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The effects of high-rise residential construction on sustainability of housing systems

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Abstract

Increase in urban population is resulting in increased population densities through high-rise residential buildings. High-rise residential buildings have some unique aspects. The purpose of the study reported in this paper is to assess the role high-rise related aspects can play in sustainable development. The research adopted a two-step approach. First, on the basis of a detailed review of the literature published on high-rise buildings, the aspects unique to high-rise buildings are identified and shortlisted through brainstorming sessions. The aspects are then allocated to some basic properties of sustainable systems obtained from published work. Second, through another explorative brainstorming on high-rise residential building aspects, a cause-effect relation among various building aspects and related issues is developed using a system dynamics modelling. This study used about 54 building aspects majorly found in high-rises. The findings show that the aspects affect sustainability in both the positive and negative ways. Linking the various building aspects together has also resulted in a cause-effect diagram visually explaining how constructing high-rise for a residential purpose can pose a fairly complex problem in terms of sustainable development. The findings show that most of the high-rise related aspects positively affect the effectiveness property of both the building and natural systems while also creating a detrimental effect on the psychological needs of humans. The qualitative assessment undertaken within this study for understanding the role of high-rise residential buildings in sustainability can lead to further research exploration in the subject area and can increase the understanding of high-rise complexity, consequently leading to well informed sustainable approaches.

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Keywords: High-rise; Sustainability orientor; Systems; Residential building

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1. Introduction

An increased migration to urban centres is critically affecting the planet. There is an ever increasing need of growth as well as increased density in urban centres. With land becoming scarce and expensive, particularly in big cities, developers and builders have no alternative but to build up and consequently high-rise buildings are beginning to appear in large numbers [1]. For instance over recent decades, in Australia the number of people living in high-rise housing has increased at a faster rate when compared with the total population of the country. Within the high density sector, the number of people living in high-rise units rose from approximately 129,000 in 1981 to around 334,000 in 2001, representing an increase from roughly 1% to 2% of people living in private dwellings [2]. This trend is also globally visible in form of high development rate of tall buildings. With the global population in 1990 being 5290 M (millions), there were 146 global tall buildings (200m+). In 2000 and 2011 as the population increased from 6115 M to 6908 M, the number of global tall buildings more than doubled from 258 to 602 [3].

High-rise buildings are often related with high resource consumption needing building materials in large amounts during construction, significant amounts of energy for building operations and also result in huge waste amounts upon getting demolished by the end of their life cycle. Being highly reliant on building systems (i.e. HVAC and vertical transportation systems), above 75% of energy consumption in high-rise buildings is given out to HVAC [4, 5]. Along with the studies relating high-rises with resource consumption, there are also number of studies that relate high-rises with different social values. Gifford [6] provided a review summarizing results of the research performed on the influences of high-rise buildings on children, residents' experiences of the building, social behaviour, satisfaction, crime and fear of crime, preferences, mental health as well as suicide. The literature explored by him suggests that for most people high-rises are less satisfactory than other housing forms, the social relations are impersonal there, that such buildings are not optimal for children, crime and fear of crime are greater there and helping behaviour is less than in other housing forms.

However, the prevailing understanding that tall buildings are less sustainable as compared to their shorter less resource-intensive counterparts because of their height might be overstated. This might be the case when tall buildings are considered in isolation, but there hardly exists the data to verify this assumption in a holistic context. Such an insight significantly ignores plenty of factors that might have a positive effect on sustainability [7]. Along with the challenges of achieving sustainability in tall building (i.e. their inherent energy requirements for vertical transportation, communication, heating and cooling), they also offer some advantages over low-rise buildings that typically use more valuable land area than vertical high-rise towers. Benefits of concentrating people and services into a vertical city becomes evident upon comparing land use and energy requirements of a high-rise building to that of a small city [8]. For instance, it is observed that with population and income held constant, spatial distribution of population acts as an important determinant of greenhouse gas production. There would be a lower production of household greenhouse gas in case urban population lives at higher population density levels closer to city centres [9].

There are several aspects that set high-rise structures apart from mid-rise and low-rise. The aspects that result in this distinction are primarily determined by ways high-rise affects people, profit and planet as well as how society, economy and environment interacts with high-rise. When it comes to sustainability and sustainable development, issues related with high-rises play both the positive and negative role. While some of the issues are real and are commonly observable the others are possibilities which are currently limited to experimental use or which yet need to be incorporated in regular building construction and operation practice. To inform the sustainable design of high-rise residential buildings while considering such buildings as an intrinsic part of sustainable built environment, it is imperative to have a thorough understanding of how verticality affects the high-rise residential building itself as well as the other related systems.

The overall goal of the paper is to quantitatively analyse and relate high-rise residential building issues (comprised of benefits delivered, potential benefits as well as the negative influence such buildings typically carry) with themselves and with sustainability orientors while considering such building type as a system and not just that, a complex system. The specific objectives are:

- To identify and consolidate high-rise related issues which have been presented in published works.
- To quantitatively assess the importance these issues have for the sustainability of the building itself, to city and the sub-systems of city.
- To explore the association of these issues with each other and with the building using cause-effect relationships.

By qualitatively analysing the effect of building height on sustainability, the study will help trigger a debate on the holistic effect of building height on the sustainability of built environment. This will help clarify decision-making and policy-making for high-rise construction. The conceptual framework employed to relate building height with sustainability is described next, elaborating the major conceptual development used in the methodology.

2. Conceptual Framework

Technically, high-rise buildings are identifiable by small roof area, small footprint, have very tall facades and are different from conventional low-rise and medium-rise buildings as they need special engineering systems due to their heights [10]. Buildings as a system need to be viable by being able to respond to various requirements during their useful life. Broadly speaking, for a system to be viable, it must fulfil some minimum requirements needed to satisfy "basic orientors" (properties) which can enable the system to respond to any environmental stimulus. To maintain its viability, the system needs adapt to threats from any external stimuli (i.e must be resilient) before some serious damage is caused. Consequently, a viable system should be able to cope with challenges it faces instead of being overwhelmed by them [11]. It is necessary to incorporate some basic level knowledge of sustainable/viable systems in this research to get a qualitative measure of the effect of building height on sustainability. Orientors which are the basic properties of viable systems are significant in this regard and are frequently used and referred in paper. By viable system it means any system organised in such a manner that it can meet the demands related to survival in changing environment. Since sustainable development is a basic property of viable systems, a system viable in its environment can also be considered a sustainable system and so in this study viable systems and sustainable systems are considered alike.

Table 1: System orientors as presented by Bossel [12]

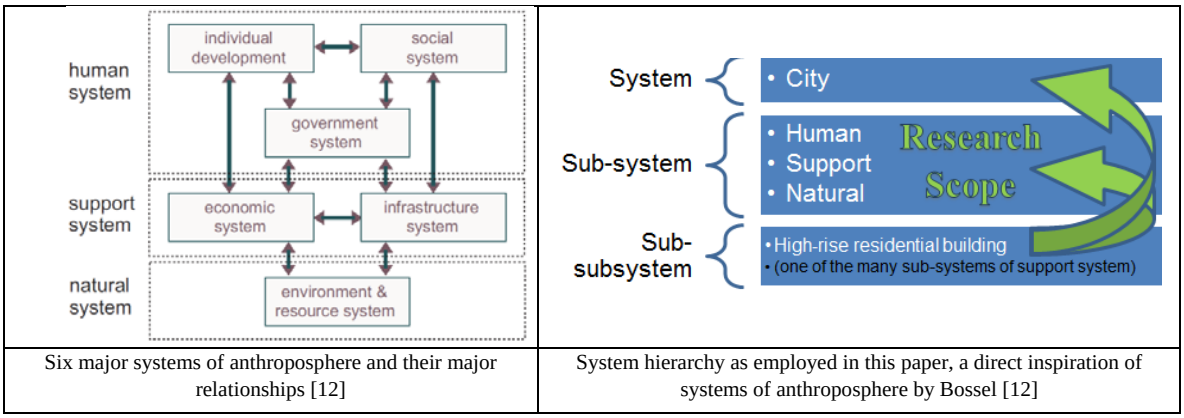
Basic orientors of systems
Environment-determined:
EXISTENCE: The system must be compatible with and able to exist in the normal environmental state. The information, energy and material inputs necessary to sustain the system must be available.
EFFECTIVENESS: The system should on balance (over the long term) be effective (not necessarily efficient) in its efforts to secure scarce resources (information, matter, energy) and to exert influence on its environment.
FREEDOM OF ACTION: The system must have the ability to cope in various ways with the challenges posed by environmental variety.
SECURITY: The system must be able to protect itself from the detrimental effects of environmental variability, i.e., variable, fluctuating and unpredictable conditions outside the normal environmental state.
ADAPTABILITY: The system should be able to learn, adapt and self-organize to generate more appropriate responses to challenges posed by environmental change.
COEXISTENCE: The system must be able to modify its behavior to account for behavior and interests (orientors) of *other* (actor) *systems* in its environment.
System-determined:
REPRODUCTION: Self-reproducing (autopoietic) systems must be able to reproduce (either as individuals and/or as populations).
PSYCHOLOGICAL NEEDS: Sentient beings have psychological needs that must be satisfied.
RESPONSIBILITY: Conscious actors are responsible for their actions and must comply with a normative reference.

Orientors while being labels for certain concern or interest categories are usually general terms such as health, freedom and existence corresponding to important interests of people or systems, but normally not directly measurable. System viability requires fulfilling a set of basic orientors identical across all systems. Table 1 conforming to six fundamental environmental properties; contain six basic orientors determined with respect to (w.r.t.) environment of a system and applicable to all autonomous self-organizing systems. The environment-determined orientors comprise of existence, effectiveness, freedom of action (freedom-action), security, adaptability and coexistence. On the other hand, the three system-determined basic orientors which are unique to self-reproducing and conscious beings encompass reproduction, psychological needs (psych. needs) and responsibility. By assessing the orientor satisfaction one can find the fitness of a system in its environment (i.e. viability and

sustainability). Furthermore, it must be noted that a viable system consciously or automatically has to pay at least a minimum of attention to these basic orientors since adequate satisfaction of each of them is required for a system to be viable. Moreover, as each basic orientor presumably stands for a unique requirement, shortage compensation of one orientor by over-fulfilment of other basic orientors is simply not possible [12].

3. Methodology

To qualitatively assess the effects high-rise character has on the building itself and surrounding systems, the methodology employed is to make the selection of high-rise related issues and potentials from published works that relate to high-rise residential buildings or high-rises in general in a variety of ways. Afterwards, through the various brainstorming sessions conducted by the authors, the issues and potentials are related to various sustainability orientors of the building itself and also to other systems that are within the scope of the study. These brainstorming sessions also are used to see how the orientors are being affected by high-rise character. The brainstorming sessions were held among the authors. For these sessions, four primary questions were investigated. The first question was "which aspects of high-rise buildings found from the literature can be categorized as issues and which aspects can be categorized as potentials", the second question was directed at identifying "how various issues and potentials are related with different orientors of buildings and other systems", and the third question was "how high-rise attribute of buildings affect orientors", and the fourth question was "how the different high-rise attributes are related with the issues and potentials from cause-effect relationship" perspective. All of these questions are systematically answered by brainstorming sessions in a sequential process whereby the outcomes of one session were used as input into the following session. Using systems thinking approach various issues and potentials identified through the literature review are also related with each other. For instance, the verticality of a building results in decreased street noise on the upper floors of a building and such a relation is better presented pictorially to provide a glimpse of system complexity. This consequently leads to the development of a cause-effect diagram (Fig. 2).



Six major systems of anthroposphere and their major relationships [12]

System hierarchy as employed in this paper, a direct inspiration of systems of anthroposphere by Bossel [12]

Fig. 1: System hierarchies

In order to assess building related issues in terms of sustainability orientors it is pre-requisite to define some systems first. The six major systems of anthroposphere are shown in Fig. 1. These individual systems can be aggregated to three subsystems: support system, human system, and natural system. These are mainly used to inform the current research in terms of its scope. As a direct inspiration from the system hierarchy model propagated by Bossel [12], a systems hierarchy is established for this paper also shown in Fig. 1, where city is considered at system level, while at subsystem level there are three entities, i.e. human, support and natural system. At the level of sub-subsystems there can be plenty of entities, however, only high-rise residential building is selected at this level. The methodology is to see how the high-rise residential building (sub-subsystem) through its exclusive aspects affects human, support and natural system (subsystem) and city (system).

4. Results and Discussion

It is found from literature that high-rise buildings are associated with some issues as well as potentials and beliefs as shown in 3rd column of Table 2. These issues comprise benefits delivered, potential benefits as well as the negative influence such buildings typically carry. The 5th, 6th and 7th columns of Table 2 show findings of preliminary analysis of high-rise related issues w.r.t. the system hierarchy as suggested in Fig. 1. The 5th column shows the system/subsystem/sub-subsystem that is being affected by respective issue. Building in this column will be used to refer to High-rise Residential Building (sub-subsystem). The 6th column shows the orientor of system/subsystem/sub-subsystem that is being affected by respective issue or that is affecting the issue. Finally, the 7th column shows the relationship the orientor in 6th column has with the issue in 3rd column. The symbolic use of P, N or I in 7th column corresponds to Positive, Negative and Indifferent effects respectively. The purpose of the research is only to analyse the aspects related with high-rise residential building that set it apart from other kind of residential buildings. While satisfying first and second objective of the study, Table 2 contains only those issues and their analyses w.r.t. systems involved, which satisfy the constraint set in this paper. An example can help explain how possible roles of different aspects are highlighted in Table 2. For aspect with Sr.no.1-S, it is concluded that the existence (orientor) of city and building is positively affected and the psychological needs (orientor) of human is positively affected by skyscrapers symbolizing supreme identity of city as well as success of owners and occupants.

Table 2: Issues relating high-rise residential building projects and their effect on orientors of different systems

Sr. no	Source	High-rise residential building related Issues, Potentials and Documented Beliefs Potentials that are currently being realized on large scales are reported as issues. For simplicity documented beliefs as found from literature are also reported as issues.	Issues (IS), Potentials (PO)	Corresponding system, subsystem, sub-subsystem	Orientor being affected i.e. Freedom	Effect on orientor
		Centralization				
1-C	[4]	Building high-rise results in centralization	IS	Building	Effectiveness	P
2-C	[7, 13]	Opportunity for application and incorporation of energy efficient systems/plants (i.e. centralized HVAC systems)	PO	Building	Effectiveness	P
				Natural	Effectiveness	P
3-C	[14]	Substantial biomass amounts present in high-rises (i.e. paper in office buildings) make it a potential source of electricity and steam generation for buildings.	PO	Building	Effectiveness	P
				Natural	Effectiveness	P
4-C	[14]	Development and refinement of geo thermal technology and its application on tall buildings could prove more relevant than any other building type.	PO	Building	Effectiveness	P
				Natural	Coexistence	P
5-C	[14]	Combined heat and power (CHP) system technology that avoids transmission losses and consumes notably less fuel can be applied to considerable loads of tall buildings.	PO	Building	Effectiveness	P
				Natural	Effectiveness	P
6-C	[6]	Crime and fear of crime can reduce by controlled entrances of high-rise dwellings. Although, findings show more crime associated with high-rise.	IS	Building	Security	I
				Human	Security	I
7-C	[15, 16]	Since congested central areas dissuade mobile usages, high densities can play an important role in furthering mass transit usage.	IS	City	Effectiveness	P
8-C	[6]	Many services and transportation options are more likely to be near high-rises.	IS	Building	Freedom-action	P
		Scale				
1-S	[15, 17, 18]	Emerging from the central areas of cities, skyscrapers create a symbolic value by presenting supreme identity of a city and success of owners and occupants.	IS	City	Existence	P
				Building	Existence	P
				Human	Psych. needs	P
2-S	[19]	An admiration of skyscrapers including and beyond the territories where they are culturally accepted.	IS	Building	Existence	P

3-S	[19, 20]	Skyscrapers bolster the status of designers and firms and are a mean of satisfaction for clients and architects competing for top visual status.	IS	Human	Effectiveness	P
				Human	Psych. needs	P
4-S	[14]	High-rises are dominant elements in urban architecture due to their scale and purpose.	IS	Building	Effectiveness	P
5-S	[4]	Building high-rise results in economies of scale.	PO	Building	Effectiveness	P
		Admiration, Aspiration, Awe and Aesthetics				
1-A	[14, 21, 22]	Even though residential masonry buildings can be built up to 60 storey high, typical materials of choice are steel and reinforced concrete.	IS	Building	Freedom-action	N
				Natural	Adaptability	N
2-A	[15]	High-rise can destroy historical character of central city.	IS	City	Coexistence	N
3-A	[23]	The popularity of tower blocks is largely a function of their placement i.e. the more fashionable areas of location the more popularity.	IS	Building	Freedom-action	N
		Verticality and Reduced footprint				
1-V	[4]	Living in high-rise results in people losing control over life conditions and safety.	IS	Human	Freedom-action	N
2-V	[4]	Living in high-rise results in a large number of people disengaged from nature and the isolation through psychological state and behavior problems results in health and productivity loss.	IS	Human	Psych. needs	N
				Human	Freedom-action	N
3-V	[7]	High-rises can maintain and enhance public realm.	PO	City	Effectiveness	P
4-V	[7]	High-rises make efficient use of scarce land resources.	PO	Building	Effectiveness	P
				City	Freedom-action	P
5-V	[7]	Possible market risk mitigation due to mixed use of buildings.	PO	Building	Effectiveness	P
6-V	[7]	Opportunity of using building form to productively interact with climate.	PO	Building	Effectiveness	P
				Natural	Coexistence	P
7-V	[14]	Tall buildings less constrained as compared to low-rise buildings by site geometry or street layout.	IS	Building	Freedom-action	P
8-V	[15, 24]	Environmental quality can be compromised by high-rises as they block natural breezes and sunlight; create urban heat islands and trap air pollution near streets.	IS	Building	Coexistence	N
9-V	[14]	High-rise verticality providing room at ground level for public uses/amenities as plazas, shopping and recreation spaces.	PO	Building	Freedom-action	P
10-V	[6, 25]	Owing to smaller footprint of high-rises as compared to equivalent number of low-rise housing units, less land area is occupied leaving more room for greenspace. Though, this open no man's land can be a danger as well by going in control of undesirable elements.	PO	City	Freedom-action	P
11-V	[6]	A big potential of great views from high-rises.	PO	Human	Psych. needs	P
12-V	[6]	High-rise provide relative urban privacy. The usual central urban location is of advantage to those desiring it.	PO	Human	Psych. needs	P
13-V	[14, 20]	To meet structural requirements and wind loads, high-rise require more energy intensive materials as compared to low-rise and have more energy embodied per gross floor area as compared to low-rise buildings that may be using materials like wood, brick, stone, etc.	IS	Building	Freedom-action	N
				Building	Effectiveness	N
				Natural	Adaptability	N
14-V	[26]	Opportunity to decrease the HVAC related energy consumption because of change in environmental conditions from bottom to top of the building.	PO	Building	Effectiveness	P
				Natural	Effectiveness	P
15-V	[26]	Opportunity to tap the increased production of solar panels as solar radiation has relatively increased values with increase in altitudes.	PO	Building	Effectiveness	P
				Natural	Effectiveness	P
16-V	[14]	Significant use of PV technology for tall buildings as opportunity of a clear path for	PO	Building	Effectiveness	P

		sunlight exists by towering over other buildings.		Natural	Effectiveness	P
17-V	[26]	Improved ventilation because of increase in wind speeds at higher altitudes.	PO	Building	Effectiveness	P
				Natural	Effectiveness	P
18-V	[14]	Tapping high speed winds at higher altitudes and amplifying it for wind turbines by using building shape to create a funneling effect.	PO	Building	Freedom-action	P
				Natural	Effectiveness	
19-V	[6]	Potentially less noise from outside in upper floors of high-rises.	PO	Building	Effectiveness	P
20-V	[6]	Potentially cleaner air in upper floors of high-rises.	PO	Building	Effectiveness	P
21-V	[14]	Tall building façade constituting 90-95% of external building surface area with insignificant roof area in comparison making energy gain/loss in building highly reliant on materiality and technology of façade treatment.	IS	Building	Freedom-action	I
22-V	[6]	High-rise residents free of yard and maintenance works but they might need to pay through their rents for the central areas being maintained on their behalf.	IS	Human	Effectiveness	P
23-V	[27]	For dwelling owners, high-rise buildings offer a lower undivided share of land as compared to low-rise buildings.	IS	Human	Effectiveness	N
24-V	[23]	Owing to height factor, repair of existing high-rise building can be expensive and difficult, especially true in case of building elements requiring repair from outside.	IS	Building	Existence	N
25-V	[23]	Owing to the absence of outside space alongside the individual dwelling in a high-rise living, such residential projects are particularly unsuitable for families.	IS	Human	Psych. needs	N
26-V	[28]	In high-rise development to support building weight, more area is occupied by load bearing members as compared to low-rise. The usable living space gets encroached as the carpet area versus super area anomaly gets more skewed against the buyer.	IS	Human	Effectiveness	N
27-V	[28]	High-rises may have greater maintenance costs owing to insurance of structure as well as strict fire safety norms.	IS	Human	Effectiveness	N
		High Density				
1-D	[29]	The taller a building, the higher its population density	IS	City	Effectiveness	P
2-D	[6]	Large number of neighbors in high-rise dwellings provide great potential for social support by making friends and acquaintances [30]. Potential for more and better social interaction exists but findings show that there are fewer friendships in high-rise buildings per capita than those in low-rise dwellings.	PO	Human	Freedom-action	P
3-D	[7]	Avoiding detrimental effects of urban sprawl.	PO	City	Adaptability	P
4-D	[31]	Apartments result in disappearing sense of neighborhood or community.	IS	Human	Psych. needs	N
		Technology related				
1-T	[4]	Reliance on technology for control of indoor environment and transport.	IS	Human	Freedom-action	N
2-T	[14]	Notably high operation/maintenance costs of elevators.	IS	Human	Effectiveness	N
		Habitat related				
1-H	[6]	High-rises are less satisfactory than other housing types	IS	Human	Psych. needs	N
2-H	[6]	High building or dwelling density results in strain.	IS	Human	Psych. needs	N
3-H	[6]	Children living in high-rises depict more behavioral problems than children who don’t.	IS	Human	Psych. needs	N
4-H	[6]	Low rates of helping others in high-rise buildings.	IS	Human	Coexistence	N
5-H	[6]	High-rise residences arousing 6 kind of fears; fear of fall/jump from a high window; trapped inside during fire; entire building falling from earthquake; building might be attacked; strangers sharing their dwelling; becoming sick from communicable diseases generated by others.	IS	Human	Psych. needs	N

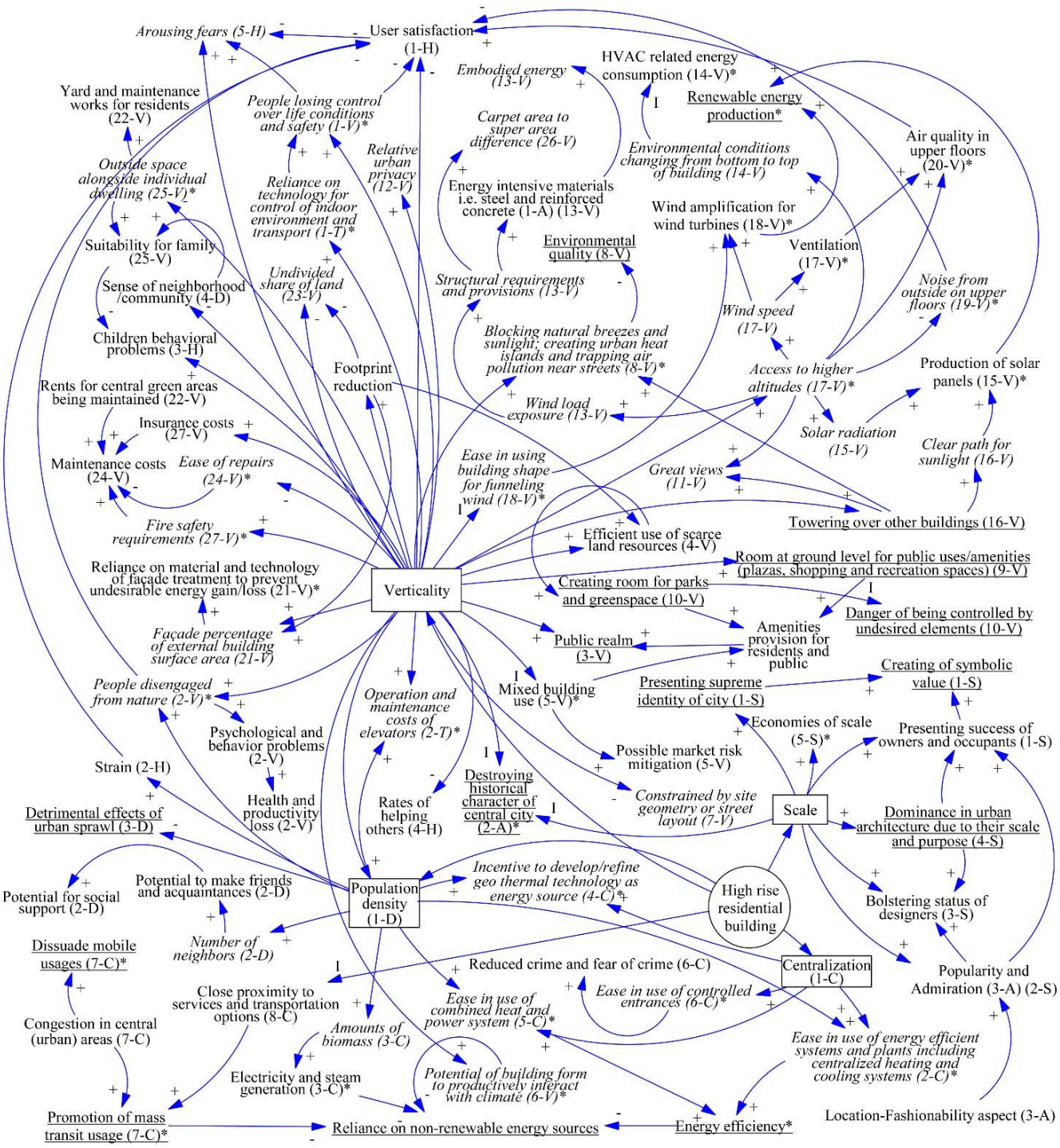


Fig. 2: Cause-effect diagram relating high-rise development with related issues

In Table 2, highest number of aspects (16) and second highest (8) are found to positively affect effectiveness orientor of building and natural system respectively. On the other hand, the third highest number (7) of aspects is found to negatively affect the psychological needs (orientor) of human system. A very low response for the other

orientors of building is observed w.r.t. the produced list of aspects. Such a qualitative analysis is yet of preliminary nature, but it still can provide a general idea that which orientors of building system viability/sustainability are significantly affected by high-rise related aspects. The various aspects of high-rise residential buildings in this study have distinct role for different orientors, contributing more towards some orientors and less towards others.

The total system is made up of a large number of component systems. The possibility of the whole functioning properly by being viable and sustainable exists, only for as long as the individual component systems function properly by being viable and sustainable. And only if total system as well as component systems are viable, sustainable development can be realized [12]. The scope of this paper limited to only the aspects unique to high-rise buildings, provide by means of Table 2, the ways in which such buildings affect and get affected by the various sub-systems in the total system. It is clear from results that not all the orientors are being affected in similar proportions.

The cause-effect relationships for high-rise residential building projects which fulfils third objective of the study is shown in Fig. 2. This is majorly informed by issues, potentials and results provided in Table 2 and in order to show that the same issues are used in Fig. 2 as in Table 2, serial numbers are used to demonstrate commonality. The cause-effect relations built on these issues are based on simple logic and though much attention is paid to present such relations as close to reality as possible, there is still room for improvement as many important and exclusive issues related to high-rise residential buildings might have been missed and many relations other than those provided among issues in figure, might be possible. Within Fig. 2 the underlined issues (variables) show the ways in which the high-rise building because of certain properties (can) interact with its surrounding environment that is comprised of nearby buildings as well as immediate environment adjacent to building i.e. earth, air and water. On the other hand, issues (variables) indicated in italics within the diagram show the exploitable opportunities as well as the aspects unique to high-rise buildings (variables seriously affected by high-rise construction). Many of these are irreplaceable features of high-rise living that can be exploited in creative ways for sustainable development. The issues (variables) indicated with * are the functions of technological innovation. They are affected by technology or have some direct relation with technological innovation. The use of technological innovation here is in context of innovation in design, materials, systems as well as processes. Moreover, the signs (+) and (-) with relation arrows show positive and negative polarity respectively while (U) sign with relation arrows shows the uncertainty/unknown factor of polarity in relation meaning that the polarity is unknown, hard to determine or varies from situation to situation.

The qualitative assessment of building related issues and potentials is a result of brainstorming sessions held by authors themselves so this section of the study is still open to interpretation and is a limitation of the study. Further, being a qualitative study only, there was no way of ascertaining that which issue/potential affects sustainability of a system by what extent. Therefore, at this stage it is not possible to determine the strength with which height affects different systems under consideration. Though a limited study in subject matter, it contributed to building related sustainability discussion by revisiting the essentials in case of high-rise residential buildings. Further development in this study can enable focus towards issues that need to be addressed in high-rise buildings to enable sustainable development.

5. Conclusion

This paper fulfilled the goal of quantitatively analysing the effect of height on building itself as well as the surrounding and enclosed systems. To realize first objective of the study, the collection of high-rise residential building related issues and potentials which act as the major data for analysis was successfully collected from published work. Then the second objective to qualitatively analyse the collection of issues and potentials was achieved by various brainstorming sessions held by authors themselves. In these exercises different issues and potentials were assigned to different systems (i.e. the building system itself, systems surrounding it and affected by it) and the effect of issues and potentials on these systems was determined. It was realized that not all sustainability aspects of building, city and other relevant systems are proportionally affected by building high-rise function. The largest number of high-rise aspects in this limited study is found to positively affect effectiveness orientor of building system, so it can be concluded that most of the high-rise building aspects tend to increase the effectiveness of building. Finally, the third objective of relating issues and potentials with building and with each other was

realized by developing a cause-effect relationship diagram which pictorially establishes that building height affecting sustainability is a complex issue rather than a simple, linear one. With the building height variable affecting one or two sustainability orientors of building system more than other orientors, it is safe to assume that the sustainability orientors ignored will result in less viable/sustainable buildings. However, being only a qualitative analysis based study, it is not yet possible to conclude the extent by which the system sustainability can get affected. This study, though of preliminary nature and constrained by the use of qualitative analysis, aims to establish a meaningful debate in relating building height variable with sustainability of building system, city system as well as the other related systems. The systems thinking approach used in this study can serve as a basis for future studies in the research area. However, future studies can use a system dynamics approach to investigate the cause-effect relationship among various attributes, issues and potentials related with high-rise buildings.

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