Project 2

A systems analysis on Jakarta's Wastewater Management Masterplan

UTC2717

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Question 1: Case Study System Dynamics Modelling

We created 2 simulations to better understand the big picture of the wastewater problem in Jakarta. The first model shows the current situation in Jakarta and what would happen if nothing was done to improve the state wastewater management. The second model shows the implementation of the New Master Plan (NMP) and whether or not it would really be feasible and effective.

Model 1: The Current Problem

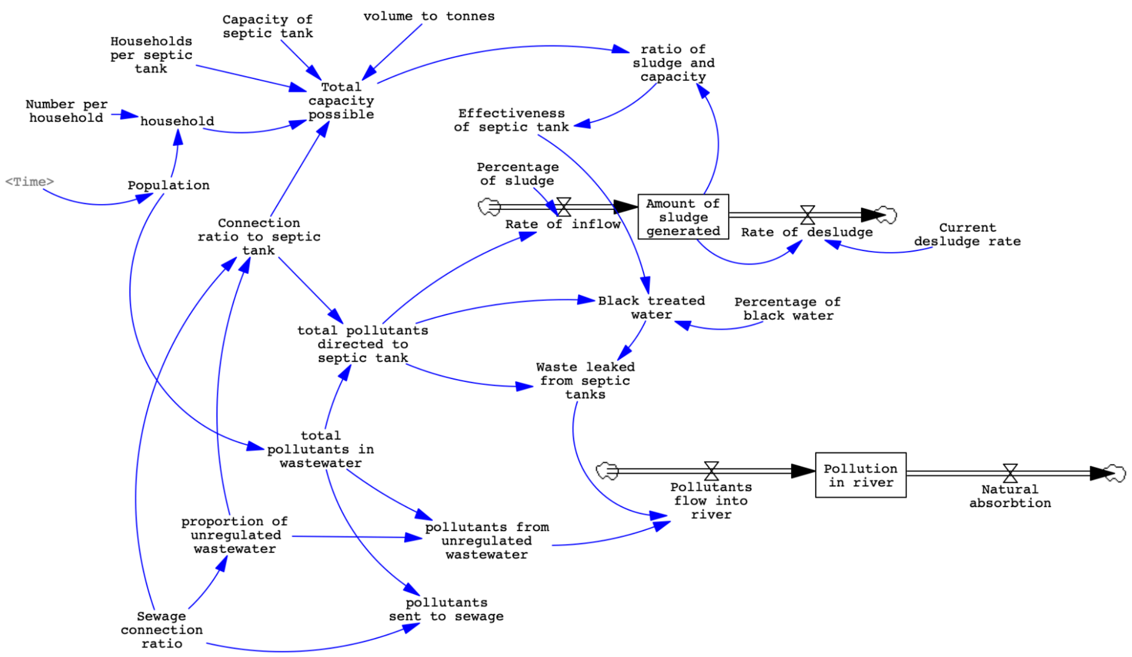


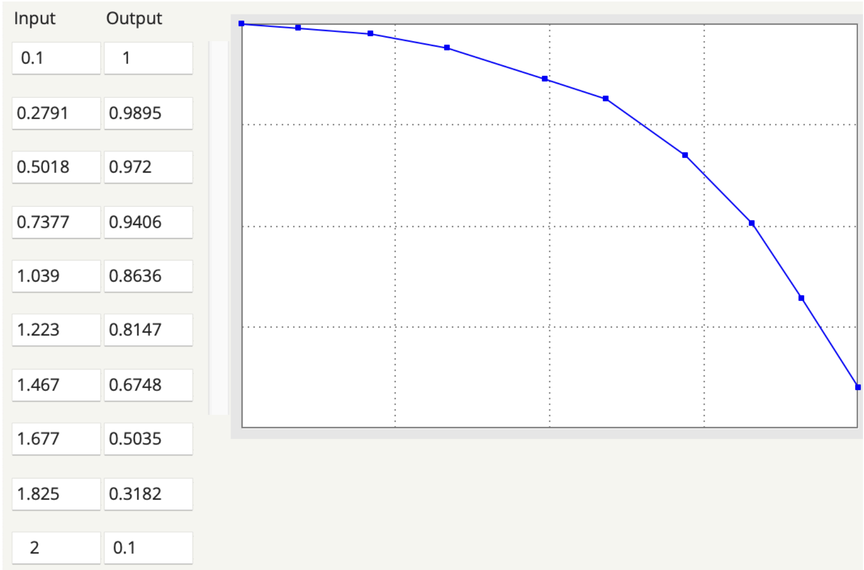
Fig.1. SFD of current problem

Stocks	Explanation and flows
Amount of sludge generated	This stock controls the build up of the total amount of sludge from all wastewater directed to septic tanks, measured in terms of BOD mass balance in tonnes. The amount of sludge stock is allowed to accumulate even beyond the capacity of the tank. The inflow is a product of total pollutants in wastewater and the percentage of sludge to ensure that only pollutants from sludge are accumulated in the stock. The outflow, rate of desludging, is controlled by how frequent desludging is carried out and this is calibrated using the PULSE TRAIN function. Every time there is a desludging, all the sludge accumulated will be removed and the stock returns to 0.

	The initial value is 0.
Pollution in river	Pollution in river refers to how much pollutants accumulate in the river and it is also measured in terms of BOD mass balance in tonnes. The inflow is the sum of pollutants from unregulated waste and pollutants leaked from the septic tank. The outflow is the estimated natural absorption of the river. The initial value is 0.

Variables	Equation
Total pollutants in wastewater	In terms of BOD mass balance: 401tonnes/day[1] * 365days = 146365tonnes/year
Number of septic tanks currently	Based on the United Nations (2019), roughly 475,000 people do not own a septic tank for their toilet facilities. With a total population of 11,436,000 people, roughly 10,961,000 people have access to septic tanks. Since each septic tank serves up to 5 people in a family, there are an average of 2,192,200 septic tanks in Jakarta today (Jakarta Ministry of Public Works and Housing Regulation, 2017).
Rate of desludging	Based on Widyarani et al (2022), there is presently no fixed rate of desludging or major maintenance – it only occurs on call basis, which is estimated to be once every five years.
Capacity of septic tanks	The structural standards for *conventional* sealed septic tanks are stipulated in the SNI 03-2398-2002 Standard National Indonesia. It stipulates that a septic tank designed for five users shall have an effective capacity of 3.5 m3.

[1] Pollutants in wastewater retrieved from Article, Page 13

Effectiveness of septic tank	 *Fig. 2. Lookup graph with ratio of sludge and capacity* When the ratio of sludge and capacity is low, the effectiveness is 1 and the tank works as it is intended to. As the ratio increases, meaning sludge begins to accumulate and fill up the tank, the effectiveness drops. As the ratio increases above 1, meaning the tank is overflowing, the effectiveness drops even more.
Black water treated	*Percentage of black water*total pollutants directed to septic tank*Effectiveness of septic tank* Conventional septic tanks are most common in Jakarta and these tanks are only able to treat black water. When the effectiveness of the tank decreases, the amount of black water that is treated is reduced.
Waste leaked from septic tanks	*total pollutants directed to septic tank-Black treated water* Since septic tanks can only treat black water, all the remaining grey water will be leaked and the leakage of black water from the overflowing of the tank is already accounted for in the 'black water treated' variable.

Model 2: Implementation of the New Master Plan

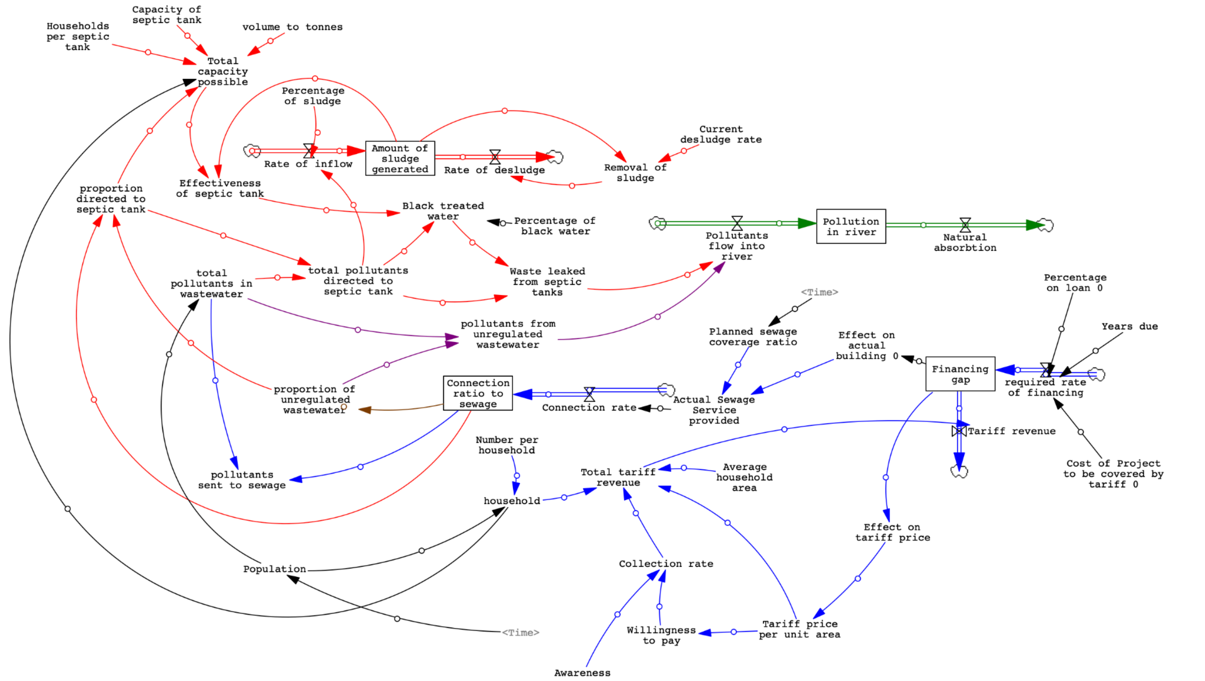
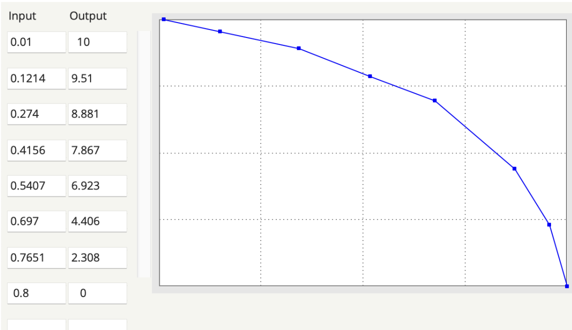


Fig.3. SFD of NMP

Stocks (excluding ones already explained)	Explanation and flows
Connection ratio to sewage	This is a dimensionless stock which should not increase beyond 1. In the New Master Plan, their goal is to increase the connection ratio from 0.02 to 0.8 by 2050[2] The inflow is the actual yearly connection rate, controlled by the intended yearly connection rate multiplied by the effect of actual building such that the intended connection rate would increase or decrease based on how high or low the effect if actual building is.
Financing Gap	This is a stock which describes the monetary gap between the cost of the masterplan and the actual tariff revenue collected to recover the cost. The inflow is the required rate of financing, which is an estimated breakdown of yearly cost. The outflow is the tariff revenue, which is calculated by how much tariff is being collected from the population.

Variables	Equations

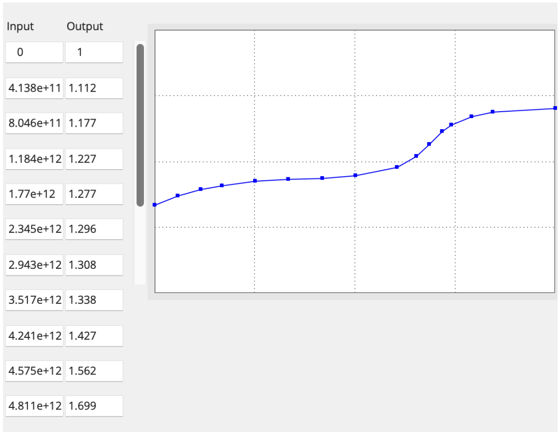
[2] Connection ratio data retrieved from Reference 1 (page)

Connection ratio to septic tanks	*1 - Sewage coverage ratio - proportion of unregulated wastewater* Thus, proportion of people reliant on septic tank should increase or decrease depending on the sewage coverage ratio
Proportion of unregulated wastewater	 *Fig. 4. Lookup graph with sewerage coverage ratio* The initial sewage coverage ratio is 0.02 and at that level of coverage, there is an unregulated waste ratio of 0.1[3]. Thus, if the sewage coverage ratio increases, the unregulated waste ratio will ideally decrease to 0.
Required rate of financing	*Cost of Project to be covered by tariff *Percentage on loan /Years due* The total cost of the entire project is around 63mil mil IDR[4], of which 50% is funded by international and local NGO donors (such as World Bank)[5], 15% is the cost incurred by the Jakarta provincial government and 35% is on loan from the Jakarta provincial government. The percentage on loan should be earned back by the government in the form of revenue collected from tariff payments by residents. The Years due refers to an estimation of 50 years, where the plan is supposed to start in 2012 and end in 2050.
Tariff Revenue	*Tariff price per unit area*household*Collection rate*Average household area* Tariff revenue is the total tariff revenue yearly, which is calculated by the above equation. This is assuming a certain collection rate based on an equation, multiplied by the total number of households linked to sewage, the average household area and tariff price per unit area. The total households is taken by *population/number per household,* and population is set to increase according to the population projection for Jakarta.

[3] Sewage coverage ratio and unregulated waste ratio retrieved from Article, Page 13
[4] Total cost retrieved from Reference 1 (page 26)
[5] Donor information retrieved from Reference 2 (page 88)

<table>
<tr><td>Tariff price per unit area per year</td><td>131*12*Effect on tariff price

This tariff price is multiplied by effect on tariff price to maintain ability for the government to recover the cost.

The wastewater tariff in Zone 1 is estimated at 8,253 IDR/HH/month (131 IDR/m2 x 63m2)[6].</td></tr>
<tr><td>Effect on tariff price</td><td>

<u>Fig. 5. Lookup graph with Financing Gap stock</u>

When there is 0 gap, the tariff price will not change as it means the tariff is just enough to recover the cost.

When the gap increases, tariff prices will increase to cover the growing financing gap. The percentage is kept under 2 to maintain affordability.</td></tr>
<tr><td>Collection rate</td><td>MIN(Awareness+Willingness to pay,1)

Collection rate refers to the proportion of people who will actually pay the tariff and it will be influenced by awareness of the importance of sewage in wastewater management and their willingness to pay depending on on their household income</td></tr>
</table>

[6] Tariff data retrieved from Reference 2 (page 135)

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<tr>
<td>Effect on actual building</td>
<td>

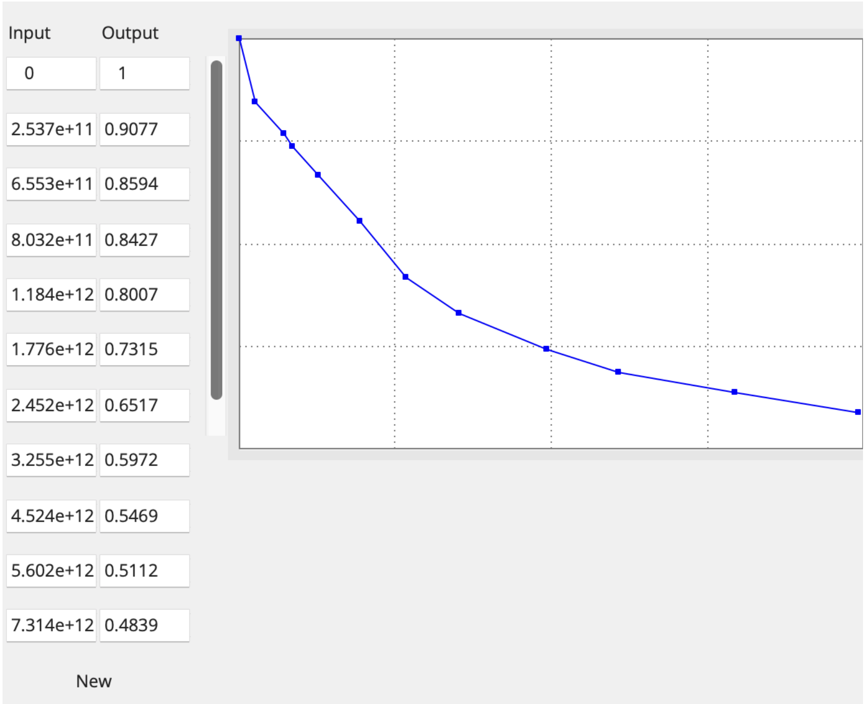

Fig. 6. Lookup with Financing Gap Stock

When the gap of financing is bigger, the government is less able to afford to keep up with the pace of building the sewage due to lack of funds and thus actual building will become lower than what it ideally should be.

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<td>Proportion of unregulated wastewater</td>
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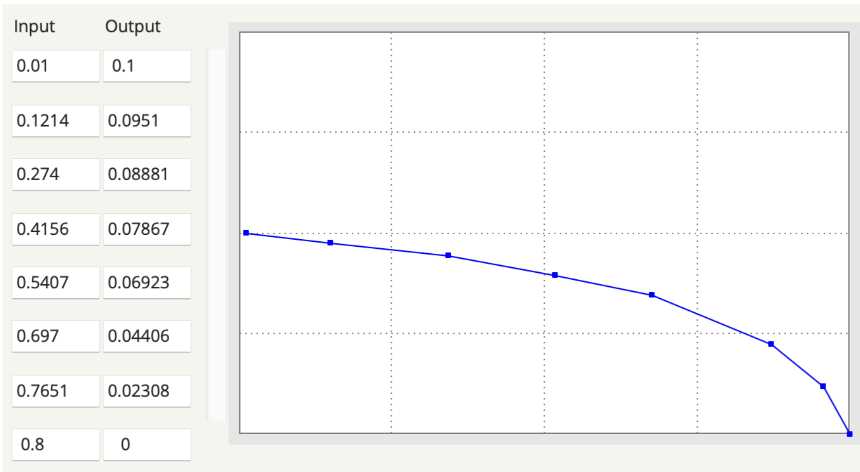

Fig. 7. Lookup with sewage coverage ratio stock

The proportion of unregulated wastewater (eg. open defecation, illegal dumping) starts at 0.1 when the sewage coverage ratio is at the current 0.02. As sewage coverage increases, it should reduce the proportion of unregulated wastewater down to zero.

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Simulation graphs

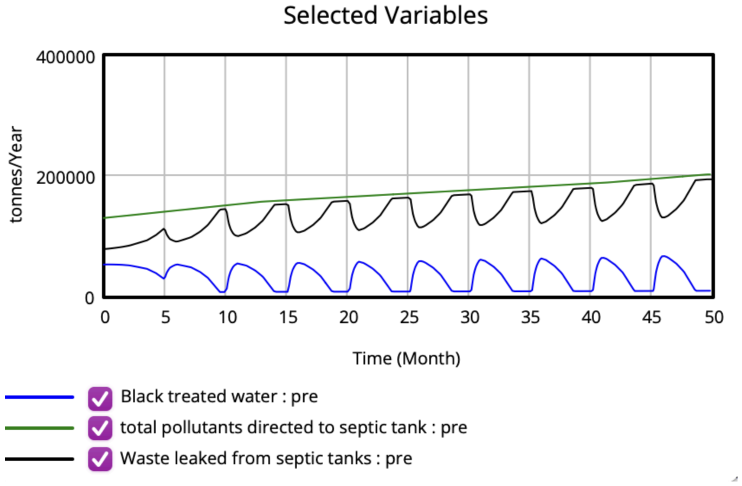

Fig. 8. Graph of total pollutants directed to septic tank (green), waste leaked (black) and black water treated (blue), from Model 1

This simulation from model 1 shows the idea of the fixes that fail archetype for septic tanks. These septic tanks were implemented originally to combat the problem of a lack of wastewater management. However, due to the lack of proper maintenance from the government, there was no regular desludging schedule in place to make sure the tanks did not overflow their capacity. Thus, the septic tanks leaked and very little waste that went to the tanks was actually being treated. As such, these tanks were ineffective at solving the problem that they were intended for. Therefore, the government wanted to phase out use of these septic tanks and instead use a sewage system to collect the wastewater which will directly be sent to proper wastewater treatment plants before being sent to the river. The government still did recognise the need for some septic tanks for the more overcrowded slum areas where a sewage system was virtually impossible to implement, so they proposed increasing the rate of desludging to once a year with an official authority in charge of the process[7].

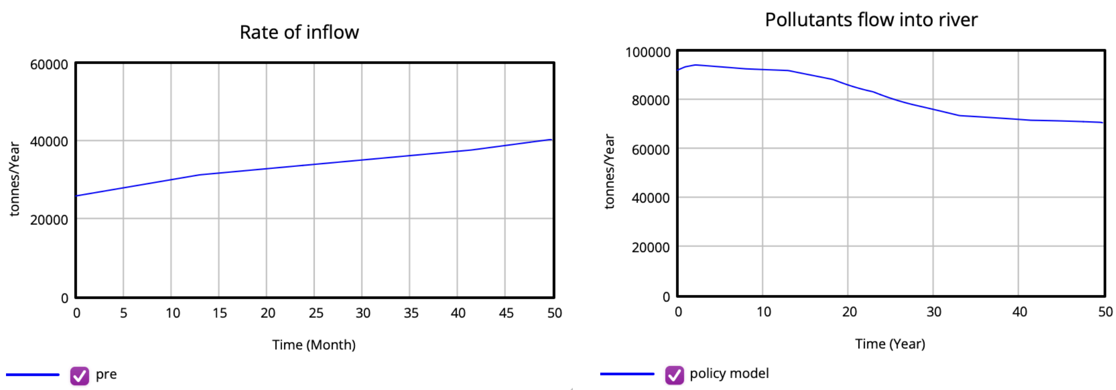

Fig. 9. Graphs of rate of inflow from Model 1 (left) and Model 2 (right)

At the current level of waste management, the rate of inflow into septic tanks will increase according to population increase. However, with the implementation of NMP, the rate of

[7] NMP Desludging information retrieved from Reference 1 (page 18)

inflow will first increase with population increase like before, but overtime as sewage coverage ratio increases, the rate of inflow to septic tanks will decrease since waste is directed to sewage instead.

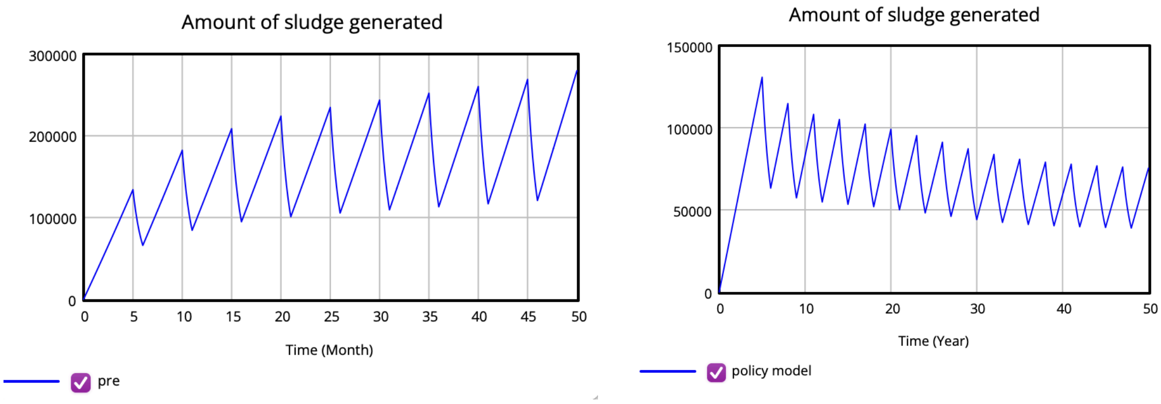

Fig. 10. Graphs of amount of sludge generated from from Model 1 (left) and Model 2 (right)

The amount of sludge generated sharply oscillates due to the action of periodic desludging. For model 1, we see that desludging occurs much less frequently compared to that of in the masterplan. Keeping the proportion of septic tanks and sewage at status quo will cause more and more sludge to be generated over time because the inflow of sludge increases as the population increases. On the other hand, with the NMP, the amount of sludge generated will overall decrease over time, even despite the increase in sludge inflow in the first 15 years.

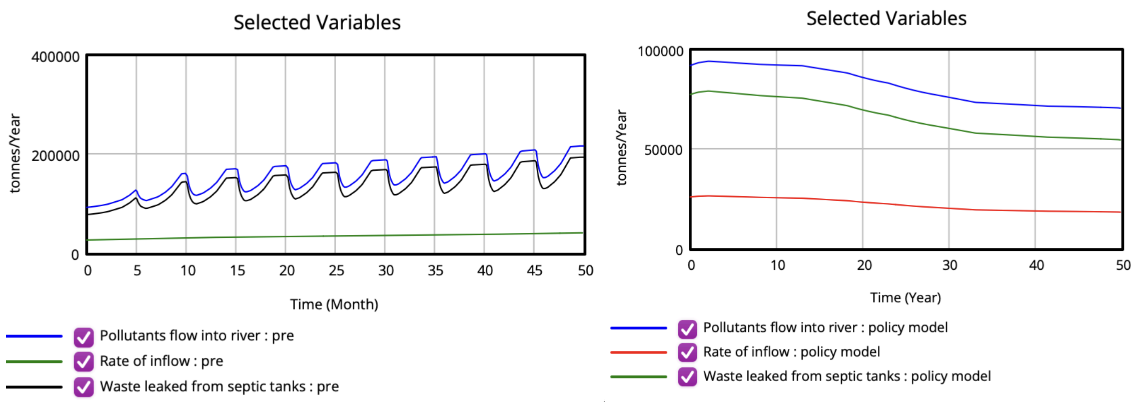

Fig. 11. Graphs of pollutants flowing into river from from Model 1 (left) and Model 2 (right)

In model 1, the pollutants flowing into the river oscillate while increasing with time. This behaviour is again caused by desludging rate. However, since the desludging rate is only once every 5 years, the septic tanks often overflow causing the effectiveness of removing pollutants to decrease. Thus, every time it overflows, pollutants flowing to the river increase, but after desludging the pollutants will decrease slightly, only to increase again when the tanks overflow. Conversely, the increased frequency of desludging in the NMP actually prevents the tanks from overflowing in the first place thus there is no periodic spike and decline of pollutants flowing to the river. Thus, pollutants flowing to the river decreases over time.

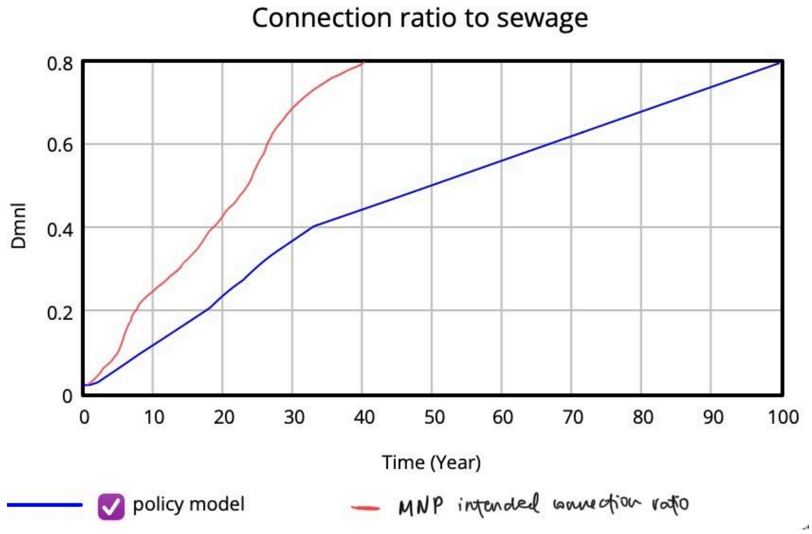

Fig. 12. Graph of connection ratio over time (Model 2)

The red line represents the planned sewage coverage and connection increase overtime[8] (the NMP assumes that connection rate will be 100% so coverage ratio and connection ratio is the same). The blue line shows how the connection ratio increases in reality. We see that the actual connection ratio is much slower than intended. By the 2050 mark (38 years in simulation), the NMP simulation only reflects 0.45 connection ratio, much lower than the intended 0.8. This is caused by the limitations brought about by the gap of financing. The actual tariff revenue collected is lower than intended to be able to cover the government loan for the project because of residents' low willingness to pay and low level of awareness. According to a study, there are still more than 30%[9] of residents who are unaware of the purpose and importance of being connected to the sewage system. Furthermore, the monthly household tariff to be paid is estimated at 8,253 IDR/HH/month (131 IDR/m2 x 63m2), whereas the in a survey asking residents how much was the maximum they were willing to pay for sewage services was mostly between 4000-5000 IDR per month[10]. This shows that people are not very willing to pay the tariff and as the government wants to gradually increase the tariff over the years, willingness to pay will decrease even further.

Conclusion

We conclude that the NMP has merits in that it is able to reduce the amount of pollutants entering the river, thus reducing the rate of pollution over time. However, due to unforeseen limitations, the rate of implementation is much slower than intended. Therefore, we are inclined to believe that the NMP is a project with much potential, as long as the limitations are adequately addressed. This shall be elaborated in the next section of the report.

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[8] Planned connection rate retrieved from Reference 2 (page 36)
[9] Awareness study data retrieved from Reference 2 (page 138)
[10] Willingness to pay values retrieved from Reference 2 (page 130)

Question 2: Policy Modelling

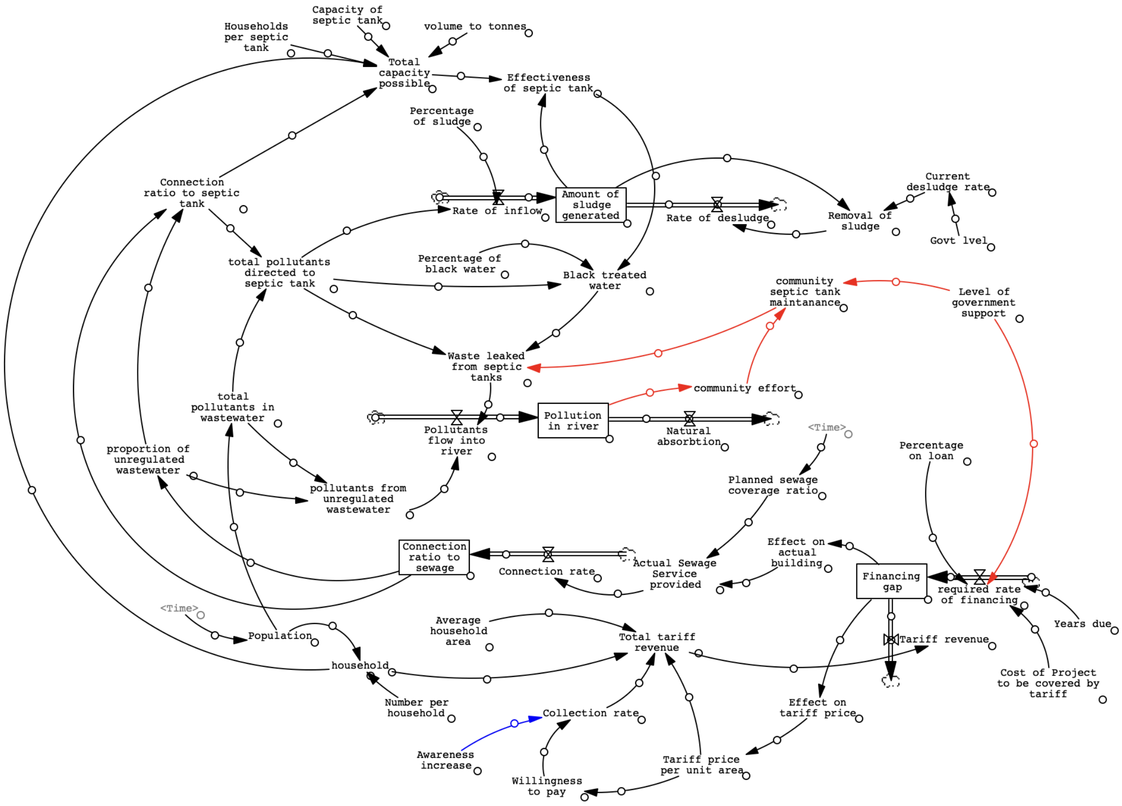


Fig. 13. SFD of policy

Policy idea 1: Campaigns that increases Awareness

Variables Changed	Explanation and flows
Awareness Increase	Affects: Collection rate (*MIN(Awareness increase+Willingness to pay,1)*) New value: 0.5 With the new awareness increased, willingness to pay will increase to 1 and collection rate will be at 1 consistently. This implies that total tariff revenue will go according to planned changes in tariff price to better bridge the financing gap.

Changes to simulation graphs

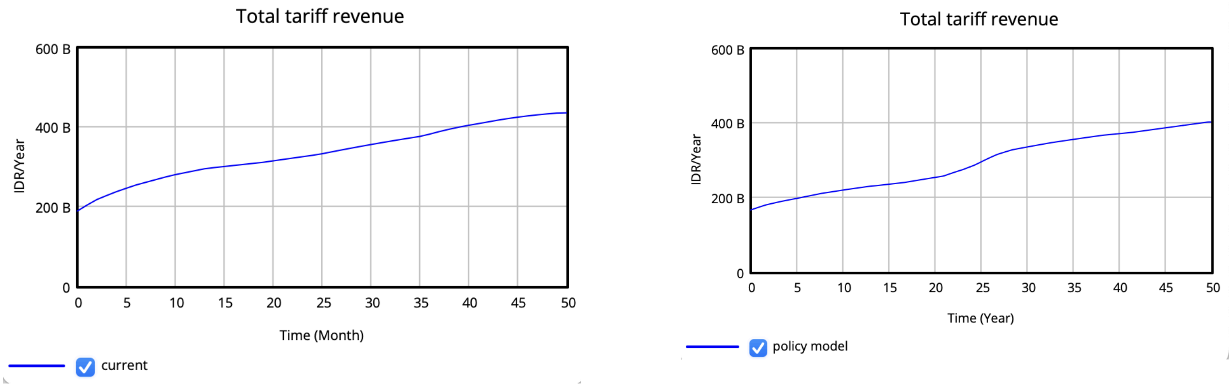


Fig. 14. Graph of Total tariff revenue from Policy model (left) and Model 2 (right)

This suggests that greater awareness will cause a prompt response to the changes in tariff revenue as collection rate is 1. Before the policy is implemented, the total tariff revenue is an S shaped graph because of the resistance of the community to pay the tariffs, hence there is a slow increase in tariffs collected. The rise in tariffs in time period 20-25 is due to a buildup of gap in financing leading to higher urgency placed on the issue, but the rate of increase in tariff revenue went back to a slow increase after the small surge.

Hence, the policy targeted at increasing tariff revenue collected is effective in changing the behaviour of the graph to a more ideal fit.

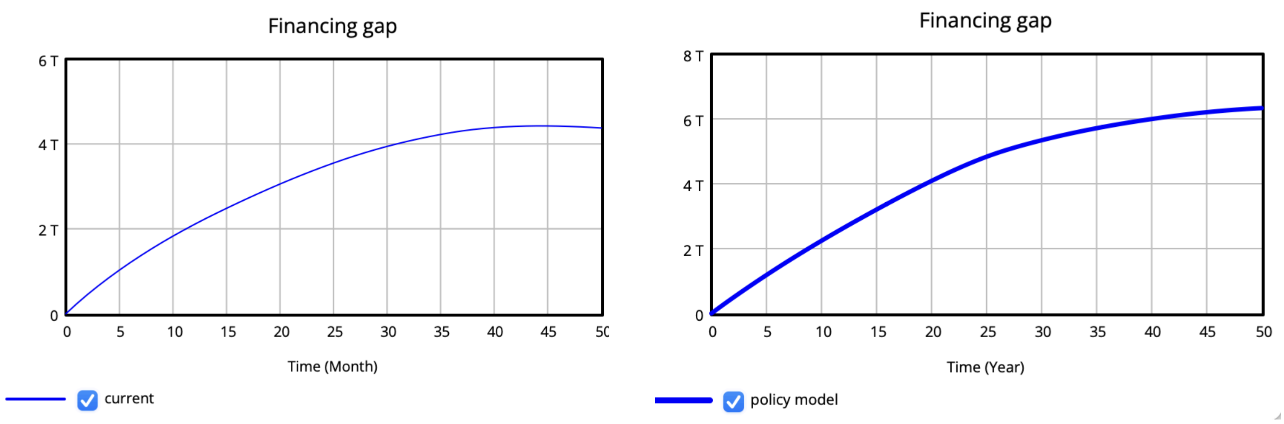
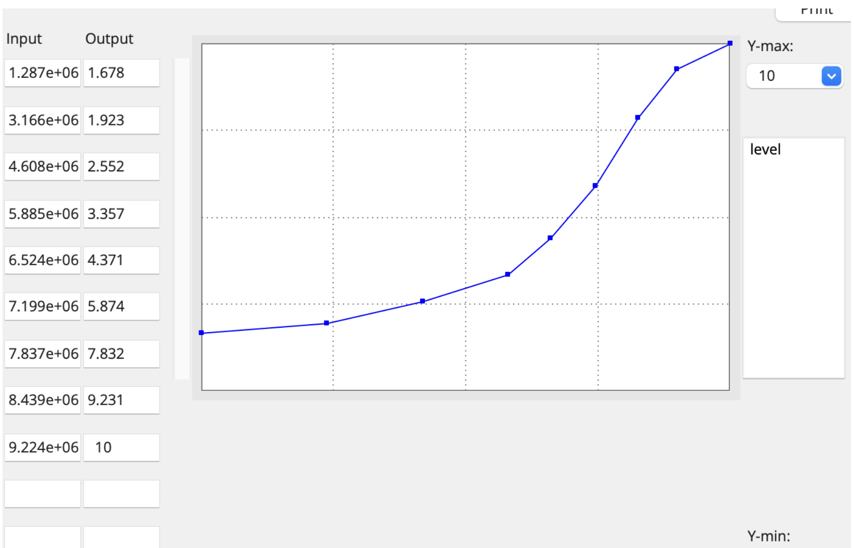


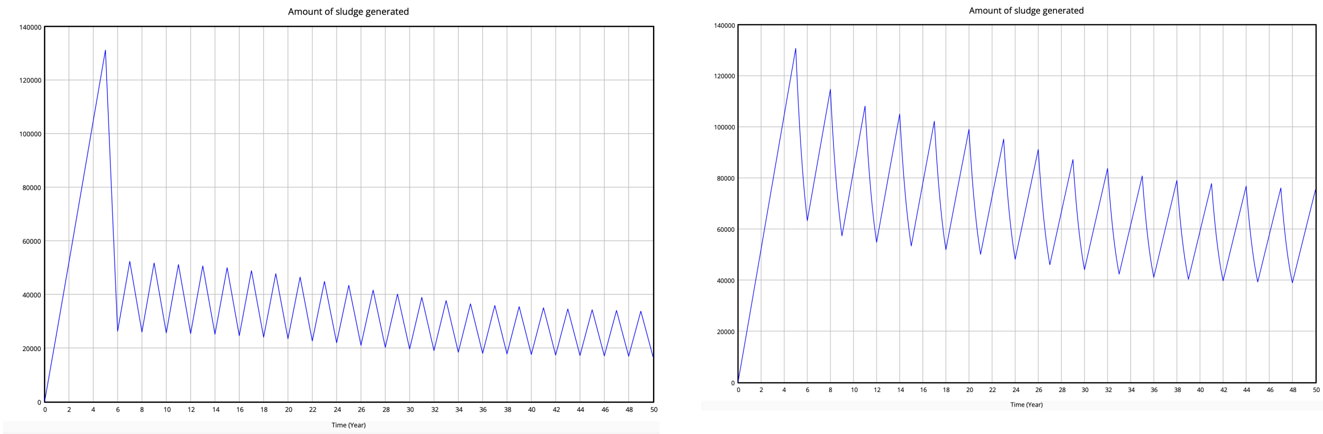
Fig. 15. Graph of Financing Gap from Policy model (left) and Model 2 (right)

In response, the financing gap will increase at a decreasing rate and eventually decrease after time period 40, representing the system where the gap is slowly closing. Before the policy, the financial gap increased steadily from the time period 1-25, before slowly going down.

Policy idea 2: Increase in government budget allocation to support community septic tank maintenance and removal of sludge

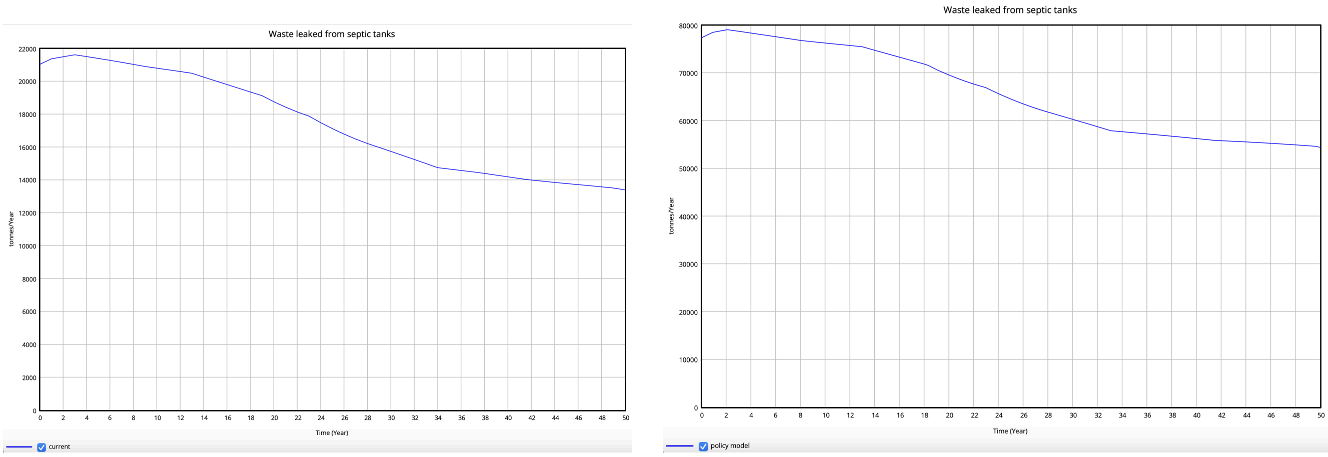
Variables Changed	Explanation and flows
Level of Government Support	This is a fixed value we added to represent the involvement of the government. This then affects 2 variables that reduces the leakage of sludge
Community septic tank maintenance	*Level of government support+community effort* This represents the extent of maintenance the community and government has on septic tanks. This is because with greater community effort and governmental subsidies, community members are able to engage in community efforts to modify septic tanks to reduce leakage.
Community effort	 This is a lookup graph from pollution in river, where we assume the increasing levels of pollution will encourage more action by the community to improve the septic tanks
Current desludge rate	*PULSE TRAIN(5,1,Level of government support,50)* Originally, the desludge rate was once every 5 years. However, the policy assumes the desludge rate is increased to once every 2 years, as the government support level is adjusted to be 1. This increases the rate of desludge, allowing for amount of leakages to decrease and pollution levels to decrease

<u>Changes to simulation graphs</u>



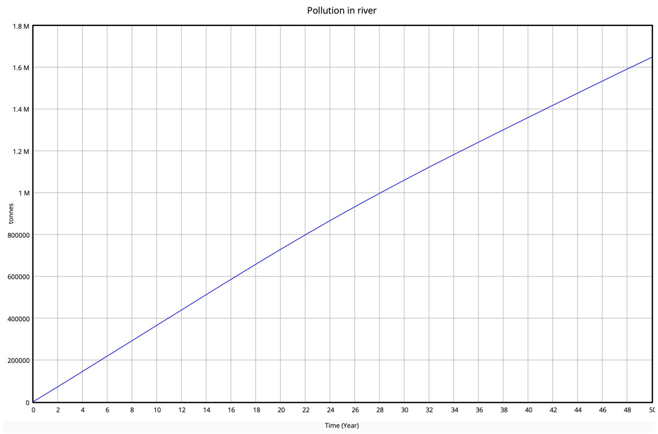
<u>Fig. 16. Amount of sludge generated from Policy model (left) and Model 2 (right)</u>

After rate of desludge increases, there is a significance fall in amount of sludge generated due to frequent clearing.



<u>Fig. 17. Graph of Waste leaked from septic tanks (left) and Model 2 (right)</u>

The increase in sludge causes a direct decrease in waste leaked from septic tanks. The original value of waste leaked is close to 80000 tonnes/year, but this value decreased to near 22000 tonnes per year. This has a significant impact on reduction of leakage, showing the importance of regular desludge.



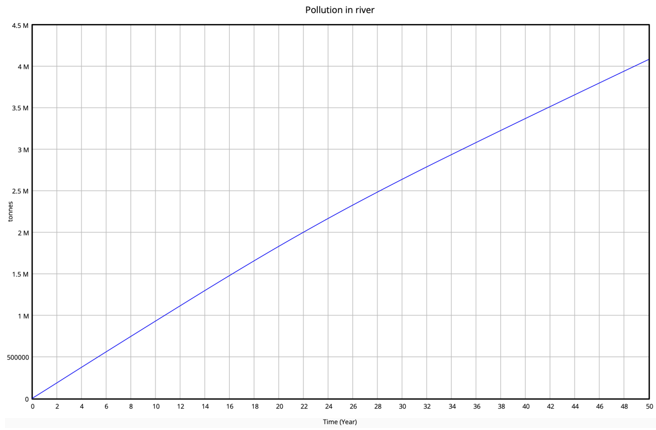


Fig. 18. Pollution in river from Policy model (left) and Model 2 (right)

By combining both policies, we see that the behaviour of the pollution stays the same but the value of pollution decreases, from the maximum hitting 4.5M tonnes/year to under 2M tonnes/year. The stock of pollution in rivers is close to a linear shape, meaning that the yearly increase of pollution is almost constant.

Conclusion

Our policies were created on the basis of empowering the community and strengthening community-government ties. Raising awareness was pivotal to ensuring that the community and the government could be on the same page, with the same goal towards reducing pollution and improving the quality of the river. Upon policy experimentation, we also noticed that when we included the community initiatives to manage septic tanks or desludging, it had a much more significant impact on the system in reducing water pollution as compared to if we attempted to improve any aspects of the masterplan. Increasing awareness did show positive effects of improving efficiency of the NMP, but ultimately, the plan is limited in its potential. This shows that there is indeed value in investing in the community instead of simply trying to let the government solve the problem, especially when they have been proven to face many issues in successfully implementing (and sticking to) such large scale projects, based on the interviews we had from the members of the community in Jakarta.

However, we acknowledge that the policies in above assume that there is enough budget to support community initiatives, desludging and there masterplan, and in reality this is not the case. There is simply not enough priority placed on managing the wastewater problem in Jakarta and therefore only a small proportion of the budget is allocated to this sector, which explains why they are so reliant on NGO funds.

Question 3: Concepts

The Urban Stream Syndrome & Water Sensitive Urban Design as the cure

The urban stream syndrome is undeniably associated with wastewater and pollution issues. As we have discussed, poor wastewater management resulted in millions of tonnes of untreated wastewater entering Jakarta's rivers every year. The result of this is a heavily polluted river devoid of its natural ecological functions. It is impossible for any marine life to survive in such harsh conditions where the BOD levels are astonishingly high and the river is way beyond its natural absorption capacity, rendering it unable to naturally undergo self-purification processes. Channel morphology is also altered as buildup of solid waste (from sludge) and this increased load causes the width depth ratio of a river to increase. Coupled with excessive surface runoff from wastewater leakage from septic tanks, this has implications on the frequency and intensity of flooding within these densely populated areas along the river. More flash floods could occur and considering the poor quality of the water, flooding could not only cause damage but also serious health impacts for those who come into contact with the polluted water. As such, proper wastewater management is pivotal in reversing the urban stream syndrome. In order to adequately address the problem, governments must utilise the concept of urban sensitive urban design such that the policies or infrastructure used conforms to the ecological needs of the environment. In the context of the NMP of Jakarta, there are concerns that construction of sewage pipes underground may cause other unintended consequences such as sewage leakage into clean groundwater sources. Therefore, environmental impact assessments must be carried out before implementation of the sewage to ensure minimal damage to the area, considering the fact that the planned sewage system is so extensive.

Institutional Fit – The social misfit of the NMP

We identified the institutional fit to be a social fit issue in the context of our project. Essentially, social fit refers to the congruence between institutions and the social systems which they operate within, in order to promote cooperation, compliance and positive environmental outcomes. As mentioned in project 1, the top down approach that the government is trying to implement with the NMP is problematic because it does not align with the current social landscape which the vast majority of Jakartans live within. Firstly, awareness about sanitation issues and waste management issues are limited. People do not see the value of having the sewage system or do not understand what benefit the system will bring for them. Secondly, those who are aware and feel concern for the state of pollution are dissatisfied with the governments' efforts so far, often lacking trust in their authorities to properly implement, enforce and ensure longevity of policies and projects. Some might even prefer a bottom up approach as they believe in empowering their own communities, but lack the resources to create sustainable large scale solutions without the help of the government. Lastly, it may be beyond the means of the poor slum community to be able to pay for sewage or septic tank maintenance on a monthly basis, making it unsuitable as a long term solution. Therefore, it is clear that the government is not sufficiently taking into consideration the interests and needs of the community and to a certain extent might be trying to force fit a solution that is unfeasible given the social systems within Jakarta. This misalignment between the governments' ideals and the citizens' expectations will limit the effective implementation of policies and therefore perpetuate the sense of discontentment from both sides and the cost to pay will be the inability to solve the pollution issue.

Institutional Fit – The unexplored spatial misfit

Beyond social issues, we have to also consider the geography of the Ciliwung river basin. Considering that the goal of the NMP is to improve the water quality of the river, the scale of the project might be insufficient to achieve this goal. Addressing the wastewater issue in Jakarta would only solve the issue of downstream pollution. However, the river flows through multiple cities upstream and midstream, all where sources of pollution can originate. Therefore, to adequately solve the pollution problem, we must approach the problem from a macro view, acknowledging that this is a transboundary problem where the stakeholders of multiple provinces must be involved in the conversation and the effort.

Furthermore, the geographical feasibility of the NMP within Jakarta had not been evaluated. Jakarta is a very densely populated city with lots of existing infrastructure as well as cramped overcrowded slums. Constructing a city wide sewage system would mean having to lay down hundreds of kilometres of pipes and building multiple huge wastewater treatment plants. Whether this will be possible or an efficient method to deal with wastewater is uncertain. As such, there has been some criticism regarding the governments' decision to prioritise construction of sewage pipelines instead of focusing on off site systems which are less invasive to the existing infrastructure.

The concept of policy transfer – studying India's community- based approach

In figuring out solutions and modelling them, another concept we followed after was the concept of policy transfer – essentially, thinking beyond the context of Indonesia or Jakarta and identifying solutions implemented by other countries in wastewater treatment management. In doing so, our knowledge of wastewater treatment broadens as well. For example, we briefly studied the cases of India's wastewater treatment and management to derive possible variations of policies that could be adapted to Jakarta's governance system.

From India, we observed their Community-Led Total Sanitation (CLTS) approach which was instrumental in promoting decentralised wastewater treatment solutions through mobilising the community and enforcing the CLTS system with incentives from the government. The key features of the initiative is essentially the collaboration between the government and residents and the reason for the strong collaboration between these stakeholders is due to mutual benefits. On one hand, residents are incentivised and recognised for their actions in serving the community, and innovations are rewarded with funding for implementation, similar to what we see today as the 'hackathon' or 'case competition' concept where a group of students pitch an idea and receive funding for. On the other hand, by involving the community for wastewater solutions, there is less burden faced by the India government in scoping out solutions for wastewater plans, which might not even appeal to the community's needs. The community, who experiences firsthand the effects of poorly managed wastewater, would have more experiences and ideas to share.

India's CLTS system employs a Behaviour Change Communication method, which is one of the key contributing factors that progressed their wastewater policies and led to some success in India’s wastewater management. The Behaviour Change Communication strategy is where awareness is communicated through the act of active involvement and having communities exude the behavioural change themselves. This has helped to build up social norms, beliefs, and practices, addressing misconceptions and taboos surrounding the wastewater treatment policy and creating a two-way communication between the government and residents.

In our context, the policy transfer was observed with our adaptation of India’s water governance case study. Since the lack of involvement we identified was rooted from differing opinions and perspectives of the wastewater treatment plans, India’s community led approach inspired our solution of budget increase and active campaigns to raise awareness – mainly to foster a bottom-up approach and ensure active incentivisation are put in place to increase involvement and awareness of the issue’s urgency.

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