land use itself), cause noticeable damages on biodiversity and on the performance of the soil to provide ecological functions. These ecological functions upon which human beings depend are also referred to as ecosystem services (Millennium Ecosystem Assessment, 2005), and together with biodiversity loss are the focus of the LCIA Land Use Impact Category.

### **B.6.10 Water Use**

Water is a renewable resource, which thanks to the water cycle, does not disappear. It is a resource different from any other for two main reasons :

- It is essential for human and ecosystem life, and
- Its functions are directly linked to its geographic and seasonal availability.

There is sufficient water on our planet to meet current needs of ecosystems and humans. About 119,000 cukm are received every year on land in different forms of precipitation, out of which 62% are sent back directly to the atmosphere via evaporation and plant transpiration. Out of the 38% remaining, humans are only about 3%, out of which 2.1% for agriculture, 0.6% for industrial uses and 0.3% for domestic uses.

The World Water Council says, ‘There is a water crisis today. But the crisis is not about having too little water to satisfy our needs. It is a crisis of managing water so badly that billions of people—and the environment—suffer badly’. This is due to growing population, changing diets (meat consumption), climate change, aggravating droughts and flooding. Water use impact assessment at midpoint level typically focuses on water deprivation. At the endpoint level, water use impact assessment is focused on the consequences of the water deprivation for humans and ecosystems. The higher the scarcity (and competition between human users), the larger the fraction of an additional water consumption that will deprive another user.

### **B.6.11 Abiotic Resource Use**

For the context of LCA, Udo de Haes et al (1999) thus defined natural resources as - ‘those elements that are extracted for human use. They comprise both abiotic resources, such as fossil fuels and mineral ores, and biotic resources, such as wood and fish. They have a functional value for society. In terms of future availability, of a resource, the issue is not the current extraction and use of the resource per se but the depletion and dissipation of the resource. When resources are used in a way that caters to their easy reuse at the end of the product life, they are still occupied and not immediately available to other use, but they are in principle available to future use for other purpose.

‘Consumption Resource Use’ converts the resource in a way so that it no longer serves as the resource it was. ‘Dispersive Resource Use’ does not lose the resource but uses it in a way that leads to its dispersal in the technosphere or ecosphere in forms that are less accessible to human use than the original resource was. Dispersive use occurs for most metals. Steen (2006) summarised different perceptions of the problem with abiotic resources in LCIA as :

- assuming that mining cost will be a limiting factor
- assuming that collecting metals or other substances from low grade sources is mainly as issue of energy
- assuming that scarcity is a major threat
- assuming that environmental impacts from mining and processing of mineral resources are the main problem.

The endpoint of the impact pathway for resource use is often assessed as the further consequences of resource extraction.

## **ANNEXURE C - United Nation's Sustainable Development Goals & their Targets**

Through their agenda, UN's 17 Sustainable Development Goals with 169 associated targets are as follows:

- **Goal 1.** End poverty in all its forms everywhere
- **Goal 2.** End hunger, achieve food security and improved nutrition and promote sustainable agriculture
- **Goal 3.** Ensure healthy lives and promote well-being for all at all ages
- **Goal 4.** Ensure inclusive and equitable quality education and promote lifelong learning opportunities for all
- **Goal 5.** Achieve gender equality and empower all women and girls
- **Goal 6.** Ensure availability and sustainable management of water and sanitation for all
- **Goal 7.** Ensure access to affordable, reliable, sustainable and modern energy for all
- **Goal 8.** Promote sustained, inclusive and sustainable economic growth, full and productive employment and decent work for all
- **Goal 9.** Build resilient infrastructure, promote inclusive and sustainable industrialization and foster innovation
- **Goal 10.** Reduce inequality within and among countries
- **Goal 11.** Make cities and human settlements inclusive, safe, resilient and sustainable
- **Goal 12.** Ensure sustainable consumption and production patterns
- **Goal 13.** Take urgent action to combat climate change and its impacts\*
- **Goal 14.** Conserve and sustainably use the oceans, seas and marine resources for sustainable development
- **Goal 15.** Protect, restore and promote sustainable use of terrestrial ecosystems, sustainably manage forests, combat desertification, and halt and reverse land degradation and halt biodiversity loss
- **Goal 16.** Promote peaceful and inclusive societies for sustainable development, provide access to justice for all and build effective, accountable and inclusive institutions at all levels
- **Goal 17.** Strengthen the means of implementation and revitalize the global partnership for sustainable development

### **Goal 1. End poverty in all its forms everywhere**

1.1 By 2030, eradicate extreme poverty for all people everywhere, currently measured as people living on less than \$1.25 a day

1.2 By 2030, reduce at least by half the proportion of men, women and children of all ages living in poverty in all its dimensions according to national definitions

1.3 Implement nationally appropriate social protection systems and measures for all, including floors, and by 2030 achieve substantial coverage of the poor and the vulnerable

1.4 By 2030, ensure that all men and women, in particular the poor and the vulnerable, have equal rights to economic resources, as well as access to basic services, ownership and control over land and other forms of property, inheritance, natural resources, appropriate new technology and financial services, including microfinance

1.5 By 2030, build the resilience of the poor and those in vulnerable situations and reduce their exposure and vulnerability to climate-related extreme events and other economic, social and environmental shocks and disasters 1.a Ensure significant mobilization of resources from a variety of sources, including through enhanced development cooperation, in order to provide adequate and predictable means for developing countries, in particular least developed countries, to implement programmes and policies to end poverty in all its dimensions 1.b Create sound policy frameworks at the national, regional and international levels, based on pro-poor and gender-sensitive development strategies, to support accelerated investment in poverty eradication actions

**Goal 2. End hunger, achieve food security and improved nutrition and promote sustainable agriculture**

2.1 By 2030, end hunger and ensure access by all people, in particular the poor and people in vulnerable situations, including infants, to safe, nutritious and sufficient food all year round

2.2 By 2030, end all forms of malnutrition, including achieving, by 2025, the internationally agreed targets on stunting and wasting in children under 5 years of age, and address the nutritional needs of adolescent girls, pregnant and lactating women and older persons

2.3 By 2030, double the agricultural productivity and incomes of small-scale food producers, in particular women, indigenous peoples, family farmers, pastoralists and fishers, including through secure and equal access to land, other productive resources and inputs, knowledge, financial services, markets and opportunities for value addition and non-farm employment

2.4 By 2030, ensure sustainable food production systems and implement resilient agricultural practices that increase productivity and production, that help maintain ecosystems, that strengthen capacity for adaptation to climate change, extreme weather, drought, flooding and other disasters and that progressively improve land and soil quality

2.5 By 2020, maintain the genetic diversity of seeds, cultivated plants and farmed and domesticated animals and their related wild species, including through soundly managed and diversified seed and plant banks at the national, regional and international levels, and promote access to and fair and equitable sharing of benefits arising from the utilization of genetic resources and associated traditional knowledge, as internationally agreed

2.a Increase investment, including through enhanced international cooperation, in rural infrastructure, agricultural research and extension services, technology development and plant and livestock gene banks in order to enhance agricultural productive capacity in developing countries, in particular least developed countries

2.b Correct and prevent trade restrictions and distortions in world agricultural markets, including through the parallel elimination of all forms of agricultural export subsidies and all export measures with equivalent effect, in accordance with the mandate of the Doha Development Round

2.c Adopt measures to ensure the proper functioning of food commodity markets and their derivatives and facilitate timely access to market information, including on food reserves, in order to help limit extreme food price volatility

### **Goal 3. Ensure healthy lives and promote well-being for all at all ages**

3.1 By 2030, reduce the global maternal mortality ratio to less than 70 per 100,000 live births 3.2 By 2030, end preventable deaths of newborns and children under 5 years of age, with all countries aiming to reduce neonatal mortality to at least as low as 12 per 1,000 live births and under-5 mortality to at least as low as 25 per 1,000 live births

3.3 By 2030, end the epidemics of AIDS, tuberculosis, malaria and neglected tropical diseases and combat hepatitis, water-borne diseases and other communicable diseases

3.4 By 2030, reduce by one third premature mortality from non-communicable diseases through prevention and treatment and promote mental health and well-being

3.5 Strengthen the prevention and treatment of substance abuse, including narcotic drug abuse and harmful use of alcohol

3.6 By 2020, halve the number of global deaths and injuries from road traffic accidents

3.7 By 2030, ensure universal access to sexual and reproductive health-care services, including for family planning, information and education, and the integration of reproductive health into national strategies and programmes

3.8 Achieve universal health coverage, including financial risk protection, access to quality essential health-care services and access to safe, effective, quality and affordable essential medicines and vaccines for all

3.9 By 2030, substantially reduce the number of deaths and illnesses from hazardous chemicals and air, water and soil pollution and contamination

3.a Strengthen the implementation of the World Health Organization Framework Convention on Tobacco Control in all countries, as appropriate

3.b Support the research and development of vaccines and medicines for the communicable and non-communicable diseases that primarily affect developing countries, provide access to affordable essential medicines and vaccines, in accordance with the Doha Declaration on the TRIPS Agreement and Public Health, which affirms the right of developing countries to use to the full the provisions in the Agreement on Trade-Related Aspects of Intellectual Property Rights regarding flexibilities to protect public health, and, in particular, provide access to medicines for all

3.c Substantially increase health financing and the recruitment, development, training and retention of the health workforce in developing countries, especially in least developed countries and small island developing States

3.d Strengthen the capacity of all countries, in particular developing countries, for early warning, risk reduction and management of national and global health risks

### **Goal 4. Ensure inclusive and equitable quality education and promote lifelong learning opportunities for all**

4.1 By 2030, ensure that all girls and boys complete free, equitable and quality primary and secondary education leading to relevant and effective learning outcomes

- 4.2 By 2030, ensure that all girls and boys have access to quality early childhood development, care and pre-primary education so that they are ready for primary education
- 4.3 By 2030, ensure equal access for all women and men to affordable and quality technical, vocational and tertiary education, including university
- 4.4 By 2030, substantially increase the number of youth and adults who have relevant skills, including technical and vocational skills, for employment, decent jobs and entrepreneurship
- 4.5 By 2030, eliminate gender disparities in education and ensure equal access to all levels of education and vocational training for the vulnerable, including persons with disabilities, indigenous peoples and children in vulnerable situations
- 4.6 By 2030, ensure that all youth and a substantial proportion of adults, both men and women, achieve literacy and numeracy
- 4.7 By 2030, ensure that all learners acquire the knowledge and skills needed to promote sustainable development, including, among others, through education for sustainable development and sustainable lifestyles, human rights, gender equality, promotion of a culture of peace and non-violence, global citizenship and appreciation of cultural diversity and of culture's contribution to sustainable development
- 4.a Build and upgrade education facilities that are child, disability and gender sensitive and provide safe, non-violent, inclusive and effective learning environments for all
- 4.b By 2020, substantially expand globally the number of scholarships available to developing countries, in particular least developed countries, small island developing States and African countries, for enrolment in higher education, including vocational training and information and communications technology, technical, engineering and scientific programmes, in developed countries and other developing countries
- 4.c By 2030, substantially increase the supply of qualified teachers, including through international cooperation for teacher training in developing countries, especially least developed countries and small island developing States

#### **Goal 5. Achieve gender equality and empower all women and girls**

- 5.1 End all forms of discrimination against all women and girls everywhere
- 5.2 Eliminate all forms of violence against all women and girls in the public and private spheres, including trafficking and sexual and other types of exploitation
- 5.3 Eliminate all harmful practices, such as child, early and forced marriage and female genital mutilation
- 5.4 Recognize and value unpaid care and domestic work through the provision of public services, infrastructure and social protection policies and the promotion of shared responsibility within the household and the family as nationally appropriate
- 5.5 Ensure women's full and effective participation and equal opportunities for leadership at all levels of decision-making in political, economic and public life
- 5.6 Ensure universal access to sexual and reproductive health and reproductive rights as agreed in accordance with the Programme of Action of the International Conference on Population and Development and the Beijing Platform for Action and the outcome documents of their review conferences

- 5.a Undertake reforms to give women equal rights to economic resources, as well as access to ownership and control over land and other forms of property, financial services, inheritance and natural resources, in accordance with national laws
- 5.b Enhance the use of enabling technology, in particular information and communications technology, to promote the empowerment of women
- 5.c Adopt and strengthen sound policies and enforceable legislation for the promotion of gender equality and the empowerment of all women and girls at all levels

**Goal 6. Ensure availability and sustainable management of water and sanitation for all**

- 6.1 By 2030, achieve universal and equitable access to safe and affordable drinking water for all
- 6.2 By 2030, achieve access to adequate and equitable sanitation and hygiene for all and end open defecation, paying special attention to the needs of women and girls and those in vulnerable situations
- 6.3 By 2030, improve water quality by reducing pollution, eliminating dumping and minimizing release of hazardous chemicals and materials, halving the proportion of untreated wastewater and substantially increasing recycling and safe reuse globally
- 6.4 By 2030, substantially increase water-use efficiency across all sectors and ensure sustainable withdrawals and supply of freshwater to address water scarcity and substantially reduce the number of people suffering from water scarcity
- 6.5 By 2030, implement integrated water resources management at all levels, including through transboundary cooperation as appropriate
- 6.6 By 2020, protect and restore water-related ecosystems, including mountains, forests, wetlands, rivers, aquifers and lakes
- 6.a By 2030, expand international cooperation and capacity-building support to developing countries in water- and sanitation-related activities and programmes, including water harvesting, desalination, water efficiency, wastewater treatment, recycling and reuse technologies
- 6.b Support and strengthen the participation of local communities in improving water and sanitation management

**Goal 7. Ensure access to affordable, reliable, sustainable and modern energy for all**

- 7.1 By 2030, ensure universal access to affordable, reliable and modern energy services
- 7.2 By 2030, increase substantially the share of renewable energy in the global energy mix
- 7.3 By 2030, double the global rate of improvement in energy efficiency
- 7.a By 2030, enhance international cooperation to facilitate access to clean energy research and technology, including renewable energy, energy efficiency and advanced and cleaner fossil-fuel technology, and promote investment in energy infrastructure and clean energy technology
- 7.b By 2030, expand infrastructure and upgrade technology for supplying modern and sustainable energy services for all in developing countries, in particular least developed countries, small island developing States, and land-locked developing countries, in accordance with their respective programmes of support

**Goal 8. Promote sustained, inclusive and sustainable economic growth, full and productive employment and decent work for all**

8.1 Sustain per capita economic growth in accordance with national circumstances and, in particular, at least 7 per cent gross domestic product growth per annum in the least developed countries

8.2 Achieve higher levels of economic productivity through diversification, technological upgrading and innovation, including through a focus on high-value added and labour-intensive sectors

8.3 Promote development-oriented policies that support productive activities, decent job creation, entrepreneurship, creativity and innovation, and encourage the formalization and growth of micro-, small- and medium-sized enterprises, including through access to financial services

8.4 Improve progressively, through 2030, global resource efficiency in consumption and production and endeavour to decouple economic growth from environmental degradation, in accordance with the 10-year framework of programmes on sustainable consumption and production, with developed countries taking the lead

8.5 By 2030, achieve full and productive employment and decent work for all women and men, including for young people and persons with disabilities, and equal pay for work of equal value

8.6 By 2020, substantially reduce the proportion of youth not in employment, education or training

8.7 Take immediate and effective measures to eradicate forced labour, end modern slavery and human trafficking and secure the prohibition and elimination of the worst forms of child labour, including recruitment and use of child soldiers, and by 2025 end child labour in all its forms

8.8 Protect labour rights and promote safe and secure working environments for all workers, including migrant workers, in particular women migrants, and those in precarious employment

8.9 By 2030, devise and implement policies to promote sustainable tourism that creates jobs and promotes local culture and products

8.10 Strengthen the capacity of domestic financial institutions to encourage and expand access to banking, insurance and financial services for all

8.a Increase Aid for Trade support for developing countries, in particular least developed countries, including through the Enhanced Integrated Framework for Trade-Related Technical Assistance to Least Developed Countries

8.b By 2020, develop and operationalize a global strategy for youth employment and implement the Global Jobs Pact of the International Labour Organization

**Goal 9. Build resilient infrastructure, promote inclusive and sustainable industrialization and foster innovation**

9.1 Develop quality, reliable, sustainable and resilient infrastructure, including regional and transborder infrastructure, to support economic development and human well-being, with a focus on affordable and equitable access for all

9.2 Promote inclusive and sustainable industrialization and, by 2030, significantly raise industry's share of employment and gross domestic product, in line with national circumstances, and double its share in least developed countries

9.3 Increase the access of small-scale industrial and other enterprises, in particular in developing countries, to financial services, including affordable credit, and their integration into value chains and markets

9.4 By 2030, upgrade infrastructure and retrofit industries to make them sustainable, with increased resource-use efficiency and greater adoption of clean and environmentally sound technologies and industrial processes, with all countries taking action in accordance with their respective capabilities

9.5 Enhance scientific research, upgrade the technological capabilities of industrial sectors in all countries, in particular developing countries, including, by 2030, encouraging innovation and substantially increasing the number of research and development workers per 1 million people and public and private research and development spending

9.a Facilitate sustainable and resilient infrastructure development in developing countries through enhanced financial, technological and technical support to African countries, least developed countries, landlocked developing countries and small island developing States

9.b Support domestic technology development, research and innovation in developing countries, including by ensuring a conducive policy environment for, inter alia, industrial diversification and value addition to commodities

9.c Significantly increase access to information and communications technology and strive to provide universal and affordable access to the Internet in least developed countries by 2020

## **Goal 10. Reduce inequality within and among countries**

10.1 By 2030, progressively achieve and sustain income growth of the bottom 40 per cent of the population at a rate higher than the national average

10.2 By 2030, empower and promote the social, economic and political inclusion of all, irrespective of age, sex, disability, race, ethnicity, origin, religion or economic or other status

10.3 Ensure equal opportunity and reduce inequalities of outcome, including by eliminating discriminatory laws, policies and practices and promoting appropriate legislation, policies and action in this regard

10.4 Adopt policies, especially fiscal, wage and social protection policies, and progressively achieve greater equality

10.5 Improve the regulation and monitoring of global financial markets and institutions and strengthen the implementation of such regulations

10.6 Ensure enhanced representation and voice for developing countries in decision-making in global international economic and financial institutions in order to deliver more effective, credible, accountable and legitimate institutions

10.7 Facilitate orderly, safe, regular and responsible migration and mobility of people, including through the implementation of planned and well-managed migration policies

10.a Implement the principle of special and differential treatment for developing countries, in particular least developed countries, in accordance with World Trade Organization agreements

10.b Encourage official development assistance and financial flows, including foreign direct investment, to States where the need is greatest, in particular least developed countries, African countries, small island

developing States and landlocked developing countries, in accordance with their national plans and programmes

10.c By 2030, reduce to less than 3 per cent the transaction costs of migrant remittances and eliminate remittance corridors with costs higher than 5 per cent

### **Goal 11. Make cities and human settlements inclusive, safe, resilient and sustainable**

11.1 By 2030, ensure access for all to adequate, safe and affordable housing and basic services and upgrade slums

11.2 By 2030, provide access to safe, affordable, accessible and sustainable transport systems for all, improving road safety, notably by expanding public transport, with special attention to the needs of those in vulnerable situations, women, children, persons with disabilities and older persons

11.3 By 2030, enhance inclusive and sustainable urbanization and capacity for participatory, integrated and sustainable human settlement planning and management in all countries

11.4 Strengthen efforts to protect and safeguard the world's cultural and natural heritage

11.5 By 2030, significantly reduce the number of deaths and the number of people affected and substantially decrease the direct economic losses relative to global gross domestic product caused by disasters, including water-related disasters, with a focus on protecting the poor and people in vulnerable situations

11.6 By 2030, reduce the adverse per capita environmental impact of cities, including by paying special attention to air quality and municipal and other waste management

11.7 By 2030, provide universal access to safe, inclusive and accessible, green and public spaces, in particular for women and children, older persons and persons with disabilities

11.a Support positive economic, social and environmental links between urban, peri-urban and rural areas by strengthening national and regional development planning

11.b By 2020, substantially increase the number of cities and human settlements adopting and implementing integrated policies and plans towards inclusion, resource efficiency, mitigation and adaptation to climate change, resilience to disasters, and develop and implement, in line with the Sendai Framework for Disaster Risk Reduction 2015-2030, holistic disaster risk management at all levels

11.c Support least developed countries, including through financial and technical assistance, in building sustainable and resilient buildings utilizing local materials

### **Goal 12. Ensure sustainable consumption and production patterns**

12.1 Implement the 10-year framework of programmes on sustainable consumption and production, all countries taking action, with developed countries taking the lead, taking into account the development and capabilities of developing countries

12.2 By 2030, achieve the sustainable management and efficient use of natural resources

12.3 By 2030, halve per capita global food waste at the retail and consumer levels and reduce food losses along production and supply chains, including post-harvest losses

12.4 By 2020, achieve the environmentally sound management of chemicals and all wastes throughout their life cycle, in accordance with agreed international frameworks, and significantly reduce their release to air, water and soil in order to minimize their adverse impacts on human health and the environment

12.5 By 2030, substantially reduce waste generation through prevention, reduction, recycling and reuse

12.6 Encourage companies, especially large and transnational companies, to adopt sustainable practices and to integrate sustainability information into their reporting cycle

12.7 Promote public procurement practices that are sustainable, in accordance with national policies and priorities

12.8 By 2030, ensure that people everywhere have the relevant information and awareness for sustainable development and lifestyles in harmony with nature

12.a Support developing countries to strengthen their scientific and technological capacity to move towards more sustainable patterns of consumption and production

12.b Develop and implement tools to monitor sustainable development impacts for sustainable tourism that creates jobs and promotes local culture and products

12.c Rationalize inefficient fossil-fuel subsidies that encourage wasteful consumption by removing market distortions, in accordance with national circumstances, including by restructuring taxation and phasing out those harmful subsidies, where they exist, to reflect their environmental impacts, taking fully into account the specific needs and conditions of developing countries and minimizing the possible adverse impacts on their development in a manner that protects the poor and the affected communities

### **Goal 13. Take urgent action to combat climate change and its impacts\***

13.1 Strengthen resilience and adaptive capacity to climate-related hazards and natural disasters in all countries

13.2 Integrate climate change measures into national policies, strategies and planning

13.3 Improve education, awareness-raising and human and institutional capacity on climate change mitigation, adaptation, impact reduction and early warning

13.a Implement the commitment undertaken by developed-country parties to the United Nations Framework Convention on Climate Change to a goal of mobilizing jointly \$100 billion annually by 2020 from all sources to address the needs of developing countries in the context of meaningful mitigation actions and transparency on implementation and fully operationalize the Green Climate Fund through its capitalization as soon as possible

13.b Promote mechanisms for raising capacity for effective climate change-related planning and management in least developed countries and small island developing States, including focusing on women, youth and local and marginalized communities

- Acknowledging that the United Nations Framework Convention on Climate Change is the primary international, intergovernmental forum for negotiating the global response to climate change.

**Goal 14. Conserve and sustainably use the oceans, seas and marine resources for sustainable development**

14.1 By 2025, prevent and significantly reduce marine pollution of all kinds, in particular from land-based activities, including marine debris and nutrient pollution

14.2 By 2020, sustainably manage and protect marine and coastal ecosystems to avoid significant adverse impacts, including by strengthening their resilience, and take action for their restoration in order to achieve healthy and productive oceans

14.3 Minimize and address the impacts of ocean acidification, including through enhanced scientific cooperation at all levels

14.4 By 2020, effectively regulate harvesting and end overfishing, illegal, unreported and unregulated fishing and destructive fishing practices and implement science-based management plans, in order to restore fish stocks in the shortest time feasible, at least to levels that can produce maximum sustainable yield as determined by their biological characteristics

14.5 By 2020, conserve at least 10 per cent of coastal and marine areas, consistent with national and international law and based on the best available scientific information

14.6 By 2020, prohibit certain forms of fisheries subsidies which contribute to overcapacity and overfishing, eliminate subsidies that contribute to illegal, unreported and unregulated fishing and refrain from introducing new such subsidies, recognizing that appropriate and effective special and differential treatment for developing and least developed countries should be an integral part of the World Trade Organization fisheries subsidies negotiation

14.7 By 2030, increase the economic benefits to Small Island developing States and least developed countries from the sustainable use of marine resources, including through sustainable management of fisheries, aquaculture and tourism

14.a Increase scientific knowledge, develop research capacity and transfer marine technology, taking into account the Intergovernmental Oceanographic Commission Criteria and Guidelines on the Transfer of Marine Technology, in order to improve ocean health and to enhance the contribution of marine biodiversity to the development of developing countries, in particular small island developing States and least developed countries

14.b Provide access for small-scale artisanal fishers to marine resources and markets

14.c Enhance the conservation and sustainable use of oceans and their resources by implementing international law as reflected in UNCLOS, which provides the legal framework for the conservation and sustainable use of oceans and their resources, as recalled in paragraph 158 of The Future We Want

**Goal 15. Protect, restore and promote sustainable use of terrestrial ecosystems, sustainably manage forests, combat desertification, and halt and reverse land degradation and halt biodiversity loss**

15.1 By 2020, ensure the conservation, restoration and sustainable use of terrestrial and inland freshwater ecosystems and their services, in particular forests, wetlands, mountains and drylands, in line with obligations under international agreements

- 15.2 By 2020, promote the implementation of sustainable management of all types of forests, halt deforestation, restore degraded forests and substantially increase afforestation and reforestation globally
- 15.3 By 2030, combat desertification, restore degraded land and soil, including land affected by desertification, drought and floods, and strive to achieve a land degradation-neutral world
- 15.4 By 2030, ensure the conservation of mountain ecosystems, including their biodiversity, in order to enhance their capacity to provide benefits that are essential for sustainable development
- 15.5 Take urgent and significant action to reduce the degradation of natural habitats, halt the loss of biodiversity and, by 2020, protect and prevent the extinction of threatened species
- 15.6 Promote fair and equitable sharing of the benefits arising from the utilization of genetic resources and promote appropriate access to such resources, as internationally agreed
- 15.7 Take urgent action to end poaching and trafficking of protected species of flora and fauna and address both demand and supply of illegal wildlife products
- 15.8 By 2020, introduce measures to prevent the introduction and significantly reduce the impact of invasive alien species on land and water ecosystems and control or eradicate the priority species
- 15.9 By 2020, integrate ecosystem and biodiversity values into national and local planning, development processes, poverty reduction strategies and accounts
- 15.a Mobilize and significantly increase financial resources from all sources to conserve and sustainably use biodiversity and ecosystems
- 15.b Mobilize significant resources from all sources and at all levels to finance sustainable forest management and provide adequate incentives to developing countries to advance such management, including for conservation and reforestation
- 15.c Enhance global support for efforts to combat poaching and trafficking of protected species, including by increasing the capacity of local communities to pursue sustainable livelihood opportunities

**Goal 16. Promote peaceful and inclusive societies for sustainable development, provide access to justice for all and build effective, accountable and inclusive institutions at all levels**

- 16.1 Significantly reduce all forms of violence and related death rates everywhere
- 16.2 End abuse, exploitation, trafficking and all forms of violence against and torture of children
- 16.3 Promote the rule of law at the national and international levels and ensure equal access to justice for all
- 16.4 By 2030, significantly reduce illicit financial and arms flows, strengthen the recovery and return of stolen assets and combat all forms of organized crime
- 16.5 Substantially reduce corruption and bribery in all their forms
- 16.6 Develop effective, accountable and transparent institutions at all levels
- 16.7 Ensure responsive, inclusive, participatory and representative decision-making at all levels
- 16.8 Broaden and strengthen the participation of developing countries in the institutions of global governance
- 16.9 By 2030, provide legal identity for all, including birth registration

16.10 Ensure public access to information and protect fundamental freedoms, in accordance with national legislation and international agreements

16.a Strengthen relevant national institutions, including through international cooperation, for building capacity at all levels, in particular in developing countries, to prevent violence and combat terrorism and crime

16.b Promote and enforce non-discriminatory laws and policies for sustainable development

## **Goal 17. Strengthen the means of implementation and revitalize the global partnership for sustainable development**

### **Finance**

17.1 Strengthen domestic resource mobilization, including through international support to developing countries, to improve domestic capacity for tax and other revenue collection

17.2 Developed countries to implement fully their official development assistance commitments, including the commitment by many developed countries to achieve the target of 0.7 per cent of ODA/GNI to developing countries and 0.15 to 0.20 per cent of ODA/GNI to least developed countries; ODA providers are encouraged to consider setting a target to provide at least 0.20 per cent of ODA/GNI to least developed countries

17.3 Mobilize additional financial resources for developing countries from multiple sources

17.4 Assist developing countries in attaining long-term debt sustainability through coordinated policies aimed at fostering debt financing, debt relief and debt restructuring, as appropriate, and address the external debt of highly indebted poor countries to reduce debt distress

17.5 Adopt and implement investment promotion regimes for least developed countries

### **Technology**

17.6 Enhance North-South, South-South and triangular regional and international cooperation on and access to science, technology and innovation and enhance knowledge sharing on mutually agreed terms, including through improved coordination among existing mechanisms, in particular at the United Nations level, and through a global technology facilitation mechanism

17.7 Promote the development, transfer, dissemination and diffusion of environmentally sound technologies to developing countries on favourable terms, including on concessional and preferential terms, as mutually agreed

17.8 Fully operationalize the technology bank and science, technology and innovation capacity-building mechanism for least developed countries by 2017 and enhance the use of enabling technology, in particular information and communications technology

### **Capacity-building**

17.9 Enhance international support for implementing effective and targeted capacity-building in developing countries to support national plans to implement all the sustainable development goals, including through North-South, South-South and triangular cooperation

## **Trade**

17.10 Promote a universal, rules-based, open, non-discriminatory and equitable multilateral trading system under the World Trade Organization, including through the conclusion of negotiations under its Doha Development Agenda

17.11 Significantly increase the exports of developing countries, in particular with a view to doubling the least developed countries' share of global exports by 2020

17.12 Realize timely implementation of duty-free and quota-free market access on a lasting basis for all least developed countries, consistent with World Trade Organization decisions, including by ensuring that preferential rules of origin applicable to imports from least developed countries are transparent and simple, and contribute to facilitating market access

## **Systemic issues**

### **Policy and institutional coherence**

17.13 Enhance global macroeconomic stability, including through policy coordination and policy coherence

17.14 Enhance policy coherence for sustainable development

17.15 Respect each country's policy space and leadership to establish and implement policies for poverty eradication and sustainable development

### **Multi-stakeholder partnerships**

17.16 Enhance the global partnership for sustainable development, complemented by multi-stakeholder partnerships that mobilize and share knowledge, expertise, technology and financial resources, to support the achievement of the sustainable development goals in all countries, in particular developing countries

17.17 Encourage and promote effective public, public-private and civil society partnerships, building on the experience and resourcing strategies of partnerships

### **Data, monitoring and accountability**

17.18 By 2020, enhance capacity-building support to developing countries, including for least developed countries and small island developing States, to increase significantly the availability of high-quality, timely and reliable data disaggregated by income, gender, age, race, ethnicity, migratory status, disability, geographic location and other characteristics relevant in national contexts

### **Means of implementation and the Global Partnership**

17.19 By 2030, build on existing initiatives to develop measurements of progress on sustainable development that complement gross domestic product, and support statistical capacity-building in developing countries.