A Conceptual Decision Tree for the Automation of Architecture Applied to Housing

Francine van Tonder[1] and Pierre Brink[2]
[1]Department of Construction Economics, University of Pretoria, South Africa
[2]Practitioner
francine.vantonder@up.ac.za
brinkpier@gmail.com

Abstract: In 1994, the Nelson Mandela government identified the lack of housing as the most severe social problem faced by South Africa. However, housing information is often inaccessible to those affected by inadequate low-cost housing. The right information at the right time has the potential to not only address the inadequacy of low-cost housing but also to address, in part, other social ills such as unemployment, poverty and government corruption, as well as larger issues such as the climate emergency. This paper presents a conceptual decision tree to govern the knowledge management of architectural information for the possible automation of architecture. Knowledge management, big data and machine learning are the precursors of artificial intelligence, a technology that could further aid in addressing the inadequacy of low-cost housing. A decision tree is the first step. For this paper, the information within frames forms the nodes on the conceptual decision tree. This decision tree is presented graphically and tested hypothetically on a low-cost housing unit. The research findings indicate that there is a noteworthy overlap in architectural information of low-cost housing information presented thereby validating the possible benefit of architectural information knowledge management.

Keywords: automation of architecture, adequate low-cost housing, decision tree, housing problem, knowledge management, knowledge power

1. Introduction

This paper introduces the inadequacy of low-cost housing in South Africa and discusses the possible impact of knowledge management of architectural information to contribute to addressing this problem. The paper then introduces existing and emerging design variables that inform the specifics of architectural information. The variables are conceptualised in graphical illustrations and colour coded to become frames, such as in a framework. The frames inform a conceptual decision tree for three case studies. The paper concludes with a discussion of the findings and lists possible further research to develop the concept. The conceptual decision tree will possibly in future inform the automation of architecture and ultimately artificial intelligence.

2. Literature review

2.1 South African housing problem

During the past 27 years in South Africa, the government-provided low-cost housing has proven ineffective in addressing the need for adequate low-cost housing. A stock of 3.3 million government-provided low-cost housing units has already been built (Marutlulle, 2021). However, these housing units have not given people the socio-economic foothold one would expect house ownership would provide. This lack of socio-economic improvement is inferred when considering that more than half (55%) of South Africans are living in poverty (World Bank, 2020). Further compounding the problem of inadequate low-cost housing is the unemployment rate which is the highest (44%) since credible measurement started in 2008 (Stats SA, 2021). It is a premise of this paper that the lack of appropriate architectural information used in government-provided housing is a major reason for the inadequate low-cost housing provided.

2.2 Possible impact of knowledge management of architectural information

Architectural organisations in South Africa rarely practice the degree of knowledge management that contributes to the automation of architecture (van Tonder & Rwelamila, 2021). The creation of architectural information is knowledge-worker and human-resource costly, as well as time-consuming, and yet architectural information already generated throughout history is near exhaustive (van Tonder, 2019). The knowledge management of architectural information may lead to exponential growth in the value of the information managed (van Tonder, 2022b).

It is a premise of this paper that unemployment and poverty are socio-economic ills that could be addressed more effectively when those affected by unemployment and poverty have access to adequate low-cost housing. This paper argues that managing knowledge will aid in addressing the inadequacy of low-cost housing, which will have a significant societal impact on employment opportunities and poverty alleviation.

2.3 Knowledge management

Knowledge management is managing knowledge and efficiently handling information (Grover & Froese, 2016). Knowledge management is the acquisition, creation, sharing and transfer of information (Pinho, Rego & e Cunha, 2012). The goal of managing knowledge is to improve performance by getting the right information to the right people at the right time (Salzano *et al*, 2016).

It is a premise of this paper that the information specific to a site, location, climatic region, or culture would have an impact on the effectiveness of the housing unit and enhance the socio-economic foothold of the occupants. Further information would have a further positive impact in addressing the climate emergency, such as climate resilience adaptation and regenerative design vested in indigenous thinking that promotes a circular economy.

2.4 Architectural information variables

All architectural projects are different and should respond to variables provided by the context and the needs of the project. These variables become generators in the architectural design process (see Table 1). This paper argues that a lack of investment and resources in housing research is partly to blame for inadequate low-cost housing. It is not cost-effective for highly educated and costly architectural professionals to process design variables creatively for application to low-cost housing units.

Table 1: Existing and emerging variables that inform the specifics of architectural information in the architectural design process (Adapted from van Tonder, 2022a)

Existing design variable	Emerging design variable
Cultural[1] topology[2]	Climate resilience adaptation[3]
Natural topology[4]	Redress of apartheid legacy
Industrial thinking typology[5]	Economic and social fairness and foothold
Indigenous[6] thinking typology[7]	Service provision system disruption
Visual tectonics[8]	Amenities system disruption
Technology[9] tectonics[10]	Regenerative potential

Currently, low-cost housing is provided as one-size-fits-all, and existing variables such as natural or cultural typology are not considered a design generator worth processing. Knowledge management and automation would be role players in adding variables worth considering. Knowledge management and automation would reduce the work hours of costly and highly educated architectural professionals, making it more feasible to have various low-cost housing types that respond to variables individually and appropriately.

[1] Cultural topology refers to the history, culture, and sense of a place.
[2] Topographic study is the study of a particular place.
[3] In climate emergency literature, adaptation refers to: Adjustments in individual groups and institutional behaviour (Pielke, 1998), and adjustments in a system's behaviour and/or characteristics (Brooks, 2003) that enhance its ability to cope with external stress and reduce society's vulnerability to the climate emergency.
[4] Natural topology refers to the physical or natural features of the site and the location of the place.
[5] Industrial thinking refers to actions and systems that strengthen a linear economy (van Tonder, 2022a).
[6] Indigenous thinking in this context refers to actions and systems that strengthen a circular economy (van Tonder, 2022a).
[7] Typology study is a study that informs the appropriateness of the type of building (van Tonder, 2022a).
[8] Visual tectonics refers to the way a building or group of buildings read visually (van Tonder, 2022a).
[9] Tectonics is one of three sources of legitimacy for architecture (Frampton, 1995). The other two sources are *topos*, referring to site, and *typos*, referring to type. "Tectonic refers to the art and science of construction" and the "artistic expression of construction" (Porter, 1995).
[10] Technology tectonics refers to the materials and construction technology used (van Tonder, 2022a).

2.5 A decision tree

A decision tree is a decision support tool with nodes that demarcate variables at the stages of a decision (Kamiński, Jakubczyk & Szufel, 2017). The decision tree is used to solve a problem, and for this paper, problems such as an inadequate architectural design brief or the need for a built environment project such as a low-cost housing unit. In order to formulate a conceptual decision tree for the architectural process, the variables in Table 1 must become nodes on the decision tree. This is the first step toward managing knowledge, automating architecture and using artificial intelligence.

2.6 Artificial intelligence

Artificial intelligence refers to computer or machine systems that perform tasks that normally require human intelligence. Therefore, artificial intelligence is the solving of complex problems by means of intelligence exhibited by an artificial entity (Boran, 2016). Artificial intelligence is facilitated by machine learning (Ghahramani, 2015). Artificial intelligence, along with machine learning and big data, form part of the same technology set (Ward & Barker, 2013).

2.7 Machine learning and big data

Machine learning refers to machines that learn how to be more effective in the future by using data collected from data about past experiences (Schapire, 2008). Big data refers to the handling and analysis of the massive datasets (Mashey, 1997) used by machine learning.

2.8 Automation

Built environment knowledge management deals with big data. The construction industry shows low levels of productivity because the same errors reoccur in each project (Grover & Froese, 2016). These low levels of productivity also affect adequate low-cost housing provision. Automation of information may assist in managing the overwhelming amount of information in construction knowledge, which is a contributing factor to the recurrence of similar errors.

3. Research methodology

3.1 Limitations

A framework is required to inform the frames of architectural information used as nodes in the decision tree. However, for this conceptual paper, the research is developed only to the extent that the paper articulates the virtues and values of knowledge management for use in a decision tree. Furthermore, the authors do not attempt to define and present in detail the variables identified for the decision tree. The authors also do not list why each of the variables is important in addressing inadequate low-cost housing. Due to the page limit and a consequent need for brevity, these concepts are not elaborated. Architectural information is exhaustive and requires a highly educated architectural professional, in most cases, to make the decision as to the information applicable and where and when to apply the information. It is a premise of this paper that a conceptual decision tree is necessary to aid in governing the knowledge management of architectural information. Once this is achieved then automation and the use of artificial intelligence to govern and generate architectural information can be hypothesised.

3.2 A conceptual decision tree

In order to present a concept such as a conceptual decision tree for the automation of architectural information, it is important to represent the information visually in frames. Therefore, the first step was to elaborate upon Table 1 and add graphic illustrations of architectural information for each of the existing and emerging variables. Due to a need for brevity, only three frames (options) were conceptualised for each of the variables.

In Table 2, the elaborations are as follows:

- Graphic illustrations are in the first column and were generated in building information modelling software
- Each illustration was then given a code in the third column
- This code was abbreviated from the variable title in the second column

- A brief description of each variable is given in the fourth column (van Tonder, 2022a)
- Coloured frames are presented in the fifth column. These frames will become the nodes for architectural information and nodes on the decision tree.

Table 2 lists existing design variables often used as design generators for architectural projects. In addition to existing variables, architectural projects must also address emerging variables. Table 3 lists emerging variables which often deal with the climate emergency and the sustainability of the built environment. The column methodology used for the Table 2 and 3 columns are the same.

Table 2: Existing design variables that inform the specifics of architectural information (Adapted from van Tonder, 2022a)

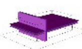
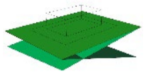
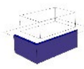
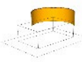
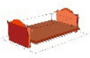
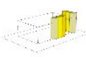
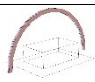
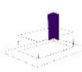
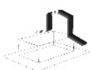
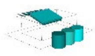
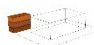
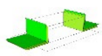
Graphical illustration	Existing design variable	Code	Description	Frame colour code for three options
	Existing design variables need	EX-N	Yes or no; the brief, programme, accommodation	
	Cultural topology	CT	History, culture, and sense of a place	
	Natural topology	NT	Physical or natural features of the site and location	
	Industrial thinking typology	UT	Most appropriate type of building for user needs within a linear economy	
	Indigenous thinking typology	GT	Most appropriate type of building for user needs within a circular economy	
	Visual tectonics	VT	Most appropriate visual integrity	
	Technology tectonics	TT	Most appropriate materials and construction technology to be used	

Table 3: Emerging design variables that inform the specifics of architectural information (Adapted from van Tonder, 2022a)

Graphical illustration	Emerging design variable	Code	Description	Frame colour code for three options
	Emerging design variables need	EM-N	Yes or no; the brief, programme, accommodation	
	Climate resilience Adaptation	CR	Climate resilience adaptation strategies for the proposal; site, technology, culture, or all supplied opportunities	
	Redress of apartheid legacy	RA	Cultural response; the decolonisation of space; indigenous thinking	
	Economic and social fairness and foothold	ES	Economic and social fairness and footholds; an escalated shift from a linear to a circular economy	

Graphical illustration	Emerging design variable	Code	Description	Frame colour code for three options
	Service provision system disruption	SP	Disruption of government service provision systems, such as electricity, water, sanitation, transportation, education, and healthcare	
	Amenities System disruption	AM	Production and consumption shift from industrial thinking into indigenous thinking	
	Regenerative potential	RP	Site restored to a former replenished state; biophilia and biomimicry; carbon management strategy such as a life cycle analysis of the building	

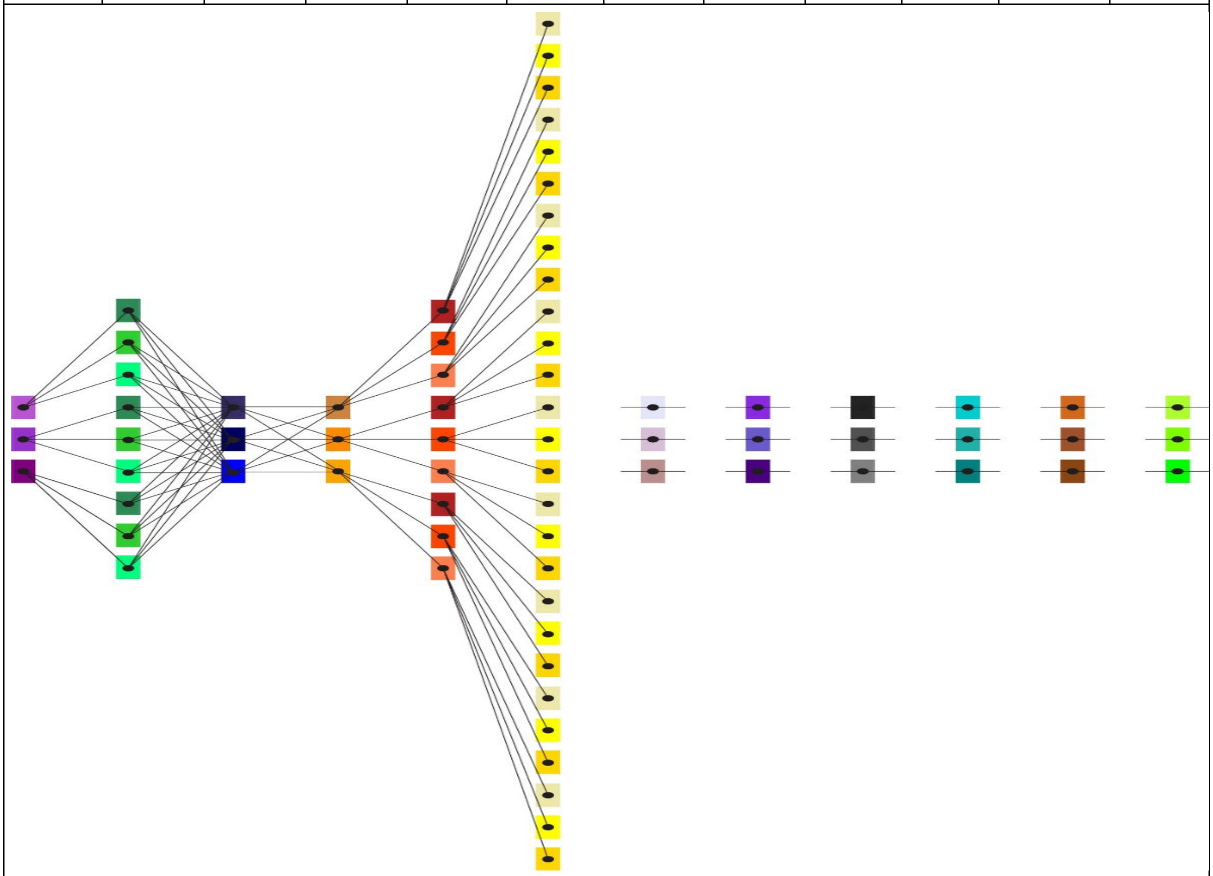
4. Research findings and discussion

4.1 Conceptual decision tree

The design variables as illustrated in frames from Tables 2 and 3 are used as the generators of the conceptual decision tree presented in Table 4. The authors acknowledge that some of the duplicated frames will remain mostly the same in information reuse. Furthermore, it is unclear if the order of the variables as presented in Table 4 is the best order for decision-making. Feedback loops or additional tiers may be required. Existing variables form the tree branch-like structure, and emerging variables form the tree trunk-like structure. The authors speculate that emerging variables will be an on-or-off step in the decision-making process. All the frames are selected, as indicated graphically with a colour fill to the rectangles. Not all frames have to be selected for information to be managed. The authors argue that any one-frame choices result in incremental improvements to the build project.

Table 4: A conceptual decision tree

Existing design variable						Emerging design variable					
CT 2	NT 1	UT	GT 1	VT 1	TT 3	CR 3	RA	ES 2	SP	AM 2	RP



Importantly, each of the design variables is a multi-layered concept that results in multiple connection possibilities. For example, cultural typology (CT) is when culture is connected to ideas and customs that establish language, heritage, and behaviour. As a topology variable, cultural topology is a nuanced variable that refers to the history, culture, and sense of a place. Place includes human-made features, such as the existing built form and culture that emerged from and informs the features of this existing built form.

Cultural topology could furthermore be connected to the natural topology of a site. Culture may inform the industrial thinking typology or indigenous thinking typology depending on how culture members produce and consume. Cultural topology may have an impact on the visual tectonics of the architecture. Technology tectonics may in turn be informed by the natural topology and the visual tectonics, in addition to the industrial thinking typology and the indigenous thinking typology when considering the production and supply of the building materials and building methods. The behaviour of a particular group of people connected to the same culture will furthermore inform the emerging variables used, as various cultures exploit natural resources to different degrees.

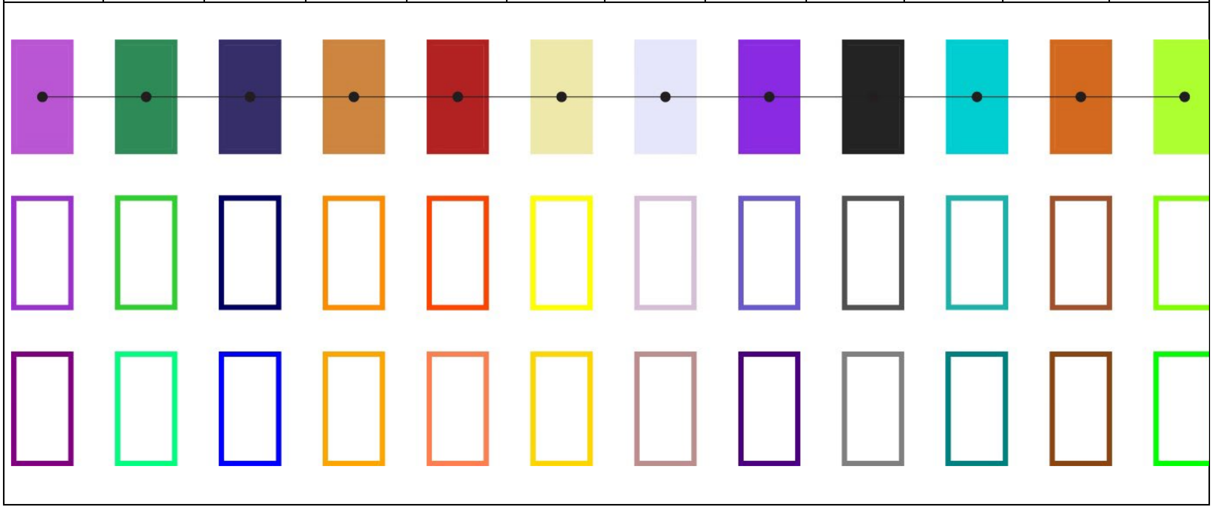
Three different case studies with various nodes activated on the decision tree are presented as part of the study. These graphically illustrate the information nodes applied to a low-cost housing unit.

4.2 Case Study 1: A conceptual decision tree

For Case Study 1, the authors present the following scenario: Should the first option frame from each of the variables be chosen then the outline for an architectural information decision tree will be as presented in Table 5, and the graphical illustration of the low-cost housing unit as presented in Figure 1.

Table 5: A conceptual decision tree for Case Study 1

Existing design variable						Emerging design variable					
CT 1	NT 1	UT 1	GT 1	VT 1	TT 1	CR 1	RA 1	ES 1	SP 1	AM 1	RP 1



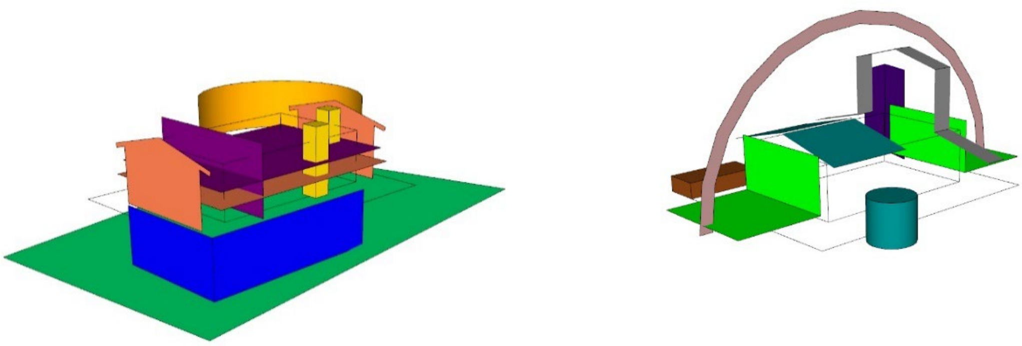


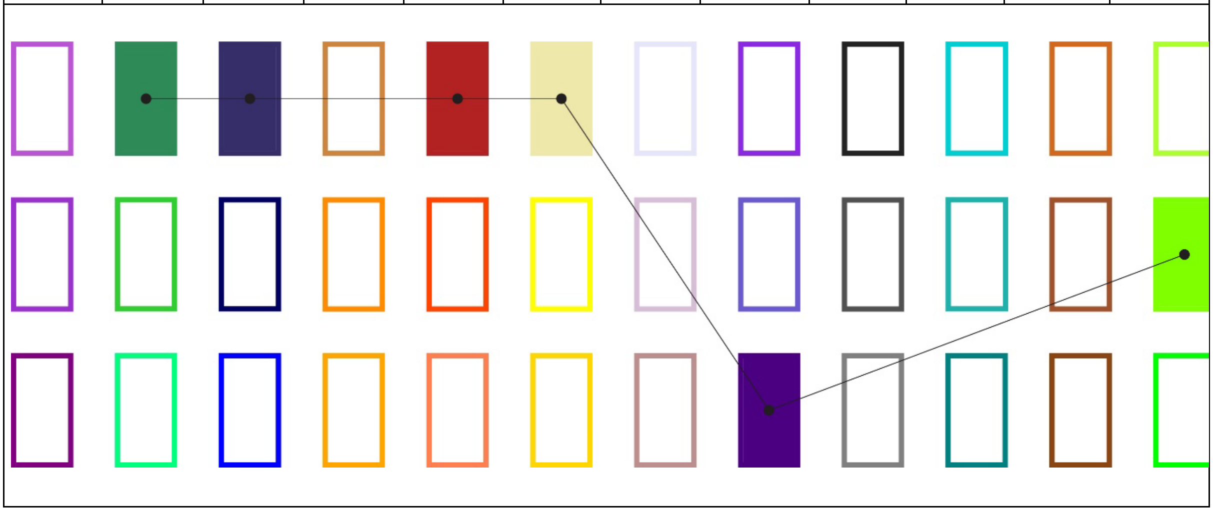
Figure 1: Graphical illustration of the low-cost housing unit for Case Study 1 with existing design variables to the left and emerging design variables to the right

Case Study 2: A conceptual decision tree

For Case Study 2, the authors present the following scenario: For existing variables, no cultural topology (CT) variable is used in the architectural design process. The natural topology (NT) and industrial thinking typology (UT) remain the same as in Case Study 1. No indigenous thinking typology (GT) variable is used. The visual tectonics (VT) and technology tectonics (TT) remain the same as in Case Study 1. For emerging variables, no climate resilience adaptation (CR) is selected and redress of apartheid legacy (RA) option 3 is selected. No economic and social fairness and foothold (ES), no service provision system disruption (SP), and no amenities system disruption (AM) variables are used in the architectural design process. Regenerative potential (RP) option 2 is selected.

Table 6: A conceptual decision tree for Case Study 2

Existing design variable						Emerging design variable					
CT	NT 1	UT 1	GT	VT 1	TT 1	CR	RA3	ES	SP	AM	RP 2



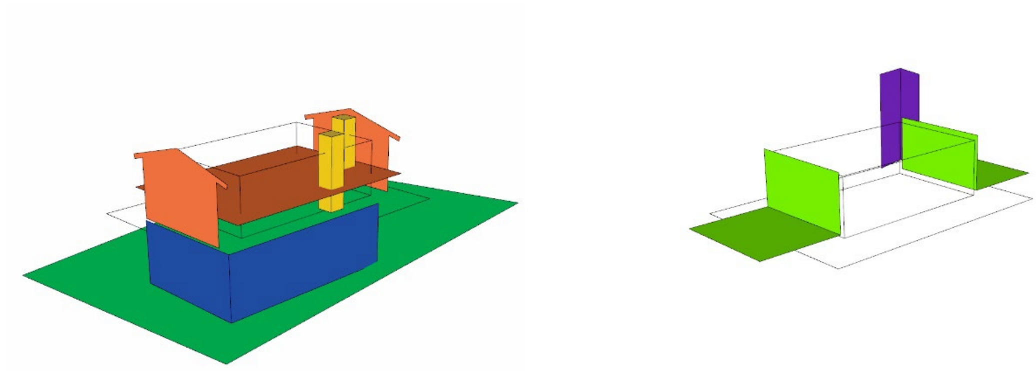


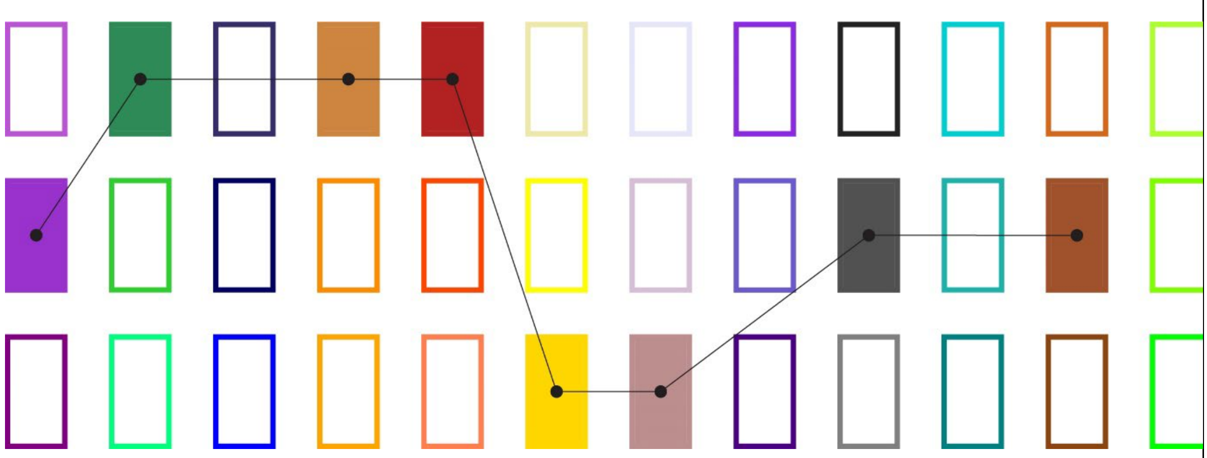
Figure 2: Graphical illustration of the low-cost housing unit for Case Study 2 with existing design variables to the left and emerging design variables to the right

4.3 Case Study 3: A conceptual decision tree

For Case Study 3, the authors present the following scenario: For existing variables, cultural topology (CT) variable option 2 is selected and used in the architectural design process. The natural topology (NT) remains the same as in Case Study 1 and Case Study 2. No industrial thinking typology (UT) variable is used. Indigenous thinking typology (GT) remains the same as in Case Study 1 and visual tectonics (VT) remains the same as in Case Study 1 and Case Study 2. Technology tectonics (TT) variable option 3 is selected. For emerging variables, climate resilience adaptation (CR) variable option 3 is selected and used in the architectural design process. No redress of apartheid legacy (RA) variable is used. Economic and social fairness and foothold (ES) option 2 is selected. No service provision system disruption (SP) is used. Amenities system disruption (AM) variables option 2 is selected and no regenerative potential (RP) option is used.

Table 7: A conceptual decision tree for case study 3

Existing design variable						Emerging design variable					
CT 2	NT 1	UT	GT 1	VT 1	TT 3	CR 3	RA	ES 2	SP	AM 2	RP



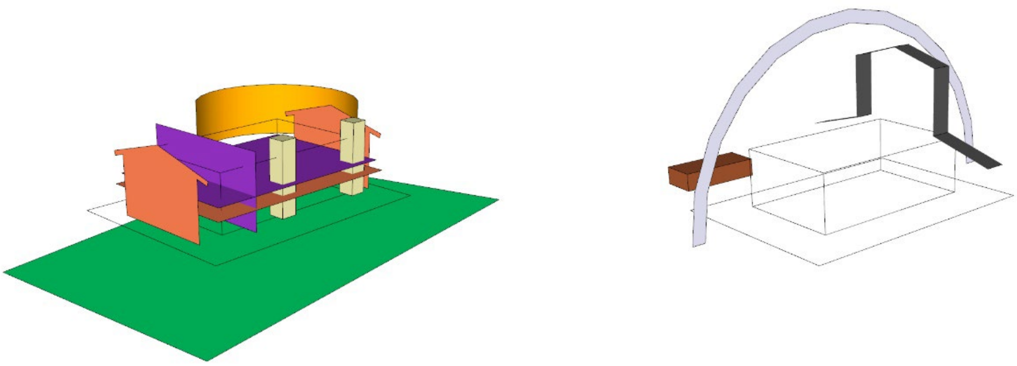


Figure 3: Graphical illustration of the low-cost housing unit for Case Study 3 with existing design variables to the left and emerging design variables to the right

5. Research findings and discussion

The research findings indicate that there is a possible overlap in architectural information regarding low-cost housing information conceptualised. Therefore, it can be inferred that efficiently handled and managed low-cost housing information that is acquired, created, shared, and transferred would contribute to solving the inadequacy of low-cost housing. As such, knowledge management would provide knowledge power to those affected by inadequate low-cost housing, resulting in improved housing.

This paper wishes to reimagine a world where a person affected by inadequate low-cost housing could provide minimal information on a platform such as a mobile phone app regarding the site, brief, programme and accommodation requirements of a house. This person could then receive an email with the information required.

This paper speculates that once automation and artificial intelligence technologies are incorporated, dissemination of architectural information would bypass the conceptual stage and become big data information packages. The information packages would include contract documentation (architectural drawings and project specifications) usually produced as architectural services by architectural organisations. In addition, the information packages would include the bill of quantities for appropriate dissemination. Quantity surveyors services would be improved with the automation of their service. Given the inadequate low-cost housing in

South Africa, many people may choose to build their own homes or upgrade their current homes. Therefore, the automated housing information would provide building instructions and procurement information.

When considering factors that affect aspects of life on earth, such as the climate emergency, emerging variables would host important information for dissemination. However, currently emerging variables are for the most part undefined and still largely theoretical with few built environment precedents. Further research on these variables is required for these variables to be applied specifically to housing.

6. Conclusion and further research

The paper concludes that as an exercise the conceptual decision tree shows potential to provide the right information to the right people at the right time. The conceptual decision tree would provide knowledge power to contribute to improving the adequacy of low-cost housing. However, the authors concluded that to develop this study further past the conceptual stages would require a large amount of additional cross-discipline research, creative thinking and skills development to manage architectural information for automation and later for artificial intelligence.

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