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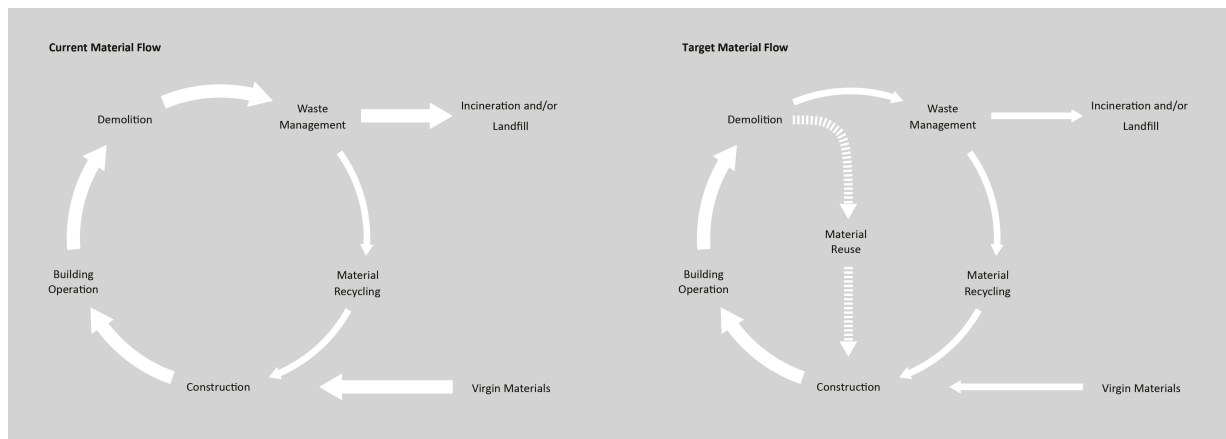


Building from End-of-Life: An Alternative Approach for Low-Cost Urban Housing

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ABSTRACT

Rapid expansion of cities poses a very hard challenge to provide adequate housing for the poor, while its social and environmental pressures demand alternative approaches to low-cost housing. An answer to the challenge of housing for poor citizens can come from cities themselves. Urban centers are concentrated nodes where vast quantities of materials and energy are consumed in constant cycles of construction, operation and demolition. Strategically intervening in the urban metabolism can help to secure very low-cost or even no-cost construction materials while reducing the environmental stresses due to resource extraction, leading to more sustainable cities.

Our research investigates the possibilities of tapping into the life cycle of construction materials as a source of unexploited building components for low-cost housing. In the informal city, a market of salvaged materials is already in place. However, in the developed world, reuse practices in construction are typically dismissed. Here we present the current building demolition methods in Singapore and a proposal to divert resources that currently go to landfill, to produce low-cost housing for developing nations. The research has two components. First, study the flow of materials, processes and related stakeholders in construction and demolition activities in Singapore, with focus on their economic and environmental dimensions. Second, we work with housing development agencies, primarily Habitat for Humanity, in the design of low-cost housing units using reclaimed building components with minimum cost.

This research contributes with strategies to secure very low-cost housing units using reused building components, focused on the functional, aesthetic and economic aspects. In this way, it proposes and supports an alternative approach to the urgent urban housing problems through sustainable end-of-life buildings management, promoting a more global-inclusive model of urbanization.

KEYWORDS: Low-Cost Housing, Urban Mining, Urban Metabolism, Construction and Demolition Waste

AUTHOR BIOGRAPHY:

Felix Raspall is an architect and design researcher investigating the relationships between design, materiality and technology. Currently, he is an Assistant Professor at Singapore University of Technology and Design. His work explores alternative design methods in which material constraints creatively inform projects.

Being a doctoral candidate, Mohit Arora is working in the area of resources efficiency, urban mining and reuse in complex urban systems. Exploring the interdisciplinary engagement of design, technology and environment remains his key interest for research.

Introduction

Cities and buildings remain central to research focus on resources and energy efficiency for reducing vulnerability towards climate change [1]. Today, flow of material in cities is highly inefficient, as the majority of construction materials come from extraction and, by the buildings' end-of-life, almost all demolition debris ends up in landfill [2, 3, 4]. Rapid expansion of cities and its social and environmental pressures demand alternative approaches to low-cost housing. Cities themselves can provide an answer to the pressing housing challenges. Strategically intervening in the urban metabolism can help to secure very low-cost or no-cost construction materials while reducing the environmental stresses due to resource extraction [4]. Our research investigates the possibilities of tapping into the life cycle of construction materials as a source of unexploited building components for low cost housing. In the informal city, a market of salvaged materials is already in place. However, in the developed world, reuse practices in construction are typically dismissed.

Through our analysis of existing demolition practices in Singapore and low cost housing construction in the ASEAN region, we identified main opportunities and challenges to accomplish a very low-cost housing production model that taps into the end-of-life of buildings in Singapore. In this ongoing research, we investigate the processes and systems in place as well as design methods to take advantage of existing urban stock, and test the implementation of designed processes.

Building Demolition and Low-cost Housing

Due to increase in the rate of building obsolescence, current demolition practices in Singapore involve substantial disposal of building components that are still in good condition and suitable for reuse for the construction of new units [4]. Although current Singaporean policies promote landfill reduction through high disposal fee, which make discarding of demolition waste expensive for developers and demolition contractors, there is no established practice or market for reused building components in Singapore. For this reason, the procurement of salvaged building components can be extremely cheap or even profitable, creating an opportunity to utilize them in the construction of very low-cost housing units for the immediate ASEAN region, where housing needs are urgent. Image 1 displays the current material flow in Singapore and the target intervention.

Here, we present the current building demolition methods in Singapore and how to better employ resources that currently go to landfill for low-cost housing or refugee shelters. This ongoing research is organized into three modules: (1) study of current demolition practices in Singapore, (2) development of low-cost housing employing reused components and (3) implementation of the reuse process.

Current demolition practices and state of art in Singapore

First, we study in detail the flow of materials, processes and related stakeholders in Singapore, with focus on their economic and environmental dimensions. The objective is to understand existing practices and identify areas of opportunity to procure used building components that today end up in landfill with a cost to the demolition contractors. The research was done through interviews with the main stakeholders, site visits, and literature review.

Research reveals that although Singapore has a high rate of concrete and metal recycling, reuse practices are negligible. The main reason is the lack of market for reused components due to the perceived decrease in construction quality within a very expensive real estate market, the preference for sleek new buildings, and the concentration of construction activities in large public and private developers.

The process of demolition largely remains a machine intensive effort with manual sorting of low value components. Once a building is designated for demolition, various demolition contractors participate in a bid to pay for building demolition. A qualitative estimation of metal scrap in building forms the basis for negative or positive cost of demolition for the building owner. If the scrap/metal components are high, most likely the owner will get paid for building demolition. Keeping heavy and voluminous nature of construction and demolition waste in mind, the National Environment Agency of Singapore follows a punitive measure for its reduction with landfill gate fee of S\$77/Ton. Under such circumstances, the construction and demolition waste is downgraded for application at land reclamation sites or as hard core alternative for bottom layers in road construction. Although the National Environment Agency estimates 99% recycling of Construction and demolition waste, the actual percentage of clean concrete recovered and recycled into structural concrete is hard to estimate but most likely remains substantially lower. Though, Singapore demolition guidelines, SS 557 (2010), provide systematic approach for building demolition to maximize resources recovery, its implementation remains largely invisible. The major reason is higher labor cost involved in resource recovery, absence of reuse market and strict timeline to complete demolition. Lack of market in many ways seems big hurdle in achieving efficient reuse of building components. Current demolition practices target metal recovery as sole source of value. Due to Singapore's Green Mark requirements (the local building rating tool), some of the portion of concrete waste reaches recycling plants to become recycle concrete aggregates (RCA) which mostly find low value applications in temporary construction. Due to lack of recycling facility and a cost for waste-to-energy plants, glass and wooden components are mostly crushed and mixed into construction and demolition debris or instead sent to a incineration/waste-to-energy plant. Occasionally informal collectors take out good conditioned wood elements and furniture for sale in nearby cities. Various piping and air-condition ducts are usually treated as metals and recovered after demolition.

To briefly summaries the building demolition process, demolition machines are landed on top floor of building after creating a passing way for vehicles (Image 2). A top down approach is followed to minimize the space requirement for logistics. Lift holes serve as a passage for building debris to ground floor where debris is crushed to remove metal rebar and other metallic components. To extract smaller magnetic metal components, a magnet is used in the presence of workers who remove any non-magnetic metal that may remain at the pile of debris. After metal extraction, debris is sent either to landfill or land reclamation sites while good quality concrete from columns and beams is sent for recycling into RCA. Current practice of demolition remains largely devoid of second life of materials in the form of reuse.

Thus, current demolition practices provide an opportunity to reuse building components for high level applications in low-cost housing. If done at a large scale, urban mining of building components in developed cities can greatly improve the efforts for achieving adequate urban housing in developing countries.

To implement this process, a number of challenges need to be overcome. The window of time when materials can be recovered is very short, around one to two weeks at the beginning of the demolition process. Today, demolition contractors usually invite "acquaintances" enter the site and "scavenge" for furniture at minimum cost. Beyond this timeframe, recovery activities, which can entail delays in the demolition process, are considered unreasonable.

Low-cost housing using reused components

Second, we study how to design low-cost housing units with proper habitability levels and minimum cost using discarded materials. We are currently working in collaboration with Habitat for Humanity in the design of prototypical unit for Batam, Indonesia, a city 15km from Singapore where Habitat for Humanity has been conducting significant construction work.

Our first step is to study how recovered materials can be used in low-cost units and how to facilitate material recovery within the short window of time that demolition practices can offer. As a case study, we studied the reusability of a building soon to be demolished, the Rochor Centre in Singapore. We proposed and tested a process to quickly survey the building using 3d point cloud scanning, which aims to simplify the identification of the existing material stock. This is crucial to expedite the tight recovery process and to facilitate the design of low-cost units. The actual survey of the building took two hours on the site, and produced a 3d model that was used to identify useful parts and locate components to be recovered for our low-cost housing units (see Images 3 and 4)

Materials that are suitable to be recovered include: windows, doors, kitchen cabinets, bathroom and kitchen fixtures, and surface finishing in good condition. In addition, concrete components such as beams, columns and slabs, if carefully taken apart, can also be reused.

The second step is the design of housing units that can be tailored to the particular characteristics of the recovered components. Designing using recovered materials presents challenges to designers due to the non-standard nature of materials [5, 6]. As a benchmark, we based our design in a prototypical unit for Batam, Indonesia, by Habitat for Humanity (see Image 5). Our design follows its basic layout, replacing new materials with reused components from the Rochor Centre. Image 6 displays a design we propose for the low cost housing.

Implementation

The implementation of the reuse process involves a number of organizational and logistic challenges. We are currently working towards understanding and overcoming those challenges by designing and building a prototypical unit.

As today, we have established a new bridge between supply and demand for reused components: demolition contractor Aiksun Engineering and Demolition Pte Ltd on the supply side and with Habitat for Humanity on the demand side. Both parties have stated their willingness to facilitate the process. Our work at SUTD involves coordination, design and execution.

We anticipate a number of logistic needs: A small warehouse space in Singapore, transportation from the demolition site to the assembly space and to the final destination, and construction in the final location. In terms of cost, uncertainties are still high. Cost of building components involve labor to disassemble and transportation from the site to the assembly space. In addition, new construction materials and labor are needed in the construction site. We aim to have a clear understanding of the actual costs through the prototypical unit.

Conclusion

This research contributes with strategies to produce very low-cost housing units using reclaimed building components, focused on the functional, aesthetic and economic aspects. In this way, it proposes and supports an alternative approach to the urgent urban housing problems through sustainable end-of-life buildings management.

We have already tested the feasibility of this approach in theory, by cooperating with the relevant stakeholders, surveyed a real demolition site and designed a possible unit. In addition, we designed a process to facilitate the survey of building stock to be demolished, the recovery of components and the design of new units using a fast 3D point cloud scanning. We tested this process by scanning the Rochor Centre in Singapore, cataloguing useful components and designing a unit.

To implement this project, we identified a large number of practical concerns including costing and logistics that we aim to answer through actual construction of a prototypical unit in the next year, including transportation of materials, assembly space in Singapore and procurement of new materials and final assembly on site in Batam, Indonesia. Success of such an attempt may facilitate to open up a new direction for second life of building components in general and urban contribution for low cost housing in particular.

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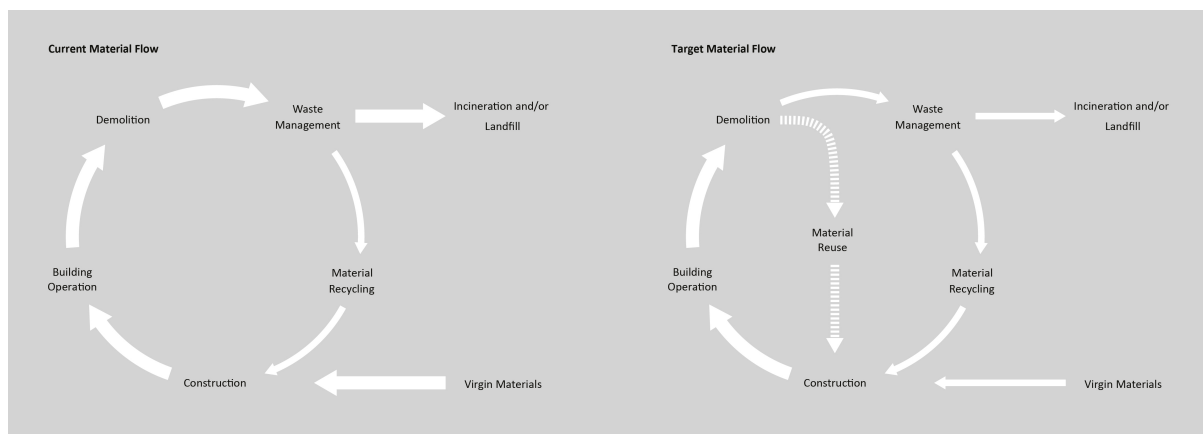


Image 1. Diagram of current material flow in Singapore (left) and of target flow after intervention (right).



Image 2. Typical demolition site in Singapore. Image Credits: Mohit Arora



Image 3. 3d point cloud scanning of the Rochor Centre in Singapore. Image Credits: Felix Raspall

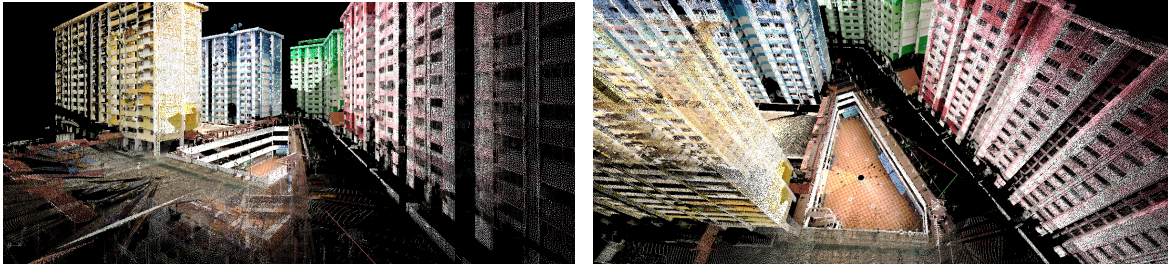


Image 4. 3D scan pointcloud of Rochor Centre in Singapore. Image Credits: Felix Raspall

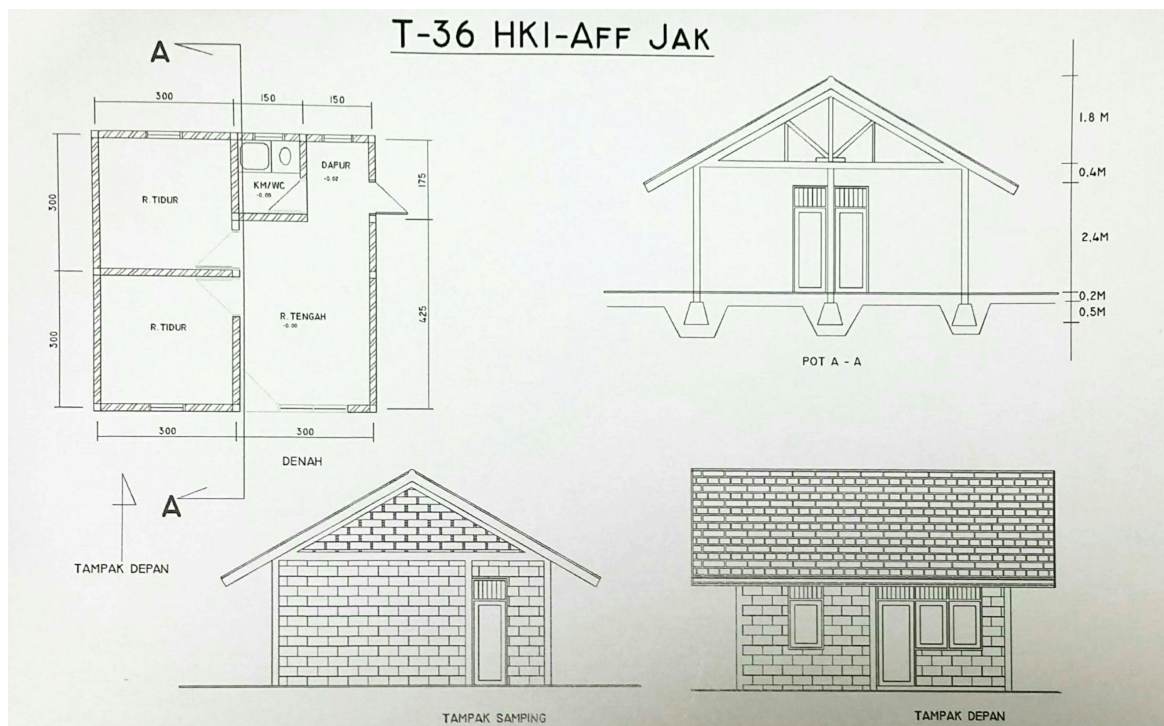


Image 5. Prototypical low-cost housing design for Batam, Indonesia by Habitat for Humanity. Image Credits: Habitat for Humanity Singapore

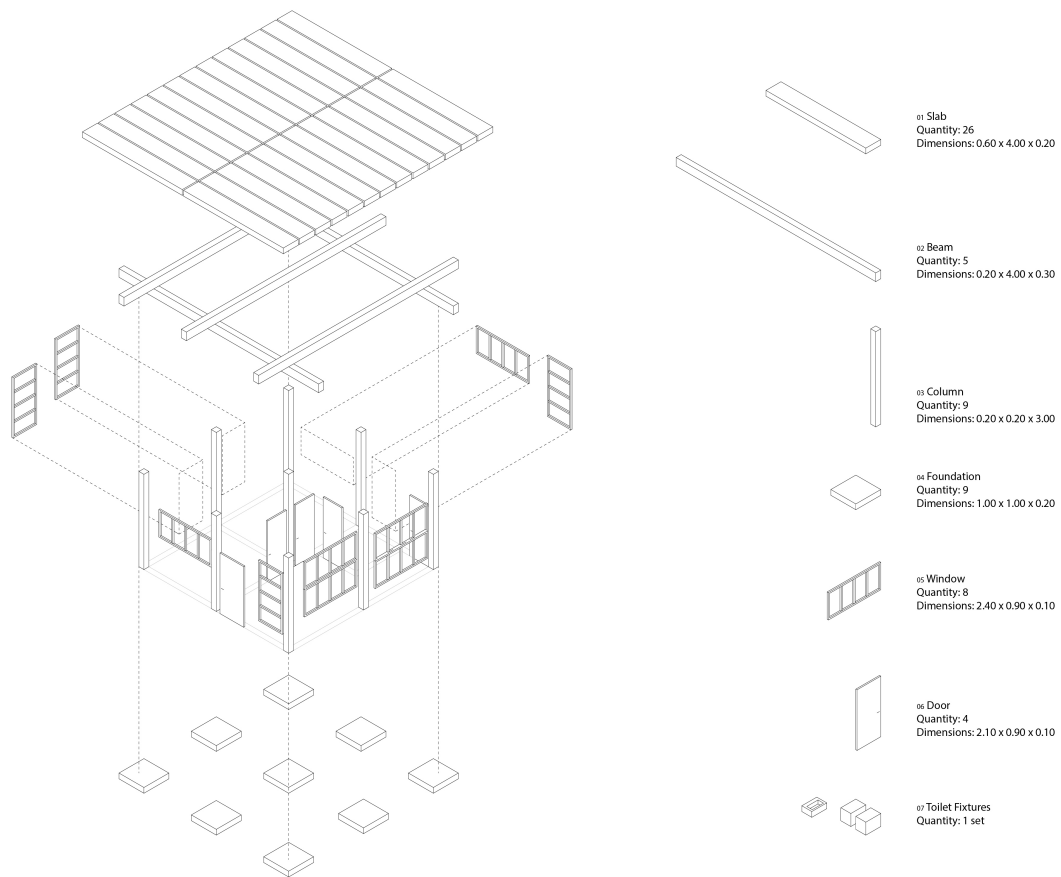


Image 6. Design for very low-cost housing using components from the Rochor Center Singapore.