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Affordance-based Design Method: A Case Study of University Campus

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Abstract. Development of a built environment encompasses urban design, land use, transportation system, and accommodates patterns of human activity within the physical environment. Holistic development of built environment requires a multidisciplinary design team of urban planners, architects and sustainability advisors from an early design stage. Literature and industry-practices show growth of designer's techniques and competencies, sustainable development capabilities, and user-centric prospective in the early design. However, there is a lack of systematic method and all-inclusive approach to design a built environment. Thus, proposed research aims to develop a design method which is user-inspired, stakeholder conducive and environmentally conscious from an early design stage. To achieve this aim, an affordance-based design method is proposed and demonstrated through a case study of university campus. Affordance-based design method has been used for design of complex systems by capturing user needs, stakeholder ideas and generating design options. The proposed design method provides decision-making guidelines to designers, design space to incorporate stakeholders, and affordances to achieve sustainability. The proposed design method has potential to shift design and development of built environment from designer-controlled process to systematically organized process.

1. Introduction

The goal of urban design of built environment is to improve the quality of life, enhance system efficiency and limit environmental impacts. Built environment encompasses all forms of buildings; civil engineering infrastructures both above and below ground such as transportation system, utility systems, and telecommunication systems; and landscapes around buildings [1]. Urban design of built environment is closely linked with the user behavior and requirements. The design of every system of built environment is initiated by analyzing the user needs. Designs are more effective when user needs are considered and retained throughout design and development of built environment [2]. Observations from design practice suggest that user needs are considered at the start of the development but are often neglected during detailed design due to inadequate user-centric approach.

Another important aspect linked with the built environment design is the need for coordination among key stakeholders such as civil engineer, architect, MEP designer, and environmental advisory during designing, planning and constructing. However, stakeholder coordination is still a bottleneck in the design management [3]. Additionally, sustainable development goals of 'sustainable cities and communities' recommend environmentally conscious design of built environment. Green building



certification programs and energy efficient technologies are some initiatives in this direction. However, incorporating environmental measures in a design process is multidisciplinary in nature and thus becomes a challenge [4].

According to the Royal Institute of British Architects, the design process consists of three sub-stages: concept design, developed design and technical design [5]. Hence, the three aspects, viz. user requirements, stakeholder integration, and environmental consideration should govern the design in all the three sub-stages. However, in practice, sequential design process is not being ensured.

To address this gap, the research extends affordance-based theory to devise a structured approach for design of built environment. Maier and Fadel have applied affordance-based theory to the design of artefacts [6]. Various systems of built environment can be treated as artefacts and designed by following a set of procedures to fulfil the needs of user. This structured approach is termed as Affordance-based Design Method (DM) which aims to incorporate user needs, stakeholder coordination and environmental consideration. The proposed DM is demonstrated through a case study on urban design of a university campus. The observations from the case study are discussed in the light of existing literature to emphasize the potential of proposed DM.

2. Literature Review

Several engineering design theories have evolved over time as summarized in Figure 1. Design has been addressed using two theoretical paradigms. First is Simon's Sciences of the Artificial (1969) based on normative, rational and structured approach. It follows certain rules and procedures, and popularly discussed under design as 'science' [7]. Second is design as reflective practice given by Schon's (1983). It aligns with industry practice driven by practitioners' creativity and ideas rather than a set of rules [8].

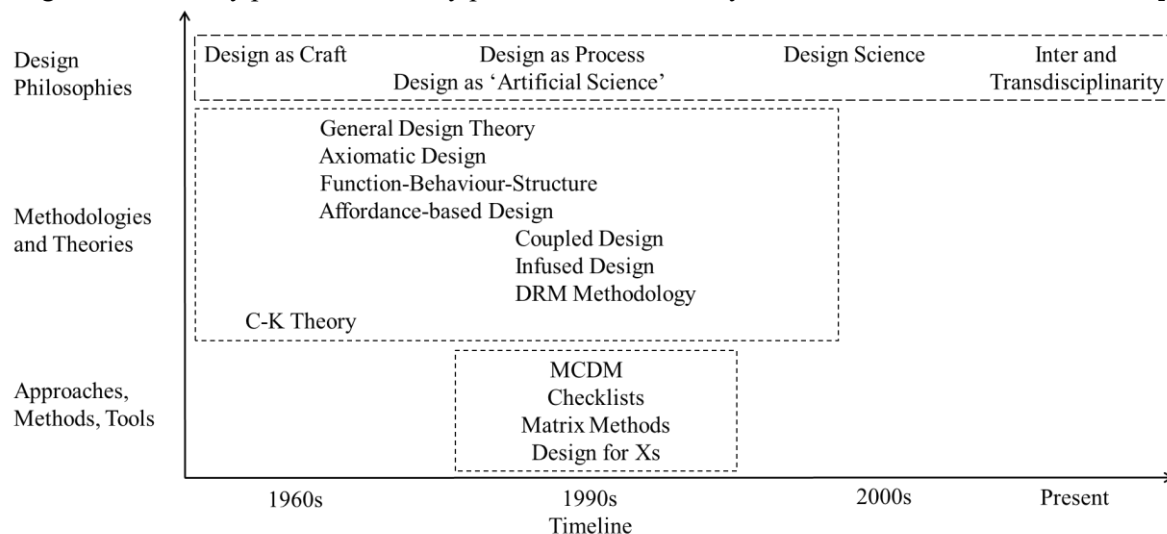


Figure 1. Evolution of Design Theories

Other major theories in engineering design research are – German systematic engineering design by Pahl and Beitz [9], Axiomatic design by Suh [10], Total design theory by Pugh [11], C-K theory by Hatchuel and Weil [12], Design research methodology (DRM) by Blessing and Chakrabarti [13], and Function-behavior-structure methodology by Gero [14].

Maier and Fadel [15-17] argued that existing engineering design theories are insufficient to provide a systematic design method. Thus, they formulated an affordance-based design method. The concept of affordance was first introduced by psychologist James J. Gibson during 1979 in the domain of ecological and perceptual psychology [18]. Later, Norman applied the affordance theory to the design domain and demonstrated human-computer interaction [19]. Maier and Fadel brought affordances in engineering design by asserting user-artefact interactions [6]. The term *affordances* of an artefact means what an artefact should provide or offer. It is described as a set of interactions between artefacts and users,

designers and users, and a pair of artefacts, as shown in Figure 2. The complex nature of these interactions give rise to two types of affordances – (i) Artefact-User Affordances (AUA) describes interaction between an artefact and users; and (ii) Artefact-Artifact Affordances (AAA) describes interaction within artefact subsystems.

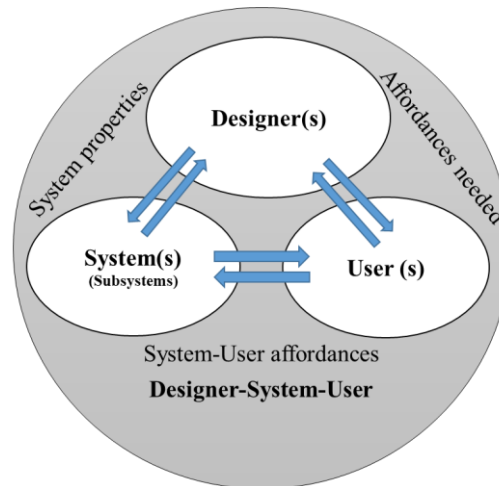


Figure 2. Affordance Interactions within Designer-System-User Structure [6]

The design of built environment is similar to the design of product. Hence, systems of built environment can be considered analogous to artefacts. In built environment design, AUA describes the relationship of a system's users with the system design, whereas AAA describes the complex interactions taking place between key stakeholders and technical aspects of the system. AAA makes it easier to communicate and concurrently design the systems. The concept of affordance in built environment design is suitable because it entails relationship between two systems, incorporates users, and allows proper use of functions of a system in design. These features are included in the DM.

3. Affordance-based Design Method (DM)

Maier and Fadel (2006) defined two fundamental affordance-based methods: a high-level affordance-based design process and a method for designing individual affordances. Previously, high-level affordance-based design process has been applied on several case studies of product design [20-22]. Some prominent works which followed affordance-based design method are generation of consumer specific design specifications [23], and automation of embodiment and detailed design phases of product design [24]. These studies demonstrate the benefits of systematizing and structuring the design process [25, 26]. Thus, affordance-based design method can be perceived as sequential method which can be adopted at the design stage. However, this method has been applied so far only in product design.

The proposed DM is similar to the existing affordance-based method in product design. Figure 3 is a schematic representation of the proposed DM which consists of two steps. In the first step, value adding and non-value adding affordances are identified and user information module is prepared. Then, a designer information module is prepared to enlist technical inputs for the affordances and develop a generic affordance structure. The module guides designers about what affordances they are expected to provide through a system. It also ensures that any affordance associated with a system are not missed. Further, affordances are prioritized based on the preferences of users and designers. Thus, the first step generates an organized affordance structure at the specification level based on system-user affordances.

In second step, individual affordances are chosen, and their detailed affordances are created. User-groups associated with individual affordances were also mapped. Then, system properties that affect the affordances were identified. Further, properties of other systems that affect the individual affordances were documented. Next, targets and bounds for each property were determined. Since built environment design is constrained by building codes and bye-law, all such constraints associated with affordances

were identified at this step. Prescribed numeric range of these constraints adds a quantifiable parameter to a design. At this point, designer gets the understanding of properties, targets, bounds and constraints of the system that affect the affordance. The second step was repeated for all individual affordances to populate detailed affordance structure. Then, effects of the property settings of an individual affordance on other affordance were analysed. This provided a comprehensive affordance structure for the system design. Such a comprehensive affordance structure will support generation of multiple design options.

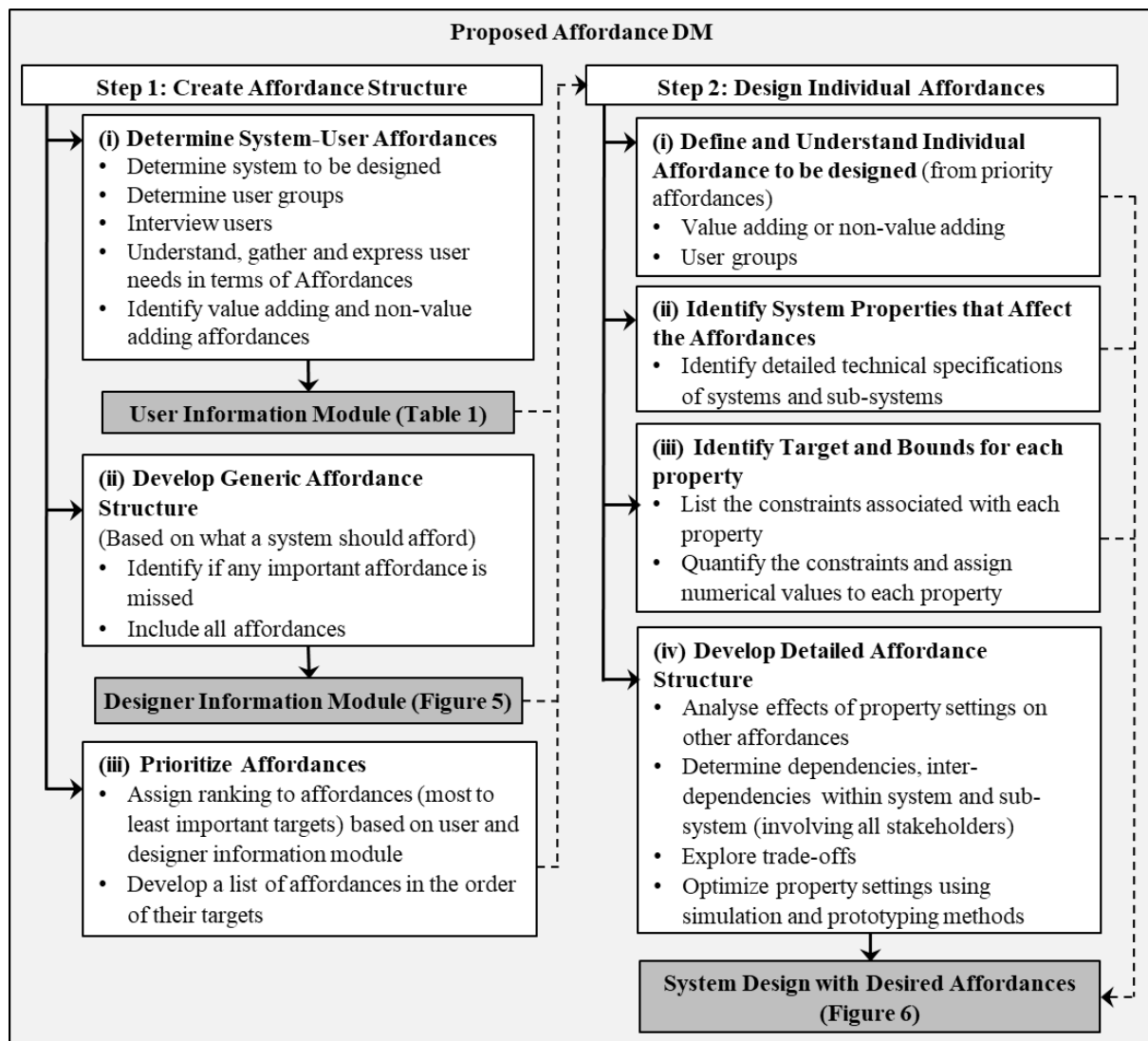


Figure 3. Framework of Affordance-based Method

4. Case Study

The application of the proposed DM is demonstrated through a case study on the design of a mobility network system in the built environment of a university campus. The campus consisted of hostels for students, residential buildings for employees, academic buildings and community buildings. The anticipated growth of campus population is 25%, and its design aims to provide sufficient built-up spaces, building services, utilities and mobility networks in future. The scope of the case study is limited to identifying the affordances and system parameters of mobility network.

The data was collected through participatory action research. The first author participated in the series of design meetings held among users, client and designers. User needs were identified by the

designers through five focused group-discussions with the user-groups listed in Figure 4. Each group was represented by five to seven users and the average length of each discussion was three hours. The data collected from the group-discussions was used to develop a designer-system-user structure as shown in Figure 4. This structure forms the basis of designing affordances for the case study.

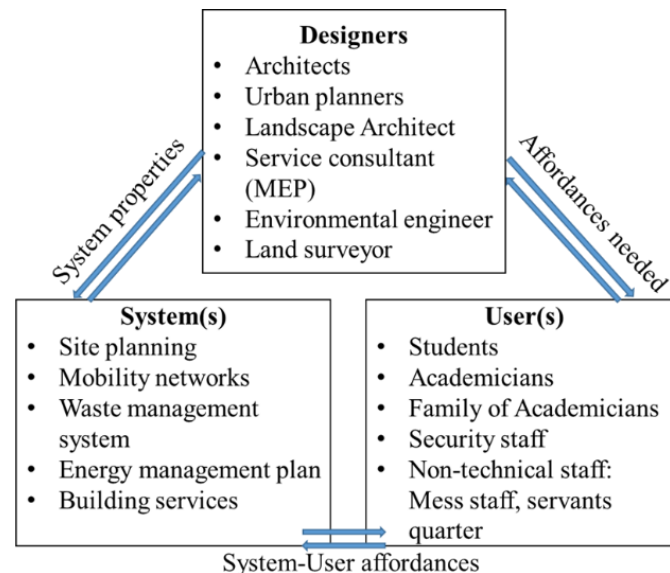


Figure 4. Affordance related Interaction within a Designer-System-User Complex Structure

The collected data from the participatory meetings was analysed for the design of mobility network system using the proposed affordance-based DM. Table 1 shows resultant User Information Module with value adding and non-value adding affordances for mobility network design (Figure 3, Step 1 (i)).

Table 1. Affordances for Mobility Network

Value adding affordances (positive)	Non-value adding affordances (negative)
Provide thorough fare movement within campus to all users	Minimize traffic conflicts at some points
Connectivity of campus with the city	Reduce travel time
Facilitate pedestrian movement to all users	Reduce trip length
Integration of all modes of transport system	No Congestion at peak hours
Incorporate comfortable, energy efficient and sustainable ways of transport	Reduce extent and distribution of roads in campus
Provide safe and secure pathways	Reduce urban heat island effect
Access to visitors/city people	
Maintain and maximize green cover	

Next, subsystems of the mobility network such as parking spaces, pedestrian pathways, and vehicular traffic system were identified (Figure 3, Step 1 (ii)). Corresponding technical input for the affordances led to a Designer Information Module as shown in Figure 5. One of the affordances—to reduce urban heat island—is selected for the illustration of ‘designing individual affordance’ (Figure 3, Step 2 (i)).

The characteristics of Urban Heat Island (UHI) which affect the design specifications of mobility network were listed by the designers. Alongside, potential interactions among the characteristics of UHI and the specifications of other systems were identified. For example, UHI is affected by building design, building form, building orientation, along with roof and wall design. Shaded blocks inscribed in circles

A1-A2 of Figure 6 depict interactions of UHI affordance with the design specifications of mobility system (Figure 3, Step 2 (ii)).

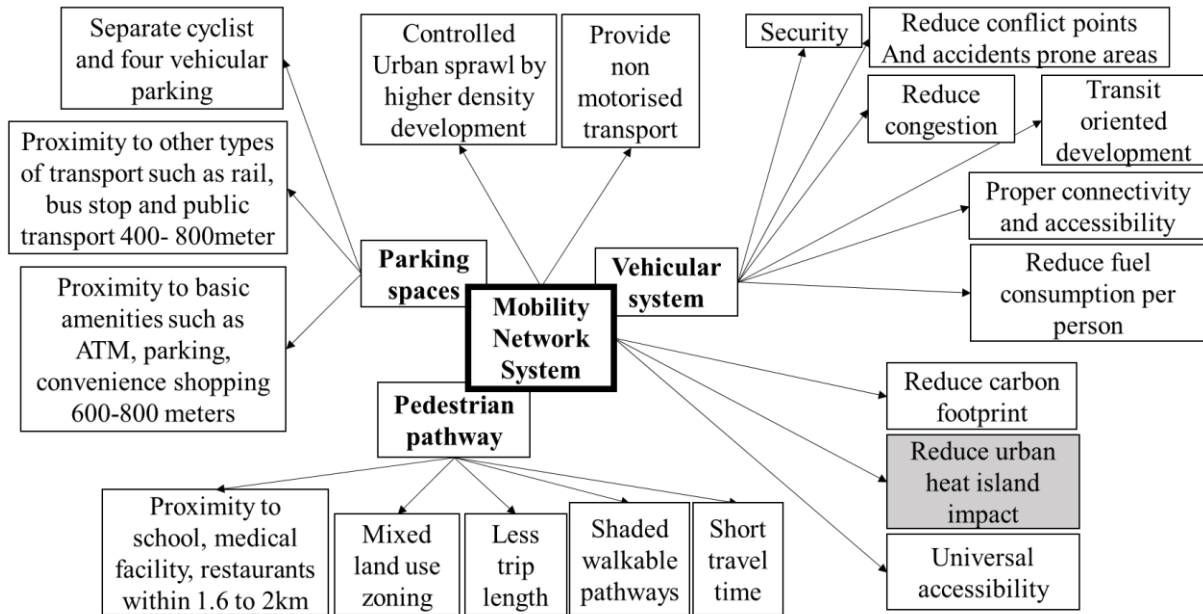


Figure 5. Generic Affordance Structure for Mobility Network System

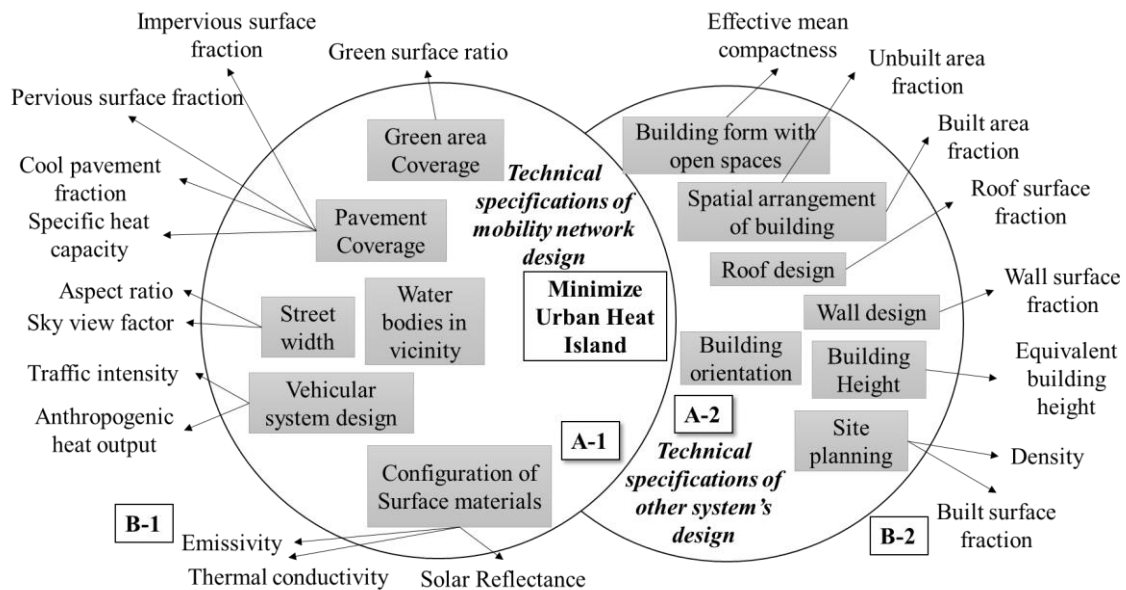


Figure 6. Detailed Affordance Structure to Minimize Urban Heat Island Impact for Design of Mobility Network

After analysing the first level of interaction in A1-A2, next level of interaction (Figure 3, Step 2 (iii)) quantifies associated characteristics of UHI as shown in zone B1-B2 of Figure 6. For instance, 'street width' is a specification of mobility network which is associated with UHI affordance. Street width is quantified using two parameters, 'aspect ratio' and 'sky view factor'. Aspect ratio is the mean height-to-width of street canyons, and sky view factor is the fraction of sky hemisphere visible from ground level. By optimizing these two parameters, UHI can be minimized in mobility network design. Similarly, other design specification can be translated into quantified parameters which will help in simulating alternate design options, analyzing trade-offs and optimizing the system design. Quantification of these

parameters will be based on bye-laws and standard code of practice. This provided a detailed affordance structure for one affordance (Figure 3, Step 2 (iv)).

Subsequently, the detailed affordance structure was extended to all affordances to obtain an overall mobility system with desired affordances. The resultant affordance structure will guide the designer as to what the system should offer and how the design should proceed with affordances.

5. Discussion

In the selected project, the designers have approached the design of university campus based on their experience and prevalent architectural knowledge. This approach is similar to design as reflective practice given by Schon. In contrast, this research has applied affordance-based DM, which comes under the theory of design as 'science', on mobility network design of university campus. In this research, the concept of affordance is applied to the design process only for problem definition and conceptual design of built environment. The affordance-based DM (Figure 3) demonstrated through the case study improves the existing design process in the following manner:

- DM paves a way to capture the user needs in the form of affordances and allows them to interact with the designer knowledge and system properties (Figure 3, Step 1(i)). Such systematic consideration of user needs cannot be ensured through existing design process. The study can also be extended to subsequent stages of detailed design and technical design.
- Example of UHI illustrates that DM allows the sustainable target values to be incorporated while deciding bounds and targets of affordances that the design is intended to provide (Figure 3, Step 2(iii)). Though, the presented case study showed the analysis of only one sustainable target, multiple sustainable targets can be analysed using simulation techniques and the DM. Detailed affordance structure will also provide information about parameters required for simulating design options.
- DM traces the web of interactions between systems and subsystems by formulating multiple affordance structures and coordinating multiple stakeholders (Figure 3, Step 2(iv)). For example, affordance structure in Figure 6 visualizes the collaboration of architects, energy analyst, civil engineer, and contractors for site planning, site zoning, and surface material selection. Such extensive affordance structure will guide decision making and assist in trade-off analysis during a design.

Overall, the DM provides a mechanism to transform the information available from users and designers into technical information which drives the conceptual design process. Further, sequential and structured affordance-based DM aids in the evolution and transition of myriad ideas of users, designers and other stakeholders into cohesive concepts which would be eventually be reflected in the designed built environment.

6. Conclusion

Despite extensive literature on managing the design process, there is lack of systematic and all-inclusive approach for incorporating user needs, stakeholder interactions and sustainable values in a design. To address these issues, this research has developed an Affordance-based Design Method for the design of built environment. This affordance-based method is drawn from product design. Potential application of proposed Design Method is demonstrated through a case study on the design of mobility network in a university campus. The research findings suggest that by deploying a sequential analysis in the early design stage of complex systems like built environment, it is possible to incorporate user needs, improve stakeholder coordination, and achieve sustainable dimensions. Evidence from the research indicates that affordance-based DM enhances capability of designers by guiding them through management of design information. These inferences establish the potential of affordances in the design management.

This paper has reported an ongoing research on the development of an Affordance-based Design Method through an example of design of mobility network system. Future research will refine the proposed method by implementing it on design of other systems and their interactions. After refinement of the method by optimizing and prototyping design options, it will be validated by implementation in real-life built environment projects to illustrate its advantages and eventual drawbacks.

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