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Land Reclamation Using Waste as Fill Material: A Case Study in Jakarta

Q. Han, W. Schaefer, and N. Barry

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. However, the reclamation activities of some islands have barely started and already the developers are facing difficulties in finding sufficient quantities of sand as 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. This paper analyses the possibilities of using waste in the land reclamation projects, considering the governmental, social, environmental and economic context of the city. The results identify types of waste that could be used, ways of using those types of waste and implementation conditions for the city of Jakarta.

Keywords**—**Waste Management systems, Land reclamation, Multi Criteria Analysis, Scenario planning.

I. 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.

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 8km toward the sea from its existing position. It is planned that Jakarta will become a Water Front City, covering the area of 5km to the land side and 8km to the sea side along its coastal line [1].

An overview of the plan area of North-Jakarta is shown in Fig. 1. The orange and yellow colors represent the planned land reclamation Islands with an overall area size of 10,000 hectares and the blue lines represent the planned road and railway track [2]. 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.

In the following section of the paper, first we briefly introduce our research design and continue with describing the conventional land reclamation materials and two exiting cases that using waste as fill material. Next, we analyze three alternative methods, alternative fill materials, the chosen alternative method with SWOT analysis, and scenario planning. Finally, conclusion and discussion are given.

II. Research Design

Fig. 2 provides an overview of the research 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 in order to determine 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 including a full range of social, environmental, technical, economic, and financial criteria.

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 [3]. In this case, the scenarios are

Q. Han is with the Eindhoven University of Technology, 5600MB Eindhoven, The Netherlands (phone: +31 40 247 5403; e-mail: q.han@ tue.nl).

W. Schaefer is with the Eindhoven University of Technology, 5600MB Eindhoven, The Netherlands (phone: +31 40 247 4037; e-mail: W.F.Schaefer @tue.nl).

N. Barry is with the Eindhoven University of Technology, 5600MB Eindhoven, The Netherlands (phone: +31 40 247 2373; e-mail: n.barry@ student.tue.nl).

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.

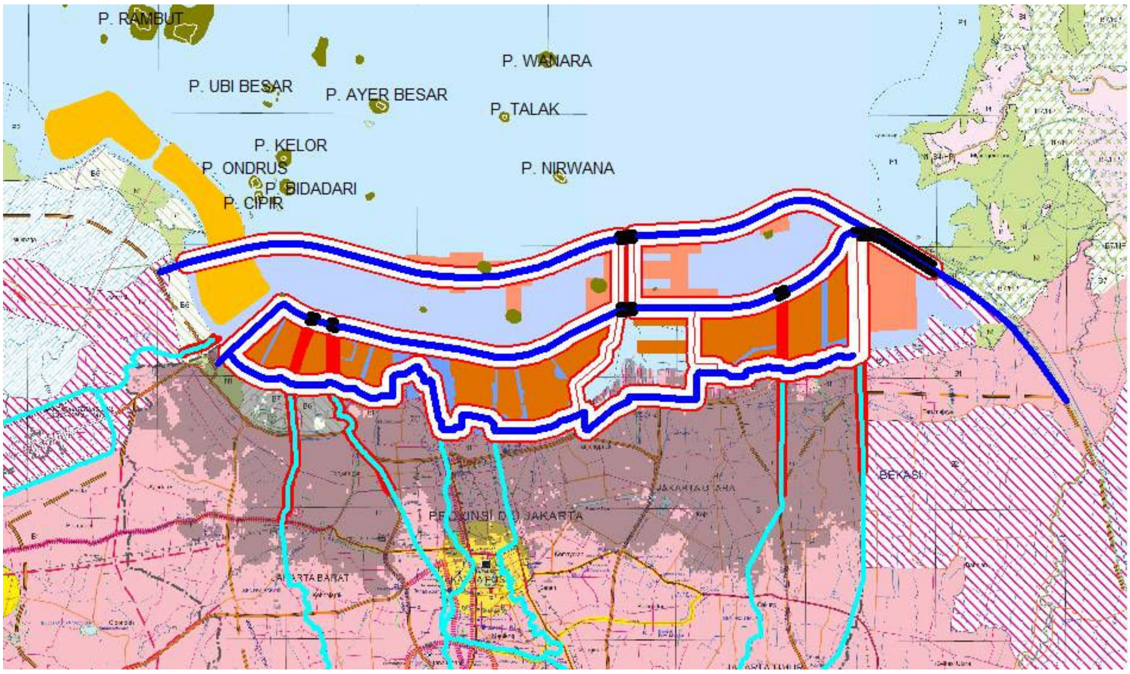

Fig. 1 Overview of the planned land reclamation area (JCDS, 2012)

III. Two Existing Cases

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 focuses 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.

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. 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]. 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 be similar as sand. 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.

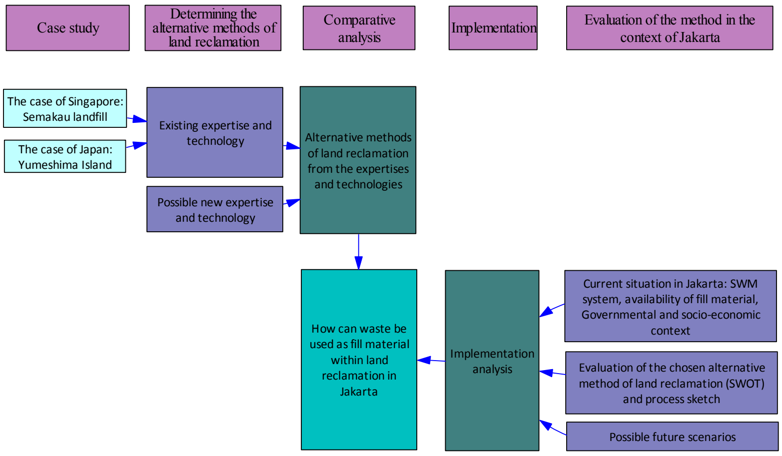

Fig. 2 Research design

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 [4]-[9]) and the case of Japan (Yumeshima Island [10]-[13]). Dependent on the purposes and context, different methods of land reclamation are used.

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, wharf age 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. There are also cases where both purposes are integrated. Although one might overweight the other. In those cases, land filling 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 main purpose is creating new land for urban development. However, after analyzing the two exiting cases, it is obvious that these two existing cases each have some deficiencies. The case of Yumeshima has its major deficiencies on the incineration capacity and waste availability, and the case of Semakau has its major deficiencies on the characteristics of the used landfill technique (innovativeness, sustainability, profitability) and the flexibility of its spatial development plan after reclamation. 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 in Jakarta, which leads to further search for new methods of waste treatment.

IV. Analysis

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. 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 needs to be collected, pre-treated (by incineration and composting) and transported to the reclamation location. 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.

After an extensive desk research on alternative ways of using waste as fill material within land reclamation projects, three alternatives were defined: (A1) based on the existing expertise and technologies of the cases of Singapore and Japan; (A2): based on a new technology of waste treatment method—Plasma gasification; and (A3) based on a new technology of land reclamation—Strengthened sediment.

A. Alternative Methods of Using Waste as Fill Material

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 (see Fig. 3 for the structure of A1).

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Further research on possible new technologies or methods that could be useful led to two other alternative methods of land reclamation for Jakarta (Figs. 4 and 5).

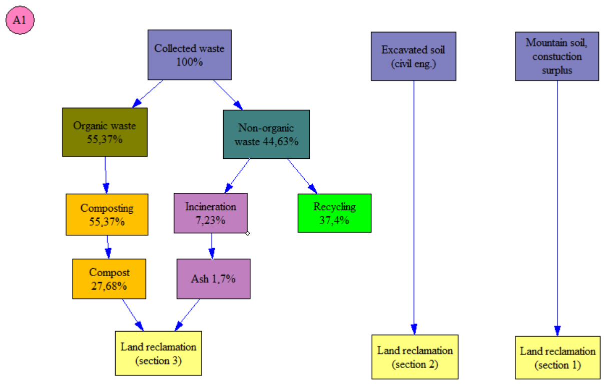

Fig. 3 The structure of A1

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.

In A1, as done in the case of Yumeshima Island in Osaka, Japan means, the land reclamation site is compartmented into 3 sections. Section 1 is expected to provide a site for heavy constructions will be reclaimed using normal mountain soil and surplus soil from construction work sites. Section 2 is 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 is 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.

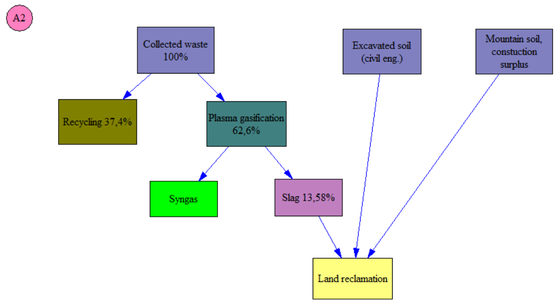

Fig. 4 The structure of A2

The method of A2 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.

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.

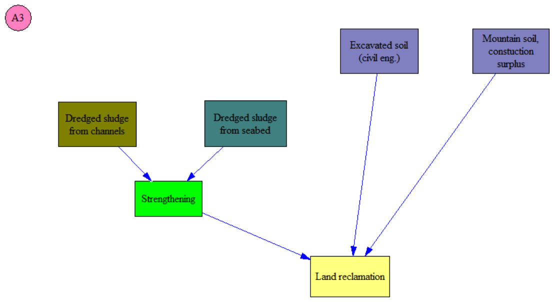

Fig. 5 The structure of A3

In A3, 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 [14]. 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.

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.

As described, these three 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.

In the following, three alternative methods were further evaluated based on the conjunctive approach and using the Triple Bottom Line (TBL) principle, also known as People, Planet and Profit (3Ps) as criteria, see Table I for more details.

A1: 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.

A3: 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.

TABLE I
COMPARISON OF THE ALTERNATIVES A1, A2 AND A3 (NOTE THAT (-) FOR A NEGATIVE INFLUENCE; (--) FOR A VERY NEGATIVE INFLUENCE)

Context	Criteria	A1	A2	A3	Elucidation
People: Social context	Health	--	-	-	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	--	-		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.
	Particip ation	-	-	-	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	--	-	-	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 cohere	-	-		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. A3 does not have a significant impact on the current social cohesion.
Planet: Environmental context	Pollution	--	-	-	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 transport 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	-	-	-	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 focuses on a limited kind of waste (sludge) and therefore cannot be marked neutral or unfavorable.
	Energy	-	-	--	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	-	-	-	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.
	Mate rial	-	-	-	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.
	Land scape	-			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	-	-	-	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.
	Afford ability	--	--	-	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.
	Employme nt	-	-	-	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	--	--		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.
	Manageabilit y	-	-	-	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.

B. Alternative Fill Materials

After an analysis based on the TBL framework, the following alternative fill materials were found to be interesting substitute of sand in Jakarta:

- Compost: directly applicable; gained through composting of organic solid waste;
- 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 in Jakarta.

C. 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 into a new alternative; The chosen method of land reclamation. This chosen method is composed of a combination of A1 and A2, where incineration is replaced by plasma gasification, and A3.

Within this chosen method, an island could be compartmented into three sections: (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; (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; (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.

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. An overview of the material flow within the chosen method is shown in Fig. 6 and Table III provides an overview of the quantities.

TABLE II
COMPARISON OF ALTERNATIVE FILL MATERIAL

	Dredged sand	Compost	Slag	Excavated soil	Mountain soil	Channel sludge	Seabed sludge	Elucidation
Social	-	+	+	+	+	+	-	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	-	+	+	+	+	+	-	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	-	+	+	+	+	+	+	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 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.

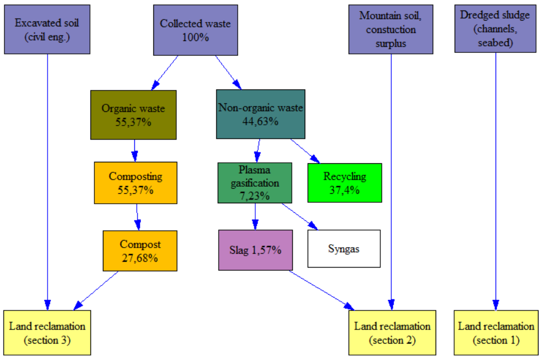

Fig. 6 Material flow of the chosen method

TABLE III
THE QUANTITY AND COST ESTIMATES OF FILL MATERIAL FOR AN ISLAND OF 300HA

	Conventional method			Method using waste		
	Material	Quantity (ton)	Cost ($)	Material	Quantity (ton)	Cost ($)
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	

D.SWOT Analysis of Implementation

As for the implementation of this method of land reclamation, SWOT analysis has been conducted as shown in Table IV.

TABLE IV
SWOT ANALYSIS OF THE PROPOSED METHOD

	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	Limited flexibility of the use of section 3 of the reclaimed land (soft soil for e.g. golf courses)
S3	Proper SWM system	W3	Expensive plasma gasification investment
S4	Economically interesting alternative	W4	Unpredictability due to the newness of the technologies
S5	Facilitating the creation of more greenery due to soft soil	W5	Involvement of a lot of stakeholders required
S6	Use of waste instead of sand		
S7	Social participation		
	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

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 solid waste management (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 compostable composted 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.

E. Scenario Planning

Scenario analyses mainly focus on uncertain factors (threats and opportunities). The most simple and reliable way to create scenarios is by picturing critical uncertainties on axes that frame poles of possible futures [14].

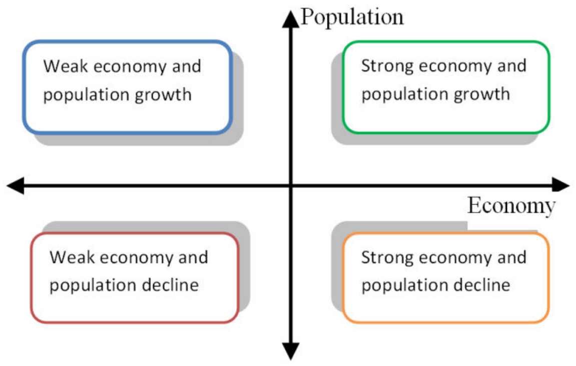

Fig. 7 Scenario planning

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 (Fig. 7). The most favorable simulated scenario for the implementation of the chosen method of land reclamation in Jakarta, taking into account the uncertainties of the city's demography and economy, was found to be the scenario where there is "Strong Economy and Population Growth".

In this scenario, 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 in Fig. 8 shows the positive loops created by this scenario.

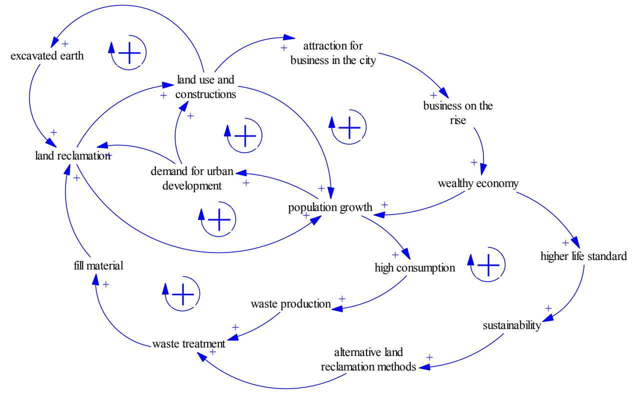

Fig. 8 Causal loop diagram of the strong economy and population growth scenario

V. Conclusion and Discussion

This paper analyses the possibility of the use of waste as fill material in the land reclamation projects of Jakarta. Considering the governmental, social, environmental and economic context of the city, the results identified four types of waste that could be used, the ways of using those types of waste and the implementation conditions for the city of Jakarta. With the scenario planning and system dynamic diagram, the most favorable approach is recommended taking into account the uncertainties of economy and demography.

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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