Recycling Plastics in Bali: Reintroducing Locally-Sourced Plastics into the Construction Industry as a Sustainable Building Alternative

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Personal Information

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Studio

Name of studio **Architectural Engineering**
Design tutor **Stephan Verkuijlen**
Research tutor **Jos de Krieger**

Argumentations of choice of the studio:
During my architectural education the focus has always been on conceptualising and developing strategies for the social side of design. As a final academic exercise, I am interested in challenging myself with better grasping the implications of the technical side of research and design, and ultimately producing an innovative project that truly works.

Keywords

Recycling, plastic waste, tourism, circular economy, sustainable building alternatives, Bali, locally sourced materials, material flow analysis

Glossary of Key Terms

Circular model: in the context of this research paper, the term signifies closing the loop on plastic waste and introducing it back into the local economy through the construction sector. It becomes a circular end to a linear economy.

Responsible waste management: Collecting and sorting waste so that there are no losses between the end of use of objects and their arrival at waste sorting centres. The precision needed in the process of dividing different types of waste/ plastics will be determined as an outcome of the present research and the technology for recycling that will be selected as most appropriate.

Sustainability: Meeting the needs of the present without compromising the ability of future generations to meet their needs. This includes: using renewable resources, decreasing and ultimately eliminating pollution through circularity, stimulating the preservation of cultural identities, etc.

Sustainable Development Goals: An agenda for sustainable development formulated by the United Nations in 2015. It synthesizes 17 goals that the global community needs to address with urgency. The goals have for objective to end poverty, battle climate change, improve health and education, reduce inequality etc.

Sustainable tourism: “Tourism that takes full account of its current and future economic, social and environmental impacts, addressing the needs of visitors, the industry, the environment and host communities.” (UN World Tourism Organization, 2022)

Waste: The total amount of household and industrial waste that is generated and piled on the island of Bali.

Waste leaked into nature: Organic and inorganic waste that ends up in the natural environment through incorrect disposal, insufficient waste management or overflow from existing landfills.

Introduction

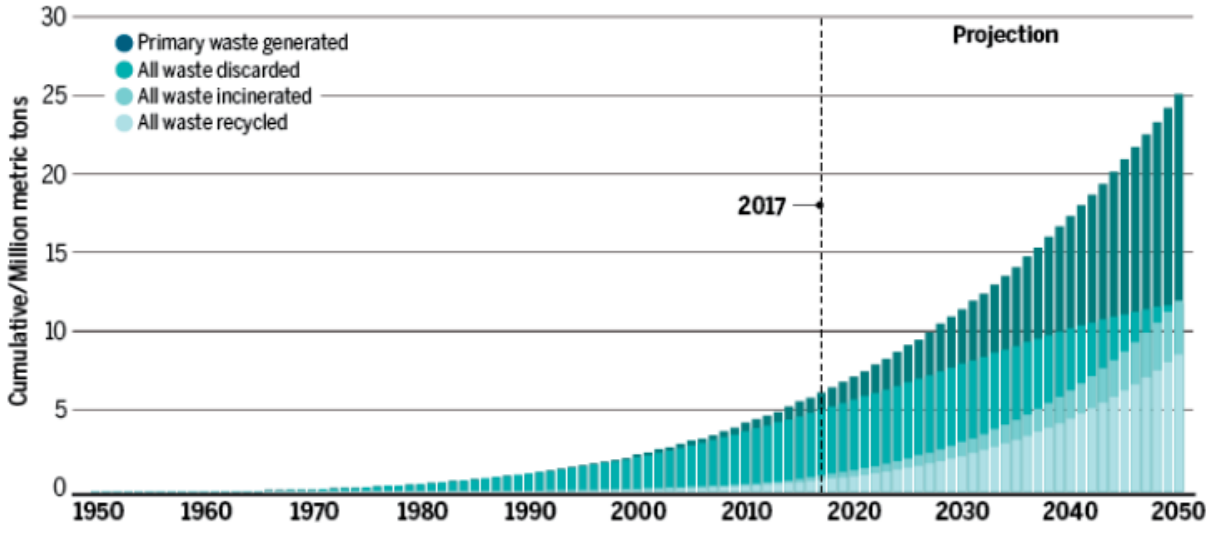
Without urgent action, global waste will increase by 70 percent on current levels by 2050 (Kaza et al, 2018)

With rapid urbanization and the growing populations, consumption is on the rise, and so is the global annual waste generation. Without immediate changes, global waste is predicted to increase by 70 percent on current levels by 2050. (Kaza et al, 2018) Plastics are specifically problematic, as their mismanagement leads to the contamination of ecosystems and waterways, where they could remain for hundreds of years.
Until the 1950s, plastic was rarely used outside the military. Yet, since then it has been mass produced, and has so far generated more than 8.3 billion metric tons of plastic, 6.3 of which are now waste. (Science, n.d.) Of them only 9% have been recycled and 12% have been incinerated, meaning that the remaining 79% are still lying somewhere on the planet. (Science, n.d.) At the current pace, by 2050, we will have produced 26 billion tons of primary plastic waste: waste of plastics that have not yet been recycled. (Geyer et al., 2017)

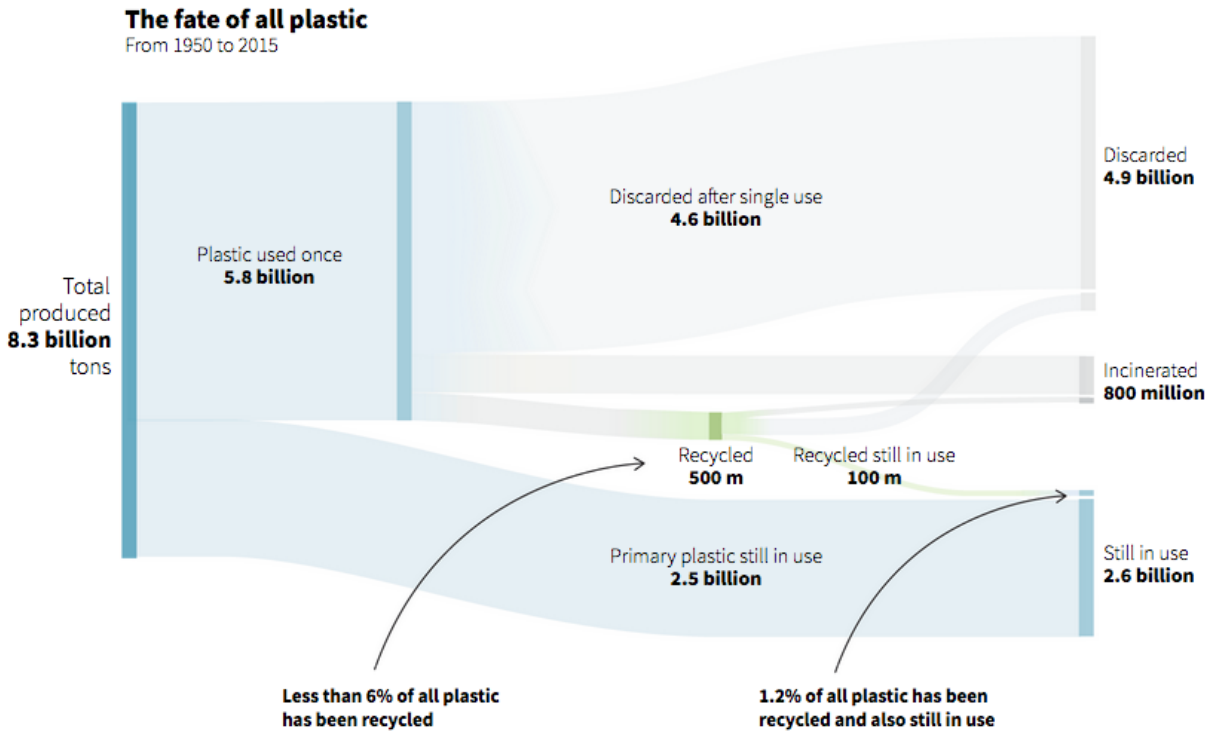
Waste management is now recognised as a pressing concern for many countries and solutions are sought at all scales: from the governmental level down to household initiatives. In March 2022 leaders of the UN member states endorsed an international legally-binding agreement to end plastic waste, addressing plastic's full lifecycle- from design to disposal. (United Nations Environment Programme, n.d.)
The challenge with the future of waste is not only an ecological problem but a social one too: recently it became known that some developed countries are shipping their waste to Southeast Asia and Africa, which are regions already struggling with managing the waste they produce themselves. This is straining local systems and requiring an ever growing amount of resources to overcome the challenge, which further deepens social inequality between rich and poorer countries.

The need for reducing, and ultimately eliminating, the use of single-use plastics is apparent, yet such a shift in consumer behaviour and production practices would be costly, timely and require strong incentivisation from governments globally.

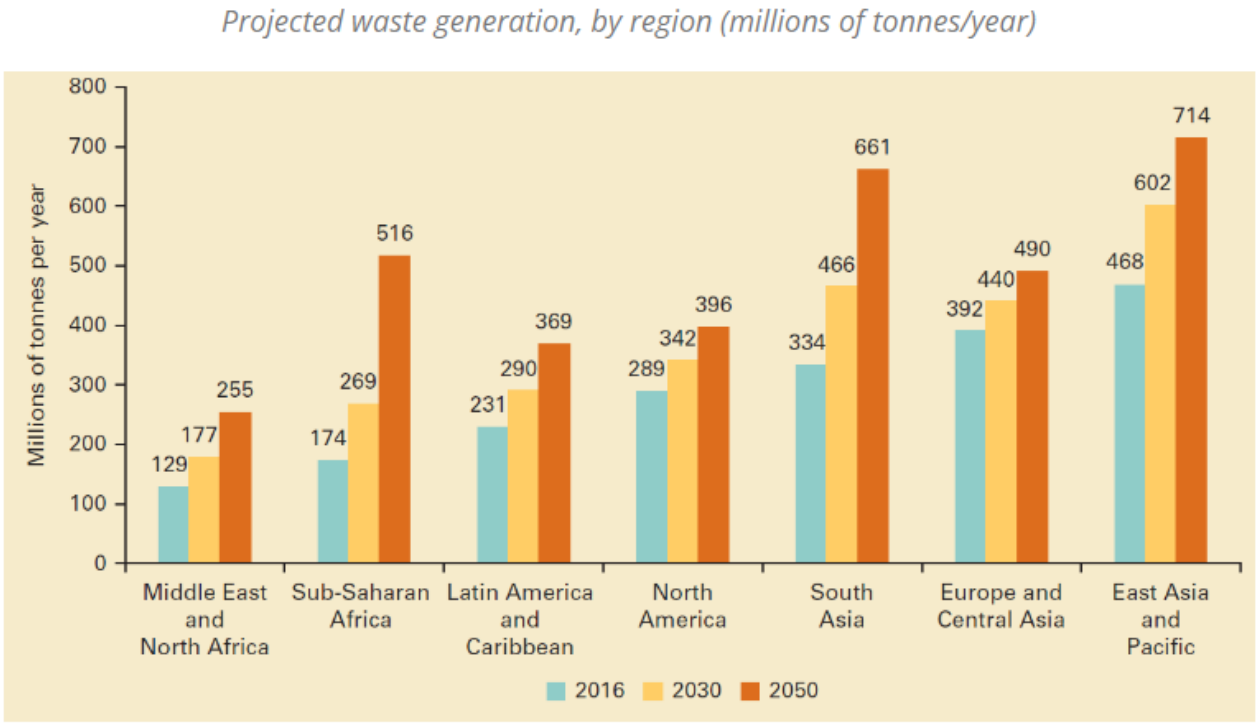
Thus, while making the shift towards sustainable products and behaviours and an eventual fully circular economy, care needs to be taken of the already accumulated waste. It is integral to define efficient ways of managing plastic waste and re-introducing it as a valuable resource and a circular end to the current linear economic model.



Projection for the generation and management of plastic waste in the coming 30 years (Geyer et al., 2017)

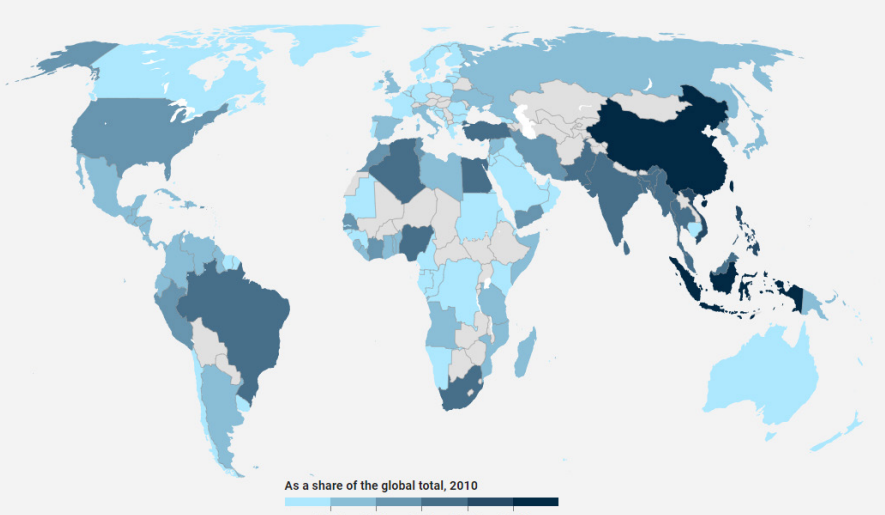


More than half of the plastic ever produced has been discarded after the first use. Only 6% of all plastic has been recycled and just above 1% is still in use after recycling. Despite warnings and prohibitions on the use of single-use plastics, the amount of plastic waste is expected to grow (Scarr & Hernandez, 2017)



The East Asia and Pacific region is generating most of the world's waste, and is predicted to continue the negative trend (World Bank, n.d.)

Problem Statement



Hotspots of mismanaged waste on a global scale (Beat Plastic Pollution, 2022)

After China, Indonesia is the largest producer of plastic waste globally. (Beat Plastic Pollution, 2022) Besides the sheer amounts being a challenge, the country has insufficient waste management practices and lack of law enforcement in the sector.

This research will focus on Bali, Indonesia as a case study for examining how this environmental issue could be addressed. Home to 4.2 million people and hosting 16 million tourists annually (6mln international and 10mln domestic arrivals), Bali generates 4,182,000 kg of waste per day, out of which 815,094 kg is plastic and only 1/4 of that plastic is recycled. (Bali Partnership, 2021) In 2017 the Balinese government declared a state of “waste emergency”, shining a light on the urgency of addressing the issue as one that affects local residents and the environment, and decreases the tourist appeal of the island, where tourism constitutes 80% of the GDP. (Ross et al., 2018)
The local population is growing: currently 29% of local residents are under 18 years old. At the same time, Indonesia is aiming for an ambitious growth of tourism, attracting 20 million international arrivals- almost double the 2019 unprecedented height of 11 million. (Unicef, 2022) So, consumption is bound to grow in coming years too, and so is waste.
It has been established that tourist activities generate 3.5 times more waste than those of locals, further straining the waste management system. (In Bali, 2020) In 2022 the local government announced the closure of the largest landfill on the island: Suwung landfill, where tourist waste is collected, as it has been operating over capacity and allowing leakages into nature. (The Suwung Landfill, 2018)

Due to the decentralised nature of the local government, each Regency has been tasked with finding a solution to its own waste management. (Waste Banks, n.d.) Thus, clean-up activities are currently organised by the numerous small-scale NGOs and volunteers. While making a step forward, such initiatives prove that a decentralised system would struggle to keep up with the increasing flows of waste.
Treating plastic as a resource and finding ways to close the economic loop on it would be integral for the sustainable development of the island. The focus of this research would be to investigate how recycled plastics could be re-introduced in the construction sector on Bali and address the need for more responsible tourist practices.

UN Sustainable Development Goals that this project will address (United Nations, 2022)

Personal Fascination

It is my personal interest which ties the topic of recycling (plastic) waste with architecture and the future of tourism.
Firstly, as a Masters student in architecture, I am fascinated with exploring the potential use of reclaimed and recycled materials in the built environment, in ways appropriate to a given location.
Currently investigation and experimentation with recycled plastics is being done by academics in various fields, so it would not be my aim to develop a new technology for it. Instead, I would be investigating the potential applications of such technologies on Bali. Through studying the opportunities at the location, its demands and some elements of the typical Balinese architecture, I will aim to arrive at an architectural component, for which I would choose the most appropriate production technology.

On the other hand, the interest which will be more thoroughly explored in the design phase of the project, is the topic of the future of tourism. Tourism is a major sector of the global economy, constituting 10% of the overall GDP. (Travalyst, 2022) By 2030 1.8 billion people will be travelling internationally, creating a higher demand for tourism-related infrastructure and jobs. I believe travelling makes us more responsible citizens, so it should be supported, not discouraged, but it should benefit host locations instead of harming or draining them. Current practices in the field have proven to be resource- heavy and unsustainable to the environment, as well as damaging to the local identity and lifestyle of permanent residents. Thus, this project will explore a more socially and environmentally sustainable model for tourist accommodation, integrated respectfully within a local setting and aiming to enhance the experience of both residents and visitors.

Scenario

For the purposes of this research, the following scenario will be used:
Plastic waste on Bali is generated at the same pace as today but it is managed responsibly, so that all of the accumulated plastic waste can be counted as available resource. This is important, as currently a quarter of the plastic waste on the island is leaked into nature, hindering any recycling processes that might wish to address it. Still, I do recognise that waste collection is a major challenge for the island and is a milestone that needs to be achieved so this project could be applied to the location.
Also, with the current state of the world economy, the production of new plastic is less expensive than the recycling of used plastic. According to economist Andrew Forrest, it would cost 300,000 USD to cause a power shift which makes recycled plastic more preferable than newly produced plastic. (TED, 2019). This is important to note in order to argument the viability of the proposal of this paper.
These two assumptions will be made with the aim to explore the potential of the entire amount of available plastic as a resource, with no losses. Through exemplifying the potential value that it could bring to the local economy, it is hoped that this research would provide yet another incentive for the enforcement of better waste management practices and for making the respective shift towards prioritising recycled plastics.

Objective

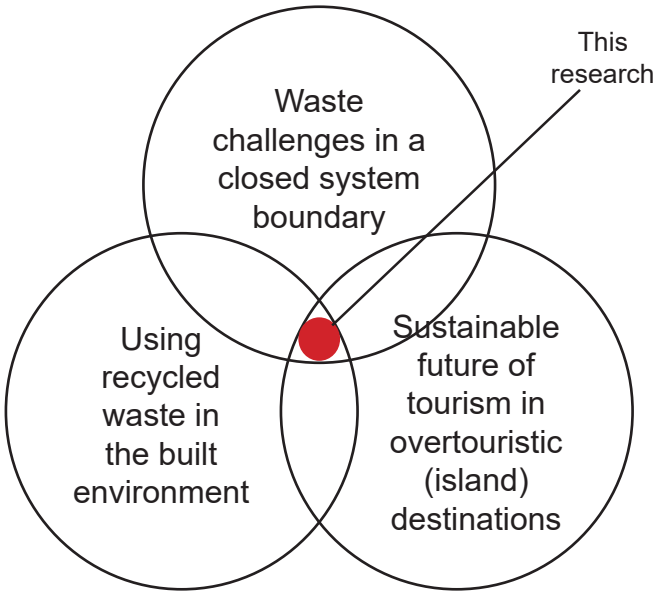
The objective of this project will be to create a pilot design which uses plastic waste as a locally available resource, that when invested into the construction sector, would give shape to the vision of a fair and sustainable way of travelling. The objective of the thematic research would be to investigate the viability of such a proposal in terms of available quantities of materials and implementable technologies.

Research Question

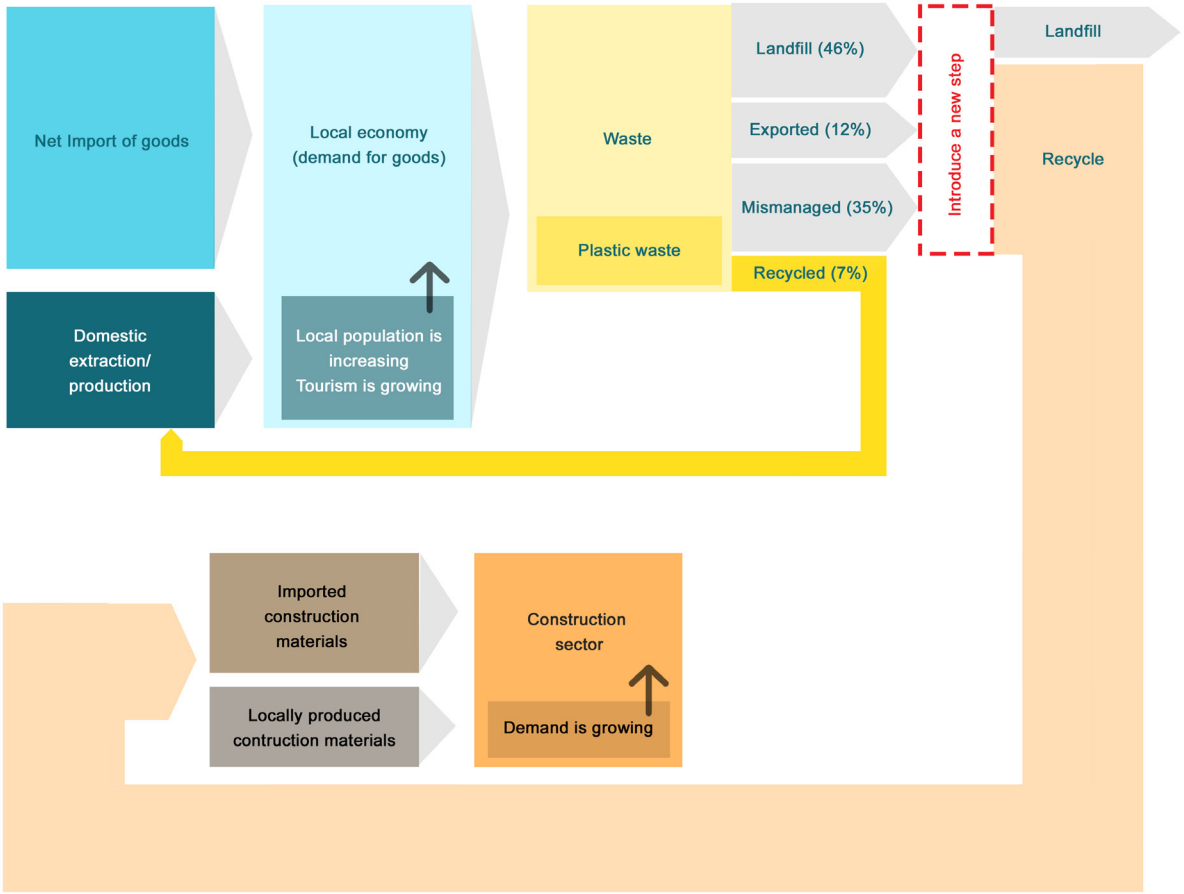
How can recycling plastic waste in a popular tourist spot with increased pollution like Bali, Indonesia create a circular model for the local construction industry?

Sub-questions

- What is the flow of plastic waste in Bali? (Quantities- kg/day)
- What are the potential applications of recycled plastic into the built environment?
- What are some building practices in Bali that can be made more sustainable with the introduction of this new material/ element?
- What are some potential hazards of using plastics in the built environment?



The research is an intersection of three main topics.
Diagram designed by Author (2022)



A concept sketch of an Material Flow Analysis diagram. Designed by Author (2022)

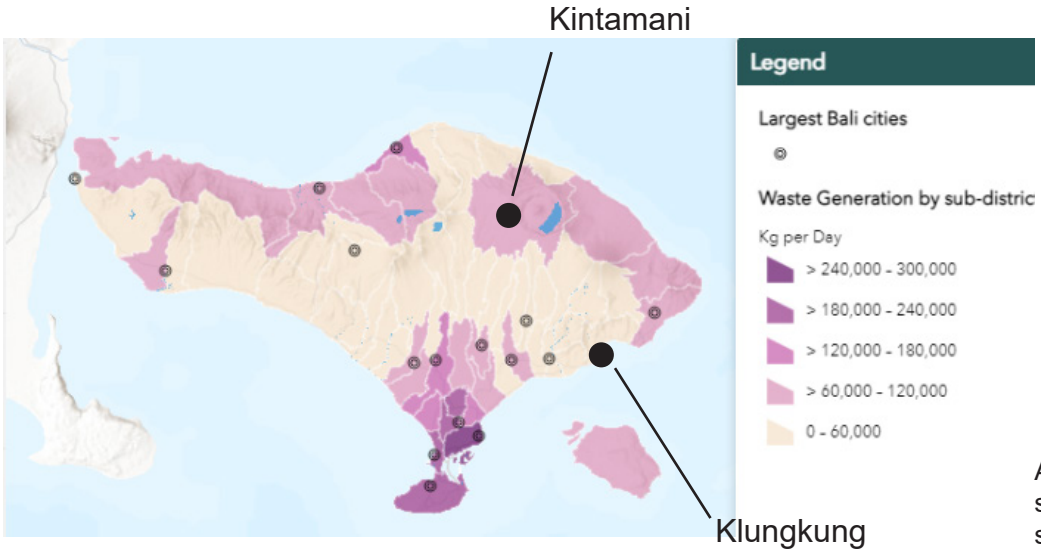
Design Question

How could a vision for sustainable tourism be achieved architecturally through the introduction of a new locally-produced recycled plastic material which empowers locals and enhances the resilience of the built environment?

Bali is one of the richest provinces in Indonesia and due to its growth of population and tourism, has planned several infrastructural projects. These projects can be opportunities for the application of a new locally-produced recycled plastic material.

With the significant amount of international attention towards Bali, a successful sustainable intervention in the built environment is bound to resonate and inspire further effort towards resilience.
In addition, in 2017 Indonesia announced its intention for developing “10 New Bali”, recognising that Bali could not sustain the country’s ambition for tourism growth alone. (*The “10 new Bali”*) The government has stated that priorities for the design of tourist infrastructure on these islands would be sustainability and eco-friendly practices.
An intervention on Bali could serve as an example of how sustainable hospitality could look like when the new destinations grow in popularity. Also, it could be an example for island-nations (ex. Sint Maarten) that do not have the option of dispersing tourists and instead need to find solutions on the land they have available.

Two developments that could be potential subjects of my graduation project are the Singamandawa Market in Kintamani, Regency of Baugi and the planned new cultural centre in Cultural Arts Center in the Regency of Klungkung. (Daniels, 2022)
The two options will be compared in terms of design opportunities and relevance, so the one better suited for completion in the timeframe and interest of this graduation project will be selected for further development. The aim would be to provide an alternative way for its construction through introducing the new recycled plastic material to its construction and combining its program with attractive tourist accommodation. That would allow visitors to directly invest in the local economy while also having the opportunity to more closely interact with their hosts, learn about the local ways of living and participate in the cultural exchange. That complies with and is part of the United Nations World Tourism Organisation’s definition of sustainable tourism. (Sustainable Tourism, n.d.)



A map of waste generation by sub-district on Bali (Bali Partnership, 2021)

Methodology

Due to the multi-layered nature of the topics that the research and design questions touch upon, the research would encompass a variety of methods, ranging from desktop and literature study, through interviews, to a site visit at the project location. Determining the precise means to reach an answer to the research and design questions is imperative, as otherwise the study of the different topics could stray in a direction where they are no longer connected.

Methods for the technical research

An answer to the research question would require a quantitative study of material flows: an **MFA analysis**. MFAs are a method for analysing the state and change of materials flow and stock within a defined system in space and time (Brunner and Rechberger, 2017). For the purposes of this research the flows of plastic waste, growth of user numbers and demand for construction materials will be examined. Through that I could establish how much plastic is available as a resource and hence study the opportunities for its application. Such analysis would also visualise whether a new recycled plastic material would satisfy a portion of the market, or to the contrary- create an oversupply, which would necessitate the export of the material to other islands.

Publications are abundant both on the topic of recycling of plastics and on waste management in Bali in particular. These themes will be investigated through **published academic papers**.

New technologies would be studied through **online research** and **discussions with professors** from the BK and 3ME faculties at TU Delft.
Currently, the main options for recycling plastic waste are into construction materials are:

- Dry compression of different types of plastics into structural building blocks (ex. ByBlock and Uppact).
- Melting selected types of plastics together into a desired shape (ex. Gjenge Makers, Nairobi)

Both methods have their advantages and shortcomings: dry compression is more environmentally sustainable and allows for the mixing of different types of disposed plastic, yet the resulting bricks are large and difficult to create light structures or experiment and innovate with architecturally. Melting, on the other hand, increases the energy consumption of the process and is more materially restrictive but allows for more architectural freedom and may result in more aesthetically valuable products.

Interviews can also be conducted with local organisations focused on clean-ups and recycling. Since governance in Bali is decentralised and laws regarding waste management are rarely enforced, such practices are often in the hands of the informal sector. (Giesler, 2018) Such organisations could provide a valuable insight into how processes regarding waste take place in reality. Interviewing NGOs, locals or governmental institutions may expose biases on different sides, which need to be acknowledged.

Past projects on circularity and the use of recycled plastics from the aE graduation studio will also be examined.
So far inspiration has been gained from Martijn Dalinghaus's research on circularity on the island of Sint Maarten, Man Ho Tong's study on plastic household waste as a building material in Haarlem, NL and Rianne Reijnders's method of studying sustainable impact of seaweed through its cultivation processes and using projections of its and other materials' usage over time. (2021)
Positioning this topic within the past research of TU Delft would allow this study to become part of the university's larger investigation of the potential applications of the material as part of the built environment.

Methods for the design research

When focusing on design, **reports by professionals** and institutions in the field of travel would be examined to determine the goals for sustainable tourism and determine how the built environment could contribute to the positive shift towards a more sustainable model of hospitality. (ex. Bill Barnett)

To gain further insight into the needs of the location, **interviews** will be conducted (depending on availability) with practitioners in the construction and hospitality fields in the area. Since Bali and Indonesia in general have and are still seeking international investment in real estate, private firms have appeared that guide investors in their decisions. People working in this sector have an overview of the local market that can bring an insight to the current shortcomings and opportunities that could be addressed through introducing a new local material and a different type of travel accommodation.

Qualitative research that would be integral for the design phase and may influence the choice of plastic recycling technology would be a study of elements of typical Balinese architecture through examining **case studies**. That would be necessary for the design phase to ensure the contextuality of the architectural proposal.

Finally, an overview of architectural **case studies incorporating recycled plastics** needs to be compiled in order to define the spectrum of applications and uses of the material. Such an investigation would highlight the opportunities and limitations that the material carries and thus define a framework for the design that this research would result in.

* See Appendix 2 for a diagram with the current structure of the methodology, encompassing leading questions about the technical aspects of the research, design considerations and conclusions to which they would lead. The diagram is a work in progress that will evolve with the accumulation of new data and the discovery of new connections between the themes of the study.

Initial Reflection

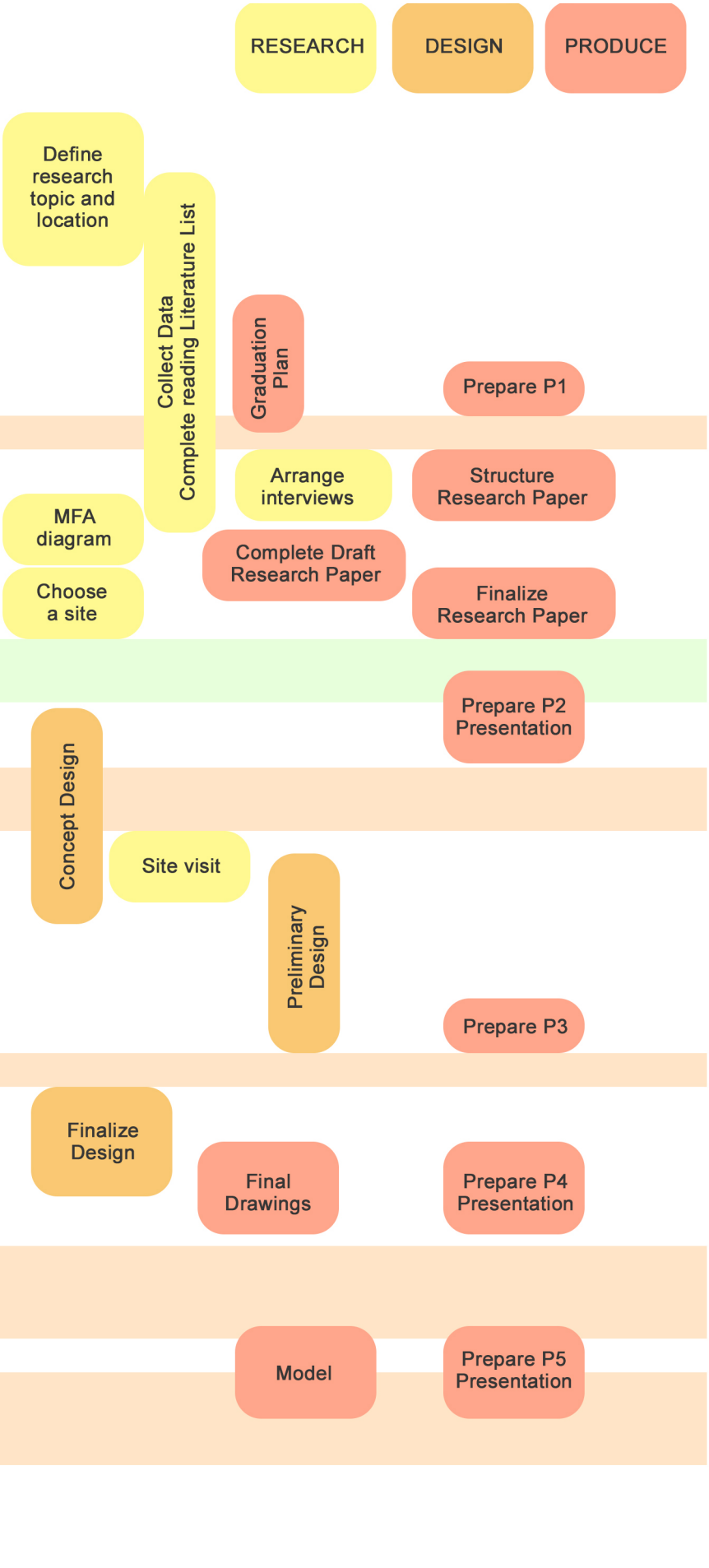
This research is broad and encapsulates three general topics: plastic recycling, use of plastics in architecture and the future of tourism. A major challenge during the process would be to stay focused on the narrative in which they are all connected and not stray away into one of them more than the other. The task will be approached and treated similarly to a business research or a feasibility study. The research would be based on the hypothesis that using plastics in construction is indeed technically and economically viable. Since the design objective is formulated, the study will focus on how it could be achieved, and not the broad question of what could be achieved with recycled plastics. That is because the extensive research on the recyclability of plastic until now has provided numerous options for its reintroduction in the economy. So, it would be testing whether it makes sense to use plastic in the construction industry, looking at how much waste is available, how much building material that could be turned into and in what scenario/ for what purposes it might be a preferred alternative to the already widely used concrete on Bali.

Potential criticism

Questions about the future use of plastics on a global scale could come to challenge the data and necessary assumptions that this research will be based on. A potential increase or decrease in the supply of “raw material” (plastic waste) would change the pace of production of the building material. This may be addressed in the Material Flow Analysis, which may potentially present possible solutions to such a shift.
Another potential point of criticism is viewing the newly created building materials also as an end product in a linear economy. Thus, design for disassembly would be fundamental in the choice of shape for the recycled plastic elements.

Planning

Week	Date	Event
36	5-11 Sept	
37	12-18 Sept	
38	19-25 Sept	
39	26-2 Oct	
40	3-9 Oct	
41	10-16 Oct	
42	17-23 Oct	
43	24-30 Oct	
44	31-6 Nov	
45	7-13 Nov	P1
46	14-20 Nov	
47	21-27 Nov	
48	28-4 Dec	
49	5-11 Dec	
50	12-18 Dec	
51	19-25 Dec	
52	26-1 Jan	Holidays
1	2-8 Jan	
2	9-15 Jan	
3	16-22 Jan	
4	23-29 Jan	P2
5	30-5 Feb	
6	6-12 Feb	
7	13-19 Feb	
8	20-26 Feb	
9	27-5 Mar	
10	6-12 Mar	
11	13-19 Mar	
12	20-26 Mar	
13	27-2 Apr	P3
14	3-9 Apr	
15	10-16 Apr	
16	17-23 Apr	
17	24-30 Apr	
18	1-7 May	
19	8-14 May	
20	15-21 May	P4
21	22-28 May	
22	29-4 June	
23	5-11 June	
24	12-18 June	P5
25	19-25 June	
26	26-2 July	
27	3-9 July	
28	10-16 July	



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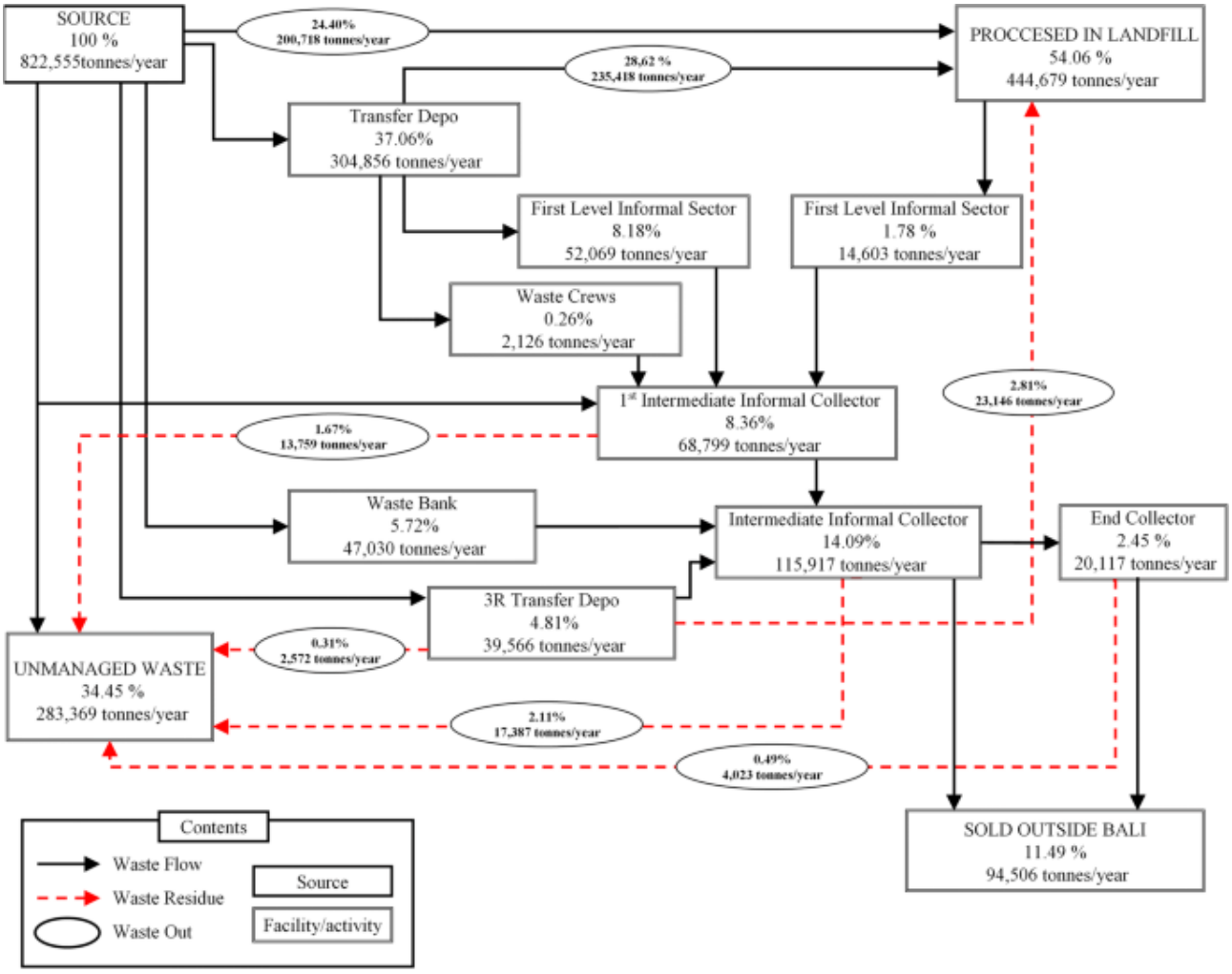
Appendix 1



An MFA of waste management in Bali. It is useful in the analysis of amounts of un-recycled waste and assessing the potential for intervention in the system. (Widyarsana, I.M.W, 2020)

Appendix 2

Research Question

How can recycling plastic waste in a popular tourist spot with increased pollution like Bali, Indonesia create a circular model for the local construction industry?

Design Question

How could a vision for sustainable tourism be achieved architecturally through the introduction of a new locally-produced recycled plastic material which empowers locals and enhances the resilience of the built environment?

Plastic in Bali

Know how much plastic is available (MFA and projections)
- This will show us how much resource we can work with to produce the new material, what quantities of it we would have and at what pace it could be made

In which areas is plastic mostly accumulated? How is it managed? In which regions can it be harvested most effieicntly?
- This could hint at locations appropriate for architectural intervention

What percentage of the plastic waste is or will be recycled back into other items once waste is collected responsibly?
- Plastics can be recycled 1-10 times, depending on their type. Could I address the final recycling cycle?

- How much can we build out of plastic? Big or small scale?
- Where might be a good location to produce those architectural elements

Recycled plastic in architecture and the built environment

What could be made out of plastic in the field of architecture and construction? How much plastic is needed to produce the respective item? What technologies are available currently?

What potential hazards does the use of recycled plastics in the built environment pose? How could they be addressed and mitigated through design?

What are the benefits of recycling plastics for application in the built environment?
- Less solid waste pollution; Boosting local economies; Using plastic's unique material qualities in the architectural design

- Choose an appropriate technology for recycling into the needed element
- Design the elements for easy assembly and disassembly

Future of tourism (in Bali)

Why is there a need for tourism to change? How can architecture contribute to the sustainability of the tourism sector?

What are some visions/ definitions for the future of sustainable tourism?

What area of Bali can be addressed? What criteria would lead the coice?

What local program/activity could be combined with hospitality and why?

Local architectural typologies & their adaptation in contemporary designs

- Choose a site
- Define programme
- Cater to users' needs