URBAN METABOLISM PLANNING BASED ON QUANTITATIVE ANALYSIS
Material Flow Analysis for Strandeiland

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QUANTITATIVE RESEARCH FOR URBAN METABOLISM

I INTRODUCTION

Architectural and urban design practices are professional fields that there is inquiry for research to be applied and situated in relevant contexts. As a result of that, qualitative analyze has priority in descripting, especially when researchers try to record phenomenon or behavior which can be observed but not measured. But data collects by this way doesn't assure adequate validity and reliability because of its strong subjectivity [McLeod,2019]. Compared with academic disciplines in other engineering subjects, quantitative analysis in architecture research and related design is less developed until the emerging of the concept of urban metabolism. Urban metabolism is a model to facilitate the description and analysis of the flows of the materials, stocks, substance and energy within cities, first developed by Baccini and Brunner during the 1980s. It provides researchers new sights and frameworks for sustainable resources management. And Material Flow Analysis (MFA) is the frequently-used tool for observing and assessing where flow goes and how flow goes within a system. It connects the sources, the pathways, and the intermediate and final sinks of a material [Paul, 2003]. The concept of MFA goes beyond simple input and output balances of single processes but reflecting a dynamic balance under different synergies.

This paper explores the use of urban metabolism as a basis for planning and design for a new neighborhood, Strandeiland, Amsterdam, focusing on how to get evidence-supported strategies through the quantitative analysis of MFA. My general approach is to analysis the water, material and energy flows by Sankey diagrams. Thus, the improvement on lower resources input and less waste export can be seen intuitive from the contrast of two MFA diagrams (one is current, the other is future visionary). After that, multiple solutions based on integrated synergies will be put up for architectural and urban design in the design process. The main method used to collect the data to construct the MFA is by online sources and literature. Additional assumption and conversion factors are also permitted. It must be noted that only direct flows are considered in this MFA, so lifecycle aspects of the considered products and materials are not considered. Secondly, durable consumption goods, infrastructure are not considered, either, for its rare chance to become waste.

My research is embedded in Architectural engineering graduation project, that aims to develop architectural and urban interventions that helps with the utilization of wasted resources and recovery of the raw materials and thus reduce the input consumption in the neighborhood. It's important to know the current situation of in and output of the neighborhood and make a reasonable vision for the future. In the end, several strategies from pioneer waste management are listed as a toolbox. Collecting greywater and blackwater separately and thus convert the undiluted into biogas and heat. It was also found that reedbeds perform well on filtering greywater, which provides possibilities for flushing toilets with low-quality water. Further research is required into utilizing reed waste and sludge as building materials and thus reduce the input of construction materials.

II RESEARCH-METHODOLOGICAL DISCUSSION

Urban research is complex, dynamic, and fluid. To make sense of urban phenomena and respond to the issues facing cities, built environment researchers, across the disciplines of architecture, landscape architecture, urban planning, and urban design, must employ innovative and robust research methodologies and methods. The methodology I choose is quantitative research by Material flow analysis. Quantitative data can be interpreted with statistical analysis, and since statistics are based on the principles of mathematics, the quantitative approach is viewed as scientifically objective, and rational (Carr, 1994; Denscombe, 2010).

Material flow analysis (MFA) is a systematic assessment of the flows and stocks of materials within a system defined in space and time. It connects the sources, the pathways, and the intermediate and final sinks of a material [Paul, 2003]. It's an attractive tool that makes constant flows visible and reflects relevant synergies undergoing in waste or resources management by clearly stating the inputs and outputs of the investigated system. MFA helps to analyze and visualize the possibilities on future proof design in a system level, which is exactly the aim of my research and design. In other words, MFA acts as a decision-supportive tool [Paul, 2003] and most of the time, a visionary scenario with improvement will be made by applying those decision. The completed and consistent set of information takes every aspect into consideration, that won't miss any pain points.

And it's worthwhile mentioning that the material not only refers to the goods, but also substances in chemistry. For example, we can also calculate and analyze the nutrient flow in a process with MFA, like tracing the nutrient N, P and K in the wastewater management to evaluate wastewater quality.

One important element in MFA is the boundary. The boundary is defined both in space and time, which consists of geographical borders (region) or virtual limits (e.g., private households, including processes serving the private household such as transportation, waste collection, and sewer system) [Paul,2003]. The boundary gives limitation on the operating scale on the urban metabolism loops in case that interventions from irrelevant factors are included. A boundary clearly-defined system offers general statistics of inhabitant's consumption on energy, material and water, etc., that helps getting to know the system performances from a bottom-up way. On the other hand, the boundary narrows the selection of strategies and technologies, which means that when you build toolbox by collecting similar case studies, only the one with appropriate scale fits the object should be taken into consideration.

The challenges for applying this method in architecture is obvious, the accounting of substances is a new, laborious, and costly task. Poor knowledge of the application of statistical analysis may negatively affect analysis and subsequent interpretation (Black, 1999). And large sample sizes are needed for more accurate analysis. Small scale quantitative studies may be less reliable because of the low quantity of data (Denscombe, 2010). This also affects the ability to generalize study findings to wider populations. For individual architects, it requires strong multiple knowledge background with interdisciplinary, and plenty of time to deal with complex statistics, which means relatively less time and focus on design process. In other words, this method may be more suitable for team workers with interdisciplinary working background and reasonable task assignments for each member.

III RESEARCH-METHODOLOGICAL REFLECTION

The first appearance of metabolism is the experimental setup of Santorio (1561–1636) to analyze the material metabolism of a person. Later the input-output method has been incorporated into LCA (life-cycle assessment) to establish the economic input–output LCA method by the economists [Von,1990]. Urban metabolism first showed up as a model in the fields of resource conservation and environmental management was in the 1970s. The two original areas of application were (1) the metabolism of cities and (2) the analysis of pollutant pathways in regions such as watersheds or urban areas. In the following decades, MFA became a widespread tool in many fields, including process control, waste and wastewater treatment, agricultural nutrient management, water-quality management, resource conservation and recovery, product design, life cycle assessment (LCA), and others [Paul,2003]. After that, it has been proved to be practical during constructions in many sustainable communities, one of which is De Ceuvel in Amsterdam.

To transform the post-industrial neighborhood of Buiksloterham into a mixed-use residential and commercial area, the City of Amsterdam awarded four plots of land to pioneering initiatives focusing on sustainability and circular urban development. In 2012, Metabolic and a group of organizations won a tender to turn the De Ceuvel site – formerly a derelict and polluted shipyard – into a 'regenerative urban oasis', with the aim of stimulating new ways of thinking about how we manage resources in our communities [Metabolic].

In general, Stock-Flow diagrams are used for Quantitative research and Feedback Loop diagrams are used for qualitative research (Wolstenholme, 1999). It uses lines from the stock to the flow, which is the observable elements and reflects a dynamic balance over time. In this research, the system boundaries are set on the property of the Ceuvel. From the perspective of self-reliance this seems necessary, because this way one can evaluate to what extent the Ceuvel relies on sources from outside the Ceuvel and the rate of self-reliance can be examined. Regarding water, the water stock is increasing when it gets water from the public water tap network and is decreasing as effluent into the greywater system. Regarding food, the crops are fertilized with extraction from organic waste. But the food production is not enough for the need within the system so there will also be extra food supply from local farms. Same as energy, that solar systems by PV panels do not succeed to provide all the energy needed [Daan Dijkatra].

In my case, for example, Waterschoon is one of the case study projects about decentralized sanitation system that I decide to apply in my neighborhood. But the system now consumes ten times

energy compared to the general situation due to the very high electricity consumption of the water treatment (780 kWhp /i.e., year), especially the very large amount of greywater. So, the energy it made by fermentation largely meets its own energy requirements. This fact is visible in the MFA diagram and urges me to find back-up strategy making up for the energy loss. Then it leads to a purification system by reed as hyper filter which require less energy when treating wastewater. The evidence-support outcome from MFA analysis is persuasive and reliable.

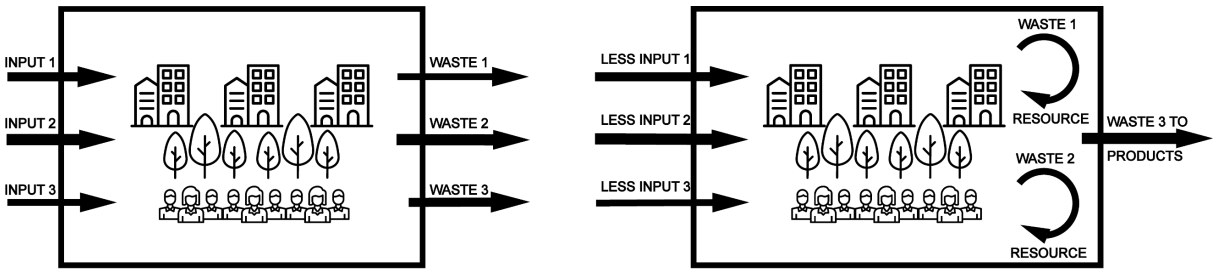
And Strandeiland is happened to be an island with very strong reed identity. The main shining points that Strandeiland can present in the future will be the leisure and water recreation activities alongside the beach and its willingness to recover the natural versatility, biodiversity and resilience, given the very attractive qualities of the island. Except the residential area, a 3-hecture nature zone consisting of 1-hectare mussel bank and 2-hectare valuable reed landscape is also being laid on the east-north edges of Strandeiland to make up for the landscape loss by land making [Strandeiland, 2018]. The current reed zone planned in the guidebook is around 2 hectares. According to the calculations in MFA, twice the size of the area is required to purify all greywater producing by the neighborhood. So, there is reasonable advice to expand the planting area for reed. It's obvious that quantitative research I have done provides directions and evidence for my next steps in architectural and urban interventions.

IV POSITIONING

First, A material flow analysis and case description will be made for the current state of Strandeiland, which is not built yet. So, relevant data will be based on literature giving Dutch averages for these situations (data from IJburg1 is prioritized).

Second, examples of pioneer metabolism system will be listed to analyze technologies for collection, transport, treatment, recycle and recovery in neighborhood scale. The system performances will be tested from the aspects of feasibility, quality, efficiency, maintenance, etc. In principle only technologies that have already been implemented on pilot scale in a comparable situation to the Strandeiland will be considered, although very promising technologies that have been extensively researched on lab scale may be considered by exception.

Third, potential strategies that helps with the utilization of wasted resources and recovery of the raw materials are selected to make a future proof improvement on the new MFA.



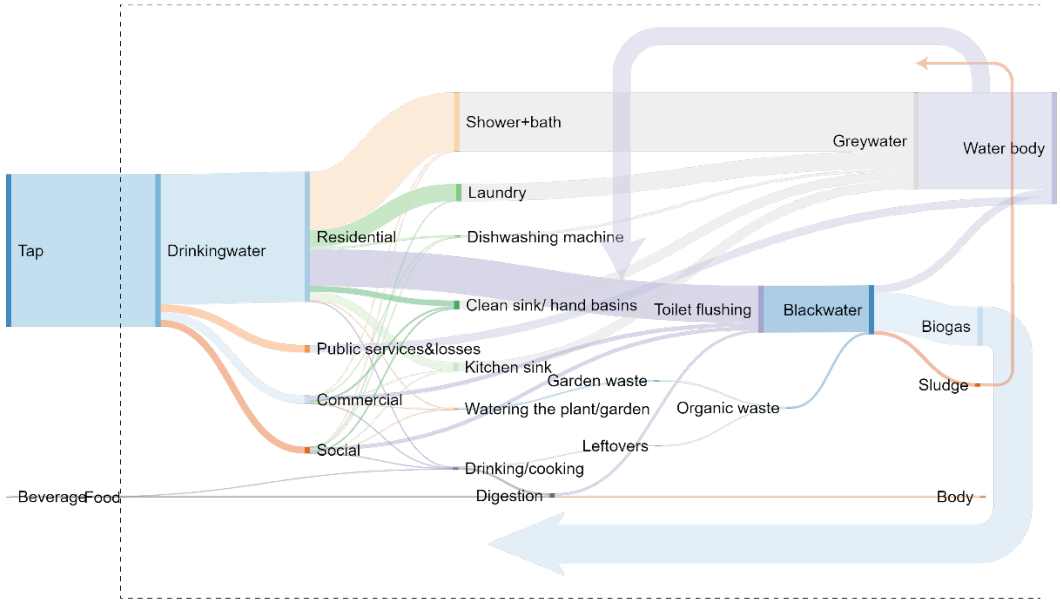
CURRENT VISIONARY

The objective of my research in AE studio is to make a visionary future proof design in a system level for a new neighborhood, Strandeiland, which is the second phase of IJburg artificial island plan in Amsterdam. My main research question is: *What are the dimensions of material flows on Strandeiland, and what are the opportunities for its being a local circular eco-neighborhood?* My sub questions are:

- *What are the dimensions of current MFA on Strandeiland?*
- *What interventions can be made to improve the system performance in Strandeiland, based on the pioneer cases in Netherlands?*
- *What are the dimensions of future MFA that shows the improvement?*
- *What is the implication for urban and architecture design?*

After putting up with those questions, statistics helps to answer. It turns quantitative data into useful information to help with decision making. We can use statistics to summarise our data,

describing patterns, relationships, and connections. One of the visualization method is by Sankey diagrams, which emphasize the major transfers or flows within a system. They help locate the most important contributions to a flow. They often show conserved quantities within defined system boundaries. Based on the current material flow diagram of IJburg1 (Haveneiland, Steigereiland and the Rieteilanden), just like most conventional neighborhoods adopting liner economy in Netherlands, discharging 892,128,299L mixed effluent to the WWTP every year, which requires a large amount of energy and all the nutrients and heat embodied in wastewater is lost. MFA provides evidence-supported possibilities for a local circular system in future Strandeiland, by applying strategies and technologies learnt from wastewater management and sanitation-energy integrated systems in Netherlands. New sanitation can be combined with an energy system for heating and cooling homes. Only the heat recovery from grey water is not enough to supply the entire Strandeiland with heat and cold (new sanitation provides for 30 percent of the heat demand). Supplementation with a system for collective heat and cold storage (WKO), using surface water from the IJmeer, is also required. [Strandeiland,2018] Also, twice the size of the area is required to purify all greywater producing by the neighborhood. So, there is reasonable advice to expand the planting area for reed. It's obvious that quantitative research provides directions and evidence for my next steps in architectural and urban interventions.



Despite the attention given the urban metabolism concept over the last 50 years, stakeholders and designers are only recently beginning to embrace it for guiding projects. The progressive acknowledgement of urban environmental problems has turned the spotlight on urban metabolism as an operational base for sustainable urban design. During the process, quantitative analyses can have important contributions to the success of the dynamics study of the boundary-defined system. In my case, this can be explained by the importance of the water, material and energy flow for this system since this is an important aspect of circularity and recovery of raw materials as used in my program. The need for using a quantitative measuring method is that the water flows, and where they originate from, are visualized which is important in order to measure circularity and versatility. Based on that, urging the technology that collects greywater and blackwater separately and thus convert the undiluted into biogas and heat. Using reedbeds purifying greywater and strategies to recover nutrients and heat and generate biogas and electricity. Further research is required into utilizing reed waste and sludge as building materials and thus reduce the input of construction materials. The outcome then will be embedded in my graduation project, that aims to develop architectural and urban interventions for a local circular eco-neighborhood with strong vernacular identity. Furthermore, objectives discussed in

my text offering me a new angle to look upon the future proof design for a metabolic neighborhood by using MFA as analytical tool.

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