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A case study on regenerating informal settlements in Cairo using Affordable and Adaptable Building System

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Abstract

This paper is a scientific review of the results from research project A²L-Mobilius, which is an ongoing research project partly funded by the German Federal Ministry of Education and Research (BMBF). Today the process of urbanization has reached an unprecedented level. Most of the rapid urbanization phenomena happen in developing countries, triggering a series of social, economic, and environmental challenges as well as opportunities. In particular, nearly two thirds of Greater Cairo Region's population are living in informal urban settlements, and the number is expected to continuously increase, which causes a series of issues such as overpopulation, land shortage, high unemployment rate, lack of adequate infrastructures, and environmental challenges. As a result, in the foreseeable future, the situation will be more problematic if no innovative measures are taken. Based on A²L-Mobilius, the goal of this paper is to present an integrated solution to improve the living condition of local residents and to catalyze the vitality of local community. With regard to the research methods, a small housing unit in Cairo's informal area is chosen as the object of the case study. Accordingly, field trip study by Egyptian partners is conducted in order to better understand the housing's condition as well as its surroundings. Based on the case study findings as well as the Open Building concept, the results consist of an Affordable and Adaptable Building System (A²BS) and a cluster of Decentralized Processing Units (DPUs), which generate key elements to improve energy efficiency, mobility, and life-work patterns. Furthermore, specifications and technological details of the proposed system will be presented in this paper. In conclusion, this case study provides a valuable model for further research on regenerating informal urban settlements.

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Keywords: Egypt; advanced building technology; informal urban settlements; open building; urban regeneration

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1. Introduction

The process of urbanization today has entered an unprecedented era. According to a recent UN study, 66% of world population will be living in urban areas by 2050 [1]. Most of the current urban sprawl phenomena happen in developing countries, which trigger a series of social, economic, and environmental challenges as well as opportunities. For instance, Greater Cairo Region is arguably the largest in Egypt, Africa, and the Middle East, and one of the most crowded metropolises in the world. Nowadays approximately two thirds of Greater Cairo Region's 20 million population live in informal urban settlements, and the number is expected to dramatically increase, thus causing serious issues such as overpopulation, land shortage, high unemployment rate, lack of adequate infrastructures, and environmental challenges [2]. Consequently, in the foreseeable future, the situation will be even more complex and problematic if no innovative and integrated solutions are implemented.

Therefore, this paper aims to present an integrated solution to improve the living condition of local residents and to catalyze the vitality of local community in the coming years (see Table 1), based on the research project A²L-Mobilius (short for Affordable and Adjustable Living and Mobility for Sustainable Integrated Urban Systems in Egypt), which is partly financed by the Federal Ministry of Education and Research of Germany (BMBF) [3]. A residential building in Cairo's informal urban area Sakiat Mekki is selected and studied. A method based on requirements engineering (RE) is developed in order to ensure the fulfillment of the stakeholders' needs in the existing housing unit [4]. Accordingly, a renovation and extension design based on Open Building is proposed to regenerate the selected case with advanced building technologies [5]. The results consist of an Affordable and Adaptable Building System (A²BS), and a cluster of Decentralized Processing Units (DPUs), generating a key component to improve energy efficiency, mobility, and life-work patterns [6]. In order to demonstrate the feasibility, specifications and technological details of the proposed system will be presented in this paper. In addition, an innovative business model for the local residents will be presented as an example which additionally supports the building system to promote local economy. In conclusion, this report will provide researchers, architects and urban planners with a valuable model of regenerating informal urban settlements.

Table 1. Existing situation, expected transition, and future vision of Cairo's informal settlements

Existing situation	Expected transition phase	Future vision
		
Existing street condition: (1) Inadequate living condition (2) Poor infrastructure system, e.g. old sewage system (3) Poor quality of housing construction (4) Lack of schools and health care facilities (5) Lack of public amenities (6) Lack of adequate planning and building regulation (7) Poor environmental conditions (8) Random rubbish disposal (9) Rising manhole cover, poor road surface (10) Poor road safety	Regeneration taking place: (1) Renovation and building improvement work (2) Single task robot is in operation (3) Improvement of the infrastructure system (4) Improvement of road surface (5) Removal of livestock from the roof top (6) Removal of rubbish pits (7) Upgrading of sewage system (8) Human and construction robot interaction at work (9) Upgrading the water supply system (10) Demolish of an existing building	Conceptual street scene: (1) Improved living condition (2) Regular rubbish removal (3) Improved road safety (4) Sufficient parking (5) Well organized street and sidewalk (6) Adequate waste recycling (7) Improved sewage system (8) Roof garden and vertical farming (9) Decentralized industry (10) Improved amenities (11) Decentralized modular pod for energy generation (12) Decentralized modular pod for live & work integration (13) Rapid logistic system (e.g. drones) (14) Improved water provision

2. Sakiat Mekki: a case study

In the Sakiat Mekki area, a plot in Farahat Street is chosen as the case study site (see Fig. 1). Sakiat Mekki area is located on the west bank of Nile River in Giza District, Cairo. According to the Egyptian partners' feedback, this informal area suffers from a series of serious issues. Specifically, the street is usually overcrowded due to the limited number of roads; the building quality of the informal settlements are usually poor since most of them are undocumented constructions; also the sanitation standard is inadequate as puddles and garbage can be often seen on the street. A²BS system will be further detailed to fit the plot as well as the existing building dimensions. Meanwhile, the dimensions of the framework producing the concrete panels in the off-site factory will also be shown in the next section.

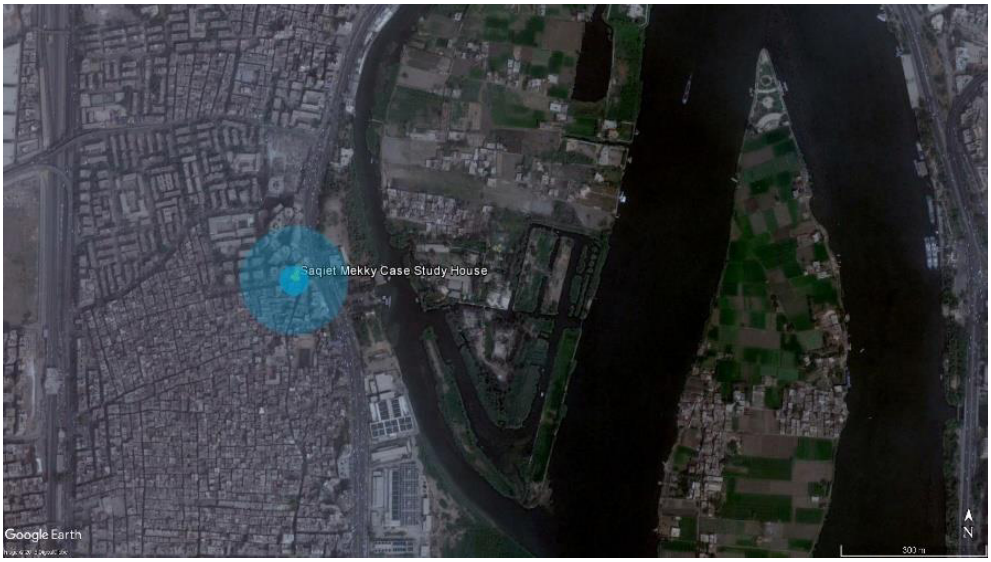

Fig. 1. Satellite map of the selected case study site location in Cairo (Source: Google Earth)

The selected case study building is a 45 m² three-story housing unit with one apartment on each floor. The tenants have the ownership of the house. Ground floor is an active mechanical workshop. The tenant of the first floor flat is a single woman who lives alone in the flat. However, she usually invites some relatives to spend a night or two with her (they usually shift the whole flat into sleeping areas). The apartment consists of a living room with natural ventilation and a bedroom without natural ventilation or day light. There is a toilet and small space for a kitchenette and in order to get more space for cocking, she puts some furniture on the stairs' landing. The user works at home to make some handmade things. The flat on the second floor is considered as a second home for a family consisting of 4 members who only spend the summer time in the apartment. The bedroom for the parents and it has no natural ventilation or day light, the second rooms is a living room and sleeping room for children. Toilet and kitchen are too small so they use part of the stairs landing as part of cooking process or washing process. The flat on the third floor is unoccupied. Currently, stairs are used as extra space for washing, cooking and storage. Stairs have no handrails and the risers have height differences. The roof is used by the users in the gathering days as an extra open space.

The structure of the building appears to be in good shape; however, to ensure full security for the existing structure as well as the extension, the attachment will be structurally independent to the existing building, while minimizing its impact to the existing plot. According to Egyptian partners' feedback, the housing unit suffers from these problems such as lack of garbage cans, noise from workshops in the ground floor, lack of ventilation, no handrails in the stairs, risers of different height, sanitation issues, and space shortage. Also, horizontal extension is not applicable in this case, since the width of the street is relatively narrow and the sidewalk is occupied by local venders. In addition, concrete casting on site is not applicable as there is no space on streets for the casting process. Besides, the condition of the existing structural system is unclear, so building extension on the existing structure is not applicable (see Fig. 2).

Fig. 2. Status quo of selected case study building (Photo credit: Dr. Wafaa Nadim, 2016)

3. A²BS and DPU: an integrated solution

The concept of the project is to insert a pleasant living and working environment into the existing and individual living environment by an intelligent and modular open building system, which is able to evolve and transform over time.

As key element, a compact and prefabricated unit will be developed, which serves as the main technical units of a residential building. The cell-like unit is called DPU (Decentralized Processing Unit) and includes three main subsystems (subsystem for energy collection, provision, wise use, and eventually production; subsystem for improving interior mobility; and subsystem for life-work balance: Mini production unit or mini office at home). The DPU itself with its subsystems will be integrated into a modular building kit (A²BS, Affordable and Adaptable Building System), which is fully reusable in the future. The building kit will be designed so that it is compatible with the investigated site residential structures and in particular informal housing settlements (see Fig. 3).

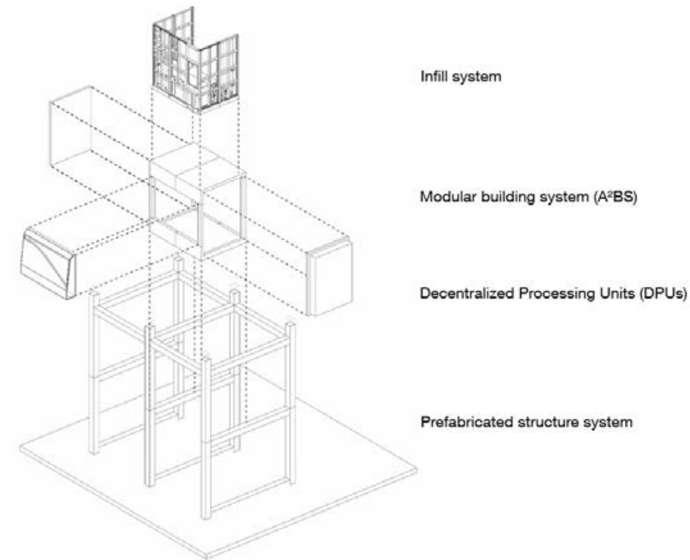

Fig. 3. Prefabricated modular open building system

The building system will be able to grow or evolve over several generations within an existing informal settlement so that it step by step replaces the old unstructured environment by a more formal environment that provides better tools, technologies and living conditions for the residents. In a dialogue with the users, who shall be empowered to support the systems evolution over time, the main building material will be specified and it will be elaborated whether a supply of components from a central large company or decentralized by local workshops is targeted.

As mentioned before, the panelized system consists of five main components; top left section panel, top right section panel, lower left section panel, lower right section panel, and vertical supporting pillars. The top left section panel and the lower right section panel are identical; the top right and the lower left likewise. Therefore, the whole panel system can be precast in parts by two frames made from recycled material. This panelized system can be produced by the local contractors at very low cost. The dimensions of each panel are listed in Fig. 4. The assembling instruction diagram of all components of the panelized system will be presented. The necessary details of the joints and connections will be designed and illustrated in order to demonstrate the feasibility of the system.

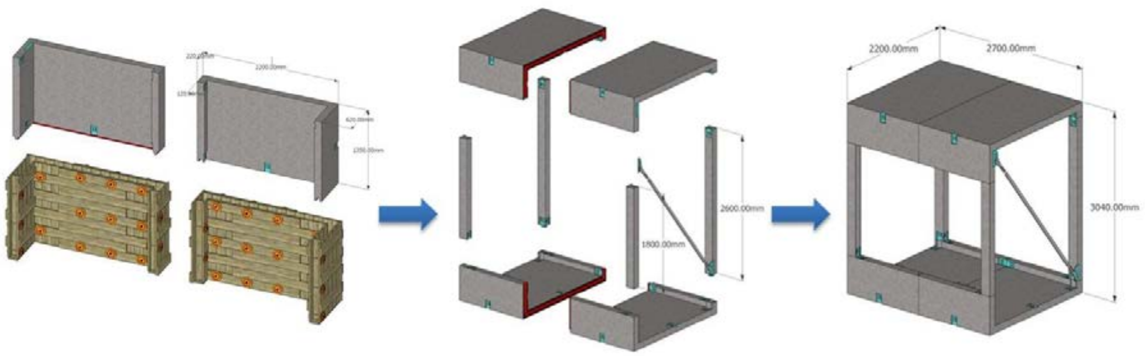

Fig. 4. Casting and assembling process of the panelized concrete module

An independent concrete structural system with flexible spread footing foundation bearing potential heavy loads from extension is proposed. The members of the system can be easily prefabricated off site by the local contractor, and thus shipped to the site. Steel reinforcing bars on top of the columns are reserved for future extension. Because of the narrow space between the existing building itself and its surrounding buildings, roads, and facilities, the beams of the concrete structure have to cross over the longer side of the rectangular, as shown in Fig. 5.

Fig. 5. Vertical extension strategy of the existing building

In addition, a mass concrete underpinning process will be needed to support and reinforce the existing foundation, because the original foundation is too close to the extension and might not be strong enough to support new structure. The underpinning in construction or renovation is the process to strengthen the foundation of an existing building or other structure. The strategy of the underpinning process of the existing foundation is shown in Fig. 6.

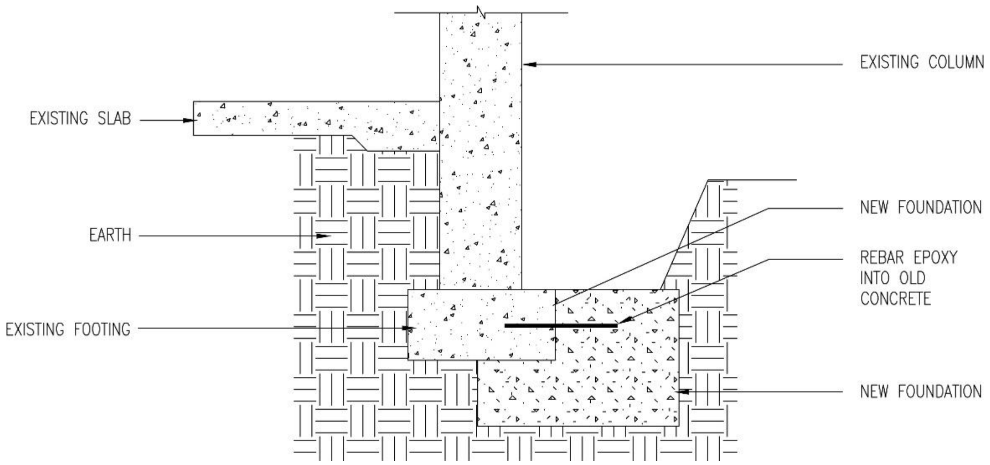

Fig. 6. Diagram showing underpinning process of the existing foundation

DPU submodules are meant to be decentralized small elements that work together as a whole. Therefore, users can decide to have the amount and type of elements they need and accordingly the cost they can afford. They are designed to be embedded easily into the A²BS unit. Here are a few examples of DPUs with three main subsystems (subsystem for energy, subsystem for mobility, and subsystem for life-work balance) providing various functions (see Fig. 7).

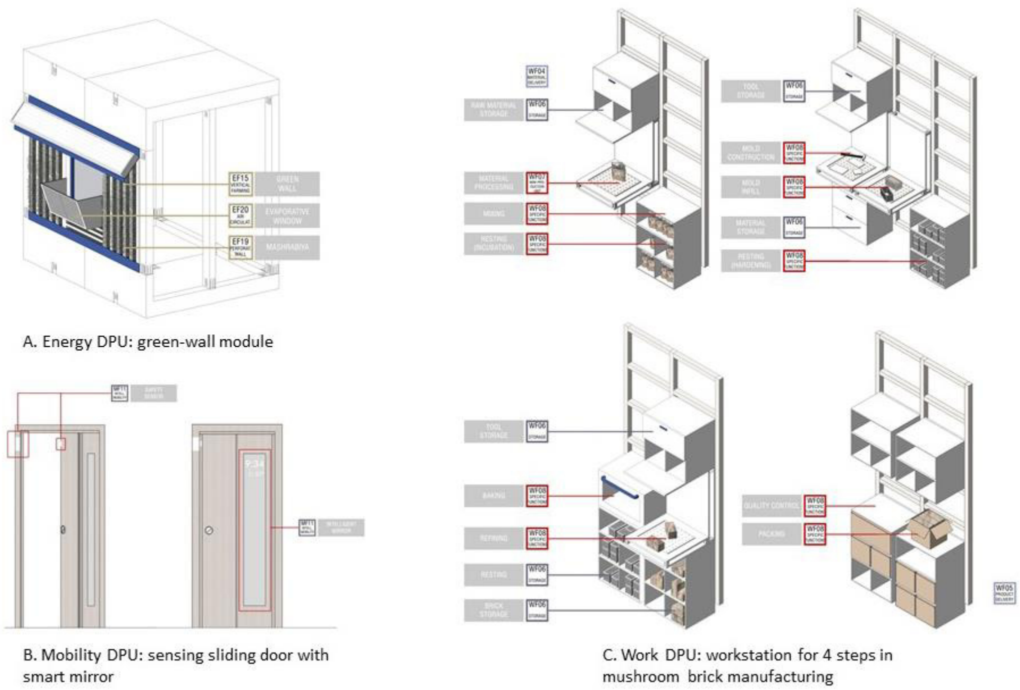

Fig. 7. Three examples of DPU submodules which can be embedded to the case study building

4. Decentralized Industrial Village: an innovative business model

Decentralized Industrial Village (DIV) is a terminology developed throughout the project to describe a type of village which contains decentralized units that manufacture a series of components of a product or products, as in the case of a stream line, meanwhile preserving the existing local business. One way to catalyze the development of the slum area is to exploit profitable business model for the local people, in order to reduce the unemployment rate. Meanwhile, there have been a variety of existing local businesses and craftsmanship (e.g. rubbish recycling). In order to promote innovative business model, part of the Cairo slum can be transformed into DIV for innovative product manufacturing without undermining the intactness of existing local business.

There are many possibilities of innovative product manufacturing within the DIV, such as mushroom bricks, recycled plastic bricks, and urban farming. While the economics behind each innovative system can be further demonstrated in future research, here is an example showing cultivating mushrooms and manufacturing mycelium bricks can be achieved in the urban farming DPU submodules. In the map below there are 4 decentralized dwellings A, B, C, and D, representing the 4 main procedures in manufacturing mycelium bricks [7]. Unlike those in a factory, the 4 procedures are distributed in 4 near but different spots in the local area. Dwelling A is for preparing cultivating molds. Crusted corn cobs, hays and wood chips will be collected to make mushroom cultivating molds. Dwelling B represents the producing and harvesting process, which means growing edible mushrooms in the prepared molds. When the mycelium is dry, it can be used to form a super strong, waterproof, mold-proof and fire-resistant building material. The testing and refining process will be conducted in Dwelling C. In this process the mycelium will be removed from the mold box and thus be sent for refining and compression testing. In the Dwelling D, the final step of the whole decentralized production line, packaging and distributing process, will be executed. After the testing procedure, the final products, the mushrooms from Dwelling B and the bricks from Dwelling C will be packed and distributed to both agricultural wholesalers and building material providers. Thus those products can be consumed by local people and beyond for daily diet and to construct their homes (see Fig. 8).

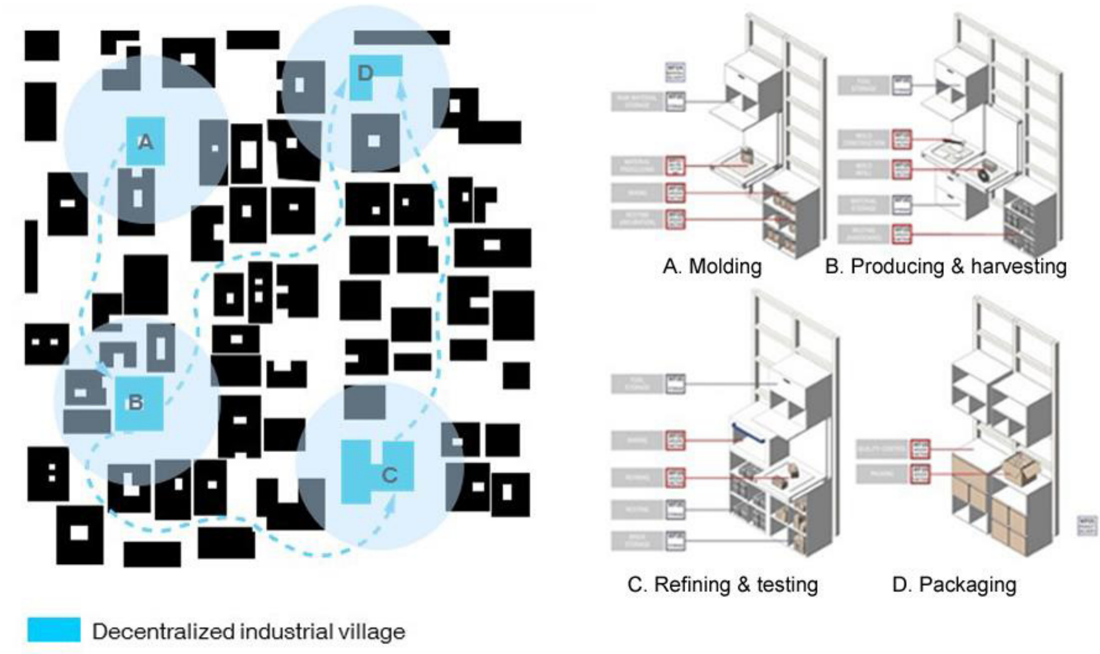

Fig. 8. Scenario of mushroom brick manufacturing in a Decentralized Industrial Village

4. Conclusion

This paper represents the intermediate work of an ongoing research project A²L-Mobilius which challenges the traditional approaches to mitigate problems in informal settlements. A residential building in Cairo's informal urban area Sakiat Mekki is selected, studied, and thus a renovation and extension design based on Open Building is proposed to regenerate the selected case with advanced building technologies. The results consist of an Affordable and Adaptable Building System (A²BS), in which future developments can be implemented in order to upgrade the informal area, and a cluster of Decentralized Processing Units (DPUs), which can be implanted into existing settlements to adaptably fulfill future socio-economic needs. A²BS and DPUs generate a key component to improve energy efficiency, mobility, and life-work patterns in Sakiat Mekki area. Furthermore, an innovative business model is developed to promote regional prosperity without undermining the intactness of existing local business. In conclusion, this report will provide researchers, architects and urban planners with a valuable example of regenerating informal urban settlements.

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