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[THE USE OF WASTE AS FILL MATERIAL IN THE LAND RECLAMATION PROJECTS OF JAKARTA]

Evaluating the possibilities of using waste as an interesting substitute of sand within the land reclamation projects of Jakarta

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Foreword

This research is the final step of my master degree in the field of Construction Management and Engineering (Urban Development) at the Eindhoven University of Technology, where I started two and half years ago.

The research was conducted within the company Witteveen + Bos, where I had Arno Kops as mentor, who gave me the needed flexibility, resources and autonomy, for which I am very grateful and I would like to thank Arno for his trust and support. I would like to thank Sawarendro for his support and for giving me the necessary insight in the Indonesian social and governmental context. I would also like to thank Henk Nieboer for making it all possible. On the TU/e front, I would like to thank my graduation committee: prof Wim Schaefer for the inspiring discussions, Bart van Weenen for his substantive guidance and Han Qi for her support within the research methods and structure. I would also like to thank them all for believing in me and granting me the necessary KENWIB support for the research.
I would also like to thank my partner Milko Lippe, my family and friends for their mental support and encouragement.

The choice of my research topic was mainly formed during my exchange program in Singapore, where I had a project within the module “Climate Change and the Built Environment” involving flood protection, urban heat island and air pollution. The project inspired me to focus on Asian countries, vulnerable to the effects of climate change. My regular consultations and brainstorm sessions with Arno Kops and eventually Sawarendro helped formulate the research topic, which turned out to be very interesting for all parties: Witteveen + Bos, TU/e en me.

Those last months of research have been very interesting with lots of interesting discussions and learning moments. I am very grateful for this opportunity and thank all the experts (see experts list) who played a role within this accomplishment. I hope this research can contribute to the challenge towards sustainable waste management and responsible land reclamation in Jakarta.

Everything comes to an end. I guess that is a good thing as there, lies the origin of progress, evolution and improvement. Therefore I am happy to turn this page of my journey book and embrace what comes next.

Nene F. Barry
The Hague, February 25th 2013.

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1 Introduction and research design

1.1 Background, context and relevance

Jakarta is the capital and largest city of Indonesia. Located on the northwest coast of Java, Jakarta is the country's economic, cultural and political center, and with a population of 10,187,595 as of November 2011, it is the most populous city in Indonesia and in Southeast Asia, and is the seventeenth-largest city in the world. Officially, the Jakarta Special District has a land area of 662 km^2 and a sea area of 6,977 km^2. Jakarta lies in a low flat basin, averaging 7 meters above sea level; 40% of Jakarta, particularly the northern areas, is below sea level, while the southern parts are comparatively hilly.
Jakarta is experiencing rapid urbanization, yet the city's urban development and infrastructure is not ready for such rapid growth in population density. Based on a survey of the Brooking Institution [4] about growth, Jakarta ranked 171st among the world's 200 largest cities in 2007, as this rang was increased to 17th in 2011, the city experienced a significant jump. With a population of 10,187,595 and a land area of 662 km^2, Jakarta has a population density of 15,389 people/km^2.

Jakarta's population growth is putting huge pressure on the urban environment, leading to problems such as:

- Land subsidence: rapid urbanization along with severe uncontrolled and over-extraction of groundwater in areas not connected to the municipality water supply distribution system leads to continuous subsidence of the ground surface. Over-pumping of the shallow and deep aquifers underlying the area causes land subsidence that, in turn, exacerbates local flooding due to poor and impeded internal drainage and reduction of outlet capacity.
- Flood: Population pressure converted half the city's small lakes into residential or commercial areas, leading to severe reductions on retention capacity and increases in peak flow discharges. At present less than 10% of DKI Jakarta area can be defined as open and green areas, while such area should cover 30%, according to the government regulations.
- Traffic congestion and air pollution: Jakarta is severely choked by smoke and carcinogenic gasses emitted by the innumerable vehicles in the city.
- Waste problems: The city's rivers are choked with human waste and garbage. Aapproximately 6000 tons of waste is produced per day and around 1,800 tons remain not processed and partially ends up, consciously and unconsciously, in the rivers [2].
- Poor sanitation also creates serious health threats.

As Jakarta has been growing not only as the Capital of Indonesia but also as the commercial, education, and service center since it is surrounded by several important industrial estates located in Jakarta and its satellites within Jabodetabek Metropolitan areas, Jakarta has required to provide all facilities to support its functions.

To coop with those urbanization issues and the economic need for expansion, the city is planning to reclaim more land in the Jakarta Bay. More land could discharge the inner city's over-population, enhance its economic growth and solve a lot of previously named environmental and health problems.

1.2 Problem definition

The government of DKI Jakarta (Indonesia) is planning to extend its land on the North-coast of Jakarta to about 8 km seaward and build a sea defense to protect the city against flooding. The reclamation activities of some Islands of about 300 ha have started recently and already the developers are facing difficulties in finding sufficient quantities of sand as fill material. After one year of work they have gained only 1.4 million m^3 of sand, while 20 million m^3 is needed. In addition to that, the whole land reclamation plan of North-Jakarta concerns 4000 ha, where more than 200 million m^3 of sand is needed [18].
Alternative fill material for reclamation works is needed to compensate the lack of sand in order to meet the required fill for the reclamation works.
On the other hand, the city is also facing an excess of waste production and a lack of dumping ground. As mentioned before around 6000 tons of waste is produced per day, of which 1,800 tons remain not processed.

1.3 Research questions

How could waste be an interesting substitute for sand as fill material in the land reclamation projects of Jakarta?

- What alternative ways of using waste as fill material within the land reclamation projects of Jakarta are there?
  - What alternative methods derived from the existing expertise and technologies of the cases of Singapore (Pulau Semakau) and Japan (Yumeshima Island) could be applied in Jakarta?
  - What other possible alternative ways of using waste as fill material within the land reclamation projects of Jakarta can be derived from new expertise and technologies?
- Which alternative or combination of alternative methods of using waste within land reclamation is more interesting for Jakarta based on the Triple Bottom Line (people planet profit) principle?
- How could this more competitive alternative method of using waste within land reclamation be implemented in Jakarta?
  - What possible changes within the land reclamation plan, the SWM system or the governmental and socio-economic context of Jakarta need to be made in order to meet the implementation conditions?

1.4 Research objective and limitations

The objective of this research is to find out whether waste can be a good substitute for sand in the land reclamation projects of Jakarta and how to apply it. Analyzing and evaluating the two example cases of Singapore and Japan and searching for alternative new technologies could lead to a useful conclusion for Jakarta. The use of waste as substitute for sand could solve a lot of problems Jakarta is coping with nowadays, as referred to in the problem definition section above.

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1.4.1 Limitations or risks

Achieving this objective could be somewhat challenging. The following risks are identified as being able to cause limitations within this research:

- Data collection: this is the most challenging aspect of this research as data is needed from Jakarta, Singapore and Japan. There is a lot of information on the internet; however it is hard to find specified and updated information. This could present the need to travel during this research in order to gather the needed data. Because the engineering company Witteveen + Bos has an office in Jakarta, it would be there easier to gather information than in Singapore and Japan.
- Language barrier: a great deal of the needed data would probably be written in Japanese of Indonesian. Translating the data could be a solution when found; however, finding the data could be a problem as the right search words will not be known. Translation also takes time and so needs to be taken into account.
- Research duration: the duration of the research may need extension. Because of the international character of the study, there could be some unplanned delays due to traveling issues, traveling time, information delay, cultural differences etc. This aspect should also be taken into account.
- Financial aspect: this research needs more funding than most other graduation researches due to the traveling aspect, which involves travel, accommodation, living and transportation costs.

1.5 Research method

1.5.1 Data collection and analysis

The data collection will be mostly done through literature study and expert consultations. Multi Criteria Analysis (MCA) will be used for the decision making process about the more suitable application for Jakarta. The cases of Singapore and Japan will also be analyzed and evaluated using MCA.

MCA is a structured approach used to determine overall preferences among alternative options, where the options accomplish several objectives. In MCA, desirable objectives are specified and corresponding attributes or indicators are identified. The actual measurement of indicators does not need to be in monetary terms, but is often based on the quantitative analysis (through scoring, ranking and weighting) of a wide range of qualitative impact categories and criteria. MCA allows decision makers to include a full range of social, environmental, technical, economic, and financial criteria. Explicit recognition is given to the fact that a variety of both monetary and nonmonetary objectives may influence policy decisions.

In this case, the conjunctive approach is used to evaluate the new and existing land reclamation methods in order to determine the most suitable method for Jakarta. This approach is based on a risk minimization. It measures the deficiencies of the methods and determines the safest alternative.

For the implementation analysis of the chosen alternative land reclamation method, a SWOT analysis will be used to evaluate the positive and negative aspects of the chosen alternative method in the context of Jakarta. To help understand the process of the alternative method and the correlation between the process elements, a system dynamics model is used and finally possible future scenarios are simulated using the scenario development approach.

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The table below shows the research sub-questions with their corresponding research method and data collection method.

Table 1: Overview of the research sub-questions and their corresponding data collection and method of analysis.

Research sub questions	**Data collection method**	**Data analysis method**
What alternative methods of using waste as fill material within the land reclamation projects of Jakarta are there? ○ What alternative methods derived from the existing expertise and technologies of the cases of Singapore (Pulau Semakau) and Japan (Yumeshima Island) could be applied in Jakarta? ○ What other possible alternative ways of using waste as fill material within the land reclamation projects of Jakarta can be derived from new expertise and technologies?	Literature study Experts consultations	Case study Comparative analysis (conjunctive approach)
Which alternative or combination of alternative methods of using waste within land reclamation is more interesting for Jakarta based on the Triple Bottom Line (people planet profit) principle?	Literature study Experts consultations	MCA (conjunctive approach)
How could this more competitive alternative method of using waste within land reclamation be implemented in Jakarta? ○ What possible changes within the land reclamation plan, the SWM system or the governmental and socio-economic context of Jakarta need to be made in order to meet the implementation conditions?	Literature study Experts consultations	System dynamics SWOT analysis Scenario analysis

An overview of the research design is shown next.

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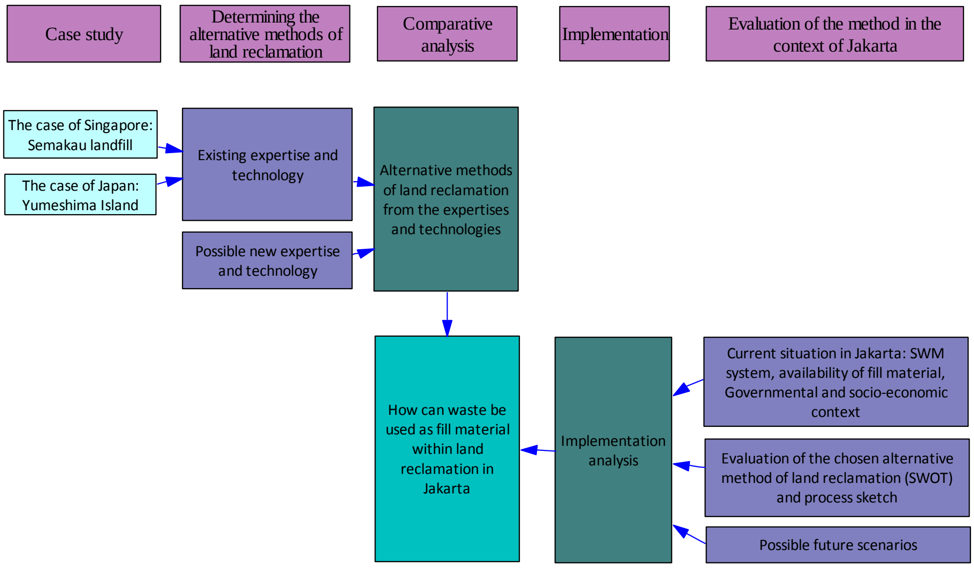

Figure 1: Research design.

Chapter 2 will give a review on literature about land reclamation (the conventional way and the alternative way with the use of waste as fill material) along with the current land reclamation plans and Solid Waste Management (SWM) system of Jakarta. Then in Chapter 3, the alternative ways of land reclamation with the use of waste as fill material and possible alternative fill materials are evaluated and compared, starting with a case study of the existing cases of Semakau landfill (Singapore) and Yumeshima Island (Japan). Finally chapter 4 discribes the process of the chosen alternative method of land reclamation and chapter 5 evaluates and analyses the implementation of this chosen method with respect to the current social, environmental and economic context of Jakarta.

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2 Literature review

The literature review starts with explaining the process of land reclamation, giving an outline of the traditional way of land reclamation and the way of land reclamation, where waste is used as fill material. Then the current reclamation plans of Jakarta are presented and finally the Solid Waste Management (SWM) system is outlined, pointing out, which types of waste could theoretically be used and what kind of treatment or environmental protection measures are needed before use.

2.1 Land reclamation

Land reclamation is the gain of land from the sea, or wetlands, or other water bodies. It is also the restoration of productivity or use to lands that have been degraded by human activities or impaired by natural phenomena. This research focusses on the first definition: the gain of land from the sea, or wetlands, or other water bodies. The land reclaimed is known as reclamation ground or reclaimed land.
The process of reclamation includes maintaining water and air quality, minimizing flooding, erosion and damage to land properties, wildlife and aquatic habitats caused by surface mining. The final step in this process is often topsoil replacement and re-vegetation with suitable plant species.

2.1.1 Traditional way of land reclamation; the use of sand as fill material

The traditional land reclamation under tidal water involves filling land (mostly sand) under tidal water to a level above the high water mark to make the land suitable for a particular purpose.
One of the most applied land reclamation methods is the Polder model. A polder is a reclamation area, surrounded by a closed loop of flood protection elements (sea defenses, dikes, water management system) to separate the water regime inside the polder areas from the water regime outside and to control the water table inside the area. A partial landfill is applied to improve the accessibility in the polder area.
Hardened shores (seawalls, revetments, etc.) are an important part of land reclamation. A hardened shoreline refers to any coastal defense structure, generally constructed of concrete or rock, that is located along the shoreline within (or above) the intertidal zone. These structures are designed to protect the backing upland areas from flooding and/or coastal erosion. Depending upon the presence of fronting beach deposits, these structures can be exposed to wave action for some or all of the tidal cycle.

Marine dredging in this case is characterized as large-scale "capital" dredging for the creation of new projects. Capital dredging works generally describe a solitary process of excavation to enable development at a site, or to extract resources for use in a development at a remote location (e.g., building aggregate or sand).
Dredging methods are divided into two primary categories, hydraulic and mechanical, with each consisting of a variety of equipment types. The impacts will vary between the individual extraction methods, with many involving some form of disturbance or excavation of the seabed while others simply involving suction of unconsolidated material from the seabed.

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2.1.1.1 Social and environmental impacts

By its nature, the activity of dredging can result in the degradation and loss of coastal resources including foreshores, wetlands and wader bird habitats. Reclamation can also adversely affect coastal processes and scenic landscape values [9]. The following summation of social and environmental impacts can be noted.

- Dredging involves the removal of seabed material or naturally accreted shoals. The footprint can be large, but ultimately depends upon the volume of material dredged;
- removal of material from the seabed can significantly modify waves and currents reaching the shoreline. Reduction of a shoal that formerly attenuated wave energy and reduced current velocity could result in greater wave and current exposure at the shoreline;
- sediment volume available for transport to the shoreline could be reduced due to sediment trapping in the dredged pit;
- turbidity will increase during the period of extraction, but tend to subside thereafter;
- there is potential for nutrients and pollutants to be released from sediment extracted from the seabed and released into the water column.

Therefore, the need for any reclamation work, as well as the extent and nature of any potential adverse impacts of this activity on coastal processes/resources and their values must be examined carefully [48].

If the use of alternative fill material, which does not involve dredging, is possible, this option should be taken into account.

2.1.1.2 Economic aspects

As the search for alternative fill material only refers to sand substitutes in this research, the other materials such as geomatress, geotextile tubes, rocks, clay, grass, bund material, drains, etc. will be assumed to remain the same.

The cost of sand in Jakarta is estimated at **\$10.32 /m^3** or **\$29.50/ton** The cost of any alternative material should be more favorable in order to be taken into account.

2.1.2 The use of waste within land reclamation

In this type of land reclamation, waste is used as fill material instead of sand. This way of land reclamation can be chosen for different purposes:

1. The purpose of creating waste disposal sites: This refers mostly to offshore waste disposal landfills which are turned into natural areas (green zones, parks, golf courses etc.) after reclamation. In this case the reclaimed land is not stable and strong enough and therefore cannot be used for other urban development purposes, but is used for greenery or recreational purposes instead.
2. The purpose of creating new land for urban development plans: These may range from residential and cultivation purposes to major development projects such as tourism, individual/commercial business ventures, wharfage and other infrastructural improvement. In this case, the use of waste is only chosen when proven to be able to replace the use of sand and the traditional way of land reclamation and also when proven to be economically more attractive.
3. They are also cases where both purposes are urgent. Although the one is always more urgent than the other. In those cases, landfilling is done with the purpose of both securing waste final disposal sites as well as creating new land for urban development after land reclamation.

The case of Jakarta is similar to the second situation, where the purpose is creating new land for urban development. Because of the sand scarcity in the surrounding areas and the abundant availability of waste, is the use of waste as fill material an interesting approach.

2.2 Land reclamation in Jakarta

2.2.1 Plans in Jakarta

The land reclamation in Jakarta Bay already dates back to the Pantura plans of the 1990's. Since then also other initiatives focused on the coastal zone, including the expansion plans of Tanjung Priok. The Government of DKI has planned to transform Jakarta into a real big city in the future by changing its coastal line to about 8 km toward the sea from its existing position. It is planned that Jakarta will become a Water Front City, covering the area of 5 km to the land side and 8 km to the sea side along its coastal line. The approach will be by constructing some small islands in the front of its shoreline instead of total reclamation to the whole water front area of Jakarta [26].

Not only the need of land expansion is taken into account, but also other problems that the city is facing; e.g. flood, land subsidence, clean water scarcity, traffic congestions etc.

The integrated plan of the Jakarta Coastal Development Strategy project (JCDS) will not only protect North Jakarta against floods, but will also solve its drinking water shortage, river water pollution and notorious traffic jams problems and will turn the city into an attractive place to live, work and invest. The JCDS plan integrates effective technical solutions to prevent floods (dikes, retention ponds, pumps) with additional measures to make the solutions sustainable (piped water supply, sewerage and sanitation, resettlement) and investment opportunities to make the overall plan financially feasible based on internal cross-subsidies and public-private partnership (land reclamation, toll roads and deep-seaport).

Flood prevention measures are based on a system of three parallel sea defenses.

- The first sea defense will be built on the existing coastline where land subsidence is worst and will provide flood protection until 2020.
- The second sea defense will be built at 3 km from the coastline at depth of 8 m where land subsidence may still occur and provides flood protection until 2030.
- The third sea defense will be built at 6 km from the coastline at depth of 14 m where no land subsidence occurs and which will provide permanent protection beyond 2030.

Between the parallel sea dikes retention ponds are projected with an overall area size of 10,000 hectares.

Between the first and the second sea defense, or between a depth of 1 m and 8 m below sea level land reclamation of about 3,000 hectares is planned in the form of 11 polder systems. On top of the first sea defense an access road of 27 m wide will be built to serve North Jakarta and the newly reclaimed land. On top of the second sea defense a toll road of 57 m wide and a double railway track will be built to connect the international airport of Soekarno Hatta International Airport (SHIA), the international seaport of Tanjung Priok and the related warehousing and industrial areas. On top of the third sea defense another toll road of 57 m wide will be built to serve as by-pass for though-traffic along North coast of Java [18].

The spatial plan will transform Jakarta into a waterfront city. The massive development plan includes industrial infrastructure, office buildings, hotels, business centers, mega shopping malls, seaports, elite housing estates, condominiums, and transportation infrastructure.

An overview of the plan area of North-Jakarta is shown below. The orange and yellow colors represent the planned land reclamation Islands and the blue lines represent the planned roads and railway track.

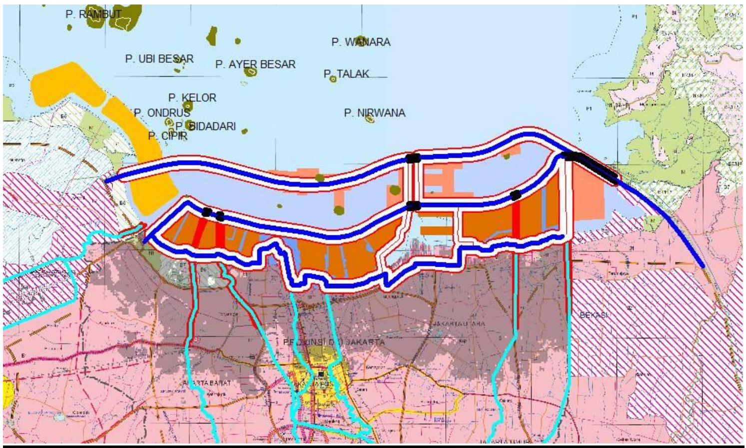

Figure 2: Overview of the planned land reclamation area [18].

2.3 Solid waste management (SWM) system of Jakarta

2.3.1 SWM system

The Cleansing Agency (Dinas Kebersihan) of Jakarta is the authority responsible for operating, maintaining, and monitoring the solid waste infrastructure in the city, with the involvement of different parties such as the Market Agency, the Public Works Agency, and some enterprises. The organization is administered by the Governor of Jakarta, and includes representative officers in each municipality, who are responsible for the day to day coordination and reporting system. In performing its operation, the Cleansing Agency works closely together with the Public Service and the Market Agency.

Another institution is the Local Development Planning Agency (Bappeda), with main task, formulating and directing local policies in certain areas of development, including the waste planning. The policy must be in accordance with the national policy framework by the National Development Planning Agency (Bappenas).

Neighborhood associations (NAs) also play an important role in the SWM within their respective areas, especially in areas where official waste management service does not exist. The work of these NAs is unfortunately not fully developed due to several factors, including the following:

- handling waste is perceived as a voluntary activity with almost no support from the government;
- the function of the NAs in municipal solid waste (MSW) management has not been studied and developed seriously;
- low appreciation from the authority of the waste service provided by the community;
- source reduction through source separation or other means was not considered as an alternative to ease the city's burden in handling waste [32].

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Furthermore, different technology and research development efforts in the area of solid waste and other environment-related study areas are continuously assessed in a ministerial level organization namely the Research and Application of Technology Agency (BPPT). The Cleansing Agency coordinates closely its effort with this organization, through technical advice and cooperation in some of their projects [41].

MSW management in Jakarta relies on a conventional collect-haul-dispose system. In order to carry this out, the Cleansing Department of Jakarta has divisions in each municipality. It mainly relies on manual labor and non-specialized trucks to collect and transport the waste to transfer stations and/or the final disposal site. In an attempt to increase productivity, a variety of collection, transfer, haulage and disposal methods have been tried with limited success. The lack of success may be attributed to:

- poorly defined long-term goals;
- lack of information for planning, monitoring and evaluation;
- and the fact that public consultation and participation is not an integral part of the system.

The other impediment is that no single ministry and agency is charged with the development and implementation of solid waste management goals and policies. Instead, policy development is divided among several ministries, and implementation is the responsibility of each municipality or regency [39]. Furthermore, within each municipality there is no separation between regulatory and operational roles and the same department performs these two tasks, leading to potential conflicts of interest.

2.3.2 MSW quantities and compositions

The average volume of solid waste in Jakarta varies in the literature. Different studies states different amounts of solid waste generated each day. Some studies indicate an average volume of solid waste of 6,400 ton/day [6, 41]; other studies indicate an amount of 6000 ton/day [2]. Based on SAPROF [35], the average volume of solid waste is 6,525 ton/day, but the volume of waste at the end of 2009 and beginning of 2010 varied between 4,500 – 5,500 ton/day. In this study, the most recent data is considered; 6000 ton/day.

Because most of the waste generated in Jakarta comes from the kitchen in the form of food waste and packaging, the organic fraction of the waste is as much as 65% of waste collected [6]. In 2005 this relation changed into an average food and non-food content of 55% and 45%, respectively [7]. In 2008 the relation food - non-food content remained approximately the same [35].
The following figure shows an overview of the waste composition.

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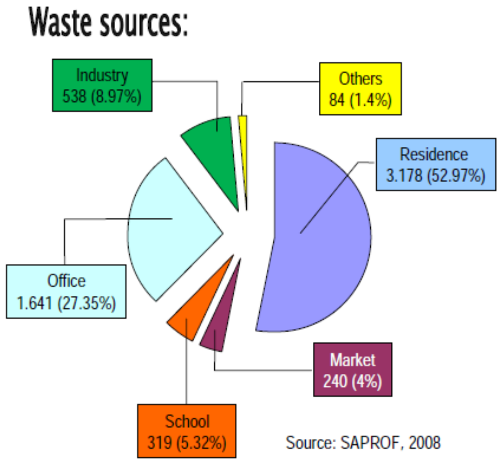

Waste Composition:

1.	Organic		:	55,37%
2	Non Organic		:	44,63%
	2.1	Paper	:	20,57%
	2.2	Plastic	:	13,25%
	2.3	Wood	:	0,07%
	2.4	Textile	:	0,61%
	2.5	Rubber	:	0,19%
	2.6	Metal	:	1,06%
	2.7	Glass	:	1,91%
	2.8	Rubble	:	0,81%
	2.9	Hazardous	:	1,52%
	2.10	Others (stone, sand, etc)	:	4,65%

Figure 3: Waste composition [35].

It is to notice that stone sand etc. form a fraction of 4.65%. However when major constructions are going on, the quantity of excavated sand, stone and earth may be significantly higher. It is also to remarque that the highest waste fraction such as paper and plastic are recyclable and therefore it is not environmentally responsible to use them as fill material for the land reclamation.

2.3.3 Solid Waste Infrastructure

The infrastructure of the SWM system consists of: collection, transportation, compaction in compaction stations, storage in temporary storages, disposal in landfill, incineration, composting and recycling as an informal system. The majority of the collected solid waste is transported to **the Bantargebang landfill** site. This landfill site is owned and operated by the municipality and receives more than the half of all collected waste in Jakarta.

Another method of treating solid waste in Jakarta is **incineration**. There are 21 small-scale incinerators with a total capacity of about 22 tons/day. Most of the facilities are operated improperly or at sub-optimum conditions because they have not been designed for high moisture content waste, have poor manual handling setups, poor operator skills, contaminated waste and high maintenance or fuel costs [21].

Given the high content of compostable materials, solid waste **composting** was started in 1991 and it reached a maximum capacity of 24.2 tons/day in 2000 at 14 composting facilities using windrow systems [21]. As is common with other parts of the overall MSW system, a lack of strategic development for composting has led to poor performance. In addition to that, the lack of community participation in any initiative and a poor local government management played an important role [32].

Recycling is not yet systematically considered as an alternative waste management system by the Government of Jakarta and is therefore carried out largely by an informal system, which involves thousands of scavengers, collectors, waste suppliers and “tukang loak” (people who come door to door, to buy cheap things, such as metal equipment, bottles, newspaper, magazines, car batteries, etc.).

Detailed information about the **collection** and **transportation** system, the waste **treatment facilities** (including incineration and composting) and the final disposal to the landfill is given in Appendix A.

An overview of the waste management flow is shown below.

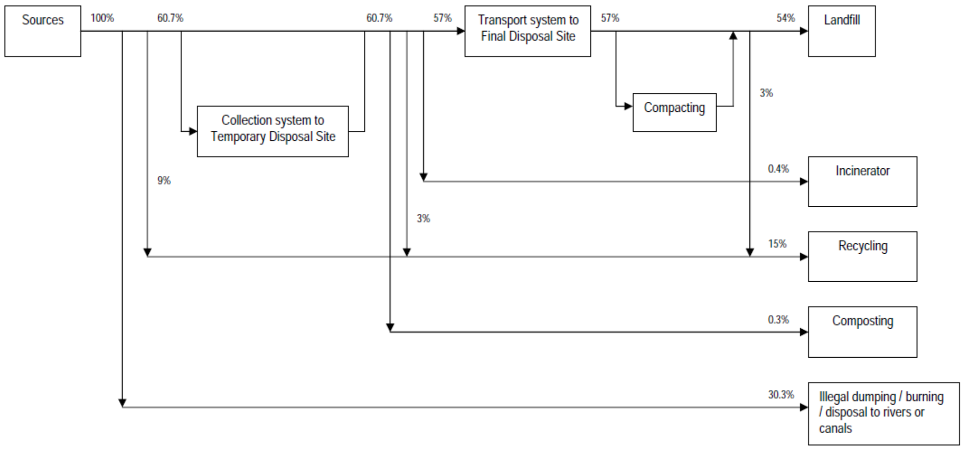

Figure 4: Solid waste flow [41].

The next table gives an overview of the landfill and waste treatment facilities based on the Waste Management Master plan.

Table 2: Waste treatment facilities and their location and status [8].

WASTE	FACILITY	LOCATION	STATUS
SOLID WASTE	Intermediate Treatment Facility (ITF)	Sunter	Upgrading from Tranfer Station to ITF
		Cakung	Upgrading from Tranfer Station to ITF
		Marunda	On Process
	Composting Center	Cakung	Operating
	Integrated Final Treatment Plant	Bantargebang	Operating
		Ciangir	On Process
SEWERAGE	Sewerage Treatment Facility	Duri Kosambi	Operating
		Pulo Gebang	Operating

The next fugure shows the location of the waste treatment facilities [8].

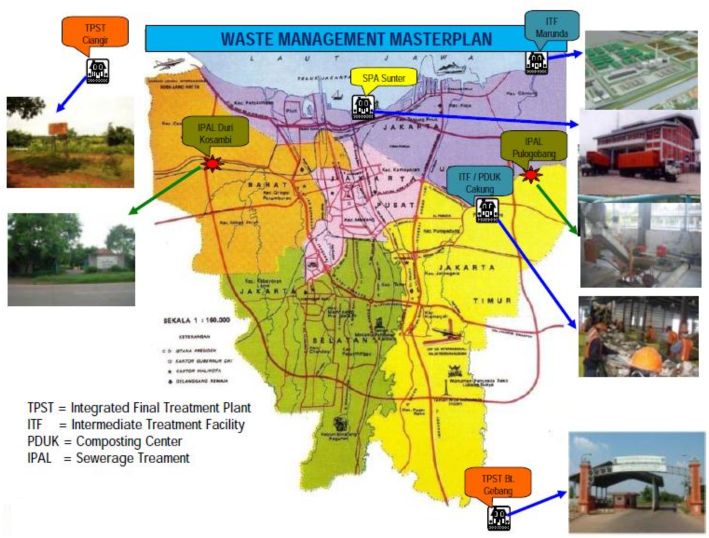

Figure 5: Landfill and waste treatment facilities from the Waste Management Master plan [8].

2.3.4 Social context

As mentioned before, the government of Jakarta has two systems of waste management; the formal system (done by municipal agencies and formal businesses) and the informal systems (done by scavengers, collectors, waste suppliers and tukang loak). Because the issue of proper waste management is not just a government task, but a shared responsibility that includes the citizens and households of Jakarta (as main end-users of waste management facilities and services), reorganizing solid waste management systems means understanding the role of households, their attitudes, their waste handling practices and their interactions with other actors in the waste system [30].

Prior studies on (1) the perceptions and behavior of householders in terms of waste management, (2) their willingness to sort waste, (3) their willingness to pay for waste sorting, and (4) their perceptions of their own role and that of waste service providers in order to improve performance in the future [2], were analyzed and described below.

People's behaviors concerning the waste management system

According to Aprilia A., et al., [2], the majority of the people surveyed store waste that is to be collected from the household for disposal in front of their house.

The waste collectors who transport waste from households to the temporary storage site are informal workers hired by neighborhood associations or private companies.

Within each neighborhood cluster (*Rukun Warga*) of usually 10 neighborhood units (*Rukun Tetangga*), in which approximately 680 households reside, there is a communal composting facility. However, of all the respondents surveyed, 88% claimed that there are no communal composters in their area of residence. Among the respondents who indicated that communal composters are available, only 7% claimed to be actively involved in communal composting activities. All respondents who were actively involved in communal composting were users of the produced compost.

Regarding home composting, of all the respondents surveyed, 8% own and use a home composter and also use the product for personal purposes.
An illustration of a communal composter and a home composter is given below.

Figure 6: Illustration of (left) a communal composter and (right) a home composter [2].

People's willingness to sort and willingness to accept waste sorting practices
Most of the people (81%) do not usually conduct waste sorting at home. However their responses regarding agreement to consider waste sorting were quite high, with 73% indicating that they would consider sorting their waste at home [2].

Willingness to pay others to conduct waste sorting
If government authorities were to require at-source waste sorting, 42% of the respondents are willing to pay and 57% would rather sort their own waste.

People's perceptions of future roles in the waste management system
According to the responses to the questionnaires of the survey of Aprilia A., et al., [2], if appropriate mechanisms, incentives and technical information are provided, the majority of respondents agreed to play future roles, such as:

- Being involved in communal composting (37%) and home composting (31%);
- Learning to sort waste properly (50%).

Despite agreeing to adopt more roles in the future, most of the respondents do not wish to be involved in monitoring and evaluation of the overall waste management system in their community.

People's perceptions regarding future roles of other waste management actors
The majority of respondents strongly agreed that there are several improvements and roles that the government and other waste management actors should make in the future, such as:

- Providing more regular waste collection (54%);
- Proper handling, treatment, and disposal of waste to reduce pollution (53%);
- Providing information to citizens regarding the methods of waste treatment and disposal and providing overviews on the waste management system (45%).

Furthermore 43% of the respondents agreed that waste management actors should actively involve citizens in waste management decision-making processes [2].

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2.3.5 Economic context

For the economic aspects of SWM, a prior study by Aprilia A., et al., [2], was used. The study was also based on prior studies (e.g. Bohma, Folzb, Kinnamanc, and Podolskyd, 2010; Aye and Widjaya, 2006; Sonneson, Bjorklund, Carlsson, and Dalemo, 2000; Reich, 2005) where the impact of economic factors in domestic solid waste management is discussed and estimated. The economic analysis of the study was performed against the background of the following five predetermined scenarios of MSW management:

- Scenario 1: the use of a landfill;
- scenario 2: 25% landfilling, combined with communal composting;
- scenario 3: anaerobic digestion;
- scenario 4: centralized composting;
- scenario 5: landfill gas for energy generation.

The financial and economic analysis refers to the study by Aye and Widjaya [3]. The costs and benefits of each of the waste management scenarios were estimated by processing the information obtained from surveys with the landfill administrator, communal composting officers, Cleansing Department, waste transporters and householders. The study also made use of secondary data that are provided by the landfill gas-to-energy-generation administrator and by the government.

The estimation takes into account, the savings from waste disposal costs (known as tipping fees) of recycled waste (costs of recycling taken into account) that would otherwise be disposed of at the landfill. The estimation also takes into account waste transportation-related costs, such as the wages for transporting waste from households to the waste treatment or disposal facility (US$/year) [2].

The following table gives an overview of the cost-benefit estimation for each scenario of the study.

Table 3: Result of the comparison of the costs and benefits for the 5 scenarios [2].

	Scenario 1 (Landfill)	Scenario 2 (Communal composting)	Scenario 3 (Anaerobic digestion)	Scenario 4 (Central composting)	Scenario 5 Landfill gas to Energy
Quantity of waste (tonne per day)	6,000	200	250	1,000	298
Quantity of waste (tonne per annum)	2,190,000	73,000	91,250	365,000	108,919
Annual rate	6.5%				
Investment cost:					
Land acquisition	1,852,941	2,575	2,670,692	5,150,882	1,291,787
Construction	62,890,366	23,529	14,803,638	7,181,643	28,356
Equipment	300,176	1,765	12,861,040	9,266,182	1,342,071
Planning, design and engineering	9,069,641	88	8,435,609	3,319,321	95,275
Total investment cost	74,113,124	27,958	38,770,978	24,918,028	2,757,488
Operation and maintenance cost (per annum)	317,698	12,395	6,767,334	6,557,486	356,560
Transportation cost	1,919,680	655,046	1,919,680	696,141	1,919,680
Total cost	76,350,503	695,399	47,457,992	32,171,655	5,033,728
Revenue:		0	0	0	0
Compost production (tonnes per annum)		706	0	46,976	0
Selling price (per tonne)		118	0	40	0
Electricity production per annum (kWh)		0	20,070,912	0	17,849,000
Selling price (US$/kWh)		0	0.11	0	0.11
Total revenue and tipping fee savings (US$ per annum)		959,045	2,303,275	1,872,553	2,048,296
Revenue:cost ratio	0	1.4	0.05	0.1	0.4

At 1 US$ = 8,500 IDR

Furthermore all households are required to pay double fees for local waste management services:

- Fee 1: levied by the NA, is meant to cover the NA's expenses for collecting and transportation
  the waste from households to a temporary transfer station.
- Fee 2: levied by the Jakarta Treasury, is meant to cover the Cleansing Department's expenses for transporting the waste from the area.

Most households are usually happy to pay for the package of IDR 15,000/month (USD 1.56/month). The actual fee depending on the agreement among communities is varying from NA to NA [32].

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Referring back to the study of Aprilia A., et al., [2], in terms of provision of services, the majority of respondents (44%) agreed that commercial services should be involved in managing waste; despite the consequences of increased fees. 47% of the respondents strongly agree that waste management is a shared responsibility to which they should be held responsible as citizens. By contrast, almost 49% of the respondents strongly agree that government and waste providers are fully responsible and must provide better services.

2.3.6 Environmental context

The SWM system in Jakarta, where landfill is responsible for 54%, incineration and composting accounts for less than 1%, and materials recycling covers 15% of the total waste, **30.3% of the total solid waste has neither been collected nor recycled**. Unfortunately, this waste is burnt at temporary transfer stations, in dwellers 's backyards, on spare blocks of land, or even in front of household premises, creating smoke and odor impacts on surrounding areas. Some of the waste is dumped in unauthorized areas and some ends up in waterways, causing local flooding during the rainy season, as well as pollution of rivers and coastal waters.

Landfilling, when not done the right way, has a big environmental impact. Landfill gas consists primarily of (greenhouse gases) methane and carbon dioxide and has therefore become significant in the debate over global warming and climate change, where methane is considered to have a big impact and landfills are thought to be a major source of methane.

When landfill gas is recovered, it could be turned into energy, leading to positive impacts [42], such as:

- greenhouse gas (GHG) emission reduction;
- improved air quality in landfills;
- reduction of methane emissions through methane capture;
- leachate management;
- disease vector control (less disease contagion from rats, flies, and vermin to people in urban centers);
- reduced passive emissions of landfill gases (LFG); and
- reduced air pollution from landfill fires and open burning of household waste.

There are currently several private companies investing in and operating landfill gas to energy generation systems. The Figure below shows the practice of using a geometric membrane cell cover to provide anaerobic conditions for the waste, and gas collection pipes to harvest methane gas contained in the waste.

Figure 7: Landfill gas to energy generation [1].

Sarto and Gunamantha M. [36] in their study on Life cycle assessment of municipal solid waste treatment to energy options compared various energetic valorization options with each other using the simplified Life Cycle Assessment (LCA) methodology. They analyzed the following scenarios (0 to 5 respectively):

- landfilling without energy recovery as a representative of existing solid waste management;
- landfilling with energy recovery;
- combination of incineration and anaerobic digestion;
- combination of gasification and anaerobic digestion;
- direct incineration;
- direct gasification.

One ton of solid waste treated was defined as the functional unit of the systems studied. The Life Cycle Inventory (LCI) analysis was done by including field and laboratory survey to characterize solid waste in area study and using emission factors which were adopted from literature to estimate environmental burdens for each scenario. Inventory's result was classified into impact categories, such as:

- global warming;
- acidification;
- eutrophication;
- photochemical oxidant formation.

The indicators of categories were quantified by using the equivalence factors of relevant emissions to determine the environmental performance of each scenario. The study shows that in most of the impact categories (except acidification), a scenario with direct gasification (scenario 5) indicated the best environmental profile. In terms of acidification, scenario 3 (gasification, anaerobic digestion) gives the highest value of saving.

2.3.7 Conclusion

It can be concluded that Jakarta's SWM needs a lot of improvement and further development in order to be able to use waste as fill material within land reclamation. The following table provides a list of problems and constraints of Jakarta's MSW management System.

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Table 4: Problems and constraints of SWM in Jakarta [32].

Waste management aspect	Problem	Constraint
Technical	○ Existing landfill congested and new sites not yet prepared ○ Inoperative monitoring facilities ○ Uncontrolled scavenging within the city and landfill	○ Lack of trained staff at all levels ○ Poorly maintained and designed infrastructure, transport and collection system ○ Limited R&D causes limited information and technology options
Institutional	○ Same agencies have both operational and regulatory role	○ Lack of strong legal system to prosecute laws ○ Lack of coordination among relevant agencies
Financial	○ Revenue from waste fee is too low to cover the costs of a complete waste management service ○ Potentially valuable resources going to landfill	○ No mechanism of revenue collection ○ No concept of producers responsibility or polluters pay ○ Cost of environmental and health damage not accounted in monetary value
Political	○ Arbitrary decisions made by a few staff based on expertise and experience without sufficient data and information	○ Public participation in decision-making does not exist ○ No transparency in political processes ○ Waste is not a fashionable political problem ○ Corruption
Socio-economic	○ Health and safety of scanvengers ○ Salary supplementation by workers through scavenging ○ Health impact	○ Low awareness of health and safety issues
Environmental	○ Illegal dumping causes health impact ○ Open incineration causes smoke pollution ○ Non-renewable resources going to landfill	○ No proper control of hazardous wastes ○ Valuable resources going to landfill

3 Alternative methods of using waste as fill material within land reclamation

After an extensive desk research on alternative ways of using waste as fill material within land reclamation projects, three alternatives where defined:

- Alternative 1, based on the existing expertise and technologies of the cases of Singapore and Japan;
- Alternative 2, based on a new technology of waste treatment method; Plasma gasification;
- Alternative 3, based on a new technology of land reclamation; Strengthened sediment.

3.1 Alternative 1: existing expertise and technology; Case study of the cases of Pulau Semakau (Singapore) and Yumeshima Island (Japan)

3.1.1 Case study protocol

The Case Study outline is proposed below using a structure that fits this particular research.
According to Miles and Huberman [28], a case study protocol should outline the procedures and rules that govern the conduct of the researcher and the research project. It is to remark that there is very few established protocols published in the literature relating to case research, despite its averred importance. Consequently, the Case Study Protocol proposed here is unique.
The objective of the study, analysis and comparison of the land reclamation cases of Singapore and Japan, where waste is used as fill material, is to evaluate how the case of Jakarta can better be addressed and realized. Evaluate which method or combination of methods to apply with respect to the different contextual settings of each project.
For this comparison, first a set of criteria is pre-defined according to the needed element for such a project in Jakarta. Those needed elements were identified during expert interviews and desk research.

3.1.1.1 Needed elements for the land reclamation project in Jakarta:

- For the realization of such a project in Jakarta, governmental and public support is needed, including the support of the private sector. Therefore the social, economic and governmental context should be taken into account.
- To be able to replace sand by waste within the land reclamation projects, waste needs to be available in its usable state. This means that the Solid Waste Management system needs to be adequate and sufficient.
- Techniques that were applied in other cases with different settings should be applicable in the settings of Jakarta as well. Therefore those techniques need to be flexible and innovative enough, in order to meet the settings of Jakarta.
- Because each project has a different purpose and different development plan after reclamation, which influences the type of waste used and the needed timeframe, financing and expertise, this aspect also needs to be considered.

Based on the needed elements for the land reclamation project in Jakarta stated above, a case study outline is developed for the cases of Semakau landfill (Singapore) and Yumeshima Island (Osaka, Japan).

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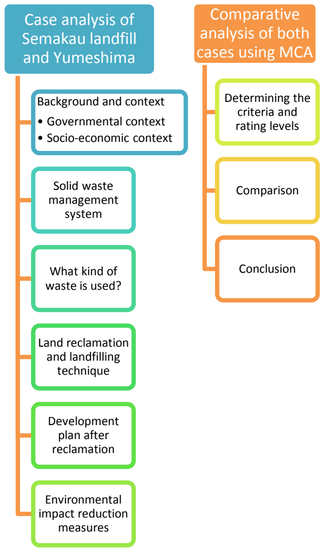
3.1.1.2 Case study outline



3.1.2 Singapore case analysis: Semakau landfill

3.1.2.1 Background and context

Semakau landfill is an island located 8 kilometers south of Singapore. The island is reclaimed from two islands, Pulau Semakau and Pulau Sakeng to build Singapore's and the world's first offshore landfill. Semakau landfill is a 350 hectares environmentally friendly waste disposal plant. Its operation started on 1 April 1999 and is expected to last until 2045 or beyond with a capacity of 63 million cubic meters of waste. After landfilling, Semakau landfill will be turned into an eco-park.
The location of the landfill and its perimeter is show below.

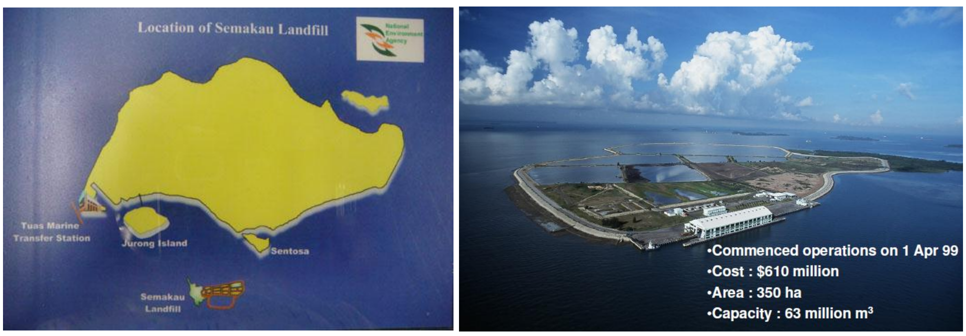


Figure 8: Semakau landfill [51].

3.1.2.1.1 Governmental context

Singapore is a highly urbanized and industrialized small island nation with a land area of 697 km2 and a population of 4.2 million. When the rate of waste disposed by its citizens rose six-

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fold between 1970 and 2000, ambitious projects to cope with this growth were put in place. Singapore's National Environment Agency (NEA) is responsible for the operation and maintenance of Semakau landfill.

The decision to build a landfill off Semakau was taken in the 1990's when the previous landfill on the main island had nearly reached capacity. The island would be designed as an environmentally friendly facility which would be used to meet Singapore's land use needs when it was eventually filled up and closed.

3.1.2.1.2 Socio- economic context

Semakau island was created entirely from the sea space at a cost of SIN$610 million (US$399 million). It has been in operation since 1 April 1999 and underscores Singapore's commitment to strike a balance between urban development and nature conservation.
Before the reclamation, both Pulau Sakeng and Semakau were home to small fishing villages. In 1987, the Singapore government relocated the islanders to the mainland. The last villager moved out in 1991.

3.1.2.2 Solid waste management (SWM)

3.1.2.2.1 SWM system

Singapore has an advanced waste management system in place. Because of the limited land area and dense population, an efficient system for the collection and disposal of waste is very important.
The National Environment Agency (NEA) has overall responsibility for the planning, development and management of solid waste disposal facilities and operations.
An overview of Singapore's Solid Waste Management system is shown below.

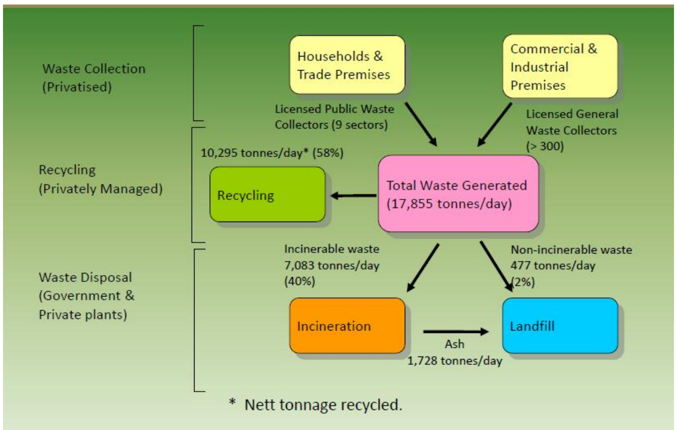

Figure 9: Singapore's SWM system [56].

Over the years, Singapore's output of solid waste has increased significantly, from 1,260 tonnes/day (1389 tons/day) in 1970 to reach the highest of 7,787 tonnes/day (8583 tons/day) in 1998. In 2008, Singapore produced 2.63 million tonnes (2,899079 tons) of incinerable solid waste. This amount would be significantly higher if Singapore did not also recycle an almost equivalent amount of waste.

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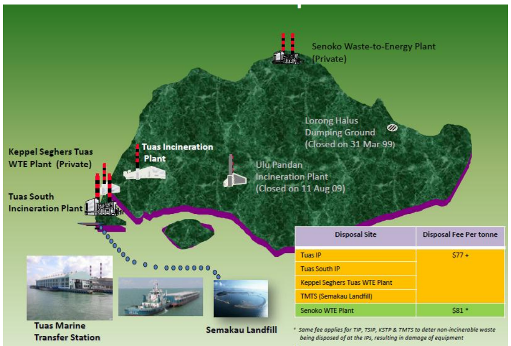
3.1.2.2.2 Solid waste disposal infrastructure

Till the 1970s, Singapore had a number of landfills around the island to handle the generated solid waste. In the late 1970s, space constraints led to the search of an alternative method of solid waste disposal. Waste-to-energy incineration was found to be the most cost effective option as it can reduce waste volume by over 76%, and in 1978, the first waste-to-energy (WTE) plant was opened. Nowadays, the solid waste disposal infrastructure consists of the four WTE plants located at Tuas, Senoko, Tuas South and the Semakau Landfill. The location, start year, capital costs and capacity of the WTE plants is shown below.



	Tuas Incineration Plant	Senoko Waste-to-Energy Plant	Tuas South Incineration Plant	Keppel Segghers Waste-to-Energy Plant
Year Commissioned	1986	1992	2000	2009
Capital Cost ($million)	200	560	890	160 (Estimated)
Designed Capacity (tonnes/day)	1,700	2,100 (Contracted)	3,000	800 (Contracted)

Figure 10: Singapore's solid waste disposal infrastructure [54].

While waste-to-energy (WTE) plants offer the best technical solution by reducing waste volume efficiently to conserve landfill space, waste minimization and recycling are key components of Singapore's integrated solid waste management system. The 3Rs (reduce, reuse, recycle) strategy play a complementary role by preventing waste at source and cutting waste sent to the disposal sites, contributing towards resource recovery. An overview of Singapore's recycling statistics for different waste types is shown next.

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Table 5: Singapore's recycling statistics [56].

Waste Statistics and Recycling Rate for 2011				
Waste Type	Waste Disposed of (tonne)	Total Waste Recycled (tonne)	Total Waste Output (tonne)	Recycling Rate (%)
Construction Debris	12,600	1,191,100	1,203,700	99%
Used Slag	5,700	335,900	341,600	98%
Ferrous Metal	67,600	1,171,600	1,239,200	95%
Non-ferrous Metals	14,500	102,800	117,300	88%
Scrap Tyres	3,700	18,300	22,000	83%
Wood/Timber	97,400	176,500*	273,900	64%
Paper/Cardboard	603,200	765,000	1,368,200	56%
Horticultural Waste	149,800	89,000*	238,800	37%
Glass	51,400	21,400	72,800	29%
Textile/Leather	113,700	17,300	131,000	13%
Plastics	656,000	77,000	733,000	11%
Food waste	605,800	69,700	675,500	10%
Others (stones, ceramics & rubber	325,200	3,200	328,400	1%
Sludge	152,900	0	152,900	0%
Total	2,859,500	4,038,800	6,898,300	59%

** Includes 66,600 tonnes used as fuel in biomass power plants*

3.1.2.2.3 What kind of waste is disposed of in Semakau landfill?

Semakau landfill receives about 1700 tonnes of incineration ash and 500 tonnes of non-incinerable waste every day. Almost all the material that comes to Semakau has passed through one of the city's four incinerators, reducing it to approximately 24% of its original volume. Waste from construction material is also processed, while toxic waste like asbestos is packaged in such a way that it cannot leak into the surrounding environment. An overview of the types of waste material disposed of in Semakau landfill is given below.

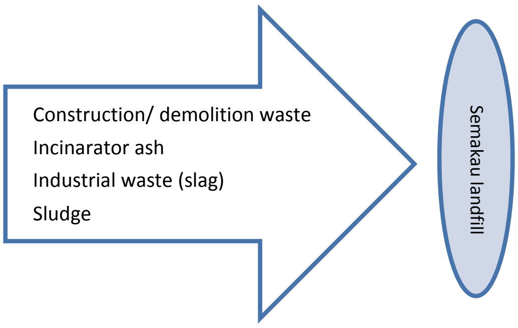

Figure 11: Waste disposed of at Semakau landfill [54].

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3.1.2.3 The land reclamation and landfilling technique

The landfill was created by reclaiming land between two small islands located 8 kilometers off the coast of Singapore. The two islands of Pulau Sakeng and Pulau Semakau were previously home to small fishing villages, but nowadays are joined by a 7 km perimeter bund (embankment) which encloses part of the eastern sea area around them. See overview below.

Figure 12: Semakau landfill's 7 km perimeter bund [58].

The entire perimeter bund is lined with an impermeable membrane and clay as outlined in Figure 13. The waste, mainly ash, is shipped there every night in a covered barge (to prevent the ash from getting blown into the air) and is compacted within the membrane.

Figure 13: Outline of the perimeter bund [58].

Any leachate produced is processed at a leachate treatment plant and regular water testing is carried out to ensure the integrity of the impermeable liners.
The area inside the landfill is divided into 11 'cells' for Phase I, which are lined with thick plastic and clay to prevent any harmful material from seeping into the sea. Phase II is not touched yet. The next fugure shows the site design.

Figure 14: Semakau landfill's site division [49, 51, 52].

3.1.2.4 Development plan after reclamation

Singapore's National Environment Agency (NEA) is looking into the feasibility of developing an eco-park on Semakau Island after landfilling. The island was opened to members of public for recreational activities in July 2005, since then, its rich biodiversity has led to its popularity with nature lovers.

Studies are being conducted by RSP Architects and Jurong Consultants on how to transform a quarter of the island or some 90 hectares into an eco-park, which will provide numerous opportunities for both public and private companies to venture into new areas of technologies.

According to NEA, the eco-park will help Singapore gain a competitive edge in driving the development of the critically important clean and green technologies. If implemented, the Semakau eco-park will become the center for the test bedding of renewable and clean technologies, such as wind, solar, tidal power, fuel cells, desalination, renewable clean fuel, etc. in Singapore. The park will also house eco-friendly recreational and educational facilities powered by renewable energy and be able to generate enough energy and water to become a self-sustaining eco island [53].

Figure 15: Overview recreational activities on Semakau landfill [56].

3.1.2.5 Environmental impact reduction measures

Semakau landfill has been constructed with innovative engineering solutions and prudence to contain all wastes within the landfill area and so prevent any kind of leach. The perimeter bund, lined with rock layers, impermeable membrane and marine clay, keeps the surrounding waters pollution-free, and any leachate generated within the site is treated in a dedicated leachate treatment plant. Great care has also been taken to ensure that the landfill is clean, free of odors and aesthetically scenic. As such, the marine ecosystem on and around Semakau landfill is well protected and flourishing.

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During the construction, a rigorous marine monitoring program was established to ascertain if there was any impact on the still extant reefs around the reclamation area. Silt screens were also erected to protect the coral reef on the western side of the island from excessive siltation.
Moreover, two mangrove groves that were destroyed when the embankment was built have been replanted near the landfill and today they serve as biological indicators for the local environment. If they were to start dying, it would be seen as a sign that harmful material had leaked from the landfill. Together with the island's other ecosystems such as sea grass meadows, coral reefs and sandy shores, the mangroves serve as a habitat for a variety of birds, fish and plants [57].

3.1.3 Japan case analysis: Yumeshima Island, Osaka

3.1.3.1 Background and context

Osaka is a centrally located, large metropolis that boasts the third largest population in Japan (2.63 million as of October 2005). Together with the Tokyo metropolitan area, it serves as the nation’s center of production and economic activity.
Yumeshima is a reclaimed island of about 2.88 million m^2 and an initial waste acceptance capacity of about 50 million m^3 in the North Port (Hokko) district, intended to secure disposal sites for wastes from the urban activities of Osaka. The reclaimed land of this island along with other islands is also valuable for Osaka as new urban development space, after completion of waste disposal. In order to make the reclaimed land ready for use, it was essential to construct reclamation seawalls and improve ground foundation. The construction commenced in 1977 and the seawalls, partition dikes and other basic structures were completed in 1994. Waste disposal began in 1985 [33]. The figure below shows an overview of the island and its surroundings.

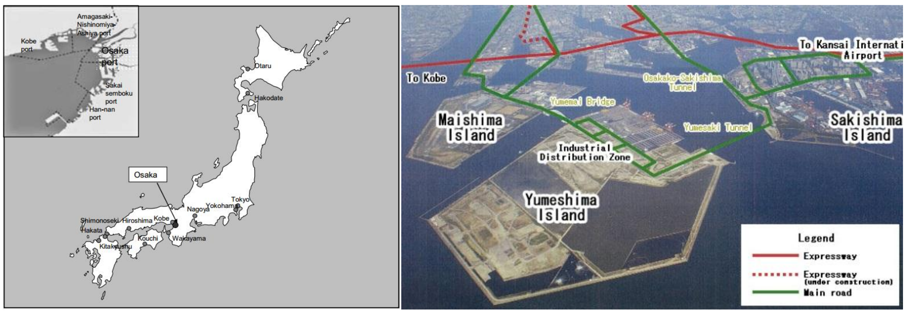

Figure 16: Overview of Osaka, Yumeshima Island and its surroundings.

3.1.3.1.1 Socio-economic context

In Japan, social and economic circumstances of ports and harbors had been dramatically changing as we entered the 21st century. To develop the Port of Osaka with functions that respond to the needs of the new era, it was essential to secure new sites for urban development.
Accordingly, reclamation of a new island was planned along with securing waste final disposal sites.
According to the [33], the necessity for this reclamation of new islands, beside the need to secure more final disposal site for the city’s waste, lies with the following:

- Development of sophisticated harbor distribution base and new urban distribution industrial base;
- Preservation of good urban environment;
- Demand for sites caused by redevelopment of existing urban areas;
- Preparation of site for new city center of Osaka;
- Development of beach to improve water quality and prepare waterfront amenities.

3.1.3.1.2 Governmental context

From the 1950s through into the 1970s, in particular, during which time Japan experienced dramatic economic growth, waste resulting from urban activities in the Osaka City area increased rapidly. Despite recycling and reuse efforts, a considerable amount of waste remained for final disposal.

Although the City of Osaka disposed of such waste in land disposal sites, it became difficult to secure additional final disposal sites in the already urbanized, overcrowded area.

To solve this problem, a project was formulated for reclaiming Maishima, Yumeshima and the New Island (Phoenix Project) in the Hokko district, so as to secure an offshore site for final disposal of waste [33].

3.1.3.2 Solid waste management (SWM)

3.1.3.2.1 SWM system

The features of Solid Waste Management in Osaka City are based on the following:

1. Adoption of incineration for the main intermediate waste treatment method
   - Reduction of waste volume (reduction rate: 1/25)
   - Energy recovery (steam, electricity generating)
2. Proper pollution control at large scale sanitary landfill sites
   - Daily covering with soil
   - Adequate leachate treatment
3. Sufficient control of emissions from incineration plants.

The following overview shows the waste management system (unit in 1000 tons).

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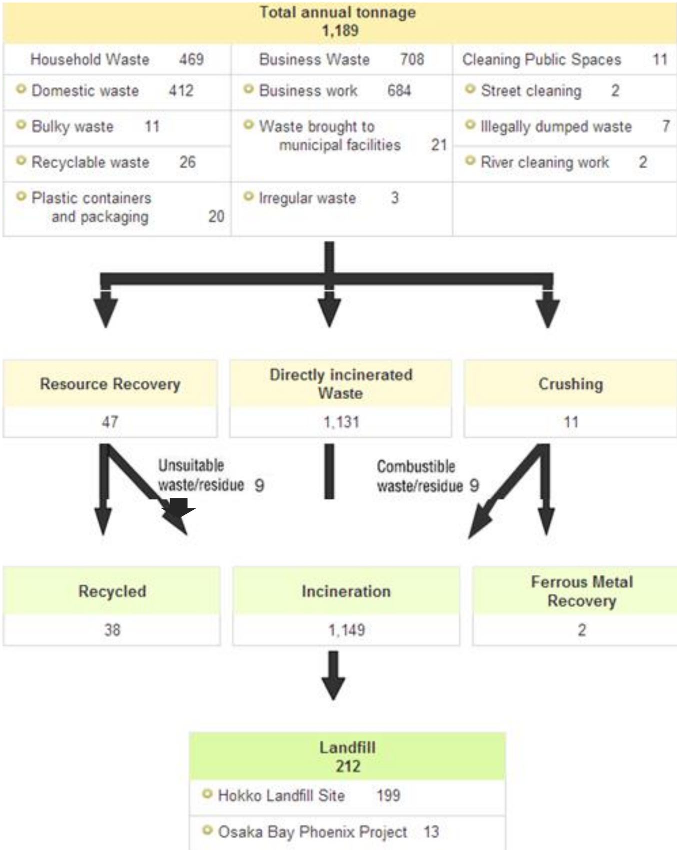

Figure 17: SWM system Osaka, unit: 1000 tons [59].

3.1.3.2.2 Solid waste disposal infrastructure

Domestic waste collection and plastic containers and packaging collection occurs respectively twice and once a week. Also recyclable waste is collected weekly and bulky waste upon request; after collection, bulky waste is slowly shredded at waste-crushing plants, where metallic (iron and aluminum) materials contained in the shredded waste are collected and recycled. After this process, the rest of the waste is incinerated.

Street and river cleaning is done respectively by street sweepers and the River Office, cleaning main roads and collecting floating waste in the city's eleven revers. In addition, efforts are made to remove and prevent illegal dumping of waste or soil.

Large amounts of waste generated by businesses are collected by waste processing firms (as of April, 2011). Individuals or businesses disposing of a large volume of waste, including earth and sand can do this directly at the municipal waste treatment facilities after completing procedures at the Environmental Management center. This Environmental Management center also offers direct waste collection services upon request [59].

Promoting Thermal Recycling, the city collects heat energy produced during incineration of waste generated. An overview of the incineration plants is given in the Figure below. The residual ash is deposited of in final disposal sites.

Table 6: List of Osaka's incineration plants and their building information [57].

Name	Capacity	Construction time	Heat utilization	ISO Acquisition
Morinomiya plant	300 tons a day 3 incinerators	1966-1968	Steam provision for nearby facilities	2001
Taisho plant	300 tons a day 2 incinerators	1976-1980	Power generation (3,000 kW)	2005
Crushing facility	Rotating 140t/5h Shear Expressions 50t/ 5h	1986-1987		
Suminoe plant	300 tons a day 2 incinerators	1985-1988	Power generation (11,000 kW) Power supply for nearby facilities	2003
Tsurumi Factory	300 tons a day 2 incinerators	1987-1989	Power generation (12,000 kW)	2002
Nishiyodo Plant	300 tons a day 2 incinerators	1990-1994	Power generation (14,500 kW) Steam power supply for Elmo Nishiyodogawa	2000
Yao Plant	300 tons a day 2 incinerators	1991-1994	Power generation (14,500 kW) Power supply for Yao Sanitary Disposal Facility Steam supply for Yao Indoor Pool	2001
Maishima Plant	450 tons a day 2 incinerators	1996-2001	Power generation (32,000 kW) Steam supply for Maishima Sludge Center	2004
Crushing equipment	Rotating 120t/5h Shear Expressions 50t/ 5h	1996-2001		
Hirano Plant	450 tons a day 2 incinerators	1998-2002	Power generation (27,400 kW) Power Supply for Rifure Uriwari	2005
Higashiyodo Plant	200 tons a day 2 incinerators	2005-2009	Power generation (10,000 kW)	2011(planning)

The city of Osaka has been promoting the improvement of its incineration plants for many years. Because of aging and changes in waste quality, some incineration plants need improvement. Therefore the city is gradually renovating those facilities with the latest pollution control equipment. A waste delivery to plants breakdown by type is given below.

Figure 18: waste delivery to plants breakdown by type [59].

3.1.32.3 What kind of waste is disposed of in Yumeshima Island?

On the island Yumeshima, waste disposal is divided into four sections:

- Section 1 will have an area of about 0.73 million m^2, and receive about 11.69 million m^3 of general wastes, including residues of incinerated domestic waste and waste generated from operation of such public facilities as waterworks and sewerage systems;
- Sections 2 and 3 will have a total area of about 2.15 million m^2, and receive about 38.31 million m^3 of excavated soil from civil engineering and construction work sites and dredged soil from rivers and harbors;
- Section 4, expected to provide a site for a harbor physical distribution base is being reclaimed using normal mountain soil and surplus soil from construction work sites.

See the following figure.

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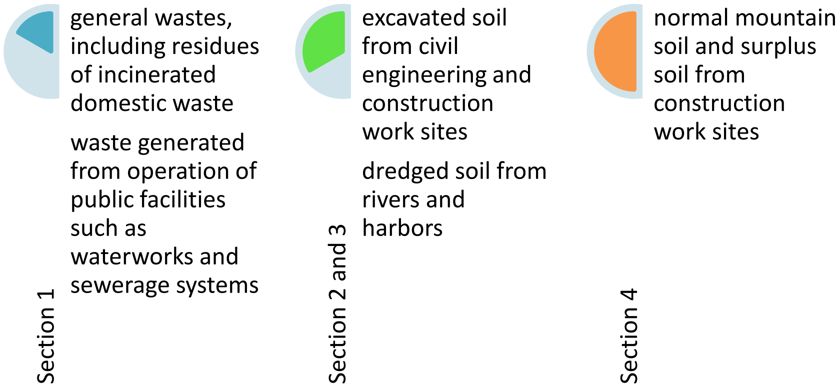

Figure 19: Waste disposed of at Yumeshima Island [33].

The following figure shows an overview of the sections on Yumeshima Island.

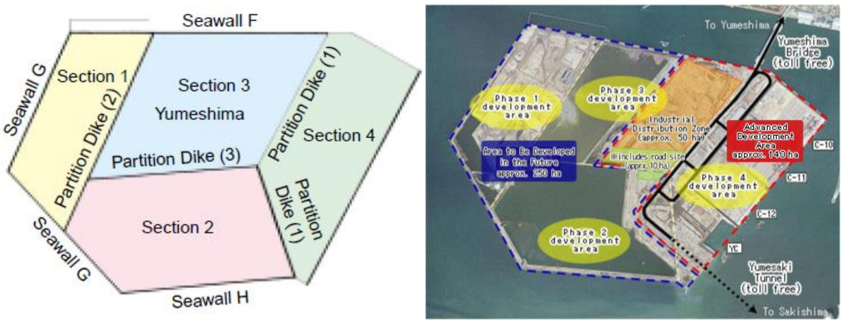

Figure 20: Plan view of Yumeshima Island [33].

3.1.3.3 The land reclamation and landfilling technique

The reclamation method for the waste disposal site is fundamentally the same as general reclamation using ordinary sand and soil, except that in this project, dredged soil is also used. The soil for reclamation is transported by barge from a waterfront loading base. After being unloaded by crane, the soil is dumped in the designated place by the use of dump trucks and bulldozers.

Concerning disposal of general waste, the “sandwich” method was adopted after the reclaimed land reached above sea level; by this method, after filling general waste to a thickness of less than three meters, a 50 centimeter-thick normal soil cover is formed on the waste layer. This is a necessary, and legally required, measure for promoting decomposition of waste into soil, preventing waste scatter, reducing contaminated water exudation and maintaining hygiene.

Regarding dredged soil, two methods are used: one is to deliver dredged soil directly to the waste disposal site using pump dredgers; the other is to load dredged soil onto barges using grab dredgers, transport it by sea to the disposal site, and then direct it to the designated location through discharge pipes from unloader ships [25].

In this district, a soft alluvial clay layer peculiar to the Osaka area has formed from the seabed to a depth of approximately 20 meters. Without ground foundation improvement, therefore, the sea bottom cannot be used as a foundation for various urban facilities.

Moreover, since Sections 2 and 3 were expected to accept as much waste as possible for disposal, various measures had to be devised, including raising the heights of surrounding seawalls and forced subsidence of the foundation ground. As a result of cost efficiency and various other studies, it was decided to adopt the sand drain method, together with lowered groundwater level using drainage wells, so as to promote compaction and subsidence of the sea bottom clay ground.
As for section 1, where incinerated general waste residues are disposed of, it is yet unclear what landfilling technique will be applied.
More details about the construction of the reclamation seawalls and the ground foundation improvement is added in Appendixe B.

3.1.3.4 Development plan after reclamation

With increasingly borderless and globalized public awareness of environmental issues in recent years, environmentally friendly urban development is desired. For the Port of Osaka, the Eco-port Project is under way with the aim of creating and protecting desirable water environments, with the Ministry of Transport as leader. As part of this project, plans were discussed to establish a beach at the seawall on the west side of Yumeshima so that the seawall, which is of the upright type, will be given a gradual incline, contributing to diversification of biota and water quality improvement. The figure below gives an impression.

Figure 21: Eco-port project Yumeshima [36].

In accordance with the “Osaka Master Plan 21” and building on the unique features of the waterfront area, Yumeshima Island has been designed as a new city center, incorporating business, residential and recreational zones. Development on the island involves utilizing the latest technology to create an environmentally-sound urban district, featuring 15,000 residential dwellings in an arbor rich setting. An artist’s impression of the master plan is given below.

Figure 22: Artist's impression Master plan Yumeshima [60].

This master plan compared to the land reclamation section's map and the current situation leads to the conclusion that the landfill material determines what function is to be developed on the reclaimed land.

- Section 1 being filled with general wastes, including residues of incinerated domestic waste and waste generated from operation of public facilities such as waterworks and sewerage systems, is meant to be a nature site (park);
- Sections 2 and 3 being filled with excavated soil from civil engineering and construction work sites and dredged soil from rivers and harbors, is meant for the city center, with residential and business buildings.
- Section 4 being filled with normal mountain soil and surplus soil from construction work sites, is meant for a harbor physical distribution base (heavy structures).

Figure 23: (left) Plan view of Yumeshima Island [33] and (right) current situation view (source: Google maps 14 Nov. 12).

The Port of Osaka, offering a range of facilities, including a yacht club, natural bird sanctuary, fishing park and Japan's first, wave-maker equipped, marine swimming resort, is widely regarded as `the place' for outdoor recreation. Aiming to create a thriving natural environment, a series of beaches and rocky shorelines are being developed on western islands of Maishima and Yumeshima. See location in the Figure below.

Figure 24: Eco-port Osaka [60].

3.1.3.5 Environmental impact reduction measures

In Section 1, waste water resulting from reclamation and contaminated water exuded through the landfill undergo surface aeration through floating aerators and biological oxidation treatment in a high-efficiency oxidation pond divided by permeable partitions. Concerning landfill layers above sea level, each layer is provided with a guide zone to which landfill gas is led for combustion at the end of the zone, to promote waste decomposition. Dredged soil is directed alternately into Sections 2 and 3. While one Section is being filled, the other is used as a sedimentation pond to prevent the release of fine soil particles from the disposal site.

In addition to the above-mentioned efforts, all possible environmental monitoring measures are taken, including water examinations in the area surrounding the disposal site to check COD (chemical oxygen demand), BOD (biochemical oxygen demand), SS (suspended solids) and other values, and ensure that there is no environmental impact [25].

3.1.4 Case comparison through MCA

The objective of the comparison of the land reclamation cases of Singapore and Japan, where waste is used as fill material, is to find out which method or combination of methods is better to be applied for the case of Jakarta with respect to the different contextual settings of each project. The eventually chosen method or combination of methods will form **Alternative 1** and will be evaluated later on and compared with the alternatives of new expertise and technologies.

For the comparison of the cases of Singapore and Japan, first the criteria is set according to the needed element for such a project with respect to the objective of the MCA being to evaluate how the case of Jakarta can better be addressed. Then the rating levels are determined based on the conjunctive approach of multi criteria evaluation and eventually the cases of Semakau landfill and Yumeshima Island are evaluated according to the criteria and rating levels. At the end the scores are determined and a conclusion is drawn.

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3.1.4.1 Determining the criteria and rating levels

After the analysis of both cases, Semakau landfill and Yumeshima Island, the following criteria, important for the implementation of any of these methods of land reclamation with the use of waste as fill material in Jakarta are detected. The following table shows these criteria and their elucidation.

As mentioned above, the rating is based on the conjunctive approach of multi criteria evaluation and measures the deficiency level of each method to meeting the criteria. The ratings are:

- Minor deficiency (min def): favorable situation where the method has a positive impact on the criteria.
- Major deficiency (maj def): unfavorable situation where the method has a negative effect on the criteria.

Table 7: Criteria.

Criteria	Elucidation
Socio-economic context	The impact of the method on the socio-economic context of the city and the contribution of this socio-economic context to the success of the method.
Governmental context	The impact of the method on the governmental context of the city and the contribution of the governmental context to the success of the method.
SWM system	The efficiency and effectiveness of the SWM system and its impact on the method, but also the impact of the method on the SWM system in the city.
Incineration capacity	The availability of enough incineration capacity.
SW availability	The availability of waste that can be used as fill material.
Used landfilling technique	The impact of the used landfilling technique on the success of the method. With respect to innovativeness, efficiency, sustainability, profitability and social aspects.
Development plan after landfilling	The way the development plan is linked to the landfill material and the flexibility of this plan.

3.1.4.2 Comparison

Now that the criteria are determined and the rating levels are known, the next table shows how the cases of Semakau landfill and Yumeshima Island are compared and what the eventual scores are. The underlying elucidation explains why a method has a minor or major deficiency to the criteria.

Table 8: Comparison of the cases of Semakau landfill and Yumeshima Island.

Criteria	Semakau landfill	Yumeshima	Elucidation
Socio-economic context	Min def	Min def	In both cases, there is support from the inhabitants, who understands the need of such project. Any opposition to the plans was not mentioned. One could imagine that the inhabitants of the fisherman's villages in Pulau Semakau and Pulau Sakeng could have been opposed to the reclamation plan of Semakau landfill, but no data was found here about.
Governmental context	Min def	Min def	In both cases the project originated from the government or governmental departments/ agencies, which were also mostly responsible for the project's realization and maintenance.
SWM system	Min def	Min def	In both cases the SWM system is well organized. Waste collections are done regularly and the inhabitants are involved.
Incineration capacity	Min def	Maj def	Amount of waste to incinerate in Singapore is 7,083 tonnes/day against a capacity of 7,600 tonnes/day. For Osaka is this 3148 ton/day against a capacity of 2900 ton/day (with a deficiency of 248ton/day).
SW availability	Min def	Maj def	Daily 2205 tonnes is disposed of at Semakau landfill and 545 ton at Yumeshima Island.
Used landfilling technique	Maj def	Min def	The technique applied in Semakau landfill is more of general approach where the case of Yumeshima knows some particular techniques.
Development plan after landfilling	Maj def	Min def	Semakau landfill is more like a traditional landfill where the reclaimed land is turned into an eco-park after landfilling. This plan is not flexible. There is no heavy structure on the land. All building developments are planned on the already existing islands of Pulau Semakau and Pulau Sakeng. The spatial plan of Yumeshima is more flexible with different functions planned.

3.1.5 Conclusion and summary of the suitable elements for the case of Jakarta

In order to use existing knowledge and expertise for the use of waste in land reclamation projects in Jakarta, similar cases from Singapore, Semakau landfill and Japan, Yumeshima Island Osaka are studied and compared with consideration of the aspects of Jakarta. The case study outline was set and the cases were analyzed and compared according to the

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conjunctive approach on the therefore pre-defined criteria. As result, both cases had 2 major deficiencies each. The case of Yumeshima scored its major deficiencies on the incineration capacity and waste availability and the case of Semakau scored its major deficiencies on the characteristics of the used landfill technique (innovativeness, sustainability, profitability) and the flexibility of its spatial development plan after reclamation. However the case of Yumeshima is more similar to the case of Jakarta, because of the multifunctionality of the spatial development plan after land reclamation. Because the context and settings of Yumeshima are different from the context and settings of Jakarta, there would probably be a lot of changes in the process, method or technique of the land reclamation project of Yumeshima in order to be able to successfully implement it in Jakarta.
The elements from this analysis that are suitable for the case of Jakarta along with the conditions they need to meet for a successful implementation form together **Alternative 1** of the land reclamation methods.

3.1.6 Alternative 1: Land reclamation method with the use of compost and incinerator ash as fill materials

This alternative is identified as the combination method of the existing cases of Semakau landfill (Singapore) and Yumeshima Island (Osaka, Japan), where the environmental and stability issues of land reclamation with the use of waste are covered as follows:

The environmental issues	• covered by the use geo-membrane to isolate the waste (incinerator ash, sludge, contaminated construction and demolition waste, contaminated industrial waste) from the surrounding environment.
The issues of the reclaimed land not being strong enough to be built on	• covered by using compartments during landfilling; • using soft fill materials (incinerator ash, sludge) for areas meant for golf courses and other functions of natural-recreational character, like the case of Semakau landfill; • using stronger fill materials (construction and demolition waste, excavated earth, and mountain soil) for areas where buildings are planned, like the case of Yumeshima Island.

Figure 25: Environmental and stability issues of A1.

The plan is to transform Jakarta to a waterfront city. The massive development plan includes industrial infrastructure, office buildings, hotels, business centers, mega shopping malls, seaports, elite housing estates, condominiums, and transportation infrastructure.

3.1.6.1 The method: SWM within Alternative 1

An effective solid waste management system is very important for the use of waste as fill material within land reclamation. Waste that can be used for the landfill need to be collected, pre-treated (by incineration and composting) and transported to the reclamation location.

Unlike the case of Singapore and partially the case of Japan, where the main objective was to secure landfill sites, the case of Jakarta's main objective is to create new land. This means that the availability of waste as fill material is very important for the time frame of the land reclamation projects. However, producing more waste than necessary is environmentally not responsible and one should make sure that all recyclable waste is recycled. Therefore, the land reclamation projects will only rely on making sure all the available waste is collected and the remaining waste after recycling is prepared for the land reclamation.
A great deal of the municipal solid waste needs to be incinerated before use. Therefore the incineration capacity needs to meet the incineration demand. Also organic waste needs to be composted.

Incineration
Incineration reduces the amount of waste up to 90 % excluding waste that cannot be burned (building debris, old refrigerators, etc.) or waste that is missed when the facility is closed for repairs. When that taken into account, incinerating reduces the waste volume up to 60-76%. In the case of Singapore was this reduction up to 76%. So the incineration ash is 24% of the incinerated waste amount [56].
When the objective is to assure landfill space for a long-term period, this will be a positive aspect, but when the objective is to secure a sufficient quantity of waste for land reclamation as it is the case of Jakarta, reducing the waste volume is rather a negative aspect. However before use within the land reclamation, the waste needs to be treated in such a way that the risk of subsidence remains very low and the reclaimed land stable enough. Incineration is then a good way of compacting waste in order to make it more stable.

Composting
As for composting, the choice of an adequate composting method is relevant. As mentioned in the literature review the windrow composting technique is used in Jakarta, however it is interesting evaluate this technique and determine if other techniques are more suitable.
In Asia, only a few composting facilities are in operation. Windrow technologies seem to be the mostly applied option. More frequently, the small and medium-sized facilities run more successfully compared to the larger facilities, which have a record of operational failures [24].

Windrow composting
Windrow composting is a cost effective active composting process that provides a quality compost and ensures environmental protection. According to [25], a financial analysis of the labor-intensive Indonesian Windrow Technique (applied in Dhaka) revealed that a revenue from compost sales covered 91% of the operation costs and 76% of the total annual costs of the plant. The analysis did not include the land acquisition cost as the land was freely given by the government. This case is one example of a viable decentralized composting plant, which saves the municipality transportation and landfill services costs. In addition, this way of composting is already applied in Jakarta, although it needs improvement especially when the compost is going to be used as fill material for the land reclamation.

Most of the existing waste separations systems in Jakarta seem to fall eventually. In the near future, making compost from mixed waste will probably be unavoidable due to the nature of

the waste management systems that are practiced in Asia [24]. Expert consultation led to the recommendation of the VM-press technology.
The VMpress is a waste pressurizing machine designed to physically separate waste into two fractions, an organic wet fraction and a solid dry fraction. The separation process consists of a chamber with a very strong mesh, in which waste is compressed using a high pressure of 600-1000 Bar. This results in changing the structure of the organic material, allowing it to be pressed through the mesh. This wet organic fraction can be composted. The dry non-organic fraction after undergoing an additional separation process to sort out any metals and minerals, will contain only refuge derived fuel and recyclables, which could directly be recycled and incinerated. The VMpress can process from 3 up to 35 tons of waste per hour [63].

With an average waste production of 6000 tons/day, where 55,37% is organic and 44,63% inorganic, 37,4% (considering a maximum recycling principle) are recyclables and 7,23% is non-recyclable (see waste composition paragraph 2.3.2), when all recyclables are recycled and all organic waste (55,37%) is composted, there will remain 7,23% for incineration and when the organic waste is also incinerated, will this be 62.6% [35].

3.1.6.2 Social context

In the cases of both Semakau landfill and Yumeshima Island, it is to remarque that the governmental support and involvement was large. This surely helped the success of those projects. In the case of Jakarta, the governmental involvement and support is also necessary. However the participation of private parties en investors as well.
The social context needs to be favorable. The city of Jakarta needs to be ready for such a complex and innovative project. The social impacts of the use of waste as fill material in land reclamation need to be limited. It is therefore recommended to conduct an extensive research on the social aspects and how to make them as favorable as possible, limiting the negative social impact of such a project.

3.1.6.3 Environmental aspects

In the cases of Semakau landfill and Yumeshima Island, the environmental impact was limited. Precautions were taken to pre-process the waste before use and during construction. The waste is isolated from the surrounding area and the sites are constantly monitored to evaluate their state and to be able to act quickly when there is any leak. Precautions are taken to collect and treat any leachate and landfill gas is led for combustion to promote waste decomposition. Great care has also been taken to ensure that the landfill is clean, free of odors and aesthetically scenic. Those precautions also need to be taken in the case of Jakarta.
As for the incineration of waste, the environmental burden is rather high. Pollution control equipment can remove some, but not all of the heavy metals from the stack gases. But the metals do not disappear; they are merely transferred from the air into the ash, which then has to be landfilled or in this case used as fill material. So the cleaner the air emissions, the more toxic the ash. Also, pollution control technologies for different pollutants are often incompatible. Scrubbers designed to filter out particulates and heavy metals, cool the exhaust gas to the ideal range for dioxin formation. So decreasing the emission of one pollutant increases the emissions of others. And no pollution control device can eliminate dioxin or heavy metal emissions completely. The leftover ash can be very toxic, containing

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concentrated amounts of lead and cadmium, as well as dioxin and furans [13]. The use of a geo-membrane can prevent the leach of those heavy metals into the sea but not indefinitely. The performance level of a geo-membrane is unpredictable after 50 years. This could mean excavating the fill materials and replacing the geo-membrane every 50 years or at least taking other reinforcement precautions. Which could be very costly and environmentally burdening, especially when natural areas are flourishing on the reclaimed land.
Composting organic waste is on the other hand one of the simplest ways to prevent emissions of methane because the organic fraction of the waste stream is diverted from any landfill. While composting does release carbon dioxide, it is currently considered to be a neutral process since the removal of carbon dioxide from the atmosphere by photosynthesis to produce organic matter is also not considered [16].

3.1.6.4 Economic aspects

In addition to the common costs of land reclamation for all different alternatives, such as the costs of reclamation sea-wall or perimeter contour and in this case, where waste is used as fill material, the costs of waste collection and separation, the following costs needs to be considered for alternative 1:

- The costs of constructions and preparations on the land reclamation site:
    - Ground foundation improvement
    - Compartmenting
    - Isolating: geo-membrane
    - Leachate treatment
    - Gas recuperation
    - Monitoring
    - Reclaimed land stabilization
- The costs of waste treatment and transportation to the land reclamation site
    - The building of sufficient incineration plants
    - Operation and maintenance costs of incineration
    - The building of sufficient community composters
    - Operation and maintenance costs of community composters

Costs of incineration and composting
When the organic waste is composted, the remaining waste is 7.23%; in the case of Jakarta is this 434 tons/day. When this waste is incinerated, assuming the incineration ash is 24% of the incinerated waste amount, the resulting ash will be **104 tons/day**.
Considering that during the composting process the organic waste will reduce in weight by up to 50% [34], when all organic waste (55,37% of 6000 tons/day) is composted there will be **1662 tons/day** of compost produced. It is to note that not all the compost can be used as fill material because it is also used as fertilizer in the agriculture sector.

Because of the lack of available data on the costs of incineration, the estimates used below may be outdated. The tables below give an indication of the costs of incineration according to a study of McCrea M., et al. [27] on the cost-benefit analysis of different Waste-to-Energy technologies for the management of MSW in Singapore. However, because these costs estimates may be outdated and because the costs in Jakarta may significantly differ from the costs in Singapore, the exact costs in Jakarta need to be investigated. The following table indicates the net social costs of incineration. Combining the estimates for benefits and costs,

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the net costs to society from incinerating 1 ton of MSW range from US$0.23 to US$13.11. The breakdown of the different components of costs and benefits is summarized in the next table.

Table 9: Summary of costs and benefits of incineration (measured in 2007 US$/ton [27]).

Costs per ton MSW		Low	High
Private costs	Incineration costs	$53.30	
	Landfill costs	$5.20	
External costs	Emissions from incineration plant	$6.05	$18.93
Total social costs=	Private costs + External costs	$64.55	$77.43
Benefits per ton MSW		High	Low
Private benefits	Electricity generation	$41.01	
External benefits	Avoided environmental cost associated with electricity generation	$23.31	
Total social benefits=	Private benefits + External benefits	$64.32	
Net social costs=	Total social costs - Total social benefits	$0.23	$13.11

Private costs = the annualized capital costs and the yearly operating costs associated with the management of one ton of MSW.
Private benefits = the avoided production costs of electricity generated from the management of each ton of MSW.
For the 434 tons/day of waste to be incinerated, based on the estimates above, the net costs will be between **US$ 100 and US$ 5,690 /day** with an average of **US$2,895**.

As for the costs of composting, the average total costs (investment, operation and maintenance costs) of communal composting is estimated at US$ 695,400/year for a 200 tons/day communal composting facility [2]. This means **US$ 9.5/ton of waste** and **US$ 19/ton of compost** (as the compost produced is 50% of the waste composted).
3322 tons/day of organic waste (55,37% of 6000 tons/day of waste produced) would cost approximately **US$ 32,388/day**.

As for the public welfare, very few jobs are created in return for this economic investment. Most of the jobs created during the building of the plant are temporary. A large incinerator may employ about 100 workers. On the other hand, if the community puts its efforts into source separation, reuse and repair, recycling and composting, many more jobs are created, both in the actual handling of the waste and in the secondary industries which utilize the recovered material.
Also, the engineering firms that build incinerators are seldom located in the host community and thus most of the money invested leaves the community. On the other hand, money invested in the low-tech alternatives stays in the community creating local jobs and stimulating other forms of community development [13].

3.1.6.5 Conclusion

Alternative 1 means compartmenting the land reclamation site, as was done in the case of Yumeshima Island in Osaka, Japan. Creating sections where:

- Section 1, expected to provide a site for heavy constructions will be reclaimed using normal mountain soil and surplus soil from construction work sites.
- Section 2, expected to provide a site for the construction of an urban area (residential and business area) will be reclaimed using excavated soil from civil engineering and construction work sites and dredged soil from rivers and harbors.
- Section 3, expected to provide a site for golf courses, light recreational activities and park functions will be reclaimed using incinerated and composted general wastes, including waste generated from operation of public facilities as waterworks and sewerage systems.

For section 1 and 2, the availability of mountain soil, surplus soil from construction work sites, excavated soil from civil engineering and dredged soil from rivers and harbors needs to be evaluated. There was no data to be found about the annual amounts of mountain soil or excavated construction earth in Jakarta. On the other hand in 2011 in Singapore **8.5 million m^3** of materials were excavated to build basement carparks and shops, underground expressways, and MRT tunnels [65]. However, the annual amounts of excavated earth in Jakarta may differ greatly from the amounts in Singapore as the need of underground constructions is assumed to be more urgent in Singapore than in Jakarta.

For section 3, the combination of incineration ash and compost seems to be the most convenient with **1766 tons/day** of landfill. As composting alone would lead to 1662 tons/day of compost (50% of the organic waste composted) and incinerating alone would lead to 901 tons/day of ash (24% of the incinerated waste, in this case 62.6% of 6000 tons of waste/day). 1766 tons/day leads to a landfill material production of **644,590 tons/year** (assuming all the waste of all days in the year is treated).

Considering the sand scarcity of the land reclamation works of Jakarta, where after one year of work only 1.4 million m^3 (2,242,585 tons when 1.60 ton of excavated wet earth fits in 1m^3) of sand was gained, while, more than 200 million m^3 (320,000,000 tons) of sand is needed, assuming that section 3 (greenery) is about 30% of the reclamation site (according to the future plans of Jakarta [40]), leading to 60 million m^3 (96,000,000 tons) of sand needed for the whole reclamation project and assuming that 1 ton of incinerator ash and compost is equal to 1 ton of excavated wet earth, the time needed to produce the amount of landfill material needed for the land reclamation will be 149 years. Considering the current situation where only 1.4 million m^3 of sand is gained per year and so 30% being 420,000 m^3 (672,775 tons) for section 3, the time needed for the same amount of landfill material (ash and compost) will also be c.a. **1 year**.

An overview of the structure of Alternative 1 is shown next.

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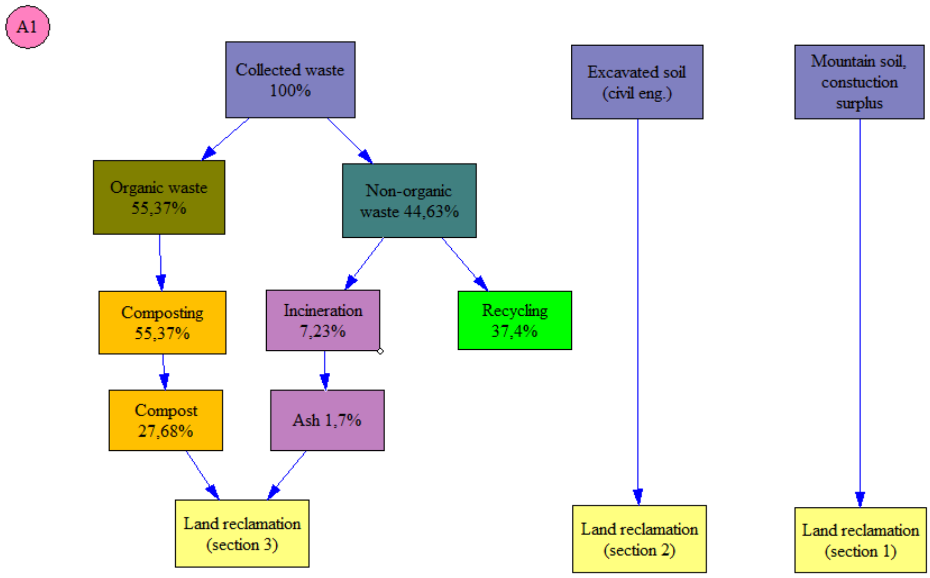

Figure 26: Structure of Alternative 1 (A1).

The table below gives an overview of the costs and amount of the fill materials within A1.

Table 10: Overview of the costs and amounts of the fill materials within A1.

Fill material	Amounts (ton/day)	Amounts (ton/year)	Unit costs ($/ton)	Costs/day	Costs/year
Incinerator ash	104	37.960	28	$2.895	$1.056.675
Compost	1.662	606.630	19	$31.578	$11.525.970

In the next paragraph, alternative possible ways of using waste within land reclamations are discussed. Because the use of waste as fill material within land reclamation is not widely applied, most of those alternatives are on pilot projects level and the data obtained is based on pilot projects reports, existing literature and expert consultations with the purpose of finding the best possible solution to the problem of Jakarta. Eventually 2 more alternatives are defined and the best possible scenario is selected.

3.2 Alternative 2 and 3: possible new expertise and technology

3.2.1 Alternative 2: land reclamation method with the use of Plasma Gasification slag as fill material

The method using plasma gasification, where the environmental and stability issues of land reclamation with the use of waste are covered as follows:

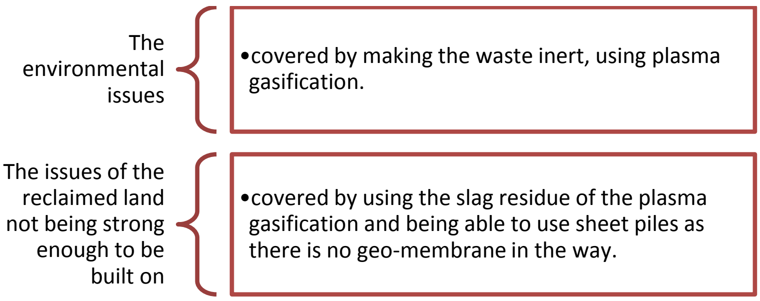

Figure 27: Environmental and stability issues of A2.

3.2.1.1 The method

This method is an emerging technology which can process MSW to extract commodity recyclables and convert carbon-based materials into fuels. Plasma gasification refers to the use of plasma torches as the heat source. Plasma torches have the advantage of being one of the most intense heat sources available, burning at temperatures approaching 5500ºC (10,000˚F). Plasma arc processing has been used for years to treat hazardous waste, such as incinerator ash and chemical weapons, and convert them into non-hazardous slag. Utilizing this technology to convert solid waste to energy is still young, but it has great potential to operate more efficiently than other pyrolysis and combustion systems due to its high temperature, heat density, and nearly complete conversion of carbon-based materials to syngas (a simple fuel gas comprised of carbon monoxide and hydrogen that can be combusted directly or refined into higher-grade fuels and chemicals) and non-organics to slag. Slag is a glass-like substance which is the cooled remains of the melted waste; it is tightly bound, safe and suitable for use as a construction material.

A study on the technical and economic analysis of Plasma-assisted Waste-to-Energy processes, by Ducharme C. [11], investigated the technologies and companies invested in forms of plasma-assisted gasification technologies. The considered companies were: Westinghouse Plasma, owned by

Alter NRG, Plasco Energy Group, Europlasma, and InEnTec, owned by Waste Management Inc. Each of these groups has developed a proprietary technology and is on the pathway to using MSW as a feedstock.

The thermal plasma technology is used extensively for surface modification and coating, vitrifying hazardous waste like asbestos and should be very interesting when applied to MSW. It has only been a few years since its application to energy production from waste. So far, only two plants using MSW as a feedstock are commercially operating in Japan, built and operated by Hitachi Metals, in Utashinai and Mihama-Makita, using the Westinghouse Plasma Corporation technology.

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The technology of Westinghouse Plasma is considered to be the most advanced of all the companies studied. Not only they have Japanese plants operating with their gasification vessel, they also have an operating pilot plant, several contracts worldwide and are the only proven economically feasible plant. The most convincing reference plant is the Utashinai Japanese plant that encountered several issues in the past but is now operating on 100% MSW. This could form a base example for the case of Jakarta when applying plasma gasification.
More information about the origin, history and development of the plasma gasification technology is added in Appendixe C along with the process of gasification and detailed information about its technology.

An overview of the plasma gasification system with its feedstock and outputs is shown below.

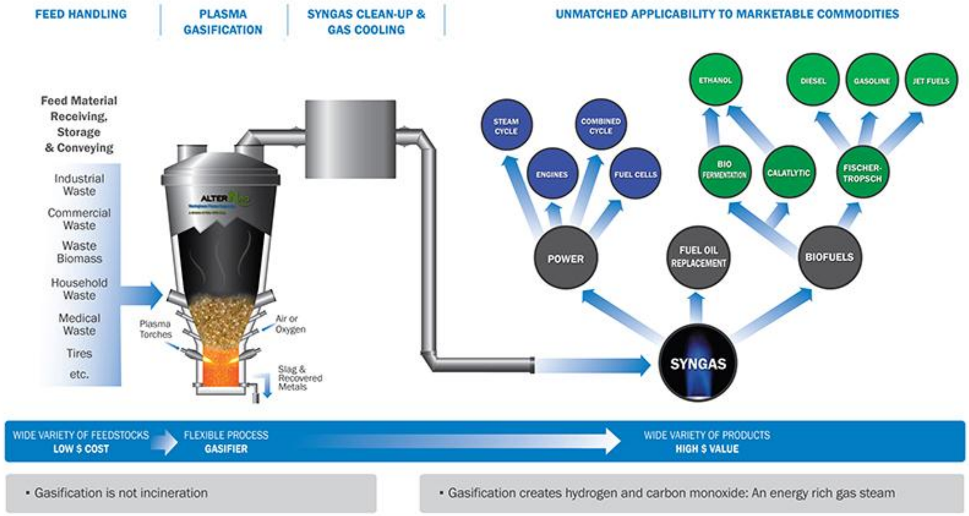

Figure 28: Plasma gasification process WPC [46].

3.2.1.2 Environmental aspects

Gasification is better than direct landfilling of the MSW or landfilling of the incinerator ash for the following reasons:

- Plasma gasification can divert waste from the traditional landfill types and create beneficial uses for the material, by maximizing recycling and cleanly using the rest for fuel. This clean material could then be used as fill material within the land reclamations projects of Jakarta.
- Gasification is better than incineration and offers an improvement in environmental impact and energy performance. Incinerators are high-temperature burners. During combustion, complex chemical reactions take place that bind oxygen to molecules and form pollutants, such as nitrous oxides and dioxins. These pollutants pass through the smokestack unless exhaust scrubbers are put in place to clean the gases. Gasification by contrast is a low-oxygen process, and fewer oxides are formed. The scrubbers for gasification are placed in line and are critical to the formation of clean gas, regardless of the regulatory environment. For combustion systems

(incinerators), the smokestack scrubbers offer no operational benefit and are put in place primarily to meet legal requirements. Plasma gasification systems employing proper scrubbers have extremely low emissions and no trouble meeting the most stringent emissions targets. The scrubbing is an integral component to the system engineering, as opposed to a legal requirement that must be met.

- Incinerator ash is also highly toxic, while the slag from plasma gasification is safe because it is melted and reforms in a tightly-bound molecular structure. In fact, one of the main uses for plasma torches in the hazardous waste destruction industry has been to melt toxic incinerator ash into safe slag. The glassy slag is subject to EPA (US Environmental Protection Agency) Toxicity Characteristic Leaching Procedure (TCLP) regulations that measure eight harmful elements. Data from existing facilities, has shown them to be well below regulatory limits [10].
- Electricity production from plasma gasification is superior to that from incinerator combustion. Incinerators typically use the heat from combustion to power a steam turbine to produce power. Gasification systems can use gas turbines that are far more efficient.
- The carbon impact of plasma gasification is significantly lower than other waste treatment methods. It is rated to have a negative carbon impact, especially when compared to allowing methane to form in landfills. The US Department of Energy has identified gasification through its clean coal projects as a critical tool to enable carbon capture [10].
- An overall superior environmental performance. The environmental benefits of a plasma gasification facility include:
    - Lower emissions: the main difference with grate combustion is the dramatic reduction of the flow of output gases, up to 75% [11];
    - Beneficial use of bi-products and a reduction in the amount of material that ultimately must be landfilled;
    - Lower greenhouse gas footprint [62].

However, environmentalists have expressed opposition to waste gasification for two main reasons:

- Although economic studies of the waste markets show that waste-to-energy favors the processing of waste to separate valuable commodities and to maximize its value for fuel, the first argument of the environmentalists is that any waste-to-energy facility will discourage recycling and divert resources from efforts to reduce, reuse and recycle.
- The second argument made against waste gasification is that it has the same emissions as incineration. These arguments are based on gasification systems which do not clean the gases and instead combust dirty syngas. There are many variations of combustion, pyrolysis and gasification, all used in different combinations. Proper engineering is required to achieve positive environmental performance.

For the land reclamation project of Jakarta the quality and availability of the slag will determine whether the alternative of plasma gasification is suitable or not. The slag from the Mihama Mikata plant (Japan) has been tested against several standards and is proven to be below the test detection limits.
More information about the advantages of plasma gasification compared with incineration and studies on lifecycle greenhouse gas emissions, where the Plasma Gasification Combined

Cycle system is proven to provide the lowest greenhouse gas emissions is added in Appendixe C.

3.2.1.3 Economic aspects

The economics of MSW plasma gasification are complex but favorable. Waste gasification facilities get paid for their intake of waste, via tipping fees. The system then earns revenues from the sale of power produced. Electricity is the primary product today, but liquid fuels, hydrogen, and synthetic natural gas are all possibilities for the future. Minor revenue streams include the sales of slag and sulphur. Slag has the potential to be used for a number of construction products, in the case of Jakarta as fill material for the land reclamation.
Additional costs are avoided by diverting waste from the current landfills which will not be needed anymore. Government subsidies for waste management, renewable energy or carbon credits may be substantial in the future, but are difficult to project.
The combination of waste management, sand saving and power production, makes this technology very interesting. The challenge for Jakarta is however to bring them all under one roof.
A base case scenario with a 750 tons/day waste gasification plant which, would cost an estimated **$150 - 190 million** to construct. This could be earned back through revenues from tipping fees, recyclables and electricity, slag and sulphur sales. However, because of the range in the values for each of these variables and differences in interest rates and taxes, any proposed development would require efforts to determine local prices for each line item.
When invested in this technology, there is need to exploit it fully in order to make it profitable. There are additional waste streams available which earn higher tipping fees than MSW. Those waste streams are toxic and yet have excellent fuel value. Refinery wastes from petroleum and chemical plants, medical waste, auto-shredder residue, construction debris, tires and telegraph poles, are all examples of potential fuels that can earn high tipping fees and provide good heat value.
Ducharme C.'s analysis [11] showed that the capital costs of plasma-assisted waste to energy (WTE) are higher than the traditional WTE plant. The reason for this could lie with the high cost of the plasma torches. The base plasma plant scenario conducted yielded a capital charge of $76.8/ton of MSW processed, which is higher than the estimated capital charge for a grate combustion WTE plant of $60/ton. The detailed costs of the processes of each company were however higher than the base case: $81/ton for Alter NRG, $86/ton for Europlasma and $86/ton for Plasco.
The energy produced per ton of feedstock is higher in plasma assisted-gasification than in grate combustion: the Alter NRG generates 617 kWh/ton of MSW, which is enough to make their process economically feasible, while the average generation for conventional (U.S.) WTE plants is 500 kWh/ton. It is interesting to underline that the sensible heat in the process gas is not recovered, otherwise, the energy generation would be higher.
More details about the costs of the different plasma gasification plants are added in Appendixe C.
The next table is also taken from the paper of Ducharme C. [11] and shows an overview of a (Alter NRG) 750 tpd plasma plant's expenses and revenues.

Alter NRG expenses $/ton		Alter NRG revenues $/ton	
Personnel	10	Gate fee	65
Other operating costs	32	Electricity to grid	61.7
Total operating costs	42	Metal recovery	2.47
		Renewable credit	0.55
Capital charges and all other	81		
Total costs	123	Total revenues at start up	129.72

Table 11: Cost data for 750 tpd WTE project [45].

Based on the table above, the immediate conclusion is that the plant is barely economically feasible with an net revenue of **$6.72/ton** of MSW.
However, the electricity generated from the waste heat was not taken into account. It can be assumed that, when the waste heat is recovered, the total electricity generated would increase from 617 kWh/ton with 332 kWh/ton to 949 kWh/ton of MSW processed, and a sale of electricity up to $86.6/ton. The total revenues at start-up would then be $155/ton of MSW, which would makes the plant feasible with **a net revenue of $32/ton** of MSW [11].
In the Alter NRG/WPC plant of 750 tpd, an annual slag production of 53,900 tons was estimated (163 tons/day with an average of 35 days shutdown per year). This means that slag produced is nearly 21.7% of the waste gasified (so 4.7 tons of waste are needed to produce 1 ton of slag, generating a net revenue of $31.6 when the waste heat is not recovered and $152.38 when the waste heat is recovered).
When 2244 tons/day (37,4% of 6000 ton/day MSW) are recycled and the remaining 3756 tons/day of MSW are treated through plasma gasification, the amount of slag available could be estimated at **815 tons/day of slag** (297,494 tons/year).
When developers reclaming the new islands are not involved within the investment of the plasmagasification, they could buy this slag at a estimated price of $ 1/ton of slag (see Appendix C).

3.2.1.4 Conclusions

Jakarta could surely use waste gasification. The world is facing profound problems in the search for new sources of energy, in addition to facing ongoing environmental degradation. For the case of Jakarta, this adds to the need of new land and the possibility to use waste (residue) as fill material for land reclamation. Plasma gasification of waste can be part of the solution to those problems. Using waste materials, as feed stocks for producing renewable fuels and clean slag that can be used as fill material for the land reclamation transforms liabilities (excess of waste production and lack of good waste management system, world's energy problem and sand scarcity) into assets.
Although, a waste gasification plant is a complex and expensive operation that presents a challenge for municipalities and private investors, it can be a municipal or publicly funded operation and can help balance budgets and provide a hedge against future increases in energy prices.
Special attention need to be put into the availability of sufficient slag for the land reclamation project. As mentioned before, this availability is estimated at **815 tons/day of slag** (297,494 tons/year).

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Considering the sand scarcity of the land reclamation works of Jakarta, where after one year of work only 1.4 million m^3 (2242585 tons when 1.60 ton of dry sand fits in $1m^3$) of sand was gained, while 20 million m^3 (32 million tons) is needed and for the whole land reclamation plan of 4000 ha, more than 200 million m^3 (320,000,000 tons) of sand is needed and assuming that 1 ton of slag is equal to 1 ton of dry sand, the time needed to produce the amount of slag needed for the land reclamation when plasma gasification is the only alternative applied will be 107.6 years for the 20 million m^3 sand projects and 1075.6 years for the 200 million m^3 projects. Considering the current situation where only 1.4 million m^3 is gained per year, the time needed for the same amount of slag will be **7.5 years**. It is therefore advisable when choosing for the plasma gasification alternative, to combine this with another alternative.
An overview of the structure of Alternative 2 is given below.

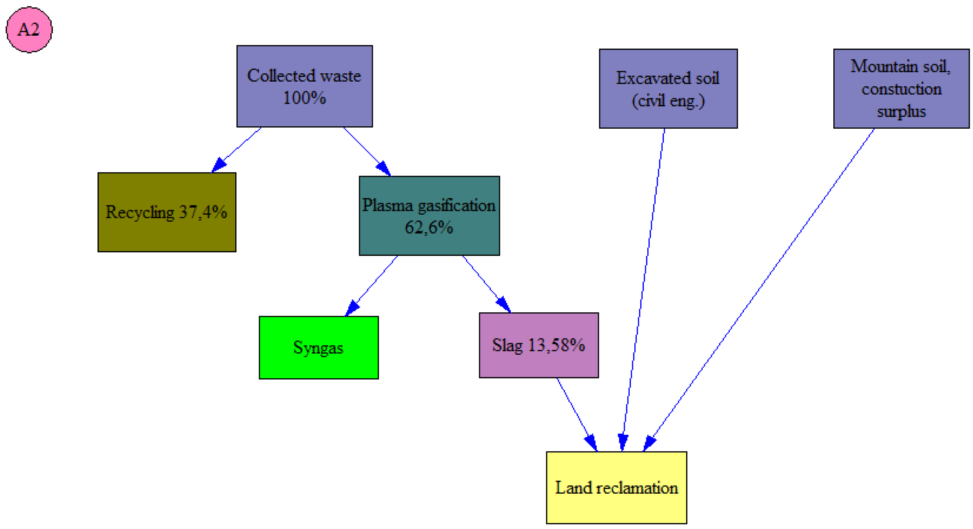

Figure 29: Structure of Alternative 2 (A2).

The table below gives an overview of the costs and amount of the plasma gasification slag, assuming the developers would just buy the slag from the energy company or any other private party.

Table 12: Overview of the costs and amounts of the plasma gasification slag

Fill material	Amounts (ton/day)	Amounts (ton/year)	Unit costs ($/ton)	Costs/day	Costs/year
Plasma gasification slag	815	297.494	1	$815	$297.494

3.2.2 Alternative 3: land reclamation method with the use of the Strengthened Sediment Technology

The method using strengthened sediment, where the environmental and stability issues of land reclamation with the use of sediment/ sludge are covered as follows:

The environmental issues	• covered by using strengthened sludge, where eventual contaminants are immobilized;
The issues of the reclaimed land not being strong enough to be built on	• covered by strengthening the reclaimed land as needed.

Figure 30: Environmental and stability issues of A3.

Strengthened sediment or in this case strengthened sludge is a new useful fill material within land reclamation projects. Research and pilot projects carried out by Deltares, together with Boskalis and the Dutch government show the safe and sustainable characteristics of this building material [43].
Strengthened sediment can be used in various above and underwater civil engineering applications/projects. Examples of applications are listed below, including land reclamation:

- Land reclamation, groins/abutments, breakwaters;
- Coverage of contaminated landfills and underwater depots;
- Soils improvement or stabilization;
- Primary and secondary dikes or embankments, levees and roads;
- River- or canal bank and bottom protections (erosion control);
- Bank and- bottom protections against hydraulic fracturing or seepage;
- Stabilizing bank constructions (e.g. sheet piling, retaining walls) by using strengthened sediment as passive weight;
- Stabilizing underwater slopes susceptible to breaching and/or liquefaction;
- Bottom protection of water reservoirs.

3.2.2.1 The method

Strengthened sediment is of good use as a substitute of sand and rubble within land reclamation projects. With this technique, dredged or excavated sludge or soft material is strengthened on-site using secondary building materials and could be directly used as fill material. The use of strengthened sediment underwater is tested during a laboratory and pilot project by Deltares and promises positive results. There is no segregation of the mixture, when being applied. The mixture hardens within a sufficiently short time preventing any flow out [47].
Process steps

- Dredging sediment: this could be sandy or organic sludge, marine clay etc. The geopolymerisation works better when the dredged sludge is directly re-used.
- Mixing with a binder: cement or a specifically selected reactive bottom or fly ash with enough free calcium. Prior to mixing, the sludge needs to be sieved, in order to remove unwanted coarse materials (plant rests, roots, bricks and stones). After mixture of the dredged and sieved sludge (high water content) with a binder, the

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base mixture remains liquid over a set period of time. This gives the advantage of having enough time for placement without getting an unwanted hardening of the base mixture directly [19].

- Placement (adding an initiator and using it directly): The mixed system is pumped on the site. In this last phase the initiator (e.g. sodium silicate) is added. This sodium silicate solution will form a gel together with the metal parts in the fly-ash to immediately convert the still liquid mixture to soft “clay”. This soft “clay” hardens further according to the mixture recipe.

The strength of the strengthened sediment can vary from clay-like to stone-like. It can therefore be used as heavy material (e.g. for river training works) or as light material (e.g. for construction on soft soils), replacing primary building materials such as sand, clay, rubble and gravel. The exact recipe depends on the specific functional or material demands of the project where it is to be applied and the composition and dry solid content of the sediment. To vary the recipe, the strengthened sediment’s characteristics can be engineered by varying the type and amount of the binder, initiator and other additives. Those characteristics are:

- Strength
- Plasticity
- Unit weight
- Permeability

For land reclamation a variable strength and unit weight is advised, as for dynamic circumstances where flow and wave attacks occur, a high strength and unit weight is advised.

The hardening of strengthened sediment involves three phases:

- Liquid phase: the mixture is liquid. The used amount of binder could determine the time that the mixture will remain liquid. This time could vary between 1 second (when using an excessive amount of Portland cement) and several minutes (when using low amounts of fly-ash and sodium silicates).
- Plastic phase: the mixture in this phase is of a plastic clay type. Its strength varies between 25 – 50 kPa. The plastic phase period also depends on the type and amount of binder used and will vary between 15 minutes and indefinitely.
- Hardening phase: also here the actual strength depends on the amount of binder used. Fly-ash will yield to the same strength as various types of cement.

An overview of the Hardening curve of strengthened sediment is given below.

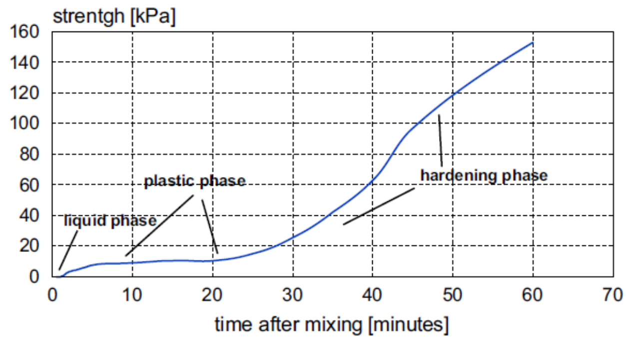

Figure 31: Hardening curve strengthened sediment [19].

Because of the high pH of the sodium silicate solution (pH = 13), the aluminum will dissolve more rapidly than the calcium ions, leading to the formation of aluminum silicate monomers, which will polymerize to aluminum-silicate chains. The calcium will crosslink the aluminum-silicate chains to a 3-dimensional feldspar-type crystal structure. In this framework, contaminants if present will be bound, resulting in chemical immobilization [19].

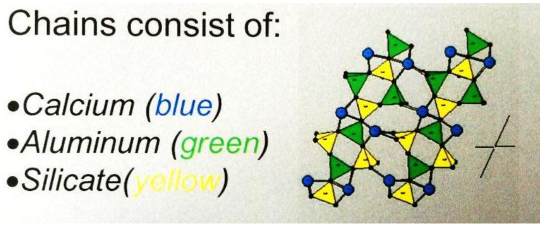

Figure 32: Structure of Anorthite /Gel structure [19].

3.2.2.2 Environmental aspects

80% of the dredged soil in the Netherlands applies to the environmental rules and will only get cleaner. Also contaminated sludge could be used for strengthened sediment because of the cold chemical immobilization of the contaminants. However, a consultative research in 2008 showed the following challenging points of the application of strengthened sediment:

- Overgrowth: pH > 7 (not applicable for underwater projects, as it is the case of Jakarta);
- Leaching (through diffusion): chemical laboratory tests are needed in case of contaminated sludge during the engineering of the recipe of the strengthened sediment. Leaching will not be a problem when the tests results comply with the environmental legislations. Monitoring is then only needed for the pH;
- Durability: more tests with time under various (climatic) conditions are needed with focus on:
  - Frost – thaw
  - Wet – dry
  - Shrinkage – swell
  - Resistance to erosion
  - Chemical bonding

For underwater applications, strengthened sediment has a great potency according to laboratory tests. The impact on the water quality is very low. A slight pH increase of 0.4 was noticed after 24 hours and after 2 weeks there was no change observed. Also preliminary resistance to erosion tests were conducted, leading to favorable conclusions [19].

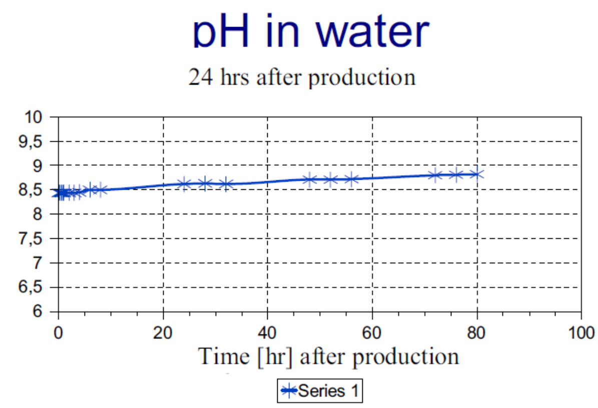

Figure 33: Impact of strengthened sediment with fly ash as binder on water quality [19].

Although water glass and cement are used in strengthened sediment, a LCA focusing on the CO_2 emission shows that underwater application of this technique could have better environmental advantages than the use of rubble. The study considered abiotic depletion, global warming, ozone layer depletion, human toxicity, aquatic Eco toxicity, terrestrial Eco toxicity, photochemical oxidation, acidification, energy, waste (hazardous and non-hazardous), etc…

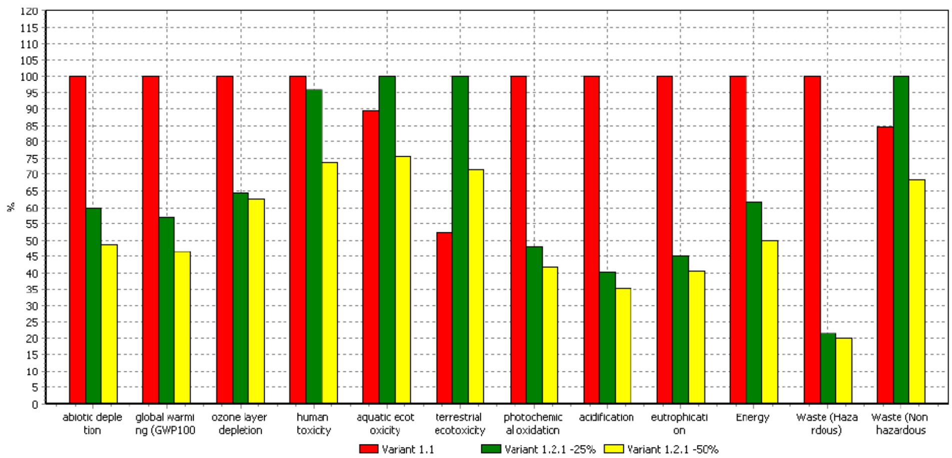

Figure 34: LCA of both protection rubble on geo-textile (red) versus light strengthened sediment with 25% less additives (green) versus light strengthened sediment with 50% less additives (yellow) [44].

3.2.2.3 Economic aspects

Strengthened sediment has proven to be economically an interesting building or fill material. According to the study of Janssen-Roelofs K., et al (2008), its costs lies between 20 a 40 % lower than the conventional approach of reinforcing embankments: independently dredging the outlet waterway (possibly followed by ripening or dumping the sludge) and strengthening the embankment with clay and possibly sand.

There are no detailed cost estimates available about the use of strengthened sediment for land reclamation. Those costs depend on the application, the recipe of the strengthened sediment mixture and the local market price of the needed materials and equipment. Therefore further research serving the costs estimate of the use of strengthened sediment for land reclamation is needed. Rough Dutch cost estimates are given in the next table.

Table 13: Rough Dutch cost estimates (source: Deltares).

Elements	**Costs**
Strengthening levees	
○ Traditional dredging and separately strengthening the levee with clay	100%
○ Alternative: dredging of the waterway combined with strengthening levee with strengthened sediment.	80%
As indication: the cost of strengthening levees with strengthened sediment is roughly estimated to be between € 25 - 45 per m^3 (Dutch price level 2008).	
Underwater application: dredging of a canal and constructing of a bank protection	
○ Traditional dredging and separately applying rubble on geotextile	100%
○ Alternative: dredging canal combined with construction of a layer of Strengthened sediment as bank protection (depending on recipe)	60 - 75%
Underwater application: measure against liquefaction of sandy subsoil under an embankment	
○ Traditional dredging and separately construction of a two-layer system (filter layer and on top of it rubble) on the slope of an embankment	100%
○ Alternative: combining a nearby dredging work with the construction of a layer of strengthened sediment on the slope of an embankment (depending on recipe and thickness of the layer)	60 - 90%

This shows that compared to traditional methods, cost savings can be reached between 10 and 40%. This gives market potency to strengthened sediment. It is to note that every project has another recipe of strengthened sediment and is different e.g. in scale, type and availability of sediment, in local market prices (e.g. for the needed additives for strengthened sediment) and in construction method.

Roughly a distinction can be made in both the research costs and the construction costs (dredging, mixing and placement).

Besides those direct costs, there are indirect costs involved: the social and environmental costs (pollution and diffusion of pollution from the transportation of dredged material and additives). However, these costs are considerably lower than the costs of the conventional approach of land reclamation (where long distance transportation is involved). In addition, there is a considerable time saving with the use of strengthened sediment because of the direct application compared to the alternatives A1 and A2. A cost-benefit analysis (CBA) possibly combined with a life-cycle analysis (LCA) could give further insight into the costs and social returns.

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3.2.2.4 Conclusion

Strengthened sediment is pilot ripe and has a great potential within land reclamation projects of Jakarta. The seabed is composed by sludge and clay of approximately -20 m underwater. Sludge, clay and soft mud could be strengthened on site and additional fill could be of strengthened sludge from the rivers/ canals of Jakarta or the surrounding seabed of the reclamation site. In summation the following conclusion can be drawn:

- Strengthened sediment hardens fast and a continuous layer can be formed when applied underwater;
- The permeability is sufficient low to create an impermeable layer;
- Rough cost estimates of some other applications indicate market potency;
- General advantages indicate a social added value and a lower CO_2 footprint than the traditional rubble;
- The durability has to be examined more closely.

The illustration below was an idea of Deltares, proposed for a case of land reclamation in Singapore.

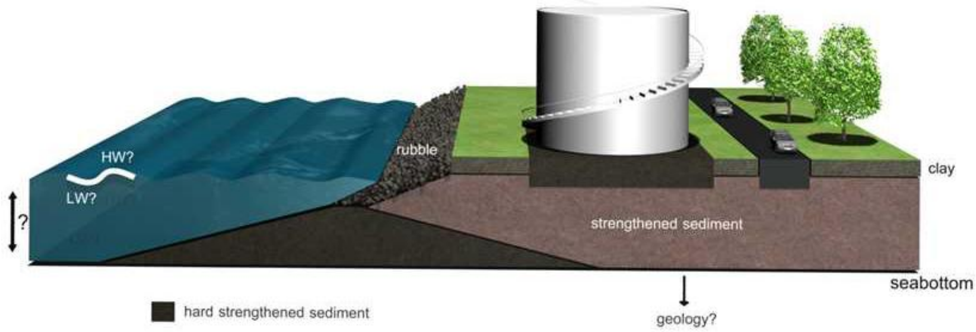

Figure 35: An illustration of the application of the strengthened sediment in land reclamation (Source: Deltares).

Furthermore:

- Dredging leads to cleaner water and increases the navigable depth;
- Selected waste streams or contaminated sediment can be used in a positive way;
- There is no unnecessary transportation and storage of the sediment; it can be directly strengthened and used on site;
- The use of primary building materials (clay, sand, gravel, rubble etc.) can be reduced;
- The storage of contaminated sediment in depots can be reduced;
- CO_2 emissions can be reduced.

Considering that there is market potency, applying the Strengthened sediment technology for the case of Jakarta would mean starting with setting up a business case (including cost estimates with the direct costs), in which in first instance functional demands and recipes for the strengthened sediment can be assessed based on available data of sediments and available suitable additives in the region. In case of positive results further research and the design phase can start.

For the case of Jakarta the result of a cost estimate will strongly depend on among others:

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- The design of the reclaimed land (on compressible soils with a thickness of approximately 20 m);
- The functional demands of the strengthened sediment: the inner part of the reclaimed land may be made of strengthened sediment with a good strength but a rather low density of e.g. 12 kN/m^3, which is lower than the density of traditional sand. This will also reduce the total settlement and the total volume of building material needed and will lead to further cost reduction;
- The cost and recipes of strengthened sediments to be used;
- The application/ construction method and cost;
- The availability of sediment: Although also sediments from the rivers/ canals of Jakarta and from the surrounding seabed of the reclamation site may be reused as strengthened sediment, there is probably not enough sediment to construct the reclaimed land from strengthened sediment only. In that case the strengthened sediment technology can be combined with other alternatives (A1 and/or A2).

An overview of the structure of Alternative 3 is given below.

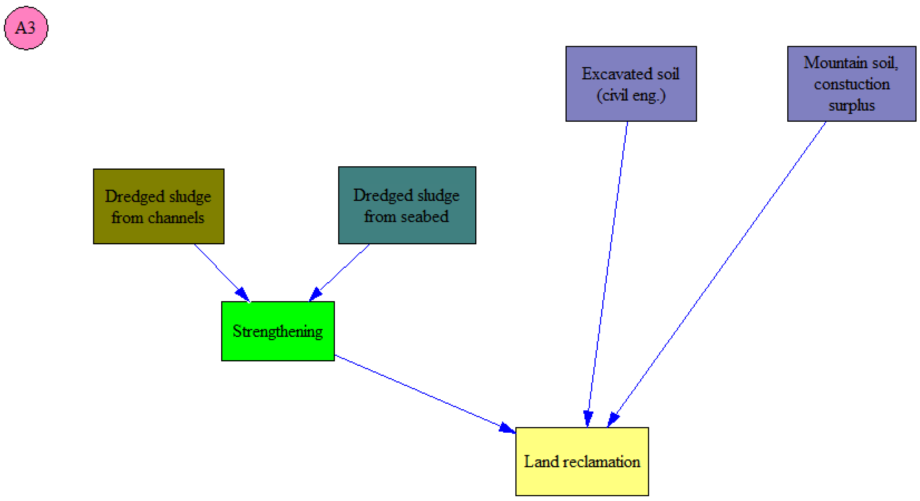

Figure 36: Structure of Alternative 3 (A3).

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3.3 Comparison of the three alternatives and their alternative fill materials through MCA

In this section, the alternative fill materials will be compared to the use of sand as fill material, to determine whether these alternative fill materials are interesting substitutes of sand. Before doing so, the different alternative methods A1, A2 and A3 will be evaluated and compared, in order to determine, which one is more suitable for Jakarta based on the conjunctive approach and using the Triple Bottom Line (TBL) principle, also known as People, Planet and Profit (3Ps) as criteria.
The conjunctive approach is about minimizing risks, making sure the most favorable alternative is determined.
For this comparison, first the TBL framework is defined and the alternatives are analyzed and generally compared in terms of social, economic and environmental impacts in Jakarta, then the MCA criteria is set according to the TBL elements, then the rating levels are determined and eventually the alternatives A1, A2 and A3 are evaluated based on their implementation possibility and according to the criteria and rating levels of the MCA. At the end the alternative fill materials are evaluated and compared to the use of sand as fill material.

3.3.1 Determining the criteria and rating levels

3.3.1.1 TBL framework as criteria

The TBL is an accounting framework that incorporates three dimensions of performance: social, environmental and financial. There is no single, specific, or agreed definition of TBL, the term coined by John Elkington in the early 1980s [12]: "The triple bottom line focuses corporations not just on the economic value they add, but also on the environmental and social value they add — and destroy".
On the one hand, in its broadest sense, TBL refers to a philosophy that may guide the overall performance of organizations, industries, communities and governments and on the other hand, in its narrowest sense, TBL refers to a framework for measuring and reporting corporate performance against economic, social and environmental parameters. The TBL framework and its elements for this study will form the criteria of the MCA and will be determined and described below. This TBL framework is based on the sustainability triangle of Brandtland, the DCBA model of prof Duijvestein K., (2010) and the particular case of Jakarta (see Figure below).

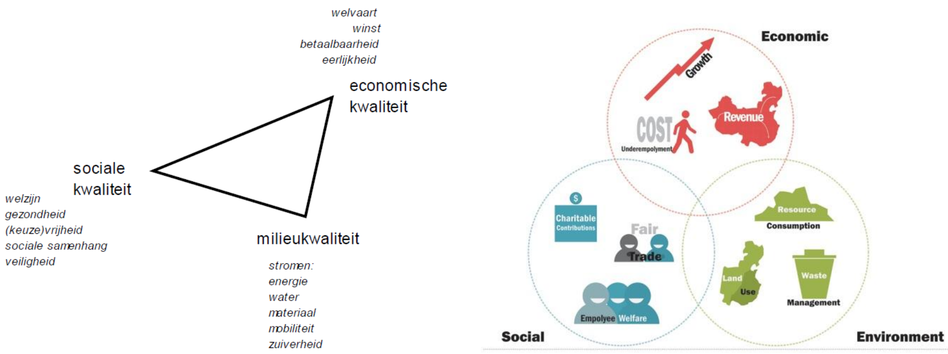

Figure 37: Sustainability triangle of Brandtland (source: UN conference Rio 1992 and Wikimedia 2012).

This sustainability triangle is translated and redefined below, with respect to the important elements for the implementation of any of the three alternative methods of land reclamation in Jakarta. The table below shows the criteria for the MCA of the alternatives.

Table 14: Criteria of the MCA of the alternatives.

People: Social aspects	Planet: Environmental aspects	Profit: economic aspects
• Health • Safety • Participation • Comfort • Social cohesion	• Pollution • Waste • Energy • Water • Materials • Nature/landscape	• Prosperity/welfare • Affordability • Transparancy • Employment • Accessibility • Manageability

Each criterion assesses the impact of the different alternatives on the stakeholders, inhabitants and the government of Jakarta. This assessment takes the following into account:

- the final product: in this case the reclaimed land;
- the process: in this case the way of land reclamation; the use of waste and the way waste is used.

It is important to note that this assessment regards the alternative land reclamation method and not the land reclamation project itself. For example, when assessing the social impact, the impact of the different reclamation methods are assessed and not the impact of the project itself. So the impact of the plasma gasification method on the scavengers for example will be taken into account, but the impact of the whole land reclamation project on the (relocated) fisherman will not be taken into account.
Further explanation of the criteria is given in the table below.

Table 15: Criteria based on the TBL principle.

Criteria	Explanation
People: social aspects	
Health	The impact of the alternative land reclamation method on the general health; (1) the impact of the new reclaimed land on the general health and (2) the impact of the used reclamation and waste management methods and techniques on the general health.
Safety	Physical safety on the site (long term usage) and within the land reclamation and corresponding waste management process.
Participation	Participation of the inhabitants in the decision making processes and the implementation.
Comfort	The impact of each alternative land reclamation method on the comfort of the stakeholders and inhabitants, during and after reclamation.
Social cohesion	The impact of each alternative land reclamation method on the social cohesion of the inhabitants of Jakarta.

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Planet: Environmental aspects	
Pollution	This aspect refers to any environmental pollution created or avoided by each alternative method of land reclamation and its corresponding waste management; leachate or any pollution of waste within the site's surrounding water, air pollution through waste transportation, possible pollution through waste treatment methods etc.
Waste	The impact of each alternative land reclamation method on the waste management system of Jakarta.
Energy	The impact of each alternative land reclamation method on the existing energy production methods and energy consumption of Jakarta.
Water	The impact of each alternative land reclamation method on the water quality, water savings and flood risks.
Materials	The impact of each alternative land reclamation method on the use of exhaustible materials, recycled materials and sustainable materials.
Nature/ landscape	The impact of each alternative land reclamation method on the conservation and creation of landscape and greenery.
Profit: economic aspects	
Prosperity/ welfare	The impact of each alternative land reclamation method on the welfare of all involved stakeholders and the city of Jakarta during and after land reclamation.
Affordability	Affordability of each alternative land reclamation method compared to the land reclamation method where sand is used as fill material.
Transparancy	The impact of each alternative land reclamation method on transparency between stakeholders.
Employment	The impact of each alternative land reclamation method on employment; conservation and creation of (new) employment.
Accessibility	The impact of each alternative land reclamation method on the accessibility around the site, during land reclamation.
Manageability	Manageability of each alternative land reclamation method.

3.3.1.2 The rating levels

Using the conjunctive approach, the rating levels measure the deficiency of each alternative on meeting the criteria. The levels are:

- Minor deficiency (min def): when the alternative meets (or almost meets) the criteria. Here the impact of the alternative method on the people, the planet and the profit is favorable or very favorable.
- Major deficiency (maj def): when the alternative is far from meeting the criteria. The impact of the alternative on the people, the planet and the profit is not favorable.
- Neutral (-): when the alternative does not have any significant effect on the criteria.

3.3.2 Comparison of the alternatives A1, A2 and A3

Now that the criteria are determined and the rating levels are known, the following table shows how the three alternatives are compared and what the rating and underlying elucidations are.

Table 16: Comparison of the alternatives A1, A2 and A3.

Criteria		A1	A2	A3	Elucidation
People: Social context	Health	maj def	min def	min def	Within A1, contaminated waste is isolated with geo-membrane and used as fill material. Because the behavior of the geo-membrane is unpredictable for the long term (>50years), this method is marked unfavorable. Also de use of incineration has a negative impact on the general health although handling the waste has a positive impact on the current situation where a great deal of the waste ends up in the city's canals. A2 is marked very favorable because the gasification turns contaminated waste into inert slag, which is then used as fill material. Doing so also solves a lot of health problems Jakarta is coping with at this moment. A3 is marked favorable because the strengthened sediment immobilizes contaminants and so creates a healthy environment. However this alternative does not consider general waste management and so does not solve actual health problems caused by the excess of waste in the city.
	Safety	maj def	maj def	-	Considering safety on the land reclamation site before, during and after reclamation, A1 presents more safety risk than A2 and A3. Concerning safety within the waste management process, both A1 and A2 presents safety risks. Those risks need to be identified and safety measures need to be taken.
	Participation	min def	min def	-	A1 is marked very favorable because it facilitates participation within waste collection, waste sorting and communal composting of organic waste. A2 is marked favorable because it facilitates waste collection and waste sorting. A3 is marked neutral because the inhabitants are not involved in sludge dredging activities.
	Comfort	maj def	min def	min def	A1 is marked unfavorable because of the idea of living above a landfill. This could impact the shareholders and future inhabitants. However the involvement of an integral waste management has a positive effect. This is also the case of A2, which is marked favorable because the used landfill material is clean in contrast with A1. A3 involves only a part of the waste management, but sludge is often not considered as waste by the general public and therefore living on strengthened sludge could sound better than living on treated waste.

	Social coherence	min def	min def	-	A1 is marked very favorable because of the communal composting activities and the waste collection and sorting activities, which is also the case of A2, marked favorable. A3 does not have a significant impact on the current social cohesion.
Planet: Environmental context	Pollution	maj def	min def	min def	A2 is environmental friendlier than A1, although both could be applied with great care limiting any environmental burden. Within A2 waste treatment has less impact on the environment than within A1. However both alternatives of waste handling methods are better for the environment than the conventional waste disposal at Bantargebang landfill. As for the land reclamation site in the case of A1, taking measures such as leachate catchment and treatment, gas recuperation and constant monitoring measures could prevent any environmental pollution on the site, but only for 50 years. Furthermore air pollution by incinerator ash could occur when the ash is not well covered during transportation and application. This needs to be considered. The overall transportation could be considered as replacement for the actual waste transportation to Bantargebang landfill, causing no additional pollution. A3 does not change much on the actual situation. It creates additional pollution related to transporting additives and dredging and transporting sludge (through water ways) to the land reclamation site. However it also prevents a great deal of environmental pollution by dredging contaminated sludge.
	Waste	min def	min def	min def	A2 is marked favorable because it includes a waste management system where all the waste is processed and turned into clean residues. A1 also manages all the waste but a part of the waste (incinerator ash) is still contaminated waste. A3 focusses on a limited kind of waste (sludge) and therefore cannot be marked neutral or unfavorable.
	Energy	min def	min def	maj def	A1 produces energy although the use of energy for incineration is higher than for a conventional landfill as it is the current case. A2 produces more green energy and is therefore very favorable. A3 uses energy and does not produce it.

	Water	min def	min def	min def	A1 has a risk of sea water contamination. This risk is very small, but the size of it in the future (after 50 years) is unpredictable. Because of the waste management system within A1 and A2, less or no waste will be dumped in the city's canal and so will the risk of flood and the water contamination caused hereby decrease. A3 focuses on sludge and so also contributes positively on the water quality improvement and flood prevention by dredging contaminated sludge out of the city's canals.
	Materials	min def	min def	min def	All alternatives reuse used materials and so limiting the use of exhaustible materials. However A3 reuses 100% of the waste (sludge), which is not the case of A1 and A2 where the waste is reduced through composting, incineration and plasma gasification.
	Nature/ landscape	min def	-	-	A1 includes the creation of landscape and greenery because of the soft landfill material to be used. A2 and A3 remain neutral on the matter.
Profit: Economic context	Welfare	min def	min def	min def	A1 is favorable because it uses waste on a known and affordable way. The investment for incineration is high but the combination of incineration composting and the use of mountain soil, excavated earth and construction and demolition debris makes it interesting to pursue. A2 is very interesting but also costly. In addition, there is no sufficient waste available for this method only. However, when combined with other methods and energy production companies, it could be very promising for the city of Jakarta. A3 is very interesting and seems to be affordable. There is no waste management system involved but the availability of sludge and modder in the city's canals, on the reclamation site and surroundings seems to be higher than the availability of other fill materials within A1 and A2. Also Jakarta will be the first city that uses this new technology in this way. This also applies to A2. This means more risks of course but also the role of initiator for the city.
	Affordability	maj def	maj def	min def	A1 and A2 could be affordable with the right public-private partnership. A2 is however not applicable alone (lack of sufficient waste) and A3 seems to be easily affordable.

	Employment	min def	min def	min def	A1 maintains employment and creates new employment within the improvement of the solid waste collection and separation system and within the incineration plant and land reclamation process. The same applies to A2. Both alternatives also eliminate employment at the current landfill site (Bantargebang). In addition A1 creates more employment within waste composting facilities. A3 maintains current employment en creates new ones within the land reclamation process (sediment dredging and strengthening).
	Accessibility	maj def	maj def	-	With A1, there will be a lot of movements going on on the site (preparing the site: compartmenting and installing the geo-membrane, leachate treatment facilities, gas recuperation installations etc…) and also a lot of transportation of waste from incineration plant and community composting stations to the land reclamation site. A2 will also involve a lot of transportation from the gasification plant to the land reclamation site. Both A1 and A2 also involve transportation during waste collection and separation. A3 involves mainly transportation through the water ways, which has less impact on the accessibility. Also the fact that a great deal of the sediment is dredged, treated and used on site has a positive impact.
	Manageability	min def	min def	min def	All methods are manageable. However, proven expertise makes a technology rather better manageable than unproven expertise, which is the case of A2 and A3. There is no application known of an integral waste management system based on only plasma gasification, let alone combined with land reclamation with the use of gasification slag. As for A3 there is yet no known application of strengthened sediment within land reclamation or island creation. Nevertheless both method are theoretically applicable and could be successfully manageable when an adequate risk management is conducted before hand.

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Table 17: Results of the comparison.

Results	A1	A2	A3
People	3 major and 2 minor deficiencies	1 major and 4 minor deficiencies	2 minor deficiencies and 3 neutral
Planet	1 major and 5 minor deficiencies	5 minor deficiencies and 1 neutral	1 major and 4 minor deficiencies and 1 neutral
Profit/prosperity	2 major and 3 minor deficiencies	2 major and 3 minor deficiencies	4 minor deficiencies and 1 neutral
Conclusion	With 6 major deficiencies, A1 is the less favorable alternative.	A2 has 3 major deficiencies.	With 1 major deficiency A3 is the most favorable alternative. This method minimizes the risks the most.

3.3.2.1 Conclusion

Alternative 3 is the most favorable with only 1 major deficiency. This major deficiency is scored on the energy criterion, where strengthened sediment uses energy instead of producing it.
This alternative remains very interesting for the land reclamation projects of Jakarta. However, the lack of expertise within this new technology could cause some reservation from the shareholders (the government, developers or other private parties). In addition to that, based on the large amount of fill material needed, it can be assumed that there is not enough sediment available for the whole land reclamation (although further research in the availability needs to be conducted). On the other hand the application of the strengthened sediment technology could also be seen as an opportunity because of its benefits in contrast with the conventional way of land reclamation and the other alternatives.

Alternative 2 is the second most favorable with 3 major deficiencies, which were scored on the criteria accessibility, affordability and safety. The major setback of this alternative is the availability of slag for the land reclamation.
When all recyclables (37.4% of 6000 ton/day MSW) are recycled and the remaining 3756 tons/day of MSW are treated through plasma gasification, assuming the produced slag is 21.7% of the gasified waste amount, the amount of slag available is estimated at **815 tons/day of slag** (297,494 tons/year), which is very low compared to the 2,242,585 tons/year of sand gained.
Another setback of this alternative is the affordability. Although a plasma gasification plant generates a net revenue of $ 32/ton of waste treated, it first needs a large initial investment before it can be productive.

Alternative 1 is the most unfavorable with 6 major deficiencies, which were scored on the criteria accessibility, affordability, safety, pollution, comfort and health. Most of this deficiencies are caused by the inclusion of incineration. Apart from being very expensive, incineration has also a large negative impact on the environment and public health. Therefore this way of waste treatment is not suitable.

Within A1, incineration could be replaced by plasma gasification, which is environmental friendlier and more affordable. However the landfill material production is then slightly lower and the project could take more time.
When all recyclables are recycled and the organic waste is composted, the remaining waste is 7.23%. In the case of Jakarta is this 434 tons/day. When this waste is gasified, the amount of slag produced will be **94 tons/day**. This would lead together with the estimated **1662 tons/day** of compost to **1756 tons/day** of fill material (instead of 1766 tons/day of fill material with incineration).
In this scenario only the uncontaminated compost and soft uncontaminated excavated soil will be used as fill material for section 3, meant for golf courses, light recreational activities and park functions. The use of geo-membrane, leachate treatment facilities and methane gas recuperation installation is then no longer required. The slag produced by the plasma gasification plant could be directly used as sand replacement within the reclamation project.

Because the availability of landfill material is limited for each alternative or scenario, the best option is to combine elements of all 3 alternatives into one chozen method of land reclamation using waste as fill materials. This chozen method will include the combination of A1 and A2, where incineration is replaced with plasma gasification and A3.

3.3.3 Comparison of the alternative fill materials and the use of sand

Within this comparison the social, environmental and economic characteristics of dredged sand, compost, gasification slag, excavated soil from construction work sites, mountain soil, dredged sludge from the city's channels and dredged sludge from the seabed will be evaluated.
The evaluation will be based on the conjunctive approach using (-) for major deficiency and (+) for minor deficiency. All characteristics (aspects and impacts) have been determined before. The following table puts those characteristics together and compares them.

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	Dredged sand	Compost	Slag	Excavated soil	Mountain soil	Channel sludge	Seabed sludge	Elucidation
Social impacts	-	+	+	+	+	+	-	Communal composting has positive aspects through the enhancement of social participation, social cohesion and the public health (dealing with the waste and so avoiding open dumping). Excavated earth is considered a waste (surplus material) as construction is going on anyway. Therefore reuse of this waste within land reclamation also avoids open dumping. The same applies to mountain soil when it is considered as waste and not extracted in the purpose of reclamation. Channel sludge also has positive aspects because although dredging the channels requires relocation of the inhabitants from its vicinity, it also removes the waste, decreasing flooding problems and so enhancing public health, comfort and safety. As for seabed sludge and sand, they involve dredging from the sea bed which could significantly modify waves and currents reaching the shoreline. Greater wave and current exposure could pose more flood issues and so affect the public safety, health and comfort.

Environmental impacts	-	+	+	+	+	+	-	Because of the dredging aspect, dredged sand and seabed sludge have negative impacts on the environment. As for mountain soil, it depends on the nature of extraction. It is assumed in this case that the soil is a waste surplus and not extracted for the purpose of land reclamation. The same applies to excavated soil from construction work sites. Compost and slag have positive impacts on the environment because of their waste "clean treatment" character, especially when the current situation, where the waste is disposed of at the landfill site is taken into account. Dredging channel sludge is also considered positive as it limits air and water pollutions due to waste dumping.
Economic aspects	-	+	+	+	+	+	+	Dredged sand costs $29.50/ton at the moment in Jakarta and making compost is estimated at $19/ton of compost. Making slag generates a net revenue estimated between $31.6 and $152.4 per ton of slag. When the developer buys slag from the plasma gasification company are the costs estimated at $1/ton of slag. Excavated soil, mountain soil and channel sludge are considered to be waste and therefore using them for land reclamation actually saves disposal costs. The only costs here are dredging and/or transport costs. Seabed sludge, when dredged in the surroundings of the reclamation site will have lower costs than the cost of sand, dredged further away.

3.3.3.1 Conclusion

It is to note from the fill material comparison conducted above that compost, slag, excavated soil, mountain soil and channel sludge are all socially, environmentally and economically more favorable than dredged sand. Seabed sludge having the similar major deficiencies within the social and environmental aspects as dredged sand is however economically more favorable than dredged sand. This makes the fill materials within the chozen method of land reclamation interesting substitutes of sand for the land reclamation projects of Jakarta.

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4 The chosen method of land reclamation using waste as fill material

This chozen method or fourth alternative method (A4) of land reclamation using waste as fill material is as mentioned before the combination of favorable elements of the three evaluated alternative methods. Using this chozen method of land reclamation, an island could be divided in three sections:

- Section 1, expected to provide a site for heavy constructions will be reclaimed using dredged soil from rivers, harbors and seabed with the strengthened sediment technology (A3);
- Section 2, expected to provide a site for the construction of an urban area (residential and business area) will be reclaimed using normal mountain soil, surplus soil from construction work sites and plasma gasification slag.
- Section 3, expected to provide a site for golf courses, light recreational activities and park functions will be reclaimed using compost, excavated soil from civil engineering and construction work sites.

See example island below.

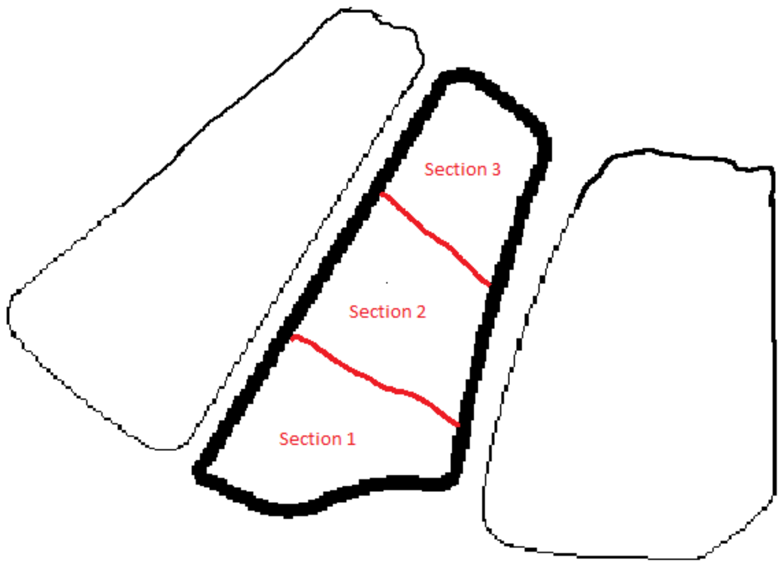

Figure 38: Example island compartments.

The next figure shows the structure of the chozen method of land reclamation.

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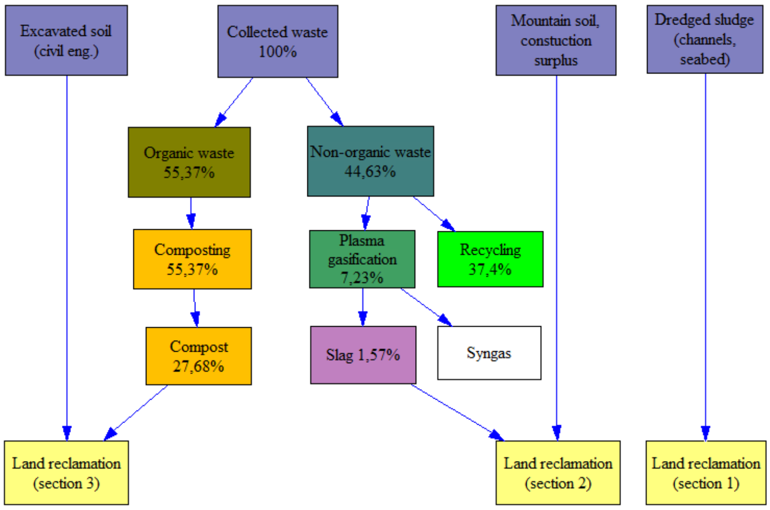

Figure 39: Structure of the chozen method of land reclamation.

4.1 Quantities of fill material within the chozen method of land reclamation

The availability of sufficient alternative fill material for the land reclamation is still unpredictable at this point. The quantity of MSW that can be used for the land reclamation is estimated and clear, but the quantities of available excavated earth from construction work sites, construction and demolition waste, mountain soil and dredged sludge are unclear at this point and unpredictable for the future.
It is to assume that when the available alternative fill material is not sufficient, one could always use sand as complement.
The table below gives an overview of the quantities of fill material.

Table 18: Quantity and cost estimates of fill material for an island of 300 ha.

	Conventional method			**Method using waste**		
	Material	Quantity (ton)	Cost ($)	Materials	Quantity (ton)	Costs ($)
Gained/year						
	Sand	2.242.585	$66.156.258	Compost	606.265	$11.519.035
				Slag	34.310	$34.310
				Excavated soil		
				Mountain soil		
				Sludge		
				Sand complement		
Total		2.242.585	€ 66.156.258		640.575	$11.553.345
Needed total		32.000.000			32.000.000	

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5 Implementation analysis of the chozen method of land reclamation in the projects of Jakarta

For the implementation analysis, the application of the chozen method of land reclamation in Jakarta will be evaluated. First the process steps of the method are defined using system dynamics (stock and flow diagram). Then a SWOT analysis is conducted to evaluate the strengths, weaknesses, opportunities and threats of the method in the particular case of Jakarta, leading to the formulation of implementation conditions, which are then checked against the governmental, social, environmental and economic aspects of Jakarta. Finally four future scenarios are sketched based on the demographics and economy of the city.

5.1 Process sketch

The system dynamics model below shows the process steps of the fill materials (compost, slag, excavated soil, mountain soil and dredged sludge) from their origine towards the land reclamation. It also shows the correlation between the steps, stakeholders and extern factors.

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5.1.1 System dynamics model of the process steps

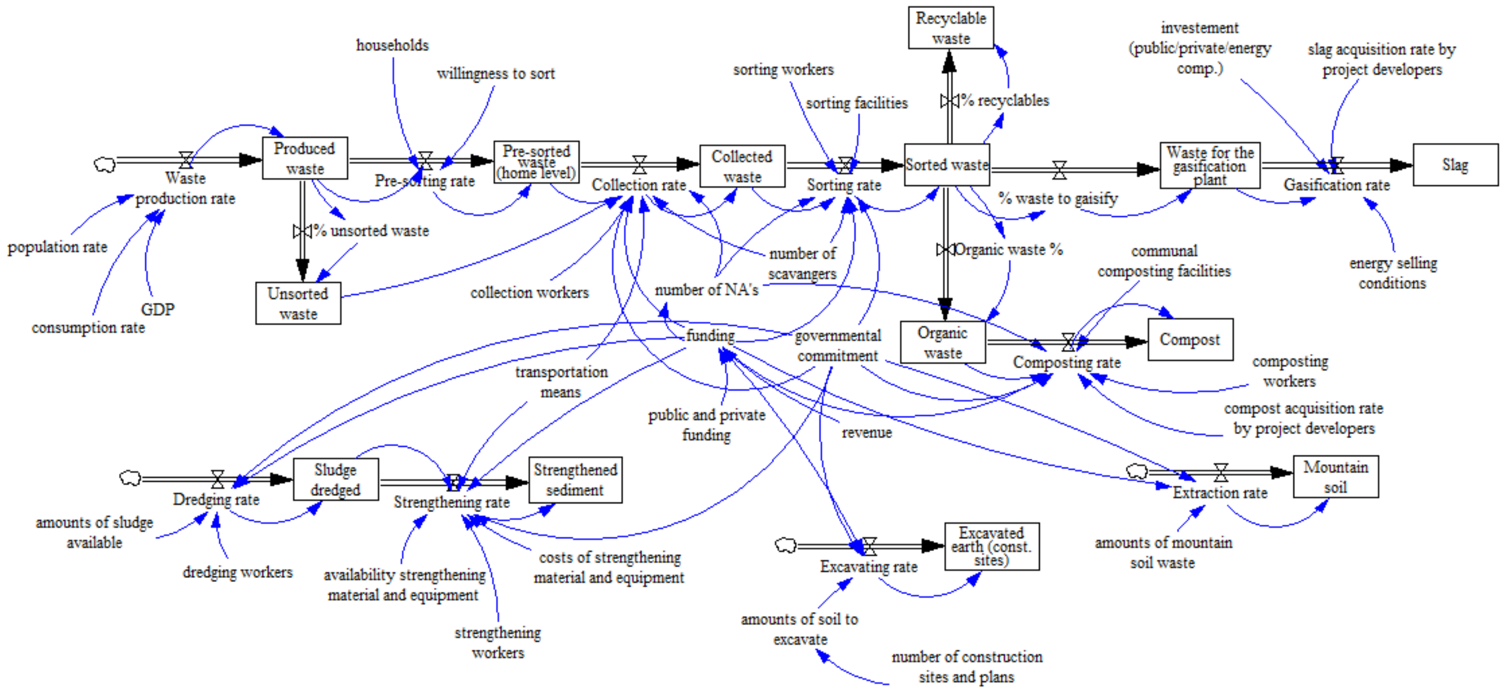

Figure 40: System dynamics model of the process steps of the chosen method of land reclamation.

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The following figures show the causes trees of the fill materials.

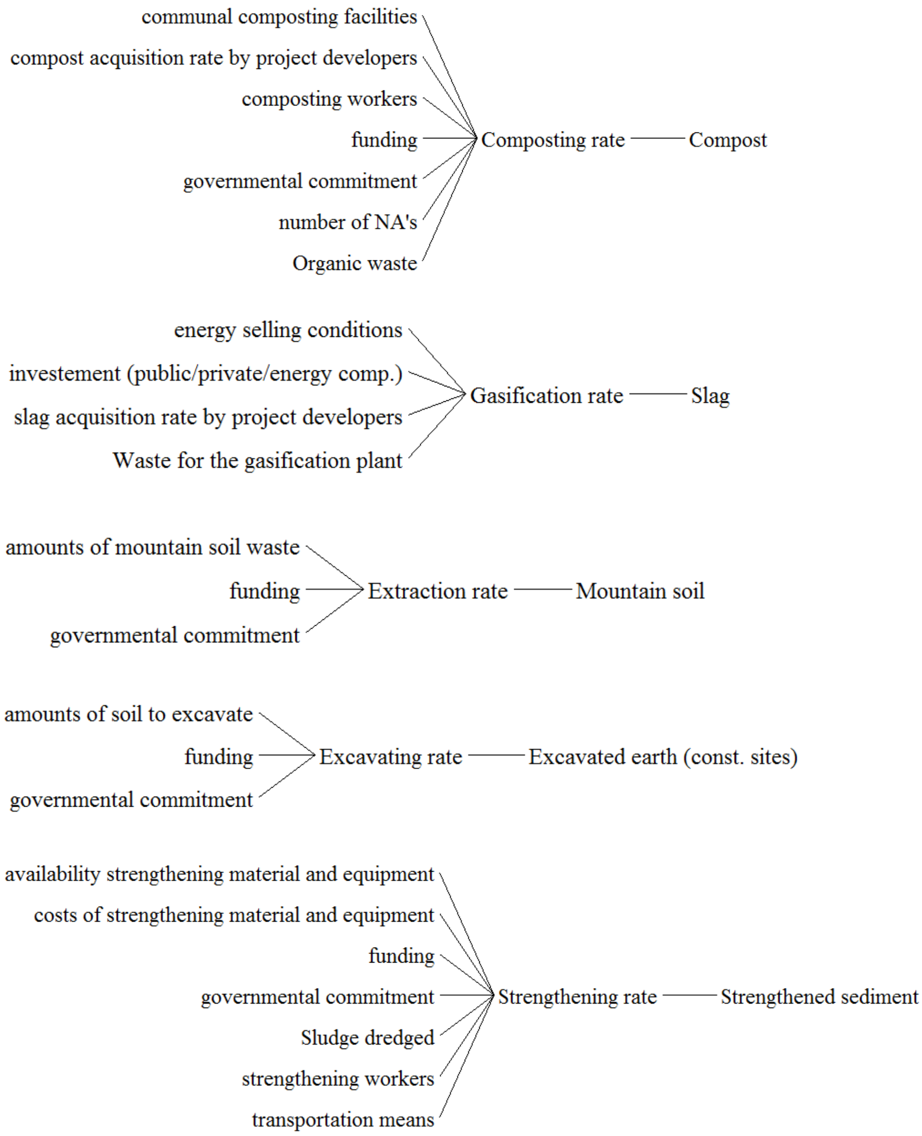

Figure 41: Causes trees of the fill materials.

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5.2 SWOT analysis

The analysis of the strengths, weaknesses, opportunities and threats of the Alternative 4 within the context of Jakarta start with a SWOT matrix where the SWOT elements are identified and then a confrontation matrix will follow, evaluating confrontation possibilities of the strengths, weaknesses, opportunities and threats. Then finaly measures are taken to enhance the occurrence chance of positive confrontations and prevent or reduce the occurrence chance of negative confrontations.

5.2.2 SWOT matrix

In the following table, strengths, weaknesses, opportunities and threats are identified.

Table 19: SWOT matrix of the chosen method within the context of Jakarta.

Strengths		Weaknesses	
S1	Reuse of waste and sludge in an environmental friendly way	W1	Manageability issues due to the combination of several technologies and the differences with the conventional method (use of sand)
S2	Improvement of the water quality and creation of better public health	W2	Unpredictability due to the newness of the technologies
S3	Proper SWM system	W3	Expensive plasma gasification investment
S4	Social participation	W4	Limited flexibility of the use of section 3 of the reclaimed land (soft soil for e.g. golf courses)
S5	Economically interesting alternative	W5	Involvement of a lot of stakeholders required
S6	Facilitating the creation of more greenery due to soft soil		
S7	Use of waste instead of sand		
Opportunities		**Threats**	
O1	Significant reduction of environmental pollution	T1	Unavailability of enough fill material (construction debris, excavated earth etc.)
O2	Jakarta as leading city in the used technologies	T2	Changes within governmental policy
O3	Integration of waste management and energy production	T3	Inadequate functioning of the SWM system (collection, sorting, composting, gasification)
O4	Creation of employment opp.	T4	Lack of governmental or social support
		T5	Changes within the existing social structure of the SWM system

5.2.3 Confrontation matrix

The following confrontation matrix shows where the strengths, weaknesses, opportunities and threats affect each other. The affection level is indicated by the following signs:

- (++) for a very positive influence;
- (+) for a positive influence;
- (-) for a negative influence;
- (--) for a very negative influence.

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Table 20: Confrontation matrix.

			S1	S2	S3	S4	S5	S6	S7	W1	W2	W3	W4	W5
			Reuse of waste and sludge in an environmental friendly	Improvement of the water quality and public health	Proper SWM system	Social participation	Economically interesting alternative	Facilitating the creation of more greenery due to soft soil	Use of waste instead of sand	Manageability issues due to the combination of several technologies and the differences with the use of sand	Unpredictability due to the newness of the technology	Expensive plasma gasification investment	Limited flexibility of the use of section 3 of the reclamed land (soft soil for e.g. golf courses)	Involvement of a lot of stakeholders required
			Strengths							Weaknesses				
Opportunities	O1	Significant reduction of environmental pollution	+	+	++	+		++	+					-
	O2	Jakarta as leading city in the used technologies							++	--	-	-		-
	O3	Integration of waste management and energy production					+				-	-		-
	O4	Creation of employement opp.			+		+		+	+				
Threats	T1	Unavailability of enough fill material (constuction debris, excavated earth, mountain soil and sludge)	+								--			
	T2	Unfortunate changes within governmental policy						-					-	
	T3	Unadequate functioning of the SWM system (collection, sorting, composting,	-	-	-	-			--	--	--	-		
	T4	Lack of governmental or social support	-	-	-	-		-	-	-		-		
	T5	Changes within the existing social structure of the SWM system			+	-				-				

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The confrontation matrix shows eight (positive and negative) extreme situations. Those situations will be further discussed below, where facilitation measures for the positive extremes and prevention/ limitation measures for the negative extremes will be recommended.

Table 21: Measures for the positive and negative extrems.

Positive extremes	**Facilitation measures**
S3: Proper SWM system **O1**: Significant reduction of environmental pollution	Significant reduction of environmental pollution is strongly dependent on a proper SWM system. The realization chances of this opportunity should be enhanced by making sure an adequate SWM system is initiated and continuously monitored and adjusted (where needed) to guarantee its success.
S6: Facilitating the creation of more greenery due to soft soil **O1**: Significant reduction of environmental pollution	Greenery is a good prevention against air pollution. The fact that a part of the land reclamation area will be filled with compost and earth, creating a soft underground which is not suitable for heavy structures makes it possible to guarantee that part for greenery.
S7: Use of waste instead of sand **O2**: Jakarta as leading city in the used technologies	Using waste within artificial island creation destined for an urban area will put Jakarta on the map as leading city in these technologies. Especially using Strengthened Sediment which is not similar to any other approach so far within the history of artificial island creation.
Negative extremes	**Prevention or limitation measures**
W1: Manageability issues due to the combination of several technologies and the differences with the use of sand **O2**: Jakarta as leading city in the used technologies	The manageability issues due to the combination of several technologies or methods and the differences with the conventional way of land reclamation using sand, is a set back on the successful realization of the project and so may have a negative effect on putting Jakarta on the map as leading city in the used technologies. A way to limit this effect would be to first conduct more research on the implementation aspects and risks of those technologies in the Jakarta land reclamation projects. Appointing clear responsibilities to involved parties and making sure all stakeholders are able, willing and motivated to realize the project within the set conditions.
W2: Unpredictability due to the newness of the technology **T1**: Unavailability of enough fill material (construction debris, excavated earth, mountain soil and sludge)	Because of the newness of the technologies of Alternative 4, the unpredictability of the project progress is higher than with the conventional method of land reclamation especially when the availability of sufficient fill material is uncertain. Extensive research on the availability of the fill material is required before pursuing this plan. It is to assume that when there is not enough fill material available, sand could still be used as complement.

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S7: Use of waste instead of sand **T3**: Inadequate functioning of the SWM system (collection, sorting, composting, gasification)	The use of waste instead of sand can only be realized if a proper and adequate SWM system is in place. This can be realized by making sure all MSW is collected, sorted, the recyclables are recycled, the remaining waste is treated (composting and plasma gasification) and the residue (compost and slag) is used within the land reclamation project along with the excavated soil, mountain soil and sludge (after strengthening).
W1: Manageability issues due to the combination of several technologies and the differences with the use of sand **T3**: Inadequate functioning of the SWM system (collection, sorting, composting, gasification)	Manageability issues combined with inadequate functioning of the SWM system, could lead to project failure. Making sure the technologies are well known by the involved parties, the needed risk assessment is done and possible prevention measures are known and taken for both the land reclamation and the SWM system before start could limit or even prevent this threat from happening.
W2: Unpredictability due to the newness of the technology **T3**: Inadequate functioning of the SWM system (collection, sorting, composting, gasification)	Making sure the risks of the SWM system functioning inadequately are avoided or very limited and that all technologies of Alternative 4 are well known and well-studied to limit the unpredictability could prevent or at least limit this threat from happening.

5.3 Evaluation of the implementation conditions for Jakarta

For such a project where not only land reclamation stakeholders are involved but also SWM parties (including scavengers), energy companies and inhabitants, the organization is rather complex. The following conditions could be applied:

1. All parties must be willing to participate in the project; Despites the large availability of coal, the energy company must be willing to invest in the production of sustainable energy and therefore be willing to invest in the realization of the plasma gasification plant;
2. The governmental support and involvement in terms of finance, regulation, monitoring and control must be sufficient;
3. The responsibility and role of each party must be clear for all parties and the responsible party should be held accountable for its responsibility;
4. Waste separation should be applied at home level. Therefore the inhabitant must be willing to collaborate and share the responsibility of the waste problems of the city, doing so also avoiding waste dumping in the city or city's rivers/channels. After waste collection, waste re-sorting before composting and gasification is however recommended;
5. The Bantargebang waste disposal site must be closed and any other form of untreated waste dumping must be stopped;
6. Waste composting must be promoted and sufficient communal composting centers must be created in order to compost all available organic waste. A part of the compost will be used within the agricultural sector and the rest will be used for the land reclamation of section 3.

7. De project developers, reclaiming the islands must be willing to buy the fill materials or invest in the processing of these fill materials;
8. Waste collection, sorting, treatment and reuse must be maximized; all available waste must be processed;
9. The city's channels must be dredged, widened and deepened in order to use the dredged sludge for land reclamation, doing so also stimulating the water evacuation out of the city and reducing/preventing flood. Therefore the inhabitants living in the surroundings of (or practically on) those channels must be relocated;
10. Further study must be conducted on:
    a. the strengthened sediment application process;
    b. the governmental and social acceptance of the whole plan and the availability of fill material in the near future (construction waste, mountain soil, excavated soil and sludge);
    c. the detailed cost and benefits situation and investment strategies among the shareholders.

The following table shows an evaluation of the implementation with those conditions and process elements in the current situation of Jakarta.
The application in the current situation is evaluated and marked with yes, no or unknown (-), an elucidation is given and possible improvement measures are recommended.

Table 22: Implementation conditions check.

Conditions and elements	**App. in current situa-tion**	**Elucidation**	**Possible improvement measures/ recommendations**
Commitment of the stakeholders (incl. government)	-	It is yet not clear whether all involved parties are willing to commit to the plan. Possible oppositions could occur e.g. from the inhabitants that need to be relocated from the surroundings of the channels.	A research should be conducted on the governmental and social acceptance of the whole plan.
Clear role and responsibility of all parties	No	No single ministry and agency is charged with the development and implementation of solid waste management goals and policies. Instead, policy development is divided among several ministries, and implementation is the responsibility of each municipality or regency [39]. Furthermore, within each municipality there is no separation between regulatory and operational roles and the same department performs these two tasks, leading to potential conflicts of interest. There is no public participation in decision making.	The project plan should include a whole regulations review of the governmental solid waste management structure in order to make sure that one ministry or agency is responsible for the development and implementation of solid waste management goals and policies and that operational and regulatory roles are within different departments. It is also important to appoint clear responsibilities to all other involved parties or stakeholders.
Waste sorting at home level	Yes	Public consultation and participation is not an integral part of the system. Most of the people (81%) do not usually conduct waste sorting at home. However 73% indicated being willing to sort their waste at home.	Providing information and education to the inhabitants regarding waste sorting and its effects is recommended.

Maximized waste collection rate	No	Handling waste is perceived as a voluntary activity with almost no support from the government; 30.3% of the waste is not collected and ends up in the streets, the city's channels or burnt. There is lack of coordination among relevant agencies and lack of strong legal system to prosecute laws. There is no concept of producers' responsibility or polluters pay. The cost of environmental and health damage is not accounted in monetary value.	Providing information and education to citizens regarding the methods of waste treatment and disposal could lead to a higher waste collection rate. Also accounting the cost of environment and health damages and following the concept of 'polluters pay' along with a strong legal system to control and execute SWM rules and regulations would help prevent waste dumping.
Closure current landfill sites (Bantargebang)	-	The willingness of the government and involved parties (operator, scavengers) to close the landfill sites is yet not clear. However closure of these sites is environmentally (e.g. through environmental pollution reduction), socially (e.g. through public health and living conditions improvement) and economically (e.g. through land use of the sites and the saving of disposal and operation costs) desirable. Practically when all waste is treated and the residue used for the land reclamation project, there will be no waste left for the landfill sites.	The willingness of the government and involved parties to close the landfill sites needs to be evaluated.
Waste sorting facilities before treatment	Yes	If government authorities were to require waste sorting, 42% of the respondents are willing to pay and 57% would rather sort their own waste.	Waste sorting facilities should be part of the waste treatment system. The collected waste needs to be sorted again to make sure waste streams are properly separated. Because the waste is pre-sorted at home level, this operation should not be very burdensome or complicated.

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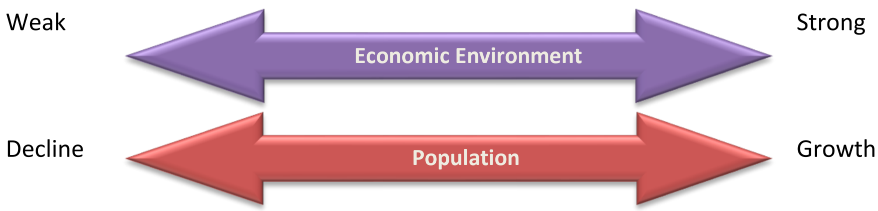
Waste composting	Yes	If appropriate mechanisms, incentives and technical information are provided, 68% of the inhabitants agreed to be involved in composting (communal and home composting). 88% claimed that there are no communal composters in their area of residence. As is common with other parts of the overall MSW system, a lack of strategic development for composting has led to poor performance so far.	Communal composting facilities need to be developed and the inhabitants need to be informed and educated regarding waste sorting and composting. Therefore the public participation needs to be promoted and the public involvement within decision making needs to be enhanced.
Waste gasification (gasification plant)	-	The willingness of public and private parties to invest in a plasma gasification plant is yet unknown. Such a plant can be economically sustainable and even generate interesting revenues, but needs a large investment to start.	Further investigation is needed on the willingness of the shareholders to invest and the investment possibilities of plasma gasification plants.
Energy re-sell to energy company	-	The energy company may not be willing to invest in sustainable energy (from the plasma gasification plant)	Further investigation is needed to establish the position of the energy company and design a suitable plan for its participation.
Developers investing in waste treatment and transport or buying the fill material	Yes	The willingness of the project developers to invest in the alternative fill material is yet not investigated. It is to assume that they will be willing to do so because of the financial interest. However, the social acceptance of the land reclamation plan also plays an important role as the developers need to sell the reclaimed land.	As mentioned before, the social acceptance of the whole plan needs to be considered.
Relocation of the people living near the city's channels	Yes	The relocation of the people who live in the vicinity of the channels has been an issue for a while now. Yet for the city's safety against flood problems and diseases, the relocation is essential.	It is recommended to consider relocation processes with the least negative impact on the inhabitants. Involving them within the process, informing them about the reasons and necessity of relocation and offering them suitable alternative living areas is thereby necessary.

Channel dredging	Yes	Necessary for the safety and defense against flood and diseases.	An EIA need to be done before starting with dredging. Precautions need to be taken to minimize environmental impacts.
Sludge dredging from seabed	Yes	If sand can be dredged it is to assume that sludge can be dredged as well.	Also here fore, an EIA is needed before starting with dredging and precautions need to be taken during the dredging activities to minimize environmental impacts.
Application of strengthened sediment technology	-	Because of the newness of this technology, it's implementation conditions are yet unknown for the case of Jakarta.	The implementation of this technology in Jakarta needs to be further evaluated. The stakeholders' willingness to opt for the technology needs to be evaluated as well.
Availability of sufficient fill material	-	The availability of sufficient fill material (construction waste, mountain soil, excavated soil and sludge) is yet unknown.	The availability of fill material in the near future needs to be evaluated.

5.4 Possible future scenarios

Scenarios are provocative and plausible stories about how the future might unfold; diverse ways in which relevant issues might evolve. Because scenarios are hypotheses, they are created and used in sets of multiple stories that capture a range of future possibilities [14].
Scenario analysis mainly focus on uncertain factors (threats and opportunities). In this case, the scenarios are used to deal with the specific system (see system dynamics model above) and they involve making explicit assumptions about the future development of the environment of the system using causal loop diagrams. Causal loop diagrams indicates the correlation between the elements of the system. When elements reinforces each other, the correlation is marked (+) and when they evolve in an opposite direction, the correlation is marked (-), leading to positive or negative loops
The method for generating scenarios used is based on reasoned judgment and intuition in describing alternative futures.
The most simple and reliable way to create scenarios is by picturing critical uncertainties on axes that frame poles of possible futures [37].
For this case two uncertainties are identified which, when combined, produce believable and useful stories of the future. These are: economy and demography. Both major drivers for the land reclamation project and alternative fill materials.



With these axes, the following matrix is formed.

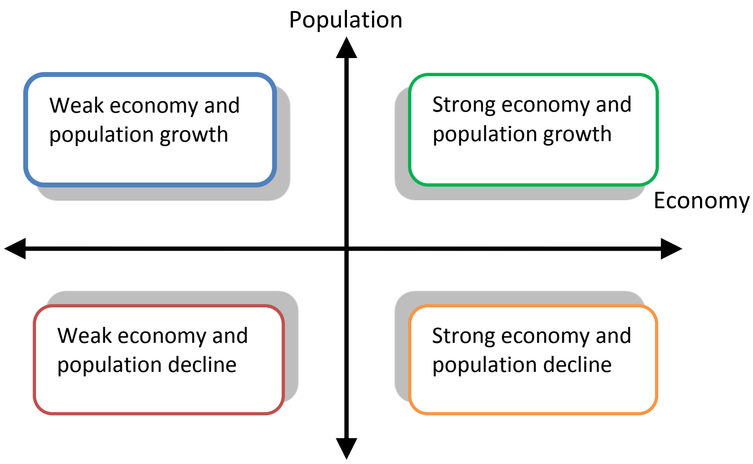


Figure 42: Scenario matrix.

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5.4.1 Strong Economy and Population Growth

Business is on the rise and the demand for urban development (residential, commercial, and office space) is increasing due to the stimulation of a wealthy economy. This leads to more land use and an extension of underground constructions (massive shopping centers, high-rise buildings, parking garages, infrastructure etc.). More construction leads to more excavated soil from construction work sites and therefore more alternative fill material for land reclamation.

Population growth combined with welfare leads to more consumption and more waste production. There is more money available for technological innovations. The higher life standards demands adequate SWM system and more environmental responsibility. Leading to more processed waste and dredged sludge due to the widening of the city's channels and so resulting in the production of more alternative fill material for land reclamation. This scenario is the most favorable for the use of waste as alternative fill material within land reclamation projects.

The causal loop diagram below shows the positive loops created by this scenario.

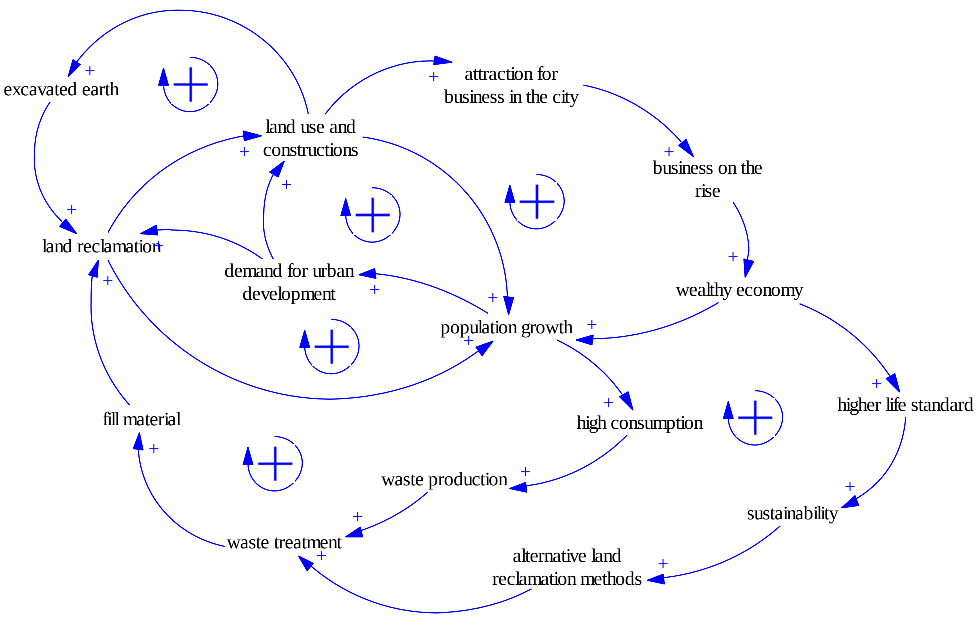

Figure 43: Causal loop diagram of the strong economy and population growth scenario.

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5.4.2 Weak Economy and Population Growth

The contrast amongst the strata's of society is well-known as the wealth gap has been increasing. Yet there are many people in demand of housing and commercial infrastructure of low quality. For example housing that attracts middle to lower class people and leads to wealthier investors abandoning the area. This limits any land reclamation possibility. The cheapest building methods and not really sustainable ways of development are being used leading to waste open dumping or on-site burning instead of any sustainable or responsible SWM system. It is somewhat chaotic.
This scenario leads to a positive reinforcement towards chaos. See the following causal loop diagram.

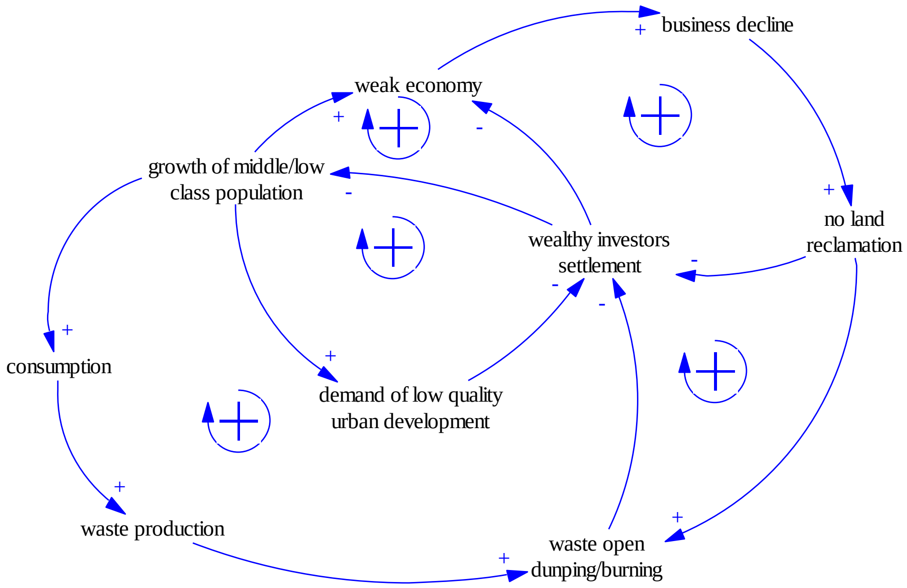

Figure 44: Causal loop diagram of the weak economy and popupation growth scenario.

5.4.3 Weak Economy and Population Decline

This scenario is more realistic than the previous one as it is more common to see how people migrate away from declining economies. It was intended that revenues from land sales would be used for financing the land reclamation project in the long run. However, if there were a population decline, this would be detrimental for the project, as there is no public financing let alone solely. The economy has affected both public and private parties and there is no easy way of pumping money into neither an adequate SWM system nor innovative technologies for land reclamation or even the conventional way of land reclamation. However weak economy often leads to innovative money saving technologies, which in this case could lead to the use of alternative fill material for the land reclamation projects, but with declining population there is no need for new land.
The fugure below shows the causal loop diagram of this scenario.

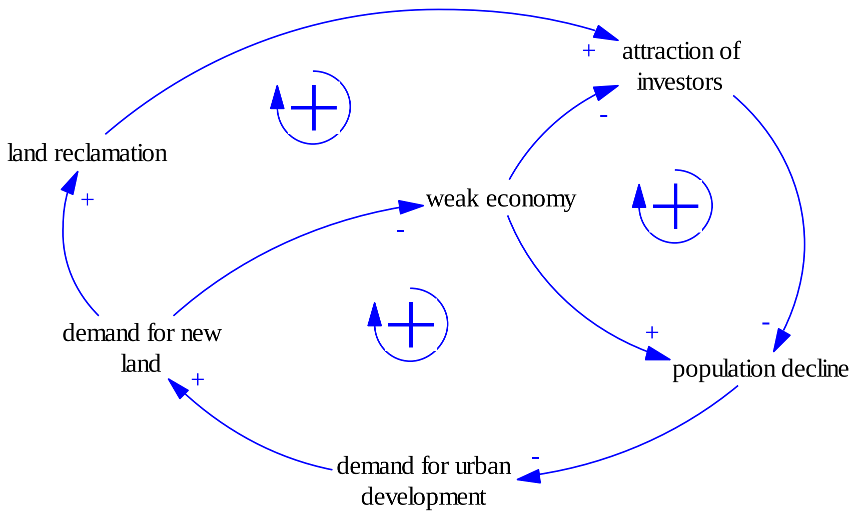

Figure 45: Causal loop diagram of the weak economy and population decline scenario.

5.4.4 Strong Economy and Population Decline

Regardless of people living the area or not, this project could still be carried on. The locale government has enough money to develop the area and at least generate employment within the SWM system, the land reclamation projects during the development process and the spatial development program. Political and economic drivers are sometimes all that is needed to undertake a project that could look somewhat non-profitable. However because of the population decline, leading to low waste production and low construction demand, the availability of alternative fill material for land reclamation could be very low. On the other hand, due to the low demand of housing, the size of the needed land reclamation is lower and therefore the availability of alternative fill material is relatively higher.

Because of the strong economy, one could argue that the costs of sand being higher than the costs of alternative fill materials wouldn't be a problem and therefore the conventional method of land reclamation (the use of sand) would be applied. However, assuming that environmental and social aspects of the use of sand as fill material compared to those of alternative fill materials will also be taken into account and that the city of Jakarta would rather invest in new and more responsible technologies or methods of land reclamation, the alternative fill materials would still be more attractive and therefore more likely to be chosen.

If there is enough employment being generated then a strategy to attract people could be developed, even from places beyond Java or Indonesia. With enough money the reclaimed land could be developed into a very attractive area that would appeal to foreigners or attract thousands of tourists, using innovative and sustainable technologies. This scenario would also place Jakarta on the map as leading city within these technologies of land reclamation.

An overview of the causal loop diagram is shown below.

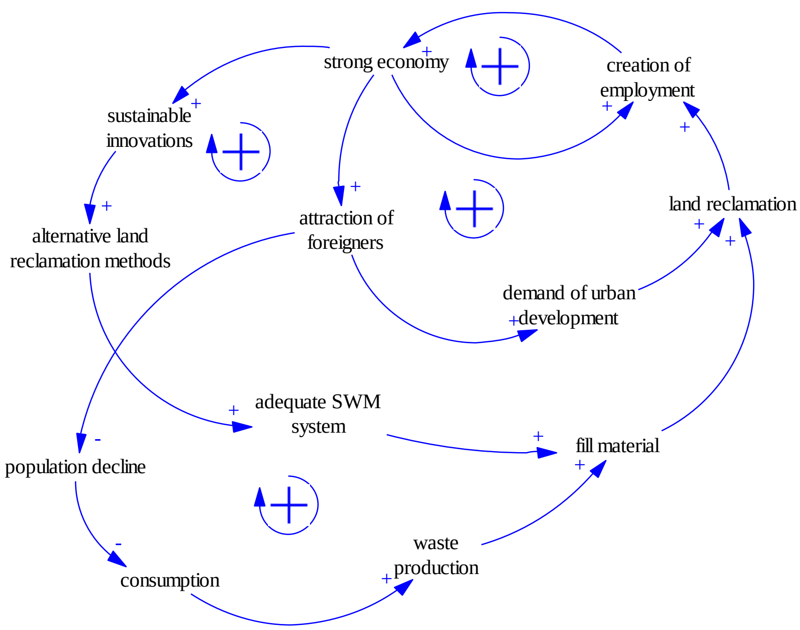

Figure 46: Causal loop diagram of the strong economy and population decline scenario.

5.6 Conclusion

The implementation analysis of the chozen method of land reclamation started with its process sketch, which shows the structure and the needed occurrence sequences of the process elements along with their correlations. The causes trees derived from the process sketch show the causes links of the production steps of the different fill materials.
Then a SWOT analysis was done, which determined the positive and negative aspects of this implementation and evaluated the impact of those positive and negative aspects when occurring at the same time. In the situations where the positive or negative aspects reinforced each other, measures were proposed to limite or prevent negative aspects and enhance or stimulate positive aspects.
Then the implementation conditions were determined based on the SWOT analysis and checked against the context and current situation of Jakarta. Whitin this implementation conditions check, recommendations for a good implementation process were also given.
Finally four future scenarios were simulated based on the possible evolutions of the city's economy and demography. The most interesting scenario for the implementation of the chozen land reclamation method was found to be the one of population and economy growth. This is actually also the most plausible scenario considering the urbanization issues the city of Jakarta is cooping with.

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5 Conclusion and recommendation

5.1 Conclusion

With the purpose of creating new land for urban development in Jakarta, the sand scarcity in the surroundings of the land reclamation areas and the abundant availability of waste in the city, made the use of waste as fill material within these land reclamation projects an interesting approach, with the resulting question: "**How could waste be an interesting substitute for sand as fill material in the land reclamation projects of Jakarta?"**

To answer the first part of this question: "What alternative methods of using waste as fill material within the land reclamation projects of Jakarta are there?", first a case study was conducted on the existing cases of Singapore (Pulau Semakau) and Japan (Yumeshima Island). An alternative method of using waste as fill material was derived from the expertise and technologies of these cases and suggested as Alternative 1 for the case of Jakarta.
After that, alternative ways of using waste as fill material within land reclamation were investigated using expert consultations, brainstorm sessions and existing literature regarding waste treatment methods. This led to two alternative new ways of using waste within land reclamation: the use of the Plasma gasification technology and Strengthened Sediment technology, which formed respectively the alternatives 2 and 3.

To answer the second part of the question: "Which alternative or combination of alternative methods of using waste within land reclamation is more interesting for Jakarta based on the Triple Bottom Line (people planet profit) principle?", a comparative analysis based on the TBL framework using the conjunctive approach of MCA was conducted and Alternative 3 was found most favorable with only 1 major deficiency (on the energy criterion, as strengthened sediment uses energy instead of producing it). Alternative 2, the second most favorable with 3 major deficiencies (accessibility, affordability and safety) and Alternative 1, the most unfavorable with 6 major deficiencies (accessibility, affordability, safety, pollution, comfort and health), which were mainly caused by the inclusion of incineration.
However, based on the large amount of fill material needed and because the availability of landfill material is limited for each alternative or scenario, the best option was found to be a combination of interesting elements of all alternatives; forming the chosen method of land reclamation.
This chosen method includes the combination of A1 and A2, where incineration is replaced with plasma gasification and A3.
Then the fill materials used in the chosen method were compared with sand to determine whether those fill materials are interesting substitutes of sand within the land reclamation projects of Jakarta.
The comparison led to the conclusion that all alternative fill materials are socially, environmentally and economically more favorable than dredged sand, except for dredged seabed sludge, which has similar major deficiencies within the social and environmental aspects as dredged sand. This makes the fill materials within the chosen method interesting substitutes of sand within the land reclamation projects of Jakarta.
However, the availability of sufficient quantities of excavated earth from construction sites, construction and demolition waste, mountain soil and dredged sludge are still unclear and unpredictable for the future. It is to assume that when the available alternative fill material is not sufficient, one could always use sand as complement.

To answer the third part of the question: "How could this more competitive alternative method of using waste within land reclamation be implemented in Jakarta?" several analyses were conducted. First a SWOT analysis to determine strengths, weaknesses, opportunities and threats of the plan of the chosen method in Jakarta and recommendations on how to exploit the opportunities and limit the threats were made. Then an ideal implementation process sketch was made using a system dynamics model and implementation conditions were drown. The current situation and governmental, social, environmental and economic context of the city of Jakarta were evaluated using those implementation conditions and recommendations on possible improvements were given. Finally four future scenarios were sketched using possible evolutions of the demography and economy of the city.

The recommendations are summed below.

5.2 Recommendations in short

5.2.1 Improvements within the current governmental, social, environmental and economic context of Jakarta

- The land reclamation plan should include a integral review of the regulations of the SWM system of Jakarta in order to make sure that:
  - clear and separate responsibilities are appointed to all involved departments or agencies;
  - only one ministry or agency is responsible for the development and implementation of solid waste management goals and policies;
  - operational and regulatory roles are within different departments;
  - a strong control system is in place, to continuously monitor and adjust (where needed) the SWM system;
- The inhabitants should be informed and educated regarding:
  - waste sorting and its effects;
  - waste treatment methods and disposal (composting, recycling, gasification);
- The cost of environment and health damages should be accounted following the concept of 'polluters pay' along with a strong legal system to control and execute SWM rules and regulations;
- Waste separation should be applied at home level. Therefore the inhabitant's awareness and willingness to collaborate should be enhanced, making them co-responsible of the waste problems of the city;
- Waste sorting facilities should be part of the waste treatment system and the collected waste should be sorted (again) even when the waste is pre-sorted at home level to make sure waste streams are properly separated before composting of gasification;
- Communal composting facilities need to be developed and the public participation, including the public involvement within decision making needs to be promoted;
- The city's channels should be dredged, widened and deepened in order to use the dredged sludge for land reclamation, doing so also stimulating the water evacuation out of the city and reducing/preventing flood. Therefore the inhabitants living in the surroundings of (or practically on) those channels must be relocated;

- Relocation processes with the least negative impact on the inhabitants should be considered. Offering suitable alternative living areas is thereby necessary. It is also important to inform the citizens about the reasons and necessity of the relocation and involve them within the process.

5.2.2 Improvements within the land reclamation projects or plans

- Promote governmental and social support and make sure all involved or needed parties are willing and motivated to participate and realize the project within the set conditions;
- The governmental support and involvement in terms of finance, regulation, monitoring and control should be clear before start. It is important that this support is sufficient;
- Make sure the responsibility and role of each involved party is clear for all parties and that the involved parties are willing to hold any responsible party accountable in case of deficiency or shortage;
- Despites the large availability of coal, the willingness of the energy company to invest in the realization of the plasma gasification plant is important. If not, make sure there is a byer of the energy produced from the gasification plant;
- The Bantargebang waste disposal site should be closed in order to maximize the waste treatment and doing so the amounts of fill material for the land reclamation;
- Investments within constructions projects on the main land, especially underground construction projects (parking garages, infrastructure etc.) should be promoted, in order to secure more excavated soil and construction waste for the land reclamation;
- De project developers, reclaiming the islands must be willing to buy the fill materials or invest in the processing of these fill materials;
- Make sure all participating parties have the skill and competences needed for the realization of their roles within the project in order to limit the manageability issues due to the combination of several technologies or methods and the differences with the conventional way of land reclamation. Making sure the technologies are well known by the involved parties, the needed risk assessment is done and possible prevention measures are known and taken for both the land reclamation and the SWM system before start.

5.2.3 Further research

Further research should be conducted on:

- the governmental and social acceptance of the whole plan, and the willingness of the stakeholders to participate;
- the availability of fill material in the near future (construction waste, mountain soil, excavated soil and sludge);
- the strengthened sediment application process in this particular case and the willingness of the stakeholders to opt for this technology;
- a detailed cost and benefits situation and investment strategies among the shareholders.

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6 If I was in charge…

I would make sure the implementation conditions are met before starting with this alternative way of land reclamation using waste. To increase the implementation chance, I would break the plan down to its three different sections because of the different needs of each section.

The involvement of the locale government and inhabitants is crucial for the success of section 3 where compost is used as fill material.

As for the use of the strengthened sediment technology, a research in the costs within the local market and a pilot project are necessary for the go/ no-go decision making. Governmental authorization is needed for the dredging works, however governmental funding for the dredging work may not be necessary when dredging and transportation costs are not too high. When that is the case, the developer could limit his dredging works to marine dredging.

As for excavated soil from construction work sites and mountain soil, the main question is what its current destination is and whether this destination can change into land reclamation. When this is the case, the availability of this fill material is assumed to be sufficient when referring to the case of Singapore where the annual amounts of excavated soil is estimated at 8.5 million m^3 as in 2011.

The following process steps with their go/ no go points could be considered:

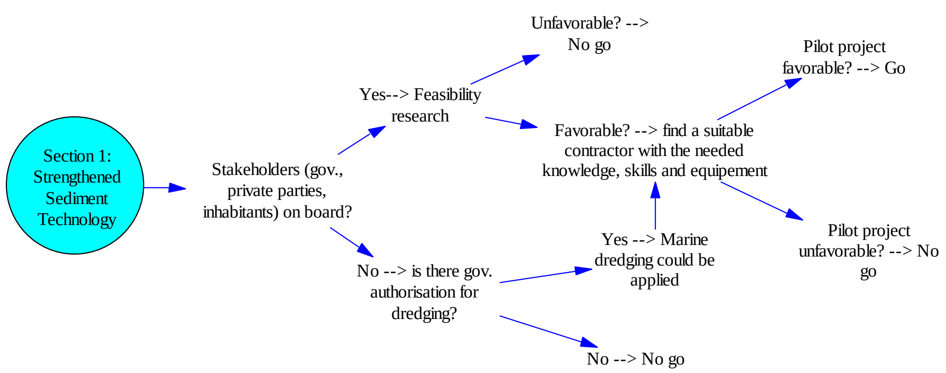

Figure 47: Process steps with Go/ No go points for section 1.

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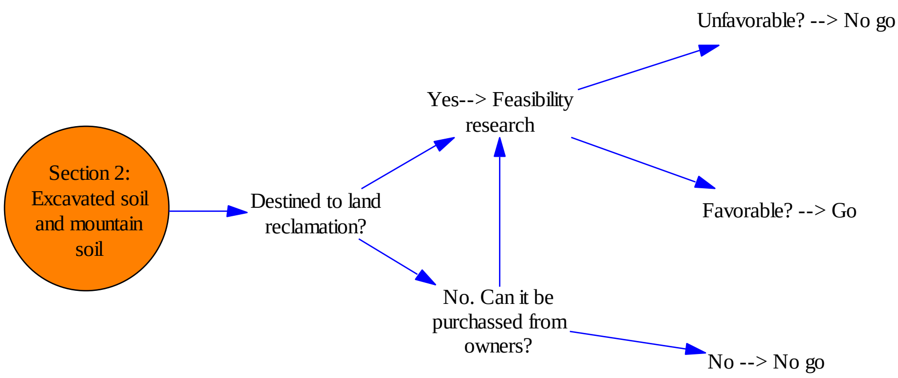

Figure 48: Process steps with Go/ No go points for section2.

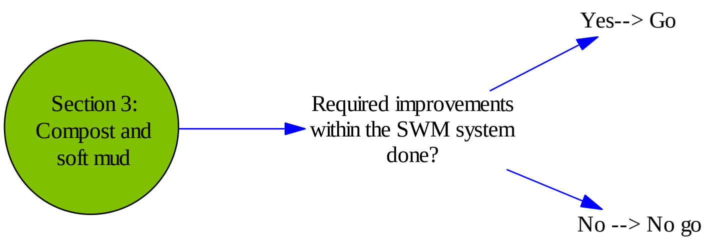

Figure 49: Process steps with Go/ No go points for section 3.

It is to note that the plasma gasification plant is not necessary for the implementation of the chosen method of land reclamation. However even though it produces low amounts of slag compared to other alternative fill materials, it does add to the total amount of fill material and so shortens the landfilling time.

The plasma gasification is mostly needed to complete the sustainable waste treatment cycle proposed while adding to the amounts of land fill material.

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Appendixes

Appendix A: SWM in Jakarta

SWM system

The following flow chart gives an overview of the waste management system in Jakarta.

Figure 50: Flow chart of the household solid waste management system in Jakarta [1].

Collection system

The Cleansing Department of Jakarta has divisions in five municipalities that operate direct and indirect collection systems.

- The direct collection system with direct transfer to the landfill serves commercial, high-income residential and densely populated areas e.g. apartments (multifamily houses), government buildings, streets, and markets (organized by the Market Agency), which are located in relatively strategic places and close to main streets; therefore easy to be reached by waste trucks. Market wastes are collected by the Market Agency, while the Public Works Agency takes care of wastes from parks, canals, and streets. The rest is collected either by the Cleansing Agency or by private means. There are about 20 private companies contracted by the Cleansing Department to undertake the collection in various kelurahan (villages) and central areas. Around 30% of city's total waste generation is collected by this method [7].
- The indirect collection system transfers the waste to a temporary disposal site area before transporting it to the landfill. This collection system depends on community collection. Communal bins in the form of either a container (c.a. 10 m^3) or an open concrete bin (c.a. 6 m^3) are placed close to communities so households can put their solid waste there prior to collection. Some households may afford a waste bin made by concrete or steel built in front of their houses that is big enough for storing their own solid waste and others simply just store them in plastic bags or in cardboard boxes in front of their house. These solid wastes are picked up by the neighborhood association's cleansing workers by car/truck, or an open wooden/steel cart, depending on the arrangement in the neighborhood and hauled to the nearest temporary transfer point. The carts dominate areas with poor car accessibility, relatively short distance to the temporary disposal site. The Cleansing Department

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truck then collects the waste and transport it to a transfer station or directly to a final disposal site.

There are 1731temporary disposal sites operated in the whole Jakarta region. Waste workers unload the solid wastes to available containers, and in some areas as part of government programs of recycling, they also sort the non-organic wastes e.g. plastics, paper, bottles, cans, and glass to be recycled.

The waste collection system in Jakarta needs to be improved and the coverage needs to be extended. More resources such as vehicles need to be provided to allow more regular and frequent collection, preventing any spread of diseases to the neighborhood through excess wastes waiting for collection. An improved waste collection would also reduce improper solid waste handling e.g. burning, river disposal or open dumping practices currently practiced by the inhabitants as some of their initiatives of getting rid of wastes [32].

The Figure below shows a typical garbage cart and a typical handcart and cleansing worker of a neighborhood association.

Figure 51: (left) A typical garbage cart [41] and (right) a typical handcart and cleansing worker of neighborhood association [32].

Transportation system

Collected solid waste is disposed of in the landfill located at Bantargebang, about 40 km from the city to the east in the neighboring city Bekasi. The different types of vehicle used are usually:

- regular truck with open container,
- truck with hydraulic loading system (tipper),
- truck with the container remaining in location (arm roll truck), and
- truck with compactor equipment

In average conditions, depending on the route, traffic density and traffic volume, one return trip of the waste truck needs around 4 à 8 hours (including stops in different places). A recent investigation showed that only 86% of the needed vehicles are effectively operated [6].

Waste treatment facilities

Compacting Station and temporary storages

In the compacting transfer station, located in Cakung-Cilincing (Sub District) in North Jakarta, the solid waste is compacted using physical means, to ease the transport process to the landfill. This system has an average transport capacity of 700 tons/day and a compacting

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ratio of 1:3. The management of this system is performed in cooperation between a private enterprise and the municipality [6].
A temporary storage is established to reduce the hauling distances for collection trucks, lowering transportation costs. There are 1,478 temporary storages available in Jakarta [8]. On the temporary storage, the wastes are transferred to waste trucks, which are operated by manual labor or shovel loader and then transported to the composting centers or landfill. According to the [21, 32], operation of the temporary storages increased the effectiveness of collection vehicles from 1.7 to 3 trips per day. This is due to the fact that the waste that is pooled in the temporary storages is easily collected and transported to the disposal site, rather than collecting the waste from various points that would otherwise reduce the efficiency of collection.

Landfill and other waste treatment facilities

The majority of the collected solid waste is transported to the Bantargebang landfill site. This landfill site is owned and operated by the municipality and receives almost all collected waste in Jakarta. The Sanitary Agency estimates that from the 6,000 ton/day of solid waste generated, approximately 5,000t/day is disposed of in Bantargebang over its design capacity of 4500 ton/day [41]. The Landfill, designed to handle 19 million m^3 of waste, has been in operation since 1989 and covers an area of 110 hectares divided into five waste deposition zones. An overview of the landfill map is shown below.

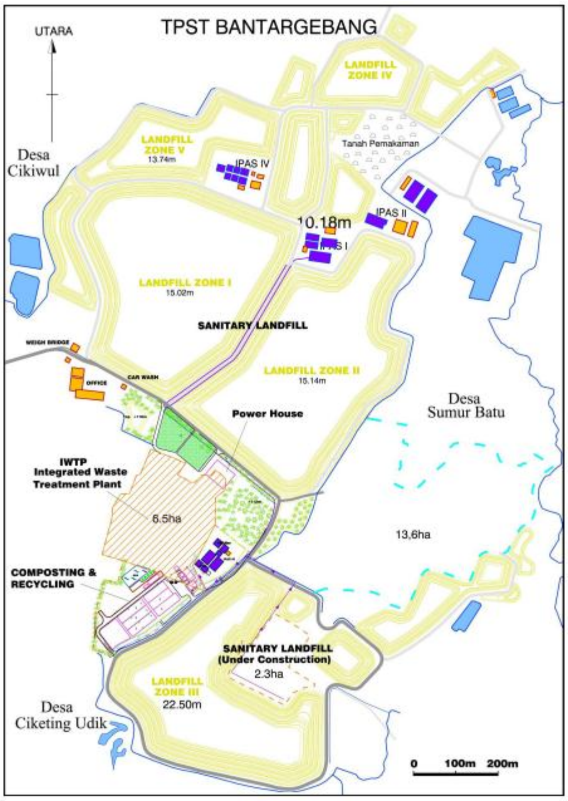

Figure 52: Map of Bantargebang Final Disposal Site and (Future) Integrated Waste Processing Site [7].

Under its master plan, Bantargebang was designed to be operated with sanitary standards, but in practice, it is only operated in this fashion in the first few years of its operation. Insufficient fund and expertise led to practices less than sanitary and resulted in numerous complaints (e.g. the self-combustion in 1999, the impacts of haze and odor, the surface and groundwater contamination, the environmental impacts and the impacts on human welfare and health) from stakeholders, and hence the necessity to find a new solution. Therefore in 2006, a plan was formulated to convert Bantargebang Final Disposal Site into Bantargebang Integrated Waste Processing Site.

According to JICA [22], another landfill at Tangerang District (Ciangir Landfill) was scheduled to operate from 1995 to serve the western region of Jakarta. Also under the JWMC project (2004), there were proposals for several new landfills to be built and operated by 2008 to provide additional capacity. However, due to a strong opposition from surrounding residents, partly a result of the poor management of the Bantargebang Landfill, these plans have not been implemented. Instead there were plans for intermediate waste treatment facilities, like:

- the **Intermediate Treatment Facilities (ITF) of Cakung - Cilincing**, a recycling and composting center, which was scheduled for operation in August 2011 and would treat 450 tons of garbage per day, from which it will gradually be increased to a total capacity of 1200 tons per day in 2012 [8]. This ITF constitutes one of the three ITF units to be constructed. The intended purpose of those ITF units is to help reduce the burden on Bantargebang integrated waste processing site (TPS), Bekasi. The technology applied at the Cakung - Cilincing ITF, uses mechanical biological treatment to recycle organic and non-organic deferments while producing fuel for electricity generation (waste to energy). The electric energy produced reaches 8 - 12 megawatts, which is to be sold to PT Perusahaan Listrik Negara and distributed to the local community.
- Another ITF is **the Sunter ITF**, where the SPA Sunter (transfer station) will be upgraded to an ITF which will reduce the waste volume up to 90 %. This transfer with a total area of 6 Ha and a capacity of 1000 ton/day is operating since 2000. It accommodates and compresses the waste, reducing the number of transporting vehicles to the Final Treatment Plant. The Sanitation Department of DKI Jakarta planned to finish the upgrade and commence the operation in early 2013 accommodating garbage up to 1200 ton/day.

An overview of the landfill and waste treatment facilities from the Waste Management Master plan is given below.

Table 23: Waste treatment facilities and their location and status [8].

WASTE	FACILITY	LOCATION	STATUS
SOLID WASTE	Intermediate Treatment Facility (ITF)	Sunter	Upgrading from Tranfer Station to ITF
		Cakung	Upgrading from Tranfer Station to ITF
		Marunda	On Process
	Composting Center	Cakung	Operating
	Integrated Final Treatment Plant	Bantargebang	Operating
		Ciangir	On Process
SEWERAGE	Sewerage Treatment Facility	Duri Kosambi	Operating
		Pulo Gebang	Operating

Figure 53: Landfill and waste treatment facilities from the Waste Management Master Plan [8].

Incineration

Another method of treating solid waste in Jakarta is incineration. There are 21 small-scale incinerators with a total capacity of about 22 tons/day. Most of the facilities are operated improperly or at sub-optimum conditions because they have not been designed for high moisture content waste, have poor manual handling setups, poor operator skills, contaminated waste and high maintenance or fuel costs [21].
Furthermore, they are not operated on a daily basis and technical information is lacking, such as a detailed description of the operation of the system, the treatment process, and how these incinerators have performed so far. This process is planned to reduce 80% of the

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incoming solid waste quantity, using 800°C heat in the incineration. The remaining ash is either transported to landfill or transformed to a kind of bricks [41].

Composting

Given the high content of compostable materials, solid waste composting was started in 1991 and it reached a maximum capacity of 24.2 tons/day in 2000 at 14 composting facilities using windrow systems [21]. As is common with other parts of the overall MSW system, a lack of strategic development for composting has led to poor performance. Problems that have been encountered but not solved are among other:

- lack of market development;
- lack of environmental guidelines to deal with odors, rodents and other environmental impacts;
- contaminated feedstock;
- insufficient provision of space to operate and expand;
- lack of quality control by untrained staff.

In addition to that, the lack of community participation in any initiative and a poor local government management, especially in providing tool kits and guidance on how to make a better compost product at household and community level played an important role [32].
The idea behind composting of organic solid waste is to reduce the waste quantity going to the landfill. The composting system comprises a centralized sorting system, where mixed solid waste is sorted and thereafter organic solid waste is composted and certain recyclable products are recycled. The remaining waste is either burned in the incinerator, where after the ash is disposed of in the landfill or directly transferred to the landfill.
This program is supported by another parallel program called 3R (Reduce, Reuse, and Recycle), that introduces a source separation (in the households) of organic and non-organic waste in different bags or containers, where non-organic solid waste (e.g. plastics, paper, metals, etc.) is left to scavengers for further separation and recycling.
Both programs have been implemented since the year 2000 in different sub-districts of Jakarta, but problems, such as: (1) a lack of community participation, (2) lack of supporting vehicles for 3R and (3) over capacity, where the time needed to sort waste has been too limited combined with a high frequency of incoming mixed waste trucks, are still present. There is need for more effort to improve the performance of these programs. The Figure below shows the windrow composting piles.

Figure 54: (left) Pilot project of windrow composting [41] and (right) Typical neighborhood-based composting [32].

Recycling

Recycling is not yet systematically considered as an alternative waste management system by the Government of Jakarta. The main existing focus as mentioned before is on landfilling or aspirations for high-technology solutions.
A number of reduce–reuse–recycle (3R) initiatives have been introduced, mainly under project-based schemes, by community-based organization (CBOs) and non-governmental organization (NGOs), but these have generally ceased to operate. Reasons for this are among others, lack of community awareness, poor ongoing commitment of the executing agency, lack of appropriate trucks allocated to collect waste already separated by households, poor co-ordination with other urban systems, lack of economic incentives and lack of a regulatory system and its enforcement [32].
Recycling in Jakarta is therefore carried out largely by an informal system, which involves thousands of scavengers, collectors, waste suppliers and “tukang loak” (people who come door to door, to buy cheap things, such as metal equipment, bottles, newspaper, magazines, car batteries, etc.). This recycling system occurs at four points: the household level, during collection (e.g. households, commercial areas and offices), at temporary transfer points and at the final disposal site.
The scavengers play an important role within this system and reduce as much as 15% of the total waste generated daily [31, 41] even though their activities generally interfere with the safe and efficient operation of the sites. The diagram below presents an overview the waste recycling activities.

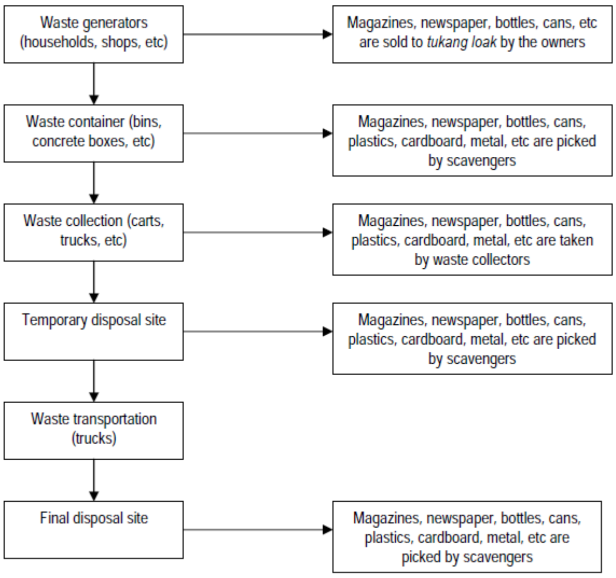

Figure 55: Informal recycling system [41].

The location of scavenging varies: about 60% of the scavengers are working in residential areas, 10% in shopping areas, 10% at markets and 20% at temporary disposal areas and at the landfill. Recycled materials collected at the waste generation point have a relatively higher value and less contaminant than recycled materials from other points.

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The waste recycling business involves different elements which are interdependent to one another and forms a network of:

- low capital people such as scavengers and *tukang loak*;
- middle capital people that pull together the wastes from scavengers (used to be called *lapak*);
- certain recyclable materials collectors (named *bandar*);
- suppliers, who are trusted by manufactures to deliver the waste as their secondary material.

The figure below gives an overview of such a network.

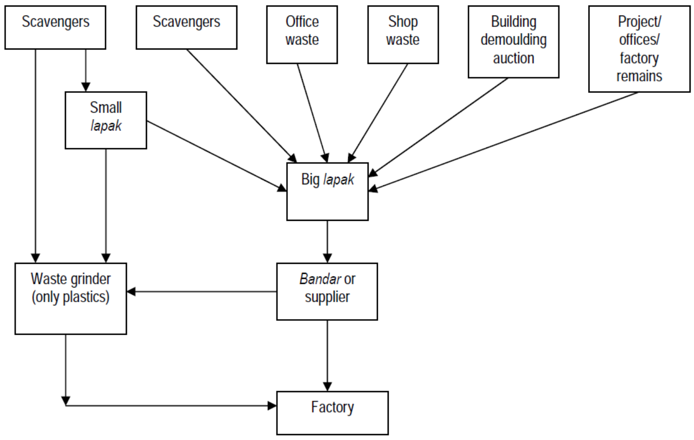

Figure 56: Overview waste recycling business network [41].

Social context of the SWM

As mentioned before, the government of Jakarta has two systems of waste management; the formal system (done by municipal agencies and formal businesses) and the informal systems (done by scavengers, collectors, waste suppliers and tukang loak). Because the issue of proper waste management is not just a government task, but a shared responsibility that includes the citizens and households of Jakarta (as main end-users of waste management facilities and services), reorganizing solid waste management systems means understanding the role of households, their attitudes, their waste handling practices and their interactions with other actors in the waste system [30].

Prior studies on (1) the perceptions and behavior of householders in terms of waste management, (2) their willingness to sort waste, (3) their willingness to pay for waste sorting, and (4) their perceptions of their own role and that of waste service providers in order to improve performance in the future [2], were analyzed and described below.

People's behaviors concerning the waste management system

According to Aprilia A., et. al., [2], the majority of the people surveyed (67%) store waste that is to be collected from the household for disposal in a plastic waste bin in front of their house; 14% store it in brick garbage bins, and 12% store it in plastic bags. The various types of waste storage containers located in front of houses in Jakarta are illustrated below.

N.F. Barry, 2013, *The use of waste as fill material in the land reclamation projects of Jakarta.*

Figure 57: Various waste storage devices (plastic waste bin, brick waste bin, and plastic bag) in front of houses [2].

The waste collectors who transport waste from households to the temporary storage site are informal workers hired by neighborhood associations or private companies. These waste collectors all use hand carts with an average capacity of up to 100 kg.

Within each neighborhood cluster (*Rukun Warga*) of usually 10 neighborhood units (*Rukun Tetangga*), in which approximately 680 households reside, there is a communal composting facility. However, of all the respondents surveyed, 88% claimed that there are no communal composters in their area of residence. Among the respondents who indicated that communal composters are available, only 7% claimed to be actively involved in communal composting activities. These respondents were mostly housewives and retirees. All respondents who were actively involved in communal composting claimed that they do not receive any financial incentive whatsoever to participate in communal composting. However they are all users of the produced compost. As users of the product, these responders (86%) perceive the product as being of high quality. The compost products are mainly purchased by householders and small to medium enterprises.

Regarding home composting, of all the respondents surveyed, 8% own and use a home composter. All of the respondents who conduct home composting use the product for personal purposes.

An illustration of a communal composter and a home composter is given below.

Figure 58: Illustration of (left) a communal composter and (right) a home composter [2].

People's willingness to sort and willingness to accept waste sorting practices

Regarding waste sorting (e.g., sorting organic from inorganic waste), most of the people (81%) do not usually conduct waste sorting at home. However their responses regarding agreement to consider waste sorting were quite high, with 73% indicating that they would consider sorting their waste at home. The respondents agreed (34%) and strongly agreed

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(25%) that if required, both sexes should be responsible for conducting sorting within the household.

Of all the respondents who have already incorporated waste sorting into their daily activities, 44% have been conducting waste sorting for less than a year, and 26% have been doing it for 1 – 5 years. The actors who motivate them to sort their waste include early adopting family members and neighbors (31%) and community leaders (25%) [2].

Willingness to pay others to conduct waste sorting

If government authorities were to require at-source waste sorting, 42% of the respondents are willing to pay and 57% would rather sort their own waste. 1% of the respondents were not sure.

People's perceptions of future roles in the waste management system

According to the responses to the questionnaires of the survey [2], if appropriate mechanisms, incentives and technical information are provided, the majority of respondents agreed to play future roles, such as:

- Being involved in communal composting (37%) and home composting (31%);
- Learning to sort waste properly (50%).

Despite agreeing to adopt more roles in the future, most of the respondents do not wish to be involved in monitoring and evaluation of the overall waste management system in their community.

People's perceptions regarding future roles of other waste management actors

The majority of respondents strongly agreed that there are several improvements and roles that the government and other waste management actors should make in the future, such as:

- Providing more regular waste collection (54%);
- Proper handling, treatment, and disposal of waste to reduce pollution (53%);
- Providing information to citizens regarding the methods of waste treatment and disposal and providing overviews on the waste management system (45%).

Furthermore 43% of the respondents agreed that waste management actors should actively involve citizens in waste management decision-making processes [2].

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Appendix B: land reclamation technique of Yumeshima Island

Construction of reclamation seawalls

On the island Yumeshima, waste disposal is divided into four sections:

- Section 1 will have an area of about 0.73 million m^2, and receive about 11.69 million m^3 of general wastes, including residues of incinerated domestic waste and waste generated from operation of such public facilities as waterworks and sewerage systems;
- Sections 2 and 3 will have a total area of about 2.15 million m^2, and receive about 38.31 million m^3 of excavated soil from civil engineering and construction work sites and dredged soil from rivers and harbors;
- Section 4, expected to provide a site for a harbor physical distribution base is being reclaimed using normal mountain soil and surplus soil from construction work sites.

Figure 10 shows an overview of the sections on Yumeshima Island.

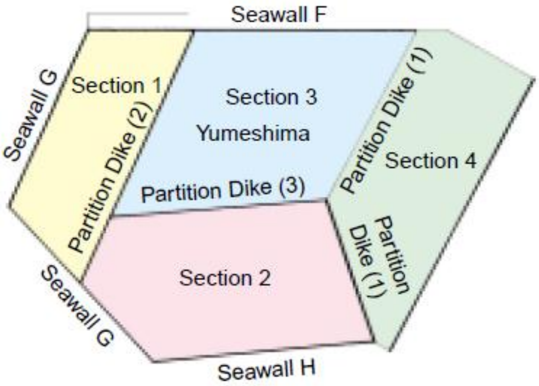

Figure 59: Plan view of Yumeshima island [25].

To secure water cutoff, back-filling (mountain soil) about 20 to 30 meters wide was formed behind the caissons, and cutoff sheet piles were driven down beneath the sand mat. Partition dikes between Sections are of double steel sheet pile structure, stabilized by sand fill. Section 1 is enclosed by Seawalls F and G (figure 10). A caisson type structure was adopted for Seawall F, for construction reliability and cost reduction. The sand compaction approach was carried out for the lower part of the seawall foundation, and sand replacement of excavated seabed was adopted for the upper part. Seawall G, which faces waves from the west caused by westerly winter winds, has a box-type slit caisson structure with wave dissipation function, to reduce the impact of reflection waves on ships sailing in front of the Seawall (see Figure below).

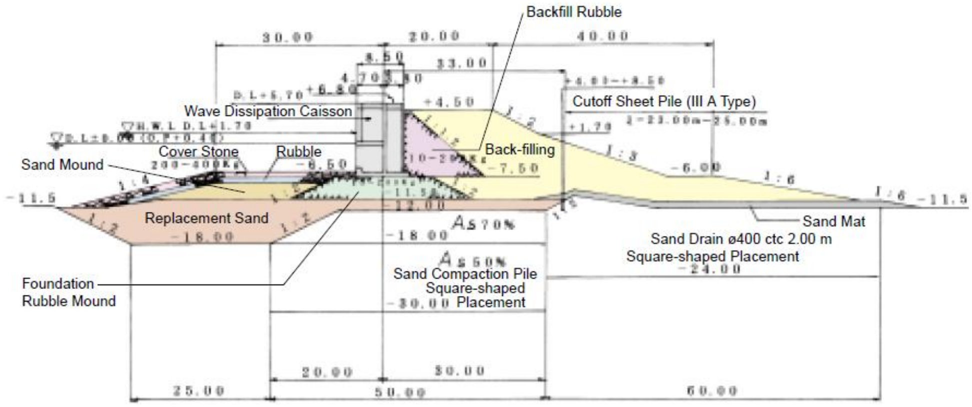

Figure 60: Seawall G, Yumeshima [25].

As in the case of Seawall G, the structure of Seawall H, a southern seawall of Section 2, is of box-type slit caisson type, with the function of dissipating waves.
Although still in the experimental stage, efforts are under way to increase capacity by using the sand mat formed on the ground foundation. Drains were installed in the vertically inverse direction, and water is drained from the sand mat via the pump wells, causing the surface of the dredged soil layer to subside and capacity to increase (see Figure below) [25].

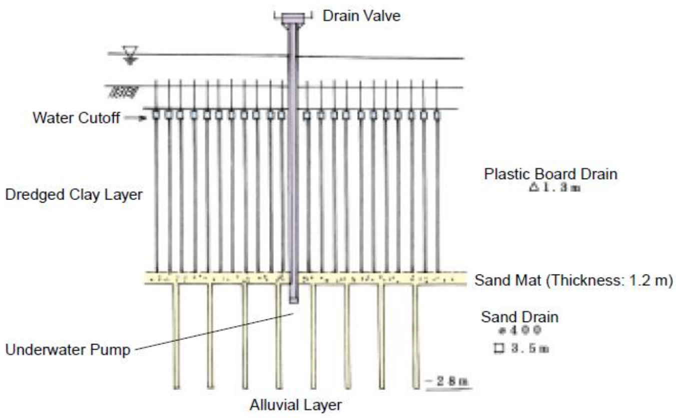

***Figure 61: Capacity increase method on Yumeshima island* [25].**

Ground foundation improvement

In this district, a soft alluvial clay layer peculiar to the Osaka area has formed from the seabed to a depth of approximately 20 meters. Without ground foundation improvement, therefore, the sea bottom cannot be used as a foundation for various urban facilities. Moreover, since Sections 2 and 3 were expected to accept as much waste as possible for disposal, various measures had to be devised, including raising the heights of surrounding seawalls and forced subsidence of the foundation ground. As a result of cost efficiency and various other studies, it was decided to adopt the sand drain method, together with lowered groundwater level using drainage wells, so as to promote compaction and subsidence of the

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sea bottom clay ground. These approaches were expected to cause forced subsidence of the foundation ground and increase waste capacity, as well as providing the foundation ground stability required to ready the reclaimed land for use (see figure below).
In ground foundation improvement, first, a sand mat was formed before filling the dredged soil. Sand drains were then driven into the alluvial clay layer. Sand mound was then formed, in which drainage wells were installed to pump water out, because water was not easily released in the vertical or horizontal direction, even when sand drains were installed; there was no vertical route for water to escape because dredged soil would be added later. Water release in the horizontal direction was difficult as well, because of the extensive ground improvement area as compared with the sand mat thickness of only 1.2 meters.
After such preparatory work, the drainage wells were operated to lower water level through the sand mat during dredged soil filling, to affect further foundation ground subsidence than that caused merely by the filled soil load. After filling of dredged soil, the landfill had to be improved due to the extreme softness of the dredged soil used. To install vertical drains for this, the landfill surface was first subjected to solar drying. However, the strength distribution of the inner part of the landfill showed considerable variation. Moreover, the landfill did not thereby acquire sufficient strength to bear construction machinery traffic. To solve these problems, a partition embankment was constructed, and a net was laid to augment load-bearing power and slide resistance through net tension and friction between net and soft, viscous soil. After forming a sand mat on the net to secure transit of construction machinery, plastic board drains were installed. Pump wells were then installed to lower water level and promote compaction.

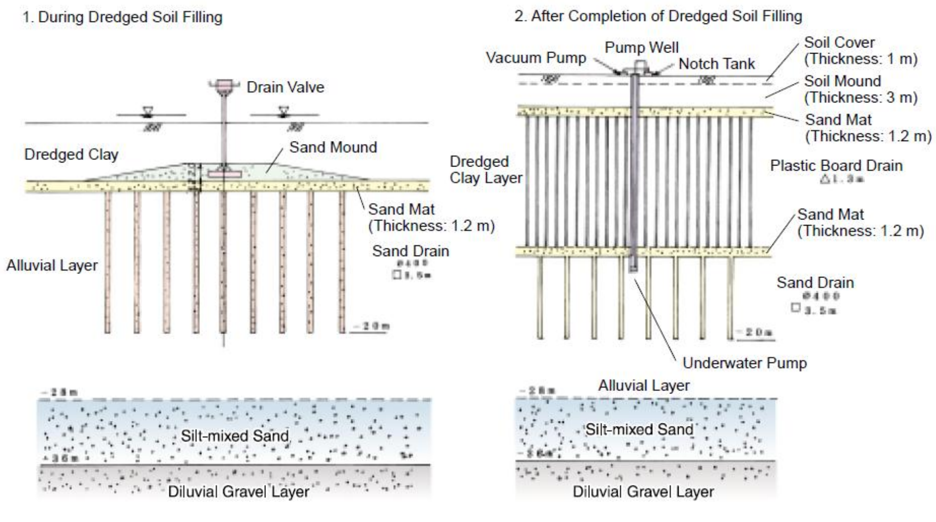

Figure 62: Ground foundation improvement method [25].

In Sections 2 and 3, where dredged soil reclamation is done, the plan was to accept approximately 2.6 million m^3 of soil dredged for establishing channels etc. in future. Upon completion of soil acceptance, improvement of the ground foundation was urgently required, to enable construction of a subway line through Yumeshima and development of housing and other facilities, to commence at the earliest possible time. Studies were done concerning a method of improving such ultra-soft ground, composed chiefly of dredged soil.

The ground foundation approach under consideration is as follows: first, an embankment was constructed for use as a temporary road for construction vehicles; the embankment was then used in laying net sheets and forming a soil mound; then drains were installed.

Appendix C: Plasma gasification history, process, technology and environmental and economic aspects

History

Currently, there are more than 150 industrial gasifiers throughout the world. They are mainly used to process biomass and coal. The use of gasification for MSW has been mostly applied in Japan, where their lack of space forced them to find alternatives to landfilling. As mentioned before, Japan has also
the only commercially interesting plasma arc facility that treats MSW, in Utashinai.
In Europe, a few plants have been operating, all under the scale of 130 tons per day. The Thermo select process was built in Germany but encountered technical difficulties and closed. Siemens also had similar issues with waste gasification at their Fürth plant, where had a serious accident occurred. This issue with waste gasification led to a very bad public opinion of the technology and Germany is no longer considering using it in the future [62]. However, gasification is generally viewed as a better option than grate combustion, because it is not associated with the polluting incinerators. Therefore, there can be a market for gasification in competition to grate combustion.
Between 1988 and 1990, Westinghouse extended the plasma cupola technology for the treatment of hazardous waste including PCB-contaminated electrical hardware, transformers and capacitors, contaminated landfill material and steel industry waste. In the mid-1990s WPC in cooperation with Hitachi Metals completed an R&D program and pilot testing program to confirm the capability of the plasma cupola to treat municipal solid waste (MSW) and other waste materials to produce a syngas which could be used in a power plant for the production of steam and electricity. The success of a series of tests provided the technical basis for the design and installation of a pilot scale 24 ton/day MSW gasification plant in Yoshii, Japan. After a demonstration of the capability of using plasma energy to reliably and economically gasify waste materials for energy production, an application to full scale facilities in Mihama-Mikata and Utashinai Japan were realized. Both facilities began commercial operation in 2002 and 2003 and continue operating till now. The experience gained here was used to create the next generation gasifier which was commissioned in 2009 by SMSIL in Pune, India.
More recently, Air Products purchased a plasma gasification reactor from Westinghouse for Air Products' 1000 tonne per day plant to be built in Northeast England [46].
The following figure illustrates the commercial history of Westinghouse Plasma Corp technology.

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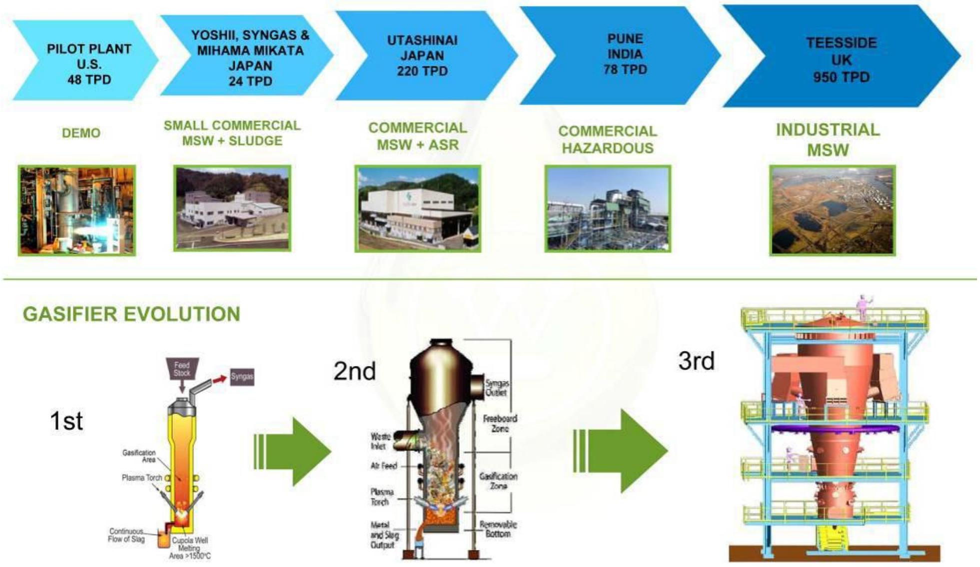

Figure 63: Commercial History of Westinghouse Plasma Corp [46].

The table below provides a summary of each facility so far.

Table 24: Summary of Operating Facilities and New Facilities [46].

	Operating Facilities			New Facilities	
	Mihama-Mikata	EcoValley	Maharashtra Enviro Power Ltd (MEPL)	Tees Valley Renewable Energy Facility	Sunshine Kaidi Energy Park
Location	Mihama, Japan	Utashinai, Japan	Pune, India	Tees Valley, England	Wuhan, Hubei, China
Owner		Hitachi, Muni and Territory Gov'ts	SMSIL	Air Products	Wuhan Kaidi
Capacity (tpd)	24	220	72	1000	150
Feedstock	20 tpd – MSW 4 tpd – sewage sludge	MSW	Various Hazardous Wastes	Sorted MSW	Mixed Wood Waste
Commissioning Date	2002	2003	2009	2014	Q4 - 2012
Output and Configuration	Heat - Boiler	Power - Boiler	Power - Boiler	Power – Combined Cycle	Ethanol - Catalytic

Process

Plasma gasification is a multi-stage process which starts with feed inputs – ranging from waste to coal to plant matter, and can include hazardous wastes. The steps of the process are as follows:

- The first step is to process the feed stock to make it uniform and dry, and have the valuable recyclables sorted out.
- The second step is gasification, where extreme heat from the plasma torches is applied inside a sealed, air-controlled reactor. During gasification, carbon-based

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materials break down into gases and the inorganic materials melt into liquid slag which is poured off and cooled. The heat causes hazards and poisons to be completely destroyed. The heat being very valuable is recycled back into the system to generate steam for other purposes.

- The third stage is Scrubbing: Once the gases are cooled, they pass through a series of gas cleaning operations which are tuned to the downstream requirements as well as environmental regulations. Heat exchangers recycle the heat back into the system as steam. Scrubbers are routinely used to clean smokestack exhaust in power plants and industry.
- The fourth and final stage is energy/fuel production: the output can range from electricity to a variety of fuels as well as chemicals, hydrogen and polymers. Electricity is produced using boilers, engines or gas turbines. Gas engines and turbines require very clean gases, but straight combustion to fire a boiler can use less clean gas and has the lowest cost. Steam systems may generate 450–550 kWh per tonne (500–600 kWh per US ton) of MSW. Gas turbines in a combined cycle may generate 900–1200 kWh per tonne (1000–1200 kWh per ton) of MSW. In theory, the torches and the facility would consume only 25% of the energy produced, leaving 75% available for sale.

Waste gasification typically operates at temperatures of 1500˚C (2700˚F), and at those temperatures materials are subject to a process called molecular disassociation, meaning their molecular bonds are broken down and in the process all toxins and organic poisons are destroyed.
The in- and outputs of a gasification plant is shown below.

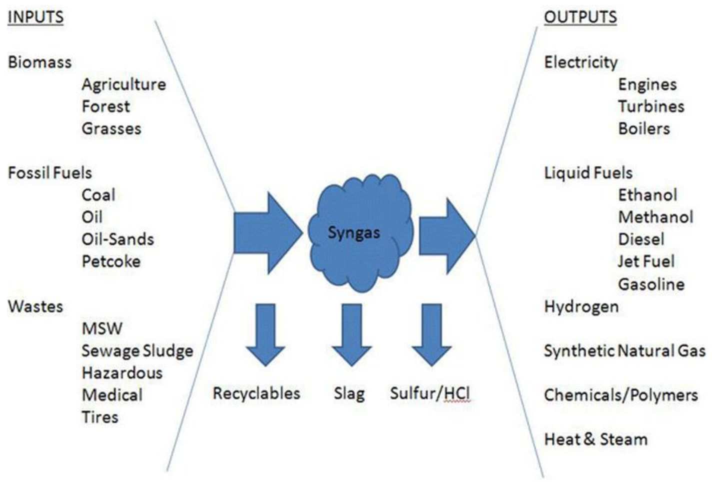

Figure 64: Plasma gasification, inputs and outputs [62].

Table 25: Feedstock and outputs of the WPC's plasma gasification plants [46].

Feedstock	Outputs

Westinghouse Plasma Corp. gasification solution is ideally suited for a number of waste streams including:
 	
• Municipal solid waste
• Commercial waste
• Industrial waste
• Petrochemical waste
• Medical waste, and
• Incinerator Ash
	The clean syngas produced by our plasma gasification solution can be converted into a wide variety of energy products including:
	
	• Electricity, through gas turbines, reciprocating engines and in the future, fuel cells
	• Heat and steam, and
	• Liquid fuels including:
	  ○ Ethanol
	  ○ Jet Fuel
	  ○ Diesel and Naptha
	  ○ Methanol
	  ○ Propanol

Technology

Plasma gasification of MSW is a fairly new application that combines well-established sub-systems (waste processing and sorting, plasma treatment, gas cleaning and energy production) into one new system.
The integration of these systems is rapidly maturing, but has still not been built in large industrial systems.
An overview of the concept of gasification is shown below.

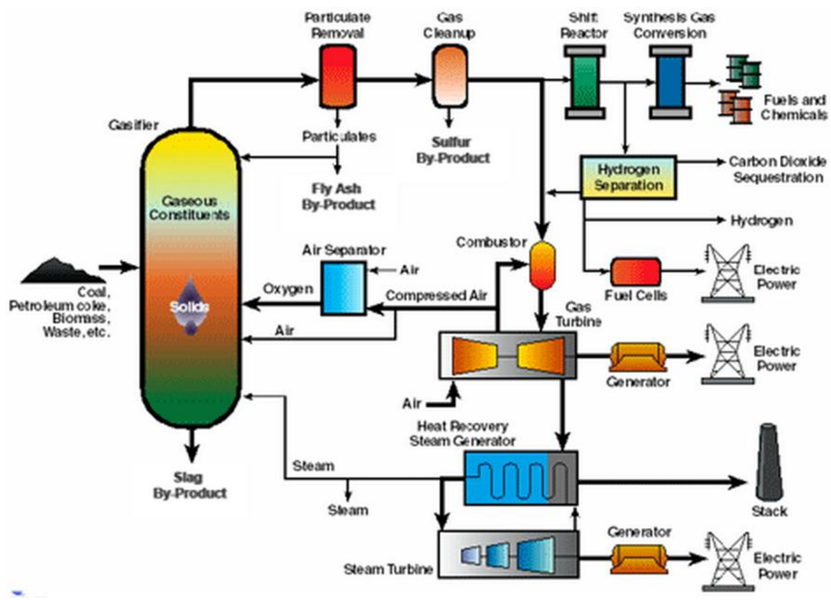

Figure 65: Gasification-based energy conversion system concepts [45].

Alter NRG acquired in 2006 the Westinghouse Plasma Corporation (WPC), a leader in plasma gasification technology as applied to waste management. The non-transferred plasma torch consists of a pair of tubular water-cooled copper electrodes. The operating gas is introduced through a small slot between the electrodes. An illustration of a torch is shown below.

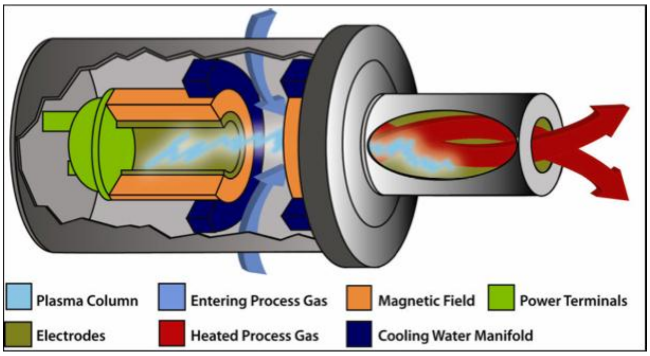

Figure 66: WPC non-transferred arc torch [62].

These torches are used for boosting the temperature in metal melting cupolas but one of their most important applications is the destruction of hazardous waste and the vitrification of WTE ash. This technology has been developed much in the last decade, especially in Japan. The thermal efficiency of the WPC torches ranges from 60-75%.
The overall process developed by Alter NRG is based on a gasification reactor that incorporates the WPC plasma cupola and plasma torches. This plasma cupola is a well-proven technology and is currently used in several plants in Japan. An overview of this cupola is shown below.

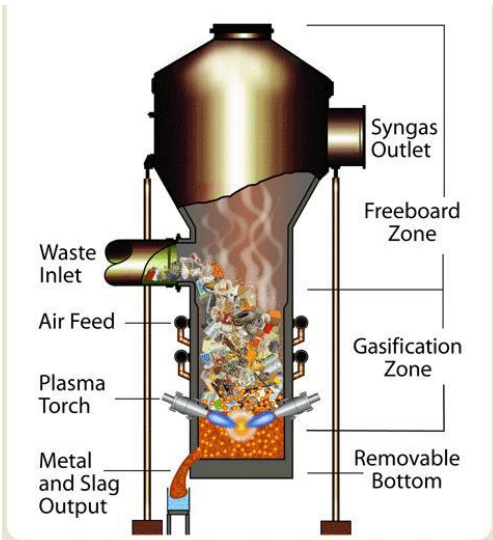

Figure 67: Alter Nrg plasma gasifier [62].

Along with a 100% feed of MSW, the Integrated Gasification Combined Cycle (IGCC, see Figure below) is the ultimate goal of Alter NRG. In this design, MSW is gasified with addition of metallurgical coke (4% by weight) to produce syngas and then electricity via a gas turbine. Metallurgical coke (met coke) is added to the heterogeneous feed in order to raise the calorific value of the feed. The main difference between the classic steam cycle (figure 19) and the combined cycle is the presence of turbines that compress the syngas instead of

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combusting it all in a steam boiler. In both cases, the waste heat is combusted through a steam boiler to recover more energy.

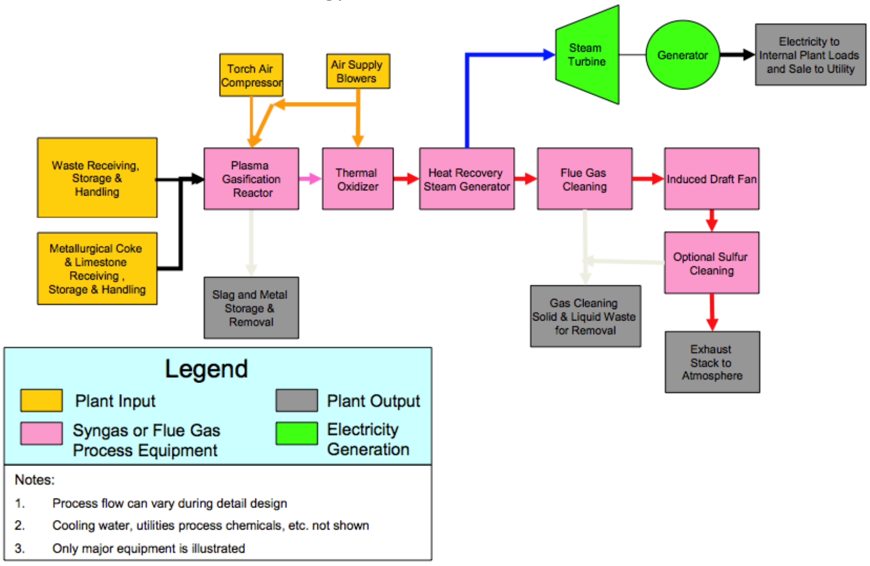

Figure 68: Alter NRG's steam cycle [11].

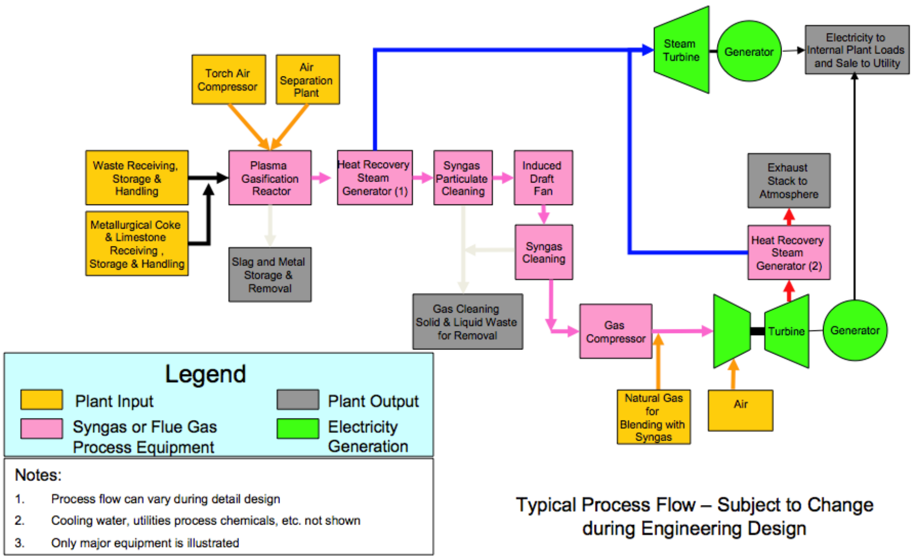

Figure 69: Alter NRG's Integrated Gasification Combined cycle [11].

Economics

The Alter NRG option, operating on a steam cycle, is very interesting for countries where the electricity price is low (as it is the case for Japan, where electricity is worth 3-4 cents per kWh) [11], allowing building a plant at lower capital cost. Also, the air separation unit (ASU) is no longer needed for the production of oxygen. The Indian plant is also operating on this steam cycle.

For the cost of the plasma system, the calculations are based on the paper of [5], who studied the case of a plasma-arc plant in Marion, Iowa. For a 300 ton per day (tpd) plant, they assume the cost of plasma arc to be $27,400,000. In the following table, the used element costs and amounts are summarized.

Table 26: Summary of the used element costs and amounts [11].

Elements for a 750 tpd plasma plant	**Costs**
The capital cost	$189,284,375; $76.8/annual ton of capacity
The labor costs are assumed to be the same as for the classic grate combustion plant	$10/ton of MSW
Maintenance costs	$43/ton of MSW
The electricity for sale is 533 kWh/ton. At a sale price of 10 cents/ kWh, the sale corresponds to	$53.3/ton of MSW
When the waste heat is recovered, the electricity for sale would increase with 332 kWh/ton = 865 kWh/ton	$86.6/ton of MSW
11,137 tons of mixed ferrous and non-ferrous metals	$50/ton = $556,850
53,900 tons slag at a price	$1/ton = $ 53,900
Renewable Energy Credit of $1 per MWh	$0.55/ton

The table below is taken from the paper of Ducharme C., [11] and shows an overview of a (base scenario) plasma plant's expenses and revenues. The costs are based on the data that Plasco Energy group provided from their 300tpd plant in Ottawa, Canada [5] and are translated for the 750 tpd scenario plant.

Table 27: Economic analysis of a plasma plant [11].

Plasma plant expenses $/ton		Plasma plant revenues $/ton	
Labor cost	10	Gate fee	65
Other operating costs	43	Electricity to grid	53.3
Total operating costs	53	Metal & slag recovery	2.47
		REC	0.55
Capital charges and all other	76.8		
Total costs	130	**Total revenues at start up**	121.32

Based on the table above, the immediate conclusion is that the plant is barely economically feasible.

However, the electricity generated from the waste heat was not taken into account. It can be assumed that, when the waste heat is recovered, the total electricity generated would increase with 332 kWh/ton to 865 kWh/ton of MSW processed, and a sale of electricity up to $86.6/ton. The total revenues at start-up would then be **$152,05/ton** of MSW, which would makes the plant feasible [11].

In the public presentation of the Westinghouse Corporation, economic costs were given for a 750 tpd plant. Like the analysis of the base scenario mentioned before, considering a plant operating on air, in a combined cycle power, the costs are mostly similar. The differences are shown in the table below, based on the costs given by Alter NRG.

Table 28: Summary of the used element costs and amounts [11].

Elements for a Alter NRG 750 tpd plasma plant	Costs
Capital costs	$200.99 millions; $81/ton
The total operating costs (incl. maintenance)	$7.92 millions/ year; $32/ton
617 kWh/ton of net energy produced	$61.7/ton of MSW
The gate fees	$65/ton

The table below is also taken from the paper of Ducharme C., [11] and shows an overview of a (Alter NRG) 750 tpd plasma plant's expenses and revenues.

Table 29: Cost data for 750 tpd WTE project [45].

Alter NRG expenses $/ton		Alter NRG revenues $/ton	
Personnel	10	Gate fee	65
Other operating costs	32	Electricity to grid	61.7
Total operating costs	42	Metal recovery	2.47
		Renewable credit	0.55
Capital charges and all other	81		
Total costs	123	**Total revenues at start up**	129.72

Environment

A report (from 2010) of Scientific Certification Systems (SCS), an independent consultancy, comparing the lifecycle greenhouse gas emissions of a plasma gasification combined cycle power plant with the emissions from a state of the art incineration facility and a landfill with energy capture facility, concluded that the Plasma Gasification Combined Cycle system provides the lowest greenhouse gas emissions of the evaluated systems for waste disposal [46]. The following figure shows this comparison.

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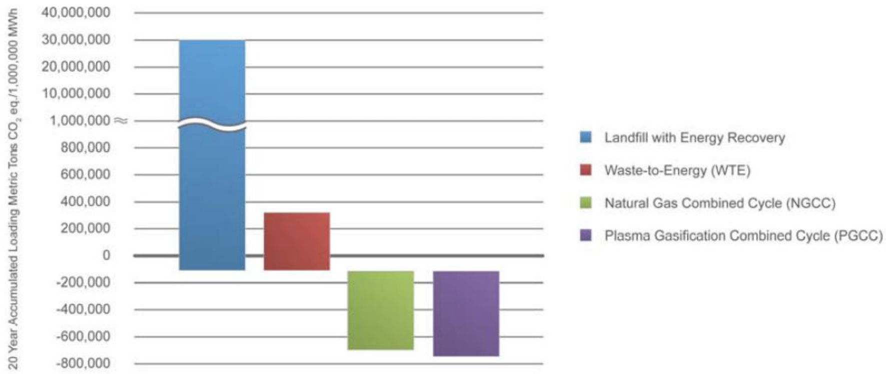

Notes:
1) Twenty year accumulated GHG loading for four power generation options.
2) Results compared on a basis of 1,000,000 MWh.
3) Northeast Power Coordinating Council region. Zero on Y-axis represents average greenhouse gas emissions from power plants per 1 million MWhs in the region.

Figure 70: Results of SCS Lifecycle Greenhouse Gas Emissions Study [46].

The following table shows details of the numerous benefits of Westinghouse plasma gasification versus incineration for the treatment of MSW.

Table 30: Westinghouse Plasma Gasification vs. Incineration [46].

	Westinghouse Plasma Gasification	Incineration
Feedstock Flexibility	Ability to mix feedstocks such as • MSW • Industrial Waste • Commercial & Industrial Waste • Hazardous Waste • Tires Waste • Biomass Fuels (such as wood waste)	MSW and other common waste streams
Fuel Created	Syngas (Carbon Monoxide and Hydrogen)	not applicable
End Product Opportunities	• Replacement Fuel for Natural Gas and Fuel Oil • Power via Steam cycle • Power via Combined cycle or Reciprocating Engines • Power via Fuel Cells (future) • Process Steam • Liquid Fuels (ethanol, bio-diesel) • Hydrogen • Fertilizer Compounds	Power via Steam cycle Process Steam

Overall Plant Efficiency	Combined Cycle Process: 1 tonne of municipal solid waste is capable of creating 1000 kWh of power via combined cycle configuration	Steam Cycle Process: 1 tonne of municipal solid waste generates between 500-650 kWh of power
Emissions	Combined Cycle Process: • Nitrogen Oxide (NOx): <36 ppmvd • Sulfur Dioxide (SO2): <1.05 ppmvd • Mercury (Hg): <1.4 µg/dscm²	• Nitrogen Oxide (NOx): 110-205 ppmvd • Sulfur Dioxide (SO2): 26-29 ppmvd • Mercury (Hg): 28-80 µg/dscm²
Dioxins and Furans	High operating temperature (>1000°C) in conjunction with an oxygen starved environment destroys any dioxins/furans that may be present in the feedstock, and eliminates the potential for the creation of dioxins/furans. Rapid syngas cooling via water quench prevents de-novo synthesis of dioxins and furans.	The presence of oxygen, chlorine, and particulate creates the right conditions for the formation of dioxins and furans.
By-product	Inert, non-hazardous and non-leaching glassy slag salable as an aggregate building product or rock wool Most particulate recovered during cleaning of the syngas is recyclable	Hazardous fly ash and scrubber residues plus incinerator bottom ash

A Typical waste-to-energy Air Pollution Control Systems is shown below, where different units are used in order to clean the off-gases.

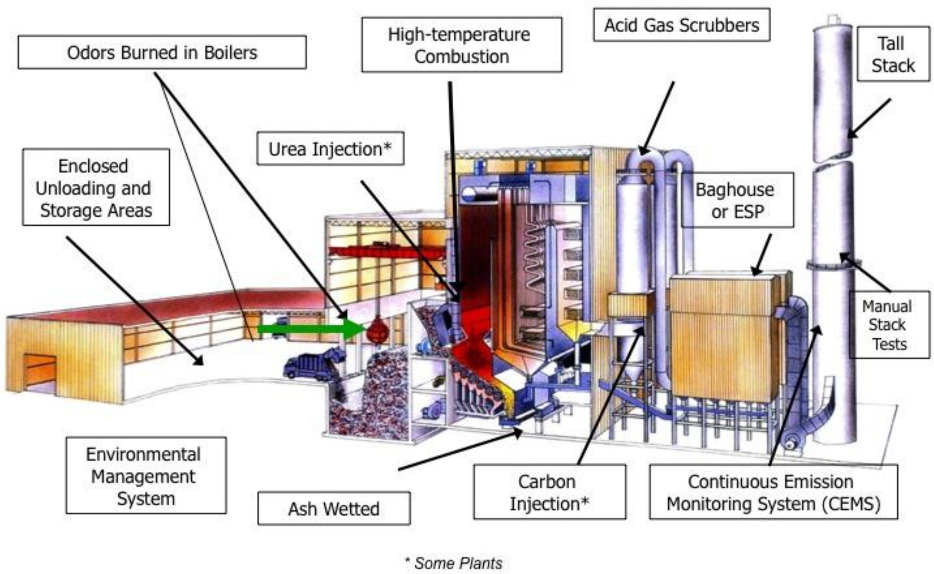

Figure 71: Typical waste-to-energy Air Pollution Control Systems from Castaldi M., Columbia University [46].

Summary

THE USE OF WASTE AS FILL MATERIAL IN THE LAND RECLAMATION PROJECTS OF JAKARTA

Evaluating the possibilities of using waste as an interesting substitute of sand within the land reclamation projects of Jakarta

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Date of graduation
07-03-2013

ABSTRACT
To coop with urbanization issues and the economic need for expansion, the city of Jakarta is planning to reclaim more land in the Jakarta Bay. More land could discharge the inner city's over-population, enhance its economic growth and solve a lot of environmental and health problems the city is facing. However, the reclamation activities of some islands have barely started and already the developers are facing difficulties in finding sufficient quantities of sand fill material.
When addressing the problem of sand scarcity in the case of Jakarta where, an excess of waste production, an inadequate solid waste management system and a lack of dumping ground pose a major problem, it is hard not to think of the use of waste as alternative fill material; the concept of "work with work". This paper evaluates the possibilities of how waste could replace or complement sand within the land reclamation projects of Jakarta considering the governmental, social, environmental and economic context of the city.
The research results identify types of waste that could be used, ways or methods of using those types of waste and implementation conditions for the city of Jakarta.

Keywords: Solid Waste Management systems, Land reclamation, artificial islands, Landfills, Multi Criteria Analysis, Scenario planning, Causal loop diagrams

INTRODUCTION
Located on the northwest coast of Java, Jakarta is the capital and largest city of Indonesia and the country's economic, cultural and political center. With a population exceeding 10 million as of November 2011, Jakarta is the most populous city in Southeast Asia, and the seventeenth-largest city in the world. With its population and a land area of 662 km^2, Jakarta has a population density of more than 15,000 people/km^2.

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The city is experiencing rapid urbanization, yet its urban development and infrastructure is not ready for such rapid growth in population density; putting huge pressure on the urban environment and leading to problems such as: (1) land subsidence, due to rapid urbanization along with severe over-extraction of groundwater, (2) flood, due to the conversion of half the city's small lakes into residential or commercial areas, (3) traffic congestion and air pollution, due to smoke and carcinogenic gasses emitted by the innumerable vehicles in the city, (4) waste problems, due to waste open dumping and burning and (5) poor sanitation creating serious health threats.
The Special Capital City District of Jakarta (DKI) has planned to transform Jakarta into a big city in the future by changing its coastal line to about 8 km toward the sea from its existing position. It is planned that Jakarta will become a Water Front City, covering the area of 5 km to the land side and 8 km to the sea side along its coastal line (Levara J.C., 2010).
An overview of the plan area of North-Jakarta is shown below. The orange and yellow colors represent the planned land reclamation Islands (JCDS, 2012).

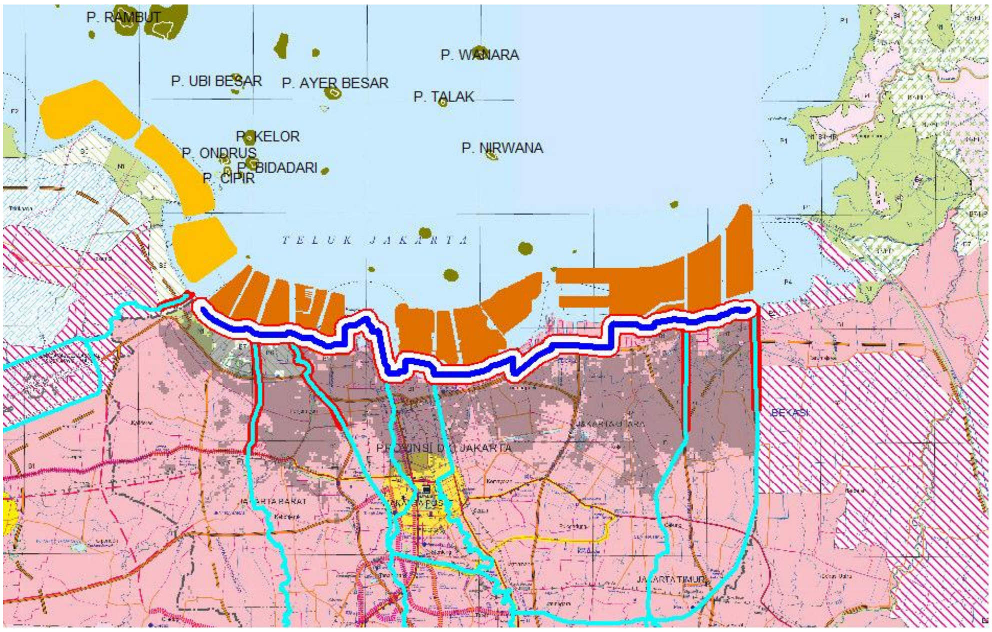

Figure 1: Overview of the planned land reclamation area (JCDS, 2012).

Using waste as fill material within the land reclamation plans of Jakarta could solve most of the urbanization problems the city is facing. Therefore the objective of this research is to find out whether waste can be a good substitute for sand within these land reclamation projects and how to apply it.

Research question and sub-questions:
How could waste be an interesting substitute for sand as fill material in the land reclamation projects of Jakarta?

- What alternative (existing or new) ways of using waste as fill material within the land reclamation projects of Jakarta are there?

- o Which alternative or combination of alternative methods of using waste within land reclamation is more interesting for Jakarta based on the Triple Bottom Line (people planet profit) principle?
- o How could this more competitive alternative method of using waste within land reclamation be implemented in Jakarta?

Case study

So far, the use of waste within land reclamation is limited. Two existing cases where waste has been used as fill material, although with different purposes and contexts, were studied: the case of Singapore (Pulau Semakau) and the case of Japan (Yumeshima Island).

The purposes of land reclamation within those existing cases differed from the purpose within the case of Jakarta. The following purposes of land reclamation were identified:

1. The purpose of creating waste disposal sites: This refers mostly to offshore waste disposal landfills which are afterwards turned into natural areas (green zones, parks, golf courses etc.). In this case the reclaimed land is not stable and strong enough and therefore cannot be used for other urban development purposes. This is the case of Singapore (Pulau Semakau).
2. The purpose of creating new land for urban development plans: These may range from residential and cultivation purposes to major development projects such as tourism, individual/commercial business ventures, wharfage and other infrastructural improvement. In this case, the use of waste is only chosen when proven to be economically more attractive and able to replace the use of sand within the conventional way of land reclamation.
3. They are also cases where both purposes are urgent. Although the one is always more urgent than the other. In those cases, landfilling is done with the purpose of both securing waste final disposal sites as well as creating new land for urban development after land reclamation. This is the case of Japan (Yumeshima Island).

The case of Jakarta is similar to the second situation, where the purpose is creating new land for urban development. Because of the sand scarcity in the surrounding areas and the abundant availability of waste, the use of waste as fill material becomes interesting to explore.

Analyzing and evaluating the existing cases of Singapore and Japan and using the expertise and technologies from those cases led to the proposition of the first alternative method of using waste as fill material (Alternative 1). In addition the search for alternative new technologies led to two other alternative methods of land reclamation for Jakarta.

RESEARCH METHOD AND DESIGN

The data collection is mostly done through literature study and expert consultations. The conjunctive approach of Multi Criteria Analysis (MCA) is used to evaluate the new and existing land reclamation methods. This approach, based on a risk minimization measures the deficiencies of the different methods determining the safest alternative.

MCA is a structured approach used to determine overall preferences among alternative options, where the options accomplish several objectives. Desirable objectives are specified and corresponding attributes or indicators are identified, allowing to include a full range of social, environmental, technical, economic, and financial criteria.

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For the implementation analysis of the chosen alternative land reclamation method, a SWOT analysis is used to evaluate the positive and negative aspects of this alternative method in the context of Jakarta. To help understand the process of the alternative method and the correlation between the process elements, a system dynamics model is used and finally possible future scenarios are simulated using the scenario development approach.
Scenarios are provocative and plausible stories about how the future might unfold. Because scenarios are hypotheses, they are created and used in sets of multiple stories that capture a range of future possibilities (Scearce D., et al., 2004).
In this case, the scenarios are used to deal with the specific system and they involve making explicit assumptions about the future development of the environment of the system using causal loop diagrams. The method for generating scenarios used is based on reasoned judgment and intuition in describing alternative futures by picturing critical uncertainties on axes that frame poles of possible futures; in this case: economy and demography. Two uncertainties, both major drivers for the land reclamation project and alternative fill materials which, when combined, produce believable and useful stories of the future.

The research design is shown below.

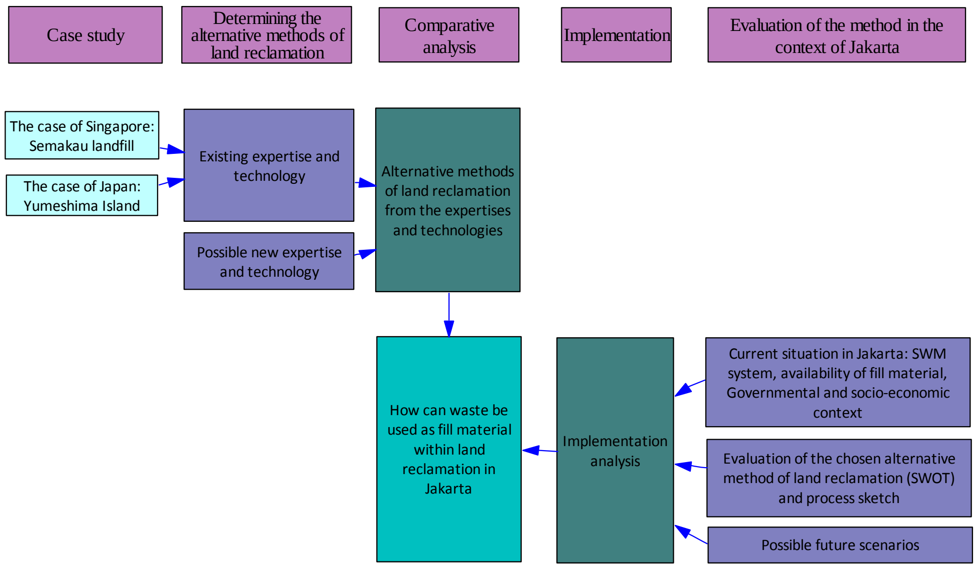

Figure 72: Research design.

RESULTS, DISCUSSION AND RECOMMENDATIONS

Using waste as fill material within land reclamation projects is more complicated than it seems. Waste needs to undergo major changes before it can be dumped into the open sea without significant environmental consequences. In addition to that, when the reclaimed land is meant for an urban area development with its heavy constructions, any alternative fill material needs to be strong and stable enough to carry this new urban area.

Alternative methods of land reclamation with the use of waste as fill material

The search for alternative methods of land reclamation with the use of waste led to the study of existing similar cases (Semakau landfill and Yumeshima Island), and further research on possible new technologies or methods that could be useful. This resulted in the identification of multiple methods of using waste as fill material for the land reclamation projects of Jakarta. Those methods of land reclamation differed from each other through the types of waste used, the method of waste treatment before use and the way of application. The following alternative methods were further evaluated:

Alternative 1:
The use of compost and incineration ash packed into geotextile to prevent leachate of contaminants. This alternative could only be used for the reclamation area where no heavy structure is to be built on the reclaimed land and was found to be the most unfavorable alternative method based on the TBL framework with 6 major deficiencies, which were scored on the criteria accessibility, affordability, safety, pollution, comfort and health. Most of these deficiencies were caused by the inclusion of incineration. Apart from being very expensive, incineration has also a large negative impact on the environment and public health. Therefore this way of waste treatment was excluded from the recommendations.

Alternative 2:
The use of the plasma gasification technology to transform waste into an inert slag, which could then be directly used for land reclamation. The method was found to be the second most favorable with 3 major deficiencies, scored on the criteria accessibility, affordability and safety. The major setback of this alternative is the availability of the needed amount of slag for the land reclamation which is estimated to be only 13.3% of the sand gained per year so far.
Another setback of this alternative is the affordability. Although a plasma gasification plant generates a net revenue estimated at $32/ton of waste treated (through its energy production), it first needs a large initial investment before it can be productive.

Alternative 3:
The use of the Strengthened Sediment technology, where first, sludge or soft material is dredged or excavated, then strengthened on-site using cement or a specifically selected reactive bottom or fly ash and an initiator (e.g. sodium silicate) and then directly used as fill material. This new technology has not yet been applied for land reclamation but turned out to be the most favorable alternative method with only 1 major deficiency. This major deficiency is scored on the energy criterion, where strengthened sediment uses energy instead of producing it.
This alternative remains very interesting for the land reclamation projects of Jakarta. However, the lack of expertise within this new technology could cause some reservation from the shareholders (the government, developers or other private parties). In addition to that, based on the large amount of fill material needed, it can be assumed that there is not enough sediment available for the whole land reclamation plan. On the other hand the application of the strengthened sediment technology could also be seen as an opportunity because of its benefits in contrast with the conventional way of land reclamation and the other alternatives.

Alternative fill materials
After an analysis based on the TBL framework, the following alternative fill materials were found to be interesting substitute of sand within the land reclamation projects of Jakarta:

- Compost (directly applicable; gained through composting of organic solid waste);

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- Slag (directly applicable; gained through plasma gasification of non-organic waste);
- Excavated soil (uncontaminated and directly applicable; gained from construction work sites);
- Mountain soil (uncontaminated and directly applicable; gained from mining);
- Sludge (directly applicable through the Strengthened Sediment technology; gained from the city's channels and the seabed).

Within the comparison of those alternative fill materials, the social, environmental and economic characteristics were evaluated based on the conjunctive approach.
Compost, slag, excavated soil, mountain soil and channel sludge were all found to be socially, environmentally and economically more favorable than dredged sand. Seabed sludge having the similar major deficiencies within the social and environmental aspects as dredged sand was however economically more favorable than dredged sand. This makes all fill materials interesting substitutes of sand within the land reclamation projects of Jakarta.

The chosen method of land reclamation
Because the availability of landfill material is limited for each alternative or scenario, the best option was found to be a combination of favorable elements from the different alternative methods in a new alternative; The chozen method of land reclamation. This chozen method is composed of a combination of A1 and A2, where incineration is replaced by plasma gasification and A3.

Within this chozen method, an island could be compartmented into three sections:

- Section 1, expected to provide a site for heavy constructions will be reclaimed using dredged soil from rivers, harbors and seabed with the strengthened sediment technology (A3);
- Section 2, expected to provide a site for the construction of an urban area (residential and business area) will be reclaimed using normal mountain soil, surplus soil from construction work sites and plasma gasification slag.
- Section 3, expected to provide a site for golf courses, light recreational activities and park functions will be reclaimed using compost and excavated soil from civil engineering and construction work sites.

An overview of the material flow within the chozen method is shown in figure 2.

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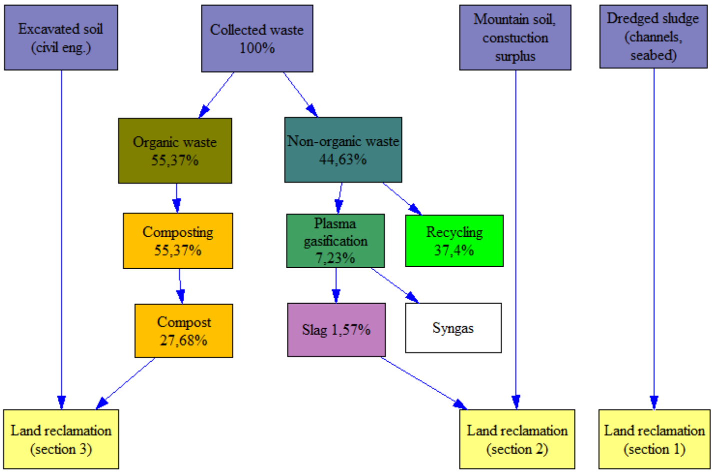

Figure 2: Material flow of the chozen method of land reclamation.

However, the availability of sufficient alternative fill material for the land reclamation is still unpredictable at this point. The quantity of Municipal Solid Waste (MSW) that can be used for the land reclamation is estimated and clear, but the quantities of available excavated earth from construction work sites, construction and demolition waste, mountain soil and dredged sludge are unclear at this point and unpredictable for the future.
It is to assume that when the available alternative fill material is not sufficient, one could always use sand as complement.
The table below gives an overview of the quantities of fill material.

Table 31: Quantity and cost estimates of fill material for an island of 300 ha.

	Conventional method			**Method using waste**		
	Material	Quantity (ton)	Cost ($)	Materials	Quantity (ton)	Costs ($)
Gained/year						
	Sand	2.242.585	$66.156.258	Compost	606.265	$11.519.035
				Slag	34.310	$34.310
				Excavated soil		
				Mountain soil		
				Sludge		
				Sand complement		
Total		2.242.585	€ 66.156.258		640.575	$11.553.345
Needed total		32.000.000			32.000.000	

Implementation analysis of the chozen method of land reclamation in Jakarta
As for the implementation of this method of land reclamation, based on the analysis of its strengths, weaknesses, opportunities and threats within the governmental, social, environmental and economic context of Jakarta, the following improvement changes are recommended; improvement within:

- the SWM system: an adequate SWM system with all needed facilities and equipment needs to be in place. A system where waste collection is maximized and all collected waste is sorted, where the recyclables are recycled, the compostables composted

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and the remaining waste is gasified. Compost and slag could then be used as fill materials for the land reclamation projects. This includes (1) getting the inhabitants involved, (2) educating them regarding the whole SWM process and (3) accounting the cost of environment and health damages by following the concept of 'polluters pay' along with (4) a strong legal system to control and execute SWM rules and regulations;

- the state of the city's channels: the channels should be dredged, widened and deepened in order to use the dredged sludge for land reclamation, doing so also stimulating the water evacuation out of the city and reducing/preventing flood. Therefore the inhabitants living in the vicinity of those channels must be relocated with the least possible negative impact. Informing them about the reasons and necessity of the relocation and involving them within the relocation process along with offering them a suitable alternative living areas are important conditions;
- the land reclamation projects' support: governmental and social support should be promoted making sure all involved or needed parties are willing and motivated to participate and realize the project within the set conditions;
- Investments in constructions projects on the main land: investment in especially underground construction projects (parking garages, infrastructure etc.) should be promoted, in order to secure more excavated soil and construction waste for the land reclamation;
- Competences and "know how" of the involved parties: making sure all participating parties have the skill and competences needed for the realization of their roles within the project in order to limit the manageability issues due to the combination of several technologies or methods and the differences with the conventional way of land reclamation. So making sure the technologies are well known by the involved parties, the needed risk assessment is done and possible prevention measures are known and taken before start, for both the land reclamation and the SWM system.

Scenario development

The most favorable simulated scenario for the implementation of the chosen method of land reclamation in Jakarta, based on the city's demography and economy, was found to be the scenario where there is "Strong Economy and Population Growth". See axes below.

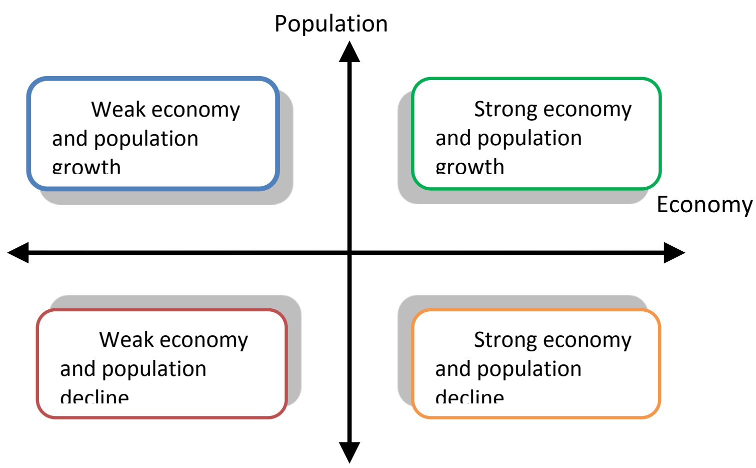

Figure 73: Scenario axes.

Business is on the rise and the demand for urban development (residential, commercial, and office space) is increasing due to the stimulation of a wealthy economy. This leads to more land use and an extension of underground constructions (massive shopping centers, high-rise buildings, parking garages, infrastructure etc.). More construction leads to more excavated soil from construction work sites and therefore more alternative fill material for land reclamation.
Population growth combined with welfare leads to more consumption and more waste production. There is more money available for technological innovations. The higher life standards demands adequate SWM system and more environmental responsibility. Leading to more processed waste and dredged sludge due to the widening of the city's channels and so resulting in the production of more alternative fill material for land reclamation. This scenario is the most favorable for the use of waste as alternative fill material within land reclamation projects.

The causal loop diagram below shows the positive loops created by this scenario.

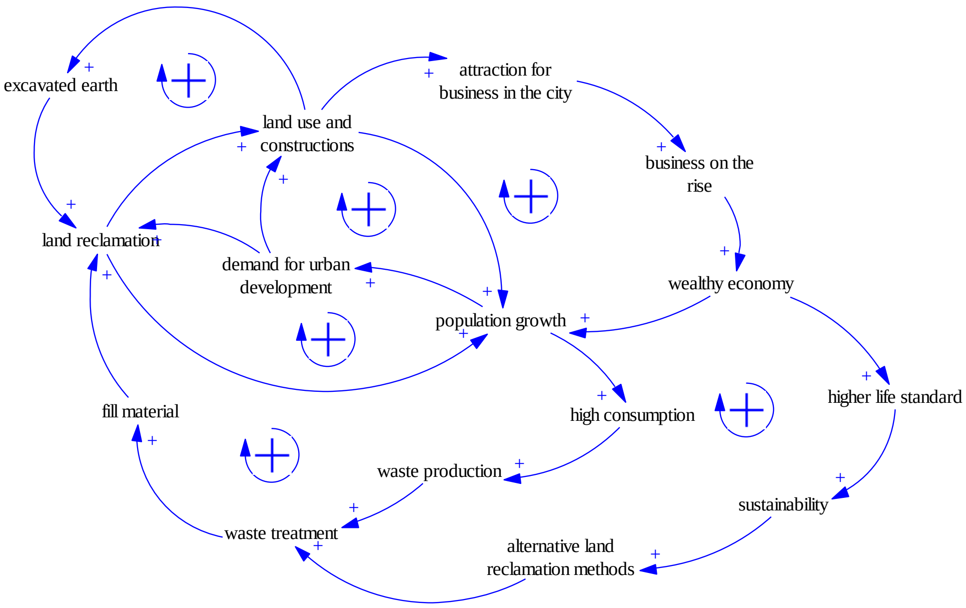

Figure 4: Causal loop diagram of the strong economy and population growth scenario.

FURTHER RESEARCH

Furthermore, further research is recommended on:

- the governmental and social acceptance of the whole plan, and the willingness of the stakeholders to participate;
- the availability of fill material in the near future (construction waste, mountain soil, excavated soil and sludge);
- the strengthened sediment application process in this particular case and the willingness of the stakeholders to opt for this technology;
- a detailed cost and benefits situation and investment strategies among the shareholder

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This research is the final part of my MSc. Construction Management and Urban Development course at the Eindhoven University of Technology. I am very grateful for this opportunity and thank everyone who played a role within this accomplishment.
Those last months of research have been very interesting with lots of interesting discussions and learning moments. I hope this research can contribute the challenge towards sustainable waste management and responsible land reclamation in Jakarta.

Curriculum Vitae

Sep 2010 – now	Master Construction Management and Engineering (Urban development) at the Eindhoven University of Technology (TU/e)
Jan – Mei 2012	Exchange program at the National University of Singapore (NUS).
Aug 2007 – Jun 2010	Architectural Engineering Business at the University of applied sciences of Utrecht (Hogeschool Utrecht). Graduated on June 2010.
Aug 2003 – Jul 2007	MBO Bol 4 Construction, Design and Architecture at Mondriaan Education in The Hague. Graduated on July 2007.

Work experience

Sep 2012- present	Graduation research on the use of waste as fill material in the land reclamation projects of Jakarta within Witteveen & Bos.
Feb – Jun 2010	Two (bachelor graduation) researches on (1) Sustainable Development within the Dutch Institute for Building Biology and Ecology (NIBE) and on (2) Collective Private Commissioning (CPO) within The Kok & Partners.
Feb – Jul 2009	Internship as assistant project and process manager at Smitshoek Melles & Partners.
Jan – Jun 2007	Internship at Van Mourik Architecten.
Sep – Oct 2005	Internship at Gemeente Werken Rotterdam, the Engineering Department of the municipality of Rotterdam.
Nov – Dec 2005	Internship at 2000 CC Architecten.

Summay (Dutch)

HET GEBRUIK VAN AFVAL IN DE LANDAANWINNING PROJECTEN IN JAKARTA
Evaluatie van de mogelijkheden om afval te gebruiken als interessante zand vervanger bij de landaanwinning projecten van Jakarta

Auteur: ing. N.F. Barry

Afstudeer programma
Construction Management and Engineering (Urban Development) 2012-2013

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Afstudeer datum
07-03-2013

ABSTRACT
Om met de verstedelijkingsproblemen en de economische noodzaak voor uitbreiding om te gaan, is de overheid van Jakarta van plan om meer land aan te winnen in de Jakarta Bay. Meer land betekent het ontladen van de binnenstedelijke overbevolking, het vergroten van de economische groei en het oplossen van veel milieu-en gezondheidsproblemen waar de stad mee wordt geconfronteerd. Echter, de landaanwinning activiteiten van sommige eilanden zijn amper begonnen en nu al worden de ontwikkelaars geconfronteerd met moeilijkheden bij het vinden van voldoende hoeveelheden zand.
Bij de aanpak van het probleem van zand schaarste in het geval van Jakarta, een stad die zich kenmerkt door overmaat aan afvalproductie, inadequate beheer van afvalstoffen en gebrek aan stortplaatsen, is het moeilijk om niet aan het gebruik van afval als alternatief vulmateriaal te denken; het begrip "werk met werk".
Dit onderzoek evalueert de mogelijkheden om zand te kunnen vervangen door afval als vulmateriaal bij de landaanwinning projecten van Jakarta binnen de sociale, ecologische en economische context van de stad.
De onderzoeksresultaten identificeren soorten afval die gebruikt kunnen worden, manieren of methoden van gebruik van deze soorten afval en toepassingsvoorwaarden voor de stad Jakarta.

Trefwoorden: Afval management systemen, Landaanwinning, artificiële eilanden, stortplaatsen, Multi Criteria Analyse, Scenario ontwikkeling, Causal loop diagrams

INTRODUCTIE
Jakarta, gelegen aan de noordwestkust van Java is de hoofdstad van Indonesië en ook het economisch, cultureel en politiek centrum van het land. Met een bevolking van meer dan 10 miljoen inwoners gemeten op november 2011, is Jakarta de meest dichtbevolkte stad in Zuidoost-Azië. Met een bevolkingsdichtheid van meer dan 15.000 mensen/km^2.

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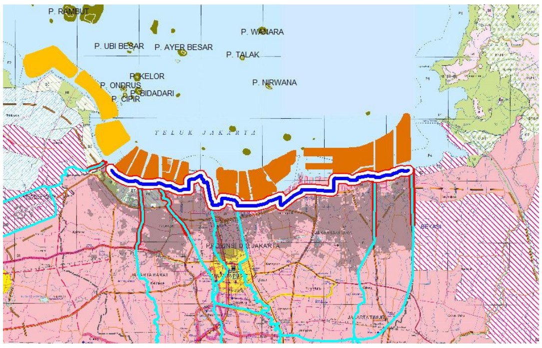

Figuur 1: Plangebied.

De stad maakt een snelle verstedelijking door, maar de stedelijke ontwikkeling en infrastructuur is daar nog niet klaar voor. Dit zet een enorme druk op de stedelijke omgeving en leidt tot problemen zoals: grondverzakking, overstroming, files en luchtvervuiling, zwerfafval en openbare afval verbranding, en slechte sanitaire voorzieningen die ernstige bedreigingen voor de gezondheid veroorzaken.
Het speciale hoofdstad District van Jakarta (DKI) heeft plannen om Jakarta te transformeren in een Water Front Stad door het verbreden van de kustlijn tot ongeveer 8 km zeewaarts. Een overzicht van het plangebied van Noord-Jakarta is weergegeven in figuur 1. De oranje en gele kleuren geven de geplande landaanwinning aan (JCDS, 2012).
Het gebruik van afval als vulmateriaal bij de landaanwinning plannen van Jakarta zou een groot deel van de urbanisatie problemen waar de stad mee wordt geconfronteerd kunnen oplossen. Hierdoor is de doelstelling van dit onderzoek: het nagaan of afval een goed alternatief vulmateriaal kan zijn en hoe deze toe te passen. Dit leidde tot de volgende onderzoeksvraag en deelvragen.

Onderzoeksvraag en deelvragen

Hoe kan afval een interessante zand vervanger zijn als vulmateriaal bij de landaanwinning projecten van Jakarta?

- Welke alternatieve manieren van gebruik van afval als vulmateriaal in de landaanwinning projecten van Jakarta zijn er?
- Welke alternatieven of combinatie van alternatieve methoden voor het gebruik van afval bij landaanwinning is meer interessant voor Jakarta gebaseerd op de 3P (People Planet Profit) principe?
- Hoe kan deze meest interessante alternatieve methode voor het gebruik van afval bij landaanwinning worden toegepast in Jakarta?

ONDERZOEKSMETHODE

De zoektocht naar de antwoorden op deze vragen leidde tot de studie van bestaande soortgelijke gevallen (Semakau Landfill te Singapore en Yumeshima Island te Japan), en de verdere zoektocht naar mogelijke nieuwe technologieën of methoden door middel van literatuur studie en het raadplegingen van deskundigen.
De conjunctieve aanpak van Multi Criteria Analyse (MCA) wordt gebruikt om de nieuwe en bestaande landaanwinning methoden en materialen te evalueren. Deze aanpak is gebaseerd op risico beperking en stelt het veiligste alternatief vast.
Voor de toepassingsanalyse wordt een SWOT analyse gedaan van de gekozen alternatieve landaanwinning methode en de correlatie tussen de proces-elementen van de methode wordt weergegeven door een "system dynamics" model waarbij mogelijke toekomst scenario's gebaseerd op de economie en demografie van Jakarta worden gesimuleerd met behulp van de scenario-ontwikkeling methode.

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RESULTAAT EN DISCUSSIE

Alternatieve methoden van land aanwinning met gebruik van afval

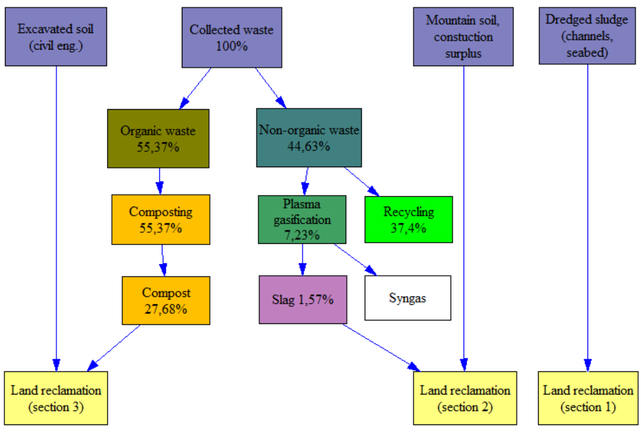
De gevonden methoden van de landaanwinning met gebruik van afval, verschillen door het soort afval dat wordt gebruikt, de manier van afvalverwerking vóór gebruik en de wijze van toepassing. De volgende alternatieve methoden zijn aangekaart en verder geëvalueerd:

- Alternatief 1: het gebruik van compost en verbrandingsresten (as) verpakt in geotextiel om uitlek van verontreinigingen te voorkomen. Dit alternatief kan alleen worden gebruikt voor landaanwinning van gebied waar geen zware structuur wordt opgebouwd;
- Alternatief 2: gebruik van het plasma vergassingstechnologie om afval te transformeren tot inerte slakken, die dan direct gestort kunnen worden bij de landaanwinning;
- Alternatief 3: het gebruik van de versterkte sediment-technologie, waarbij bagger /slib wordt versterkt en direct aangebracht. Dit is een nieuwe technologie, die nog niet is toegepast voor landaanwinning.

Na een analyse op basis van het 3P principe zijn de volgende alternatieve vulmaterialen geïdentificeerd als interessante zand vervangers: compost, plasma vergassingsslakken, uitgegraven bodem vanuit de bouw of civiele technische werken, berg bodem vanuit de mijnbouw en bagger/slib uit de kanalen en zeebodem.

De gekozen alternatieve methode

Door de beperkte beschikbaarheid van de vulmaterialen, bleek het combineren van deze materialen en toepassingsmethoden in een nieuwe alternatieve methode (de gekozen methode) het meest geschikt. Een eiland zou dan kunnen worden verdeeld in drie gebieden Zie figuur 2:



- gebied 1, bedoeld voor zware constructies zal gewonnen worden met gebruik van bagger/ slib met het versterkt sediment technologie;
- gebied 2, bedoeld voor stedelijke ontwikkeling (woon-en werk gebied) zal worden gewonnen met normale berg bodem, overschot aarde vanuit de bouw en plasma vergassingslakken;
- gebied 3, bedoeld voor golfbanen, licht recreatieve activiteiten en park functies zal worden gewonnen met compost, opgegraven zachte bodem vanuit de bouw en civiele technische werken.

Figuur 2: Materialen stroom van de gekozen methode

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AANBEVELINGEN

Wat de uitvoering van deze methode van landaanwinning betreft zou volgens de SWOT analyse en de simulatie van mogelijke toekomstscenario's op basis van demografie en economie, veel verbeteringen plaats moeten vinden.

Verbetering in:

- het afvalverwerkingssysteem: een adequaat afvalverwerkingssysteem waarbij alle benodigde faciliteiten, apparatuur en draagkracht aanwezig zijn;
- de toestand van de kanalen van de stad: de kanalen moeten worden uitgebaggerd, verbreed en verdiept om de baggerspecie te kunnen gebruiken voor landaanwinning. Daarmee wordt ook de waterafvoer uit de stad en het verminderen/ voorkomen van overstroming gestimuleerd. Hiervoor zullen de bewoners van de nabijheid van die kanalen moeten worden verplaatst. Dit dient zorgvuldig te gebeuren met het aanbieden van geschikte alternatieve woonruimtes als belangrijke voorwaarde. Het tijdig informeren van deze bewoners over de redenen en noodzaak van de verhuizing kan een belangrijk rol spelen;
- de ondersteuning van de landaanwinning projecten: overheid en sociale steun moet worden bevorderd om ervoor te zorgen dat alle betrokken of nodige partijen bereid en gemotiveerd zijn te participeren en het project te realiseren binnen de gestelde rand voorwaarden;
- investeringen in bouwprojecten op het vaste land: investeringen in voornamelijk ondergrondse bouwprojecten (parkeergarages, infrastructuur, enz.) moeten worden bevorderd, om meer uitgegraven bodem en bouwafval voor de landaanwinning beschikbaar te stellen;
- competenties en "know how" van de betrokken partijen: zorg ervoor dat alle deelnemende partijen de vaardigheden en competenties hebben die nodig zijn voor de realisatie van hun rol binnen het project. Dit voornamelijk door de combinatie van verschillende technologieën of methodes en de verschillen van deze alternatieve landaanwinning methode met de conventionele methode van landaanwinning.

Daarnaast wordt verder onderzoek aanbevolen over:

- de bestuurlijke en maatschappelijke acceptatie van het hele plan, en de bereidheid van de belanghebbenden om deel te nemen;
- de beschikbaarheid van vulmateriaal in de nabije toekomst (bouwafval, berg bodem, uitgegraven bodem en bagger/ slib);
- de versterkte sediment toepassingsprocedure in landaanwinning en de bereidheid van de belanghebbenden om voor deze nieuwe technologie te kiezen;
- gedetailleerde kosten en baten situatie analyse en investeringsstrategieën onder de belanghebbenden.

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