The case studies, situated in South Africa from the past 15 years, will be selected if the specific project includes the use of an EBT and placed within a catalogue created by the research team.The EBTs level of technology and development status will be reviewed and the project's value will then be assessed and listed in the catalogue.

Fidel states that "case studies are not rigorously planned," (Fidel, 1984: 274) and so the author of this paper acknowledges that although certain parameters were put in place to investigate the case studies as data, information might arise throughout the process that might fall without the expectations and planning of the data gathering and analysis.

3.4 Definition formulation

The prominent definitions in this research project include e*merging building technology (EBT)* along with accompanying terms such as *Building Technologies* and *Current Practice,* that all form part of the built environment.

To start off with, the definitions for *Current Practice*, *Building Technologies* and *Conventional building technologies* were formulated from desktop research. A third definition was made by looking at published sources as well as consulting with fellow researchers to find out what the definition of EBTs should be.

The research team met up and discussed the criteria for the formulation of the definitions. During this stage different literature sources were looked at (Wu, Wei, Peng, 2019., Steyn, 2018., Loh, 2019., Louw, 2021) and the researchers collaborated with each other in order to fix terms that should be present in the definition of *Emerging Building Technologies.* These diagrams were drawn up in order to visually represent the main concepts involved in the formulation of the definition for the term of *Emerging Building Technologies.*

For an initial draft, the separate concepts within the terms that were identified in the articles were placed on a mind map in order to derive an encompassing definition of EBTs.

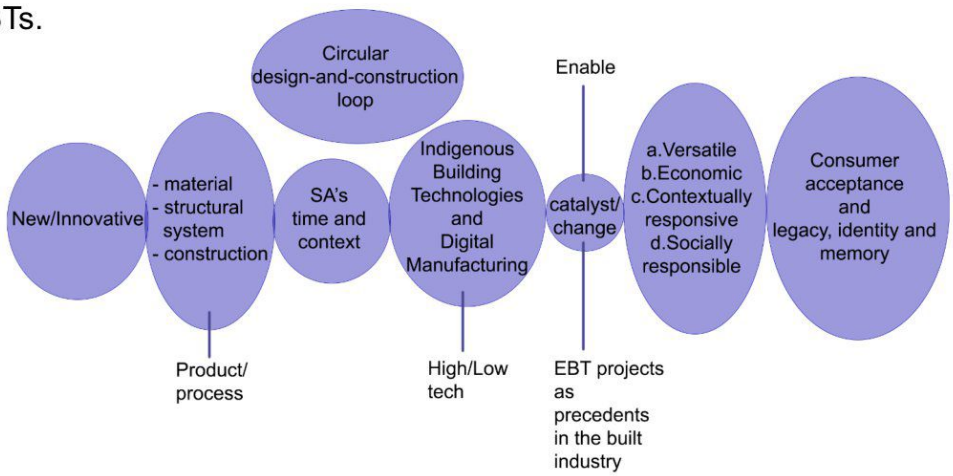

Figure 6: Diagram illustrating process followed to arrive at definition (Author, 2023)

For a second draft, the terms were again placed on a mind map, then meticulously organised and iterated until the sequence was correct.

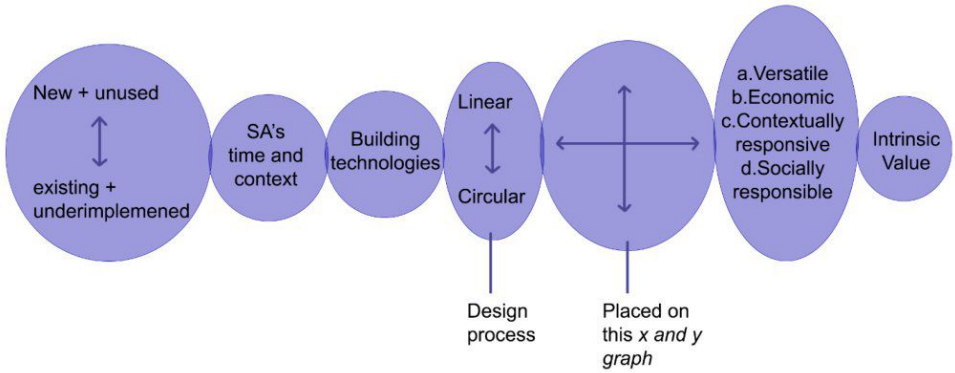

Figure 7: Diagram illustrating process followed to arrive at definition a second time (Author, 2023)

The final draft depicted below is similar to figure 4, but contains a diagram that differentiates between high- and low tech and developed and underdeveloped instead of the cartesian plane, as well as the rearrangement of ideas with the addition of new ideas,

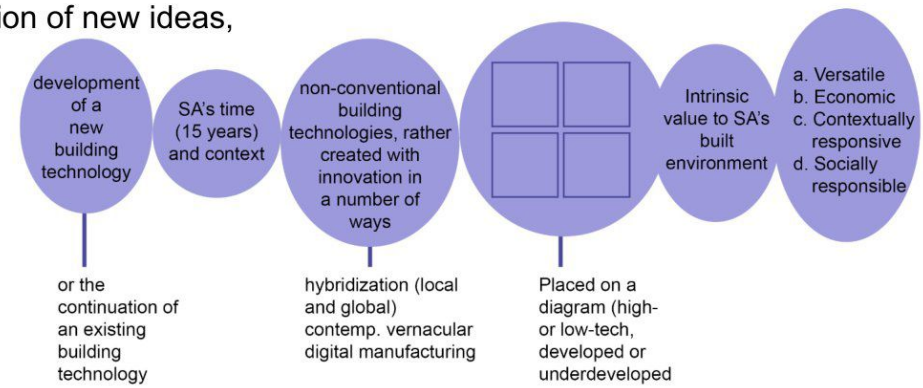

Figure 8: Diagram illustrating process followed to arrive at definition a second time (Author, 2023)

Figure 6 illustrates the diagram more closely from the definition diagram in figure 5 that acts as a scope of where an emerging building technology as a material, construction process or structural system (Wu, Wei & Peng, 2019: 1) can be plotted, depending on the production process being high- or low-tech and the development status being developed or underdeveloped.

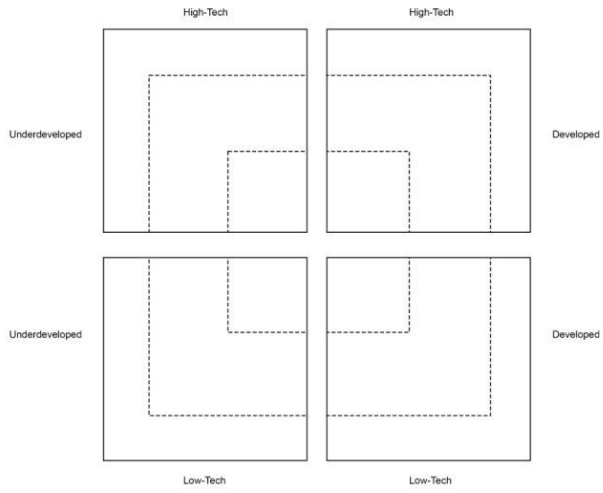

Figure 9: The chart on which a building technology can be plotted, with the innermost sections of each quadrant ranking the building technology as less emerging and the outermost quadrant ranking the building technology as more emerging (Author, 2023).

3.5 Literature review

The literature review will look at published sources on every topic mentioned in the introduction that has a link to the theme of EBTs. The current state of the built environment will be analysed and from there the inclusion of emerging building technologies and the possibilities they offer will be explored as well as the professionals who should involve them. The purpose of the literature review is to summarise the existing knowledge regarding the research topic and to identify gaps that could be filled by the author's research and conclusion.

The structure of the literature review will be as seen in figure 9, which contains key themes in the study. The key themes that were prominent in the earlier stages of the literature review were *hybrid tectonics, digital manufacturing, traditional tectonics, global and local tectonics* as well as *current practice, values of emerging building technologies* and the *tectonic trajectory.* The idea of *craft* as a theme came to the forefront during the research stage, but was discarded as it did not contribute to the larger theme of the study. The turning point for the literature review occurred when *architectural academia* became considered as a key theme along with *environmental and economic issues* caused by the built environment. Ultimately, the *tectonic trajectory* was introduced as the initial key term that would lead the other themes as seen in figure 9. These themes can also be seen as theoretical frameworks that were linked with each other and used to contribute to the study's literature that was used along with the data to reach a conclusion.

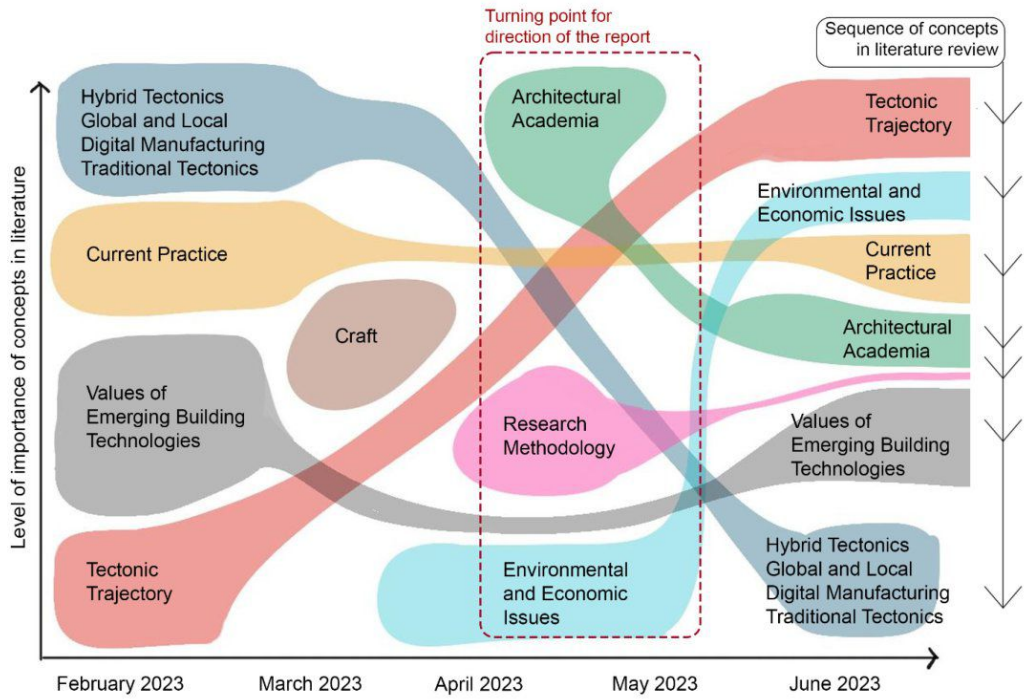

Figure 10: A diagram that depicts the level of importance of concepts in literature over time from February 2023 - June 2023. The turning point is highlighted and the final sequence of concepts will be the order of discussion in the literature review (Louw, 2021, p. 20-21).

3.6 Positivist paradigm

This research is mostly conducted within the positivist paradigm, as an objective pursuit is made to obtain facts while the scientific method is largely employed within the study (Kivunja, Kuyini, 2017: 30-33). This is principal to this report as the discoveries of the research will depend on the essence of the data collected, as done in this study. The positivist paradigm credits “reality is imperfect and that truth is not absolute but probable” (Kivunja, Kuyini, 2017: 32). Research methods can be used in the positivist paradigm to demonstrate if similar findings can be detected in the same context by repeating activities and investigating the results (Kivunja, Kuyini, 2017: 40).

The study is primarily conducted in a qualitative manner, as it “...draws on cases chosen in an opportunistic or purposive fashion…” where certain samples are selected to work with (Gerring, 2017: 18). This refers to the case studies that are selected by the researcher. The data is, however, analysed in a quantitative manner to confirm identified patterns (Gerring, 2017: 20) as the data is coded in a catalogue after the selection took place, in order to arrive at results that can be compared (Gerring, 2017: 18).

4 Data Analysis

The data collection process provided a substantial amount of information regarding the emerging materials, construction technologies and structural systems as well as the values were a result of the EBTs used in the projects. The majority of these diagrams were added as an annexure to this section of the report, as seen in figure 11, and will be referred to during the analysis, however diagrams that were derived from the ones in the annexure will be included as it will be part of the developed analysis.

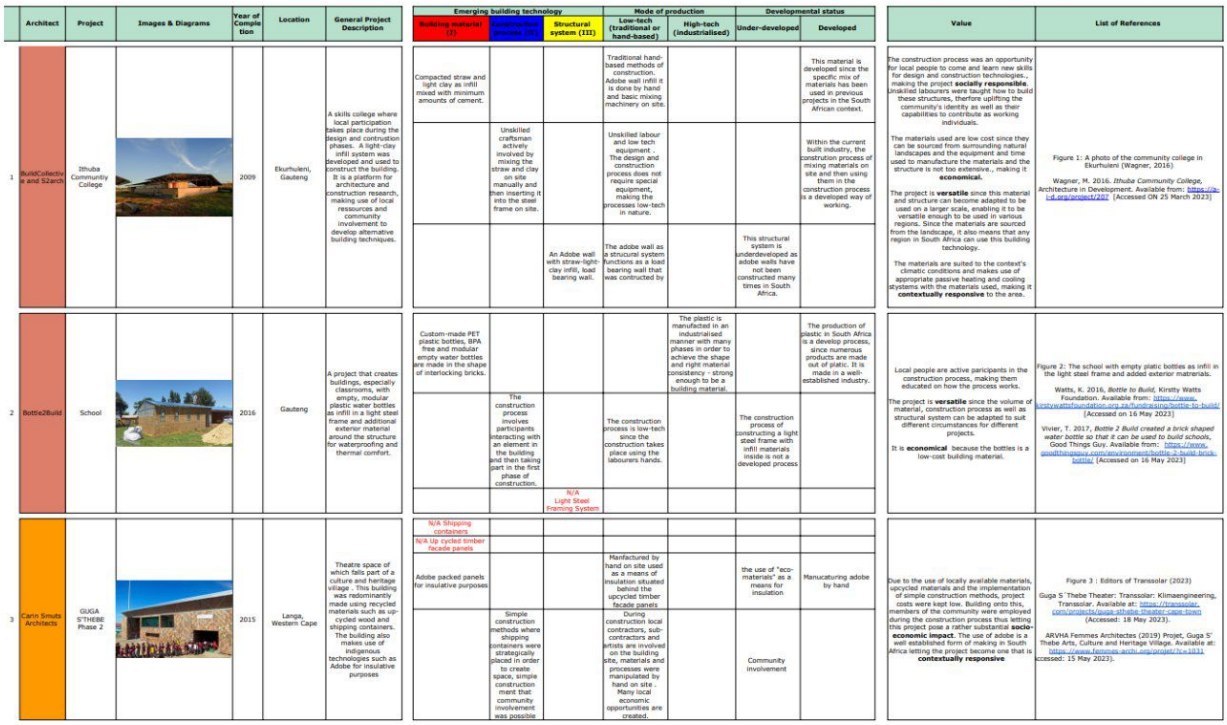

Figure 11: An example of the first three projects in the catalogue (Author 2023).

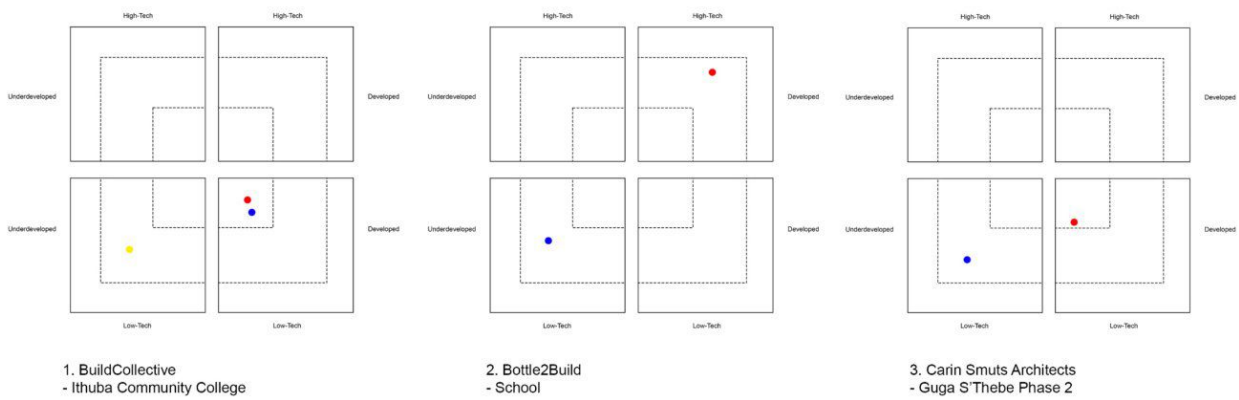

Figure 12: An example of the diagrams 1-3 in the annexure as extracted from the first three projects in the catalogue (Author 2023).

A diagram system was used as explained in the methodology section, that will not only differentiate the building technologies' mode of production being high-tech (industrialised) or low-tech (traditional/hand-based) but also classifies their development status being either underdeveloped or developed in South Africa's context. The innermost section of each quadrant indicates that the emerging building technology is not extremely emergent in South Africa, meaning that it can be found more commonly, as seen in figure 13. The outermost section of each quadrant indicates that the EBT is classified as extremely emergent, i.e. most likely making it the first of its kind, as seen in figure 14. The middle quadrant indicates EBTs that are in between the two extreme classifications, as seen in figure 15.

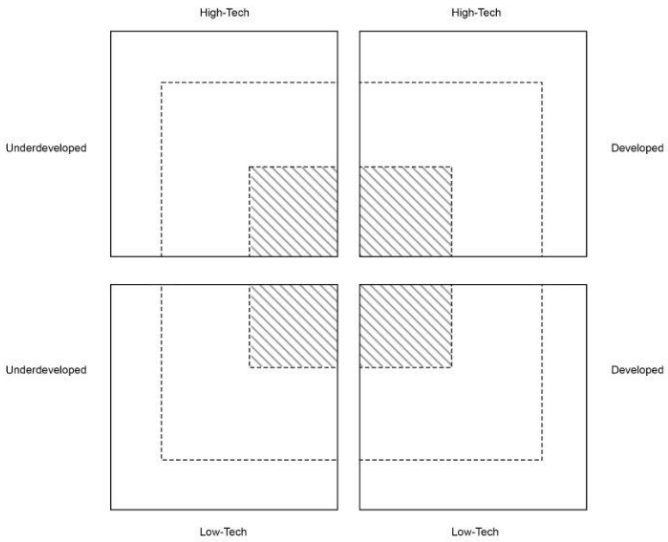

Figure 13: The section of the diagram where EBTs that are not extremely emerging in South Africa are placed (Author 2023).

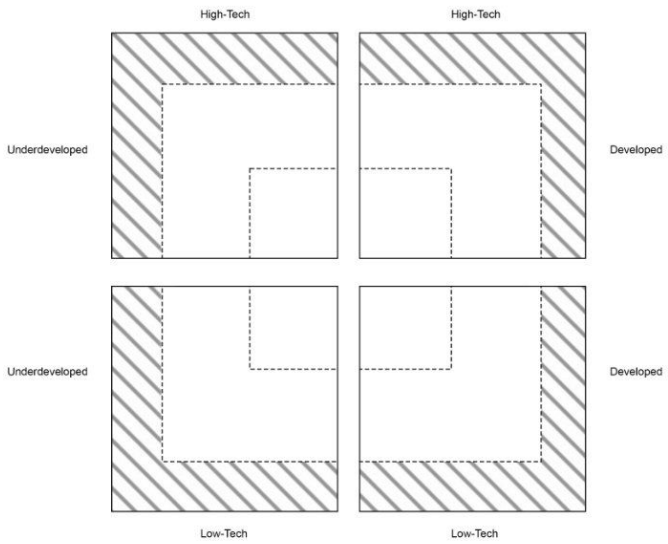

Figure 14: The section of the diagram where EBTs that are extremely emerging in South Africa are placed (Author 2023).

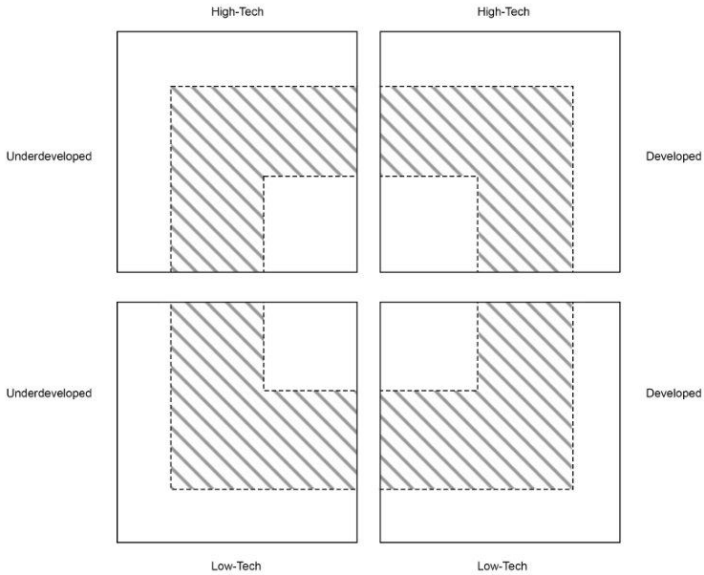

Figure 15: The section of the diagram where EBTs that are relatively emerging in South Africa are placed (Author 2023).

This will place each building technology, represented as a different colour as seen in figure 16 (material as red, construction process as blue and structural system as yellow), in a quadrant, made with the research teams' discretion of the building technology's level of emergence.

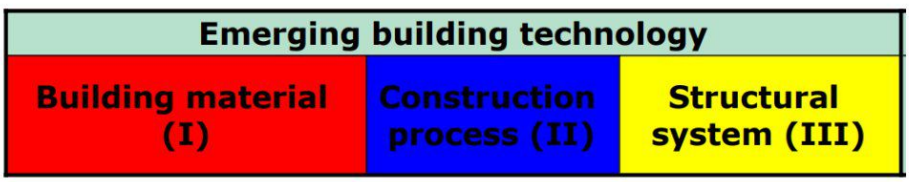

Figure 16: An extract from the catalogue to indicate the colour system of the EBTs (Author 2023).

The following diagrams provide a more general insight into the data before moving on to the specific direction of this research paper. The diagram below, figure 17, illustrates the total sum of data captured on a single diagram. Here we can see that most of the EBTs in South Africa are evenly divided between being high-tech and low-tech, although the data shows that most EBTs are underdeveloped in the South African context. In total, there are far more emerging construction processes than there are materials or structural systems, as the blue dots appear much more frequently on the diagram.

The diagram also indicates that most EBTs are of medium-emergence in the country, meaning that it can't be considered to be extremely rare, but it is also not very common. The emergence of these building technologies are thus not stable within the industry, but with time can become more commonly used and thus an integrated part of South Africa's built industry as time progresses.

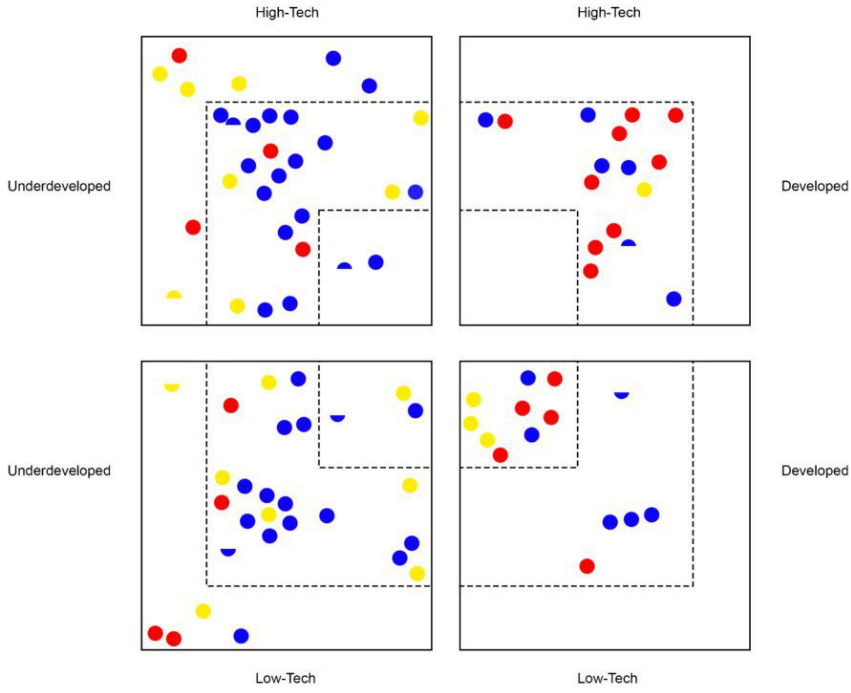

Figure 17: A diagram that illustrates the total sum of EBTs plotted according to the method of production and development status (Author 2023).

This next diagram, figure 18, shows only the emerging building materials (red dots) of the case studies, with most of the dots being in the medium range of emergence.

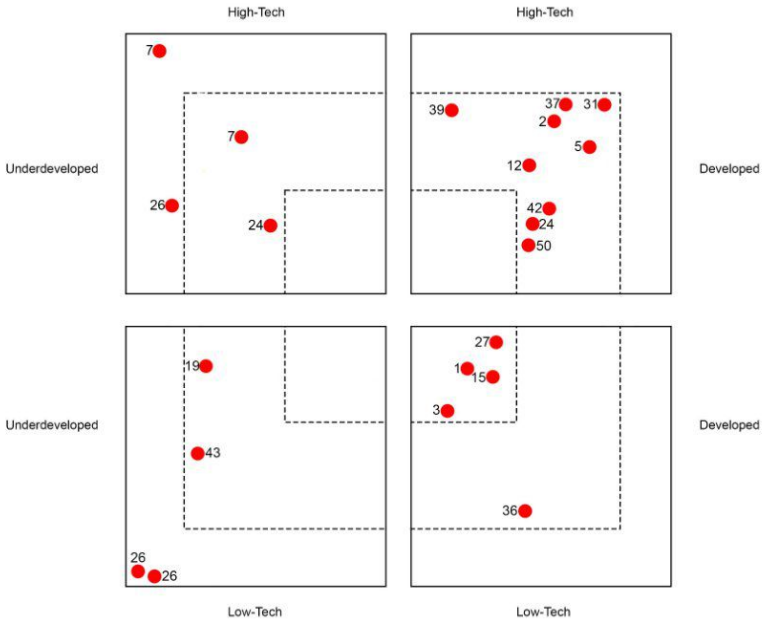

Figure 18: A diagram that illustrates the emerging building materials plotted according to the method of production and development status along with the project numbers (Author 2023).

Project 1, namely Ithuba Community College by CollectiveBuild makes use of natural materials that can be found on site and used in production immediately after. The same was done in project 3, Guga S'Thebe Phase 2 by Carin Smuts, project 15, Witklipfontein Eco lodge Residential by GLH Architects and project 27, Sandbag Houses Residential by MMA Architects as can be seen in the diagrams below.

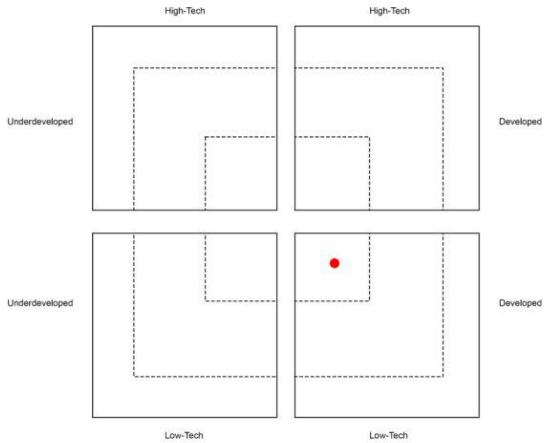

Figure 19: Project 1 - material (Author 2023).

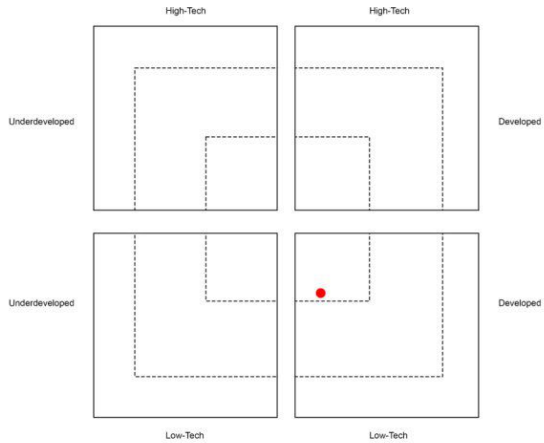

Figure 20: Project 3 - material (Author 2023).

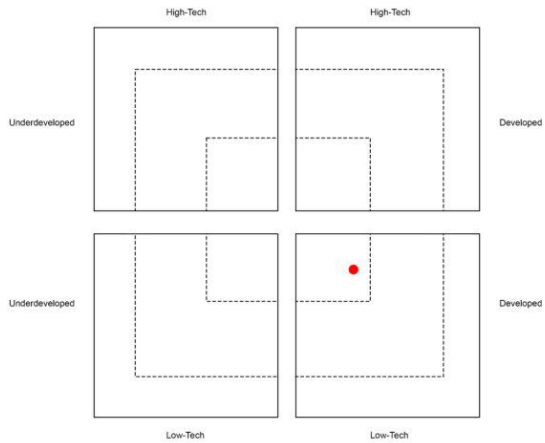

Figure 21: Project 15 - material (Author 2023).

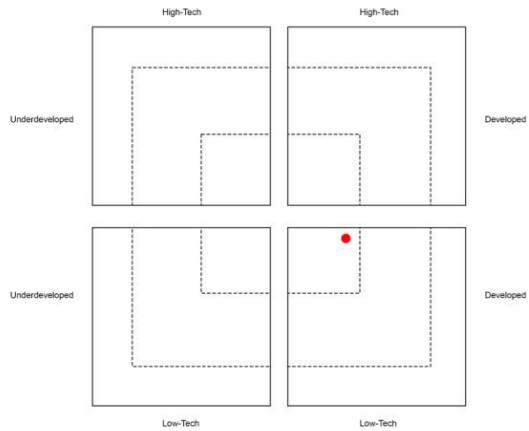

Figure 22: Project 27 - material (Author 2023).

The emerging building materials that are considered to be the most emergent, include the use of cork panels in project 7 and polymer stabilised rammed earth foundations as used in project 26. These materials are considered to be extremely emerging as they have not been found as examples of EBTS in other projects in South Africa. These EBTs as materials are both under-developed due to the above mentioned fact, but differ in mode of production as the cork panels involved with machine manufacturing and prefabrication in project 7, while the stabilised rammed earth foundations in project 26 are low-tech since the material is sourced locally and functions as a material due a combination of hand production and conventional machinery.

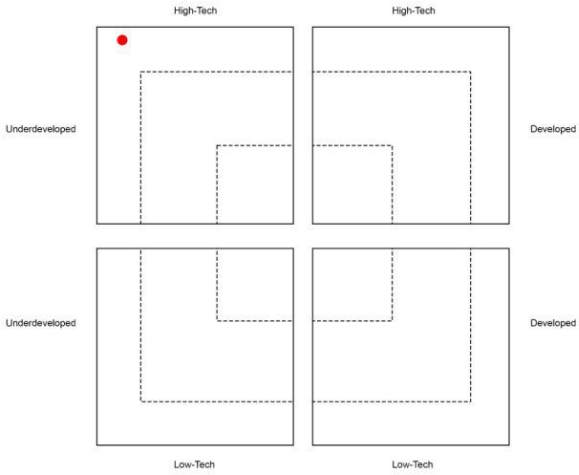

Figure 23: Project 7 - material (Author 2023).

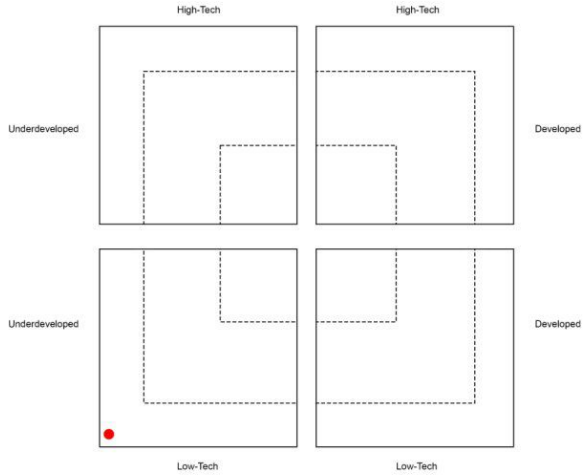

Figure 24: Project 26 - material (Author 2023).

The next diagram, figure 25, depicts the mode of production and development status of the construction processes used in the case studies. This diagram is the most populated among all three building technology diagrams, which indicates that emerging construction processes are the most prominent emerging building technology in South Africa. Most of the construction processes were considered to be of medium-level emergence.

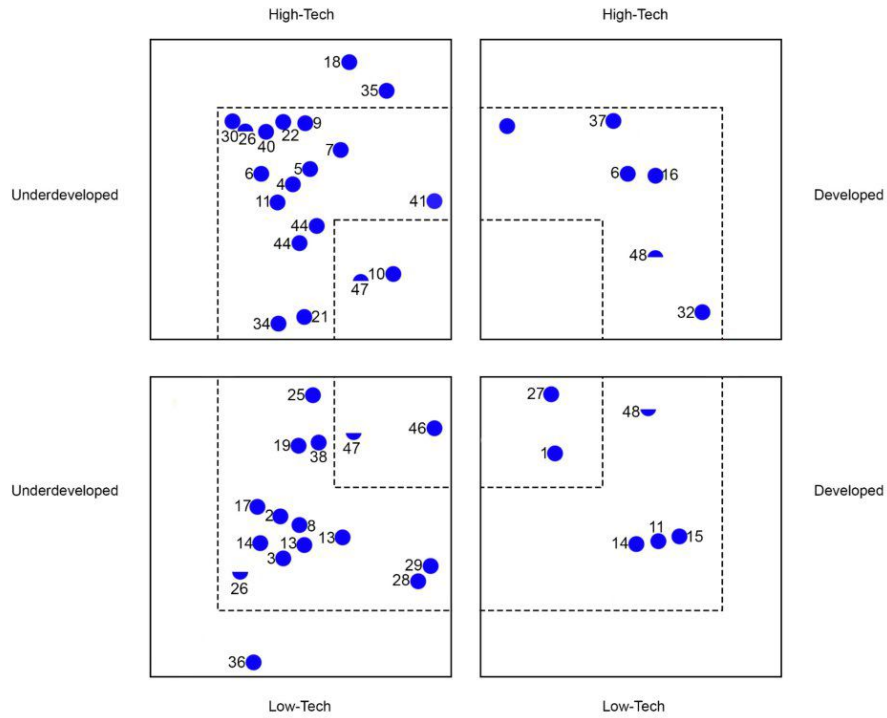

Figure 25: A diagram that illustrates the emerging building construction processes plotted according to the method of production and development status along with the project numbers (Author 2023).

A project that will be highlighted for the sake of the discussion is project 13's construction process, Walmer Creche by Simon Galland and LYT Architecture along with undergraduate architecture students from the University of Port Elizabeth. This project entailed a creche that was constructed by students on campus and then dismantled and re-assembled on site again - the building process continued for 10 weeks. Figure 17 shows that there are two medium-level emerging construction processes that are both low-tech and underdeveloped, namely the student participation and the prefabrication process where the entire building was constructed off-site and the reassembled on site by the students. This is low-tech due to the university students building this structure, making them part of the construction process, where skilled labourers would usually have this role. It can also be considered to be underdeveloped since this process of assembling the structure in an academic environment is not a developed process. The project also entailed prefabrication of an entire structure which is rare in the cases of South Africa.

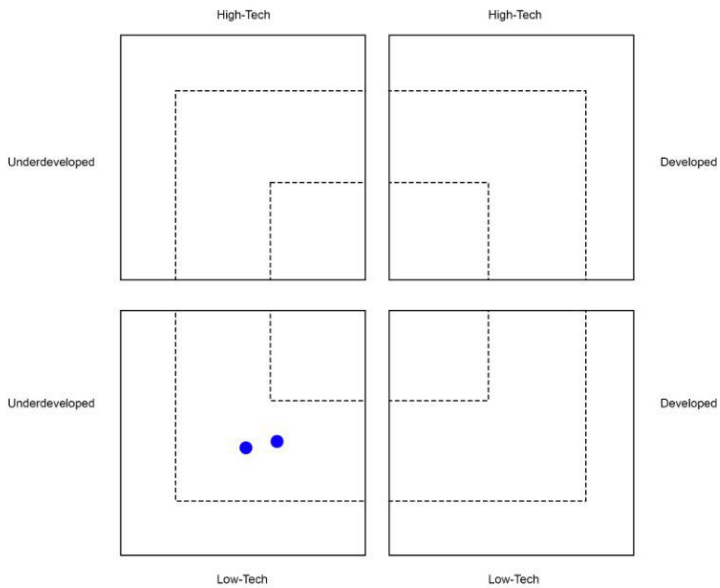

Figure 26: Project 13 - construction process (Author 2023).

This project consists of many values including being versatile, economic, socially responsible as well as contextually responsive. This structure can be assembled on various sites due to its transportability, making it versatile - it can be applied in many contexts. The size and form can also be changed depending on the function that the building will have. The building is placed on plinths with the intention of removing the structure from the surroundings to create a safe and isolated environment where the children can become immersed in a learning experience, making it contextually responsive. The clerestory windows is another way in which the building is contextually responsive - it allows light and air into the building but restricts one's view at eye level, to create a safe environment where the students and teacher are able to focus on the programme. This project is economical because recycled materials are used to construct the building as well as the labour of students who did

the project as part of a university module. The project is socially responsible because students are taught to participate in community upliftment projects and equip them with the skills and experience to become a part of these types of schemes.

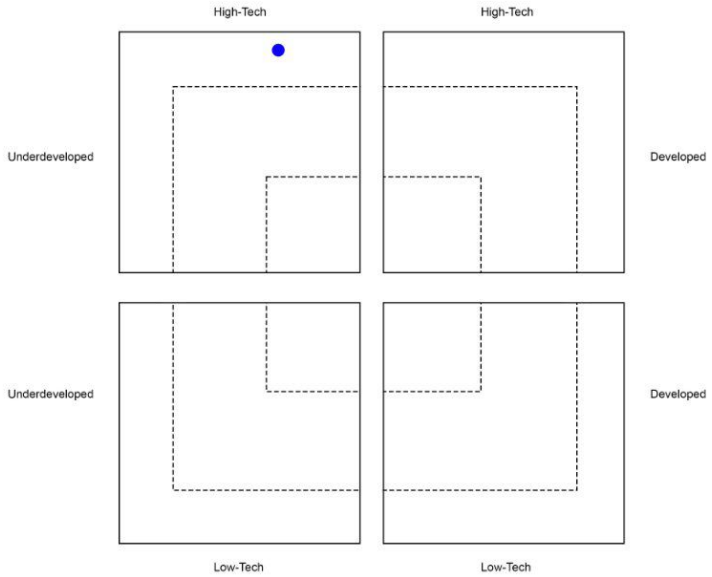

Figure 27: Project 18 - construction process (Author 2023).

Lastly, the diagram that depicts the emerging structural systems are shown below in figure 15. Here, there is an evident difference between the development status of the technologies. The majority of structural systems that are considered to be emerging in South Africa are underdeveloped.

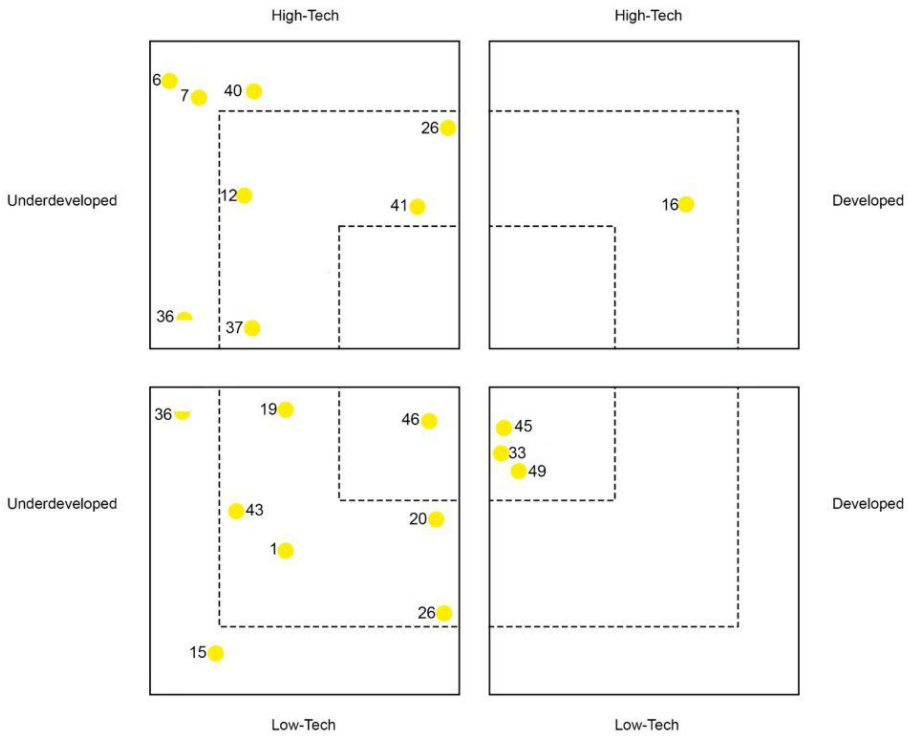

Figure 28: A diagram that illustrates the emerging building structural systems plotted according to the method of production and development status along with the project numbers (Author 2023).

The commonly developed emerging structural systems include shipping containers as the building's shell as can be seen in project 33, Spout Coffee Shop by Phillip Exter, project 45, the Vissershok School by Tsai Design Studio and project 49, the New Jerusalem Orphanage by Sean Wall.

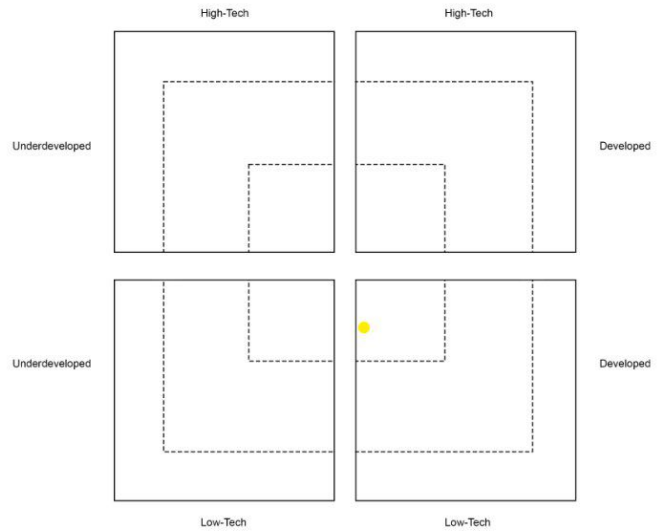

Figure 29: Project 33 - structural system (Author 2023).

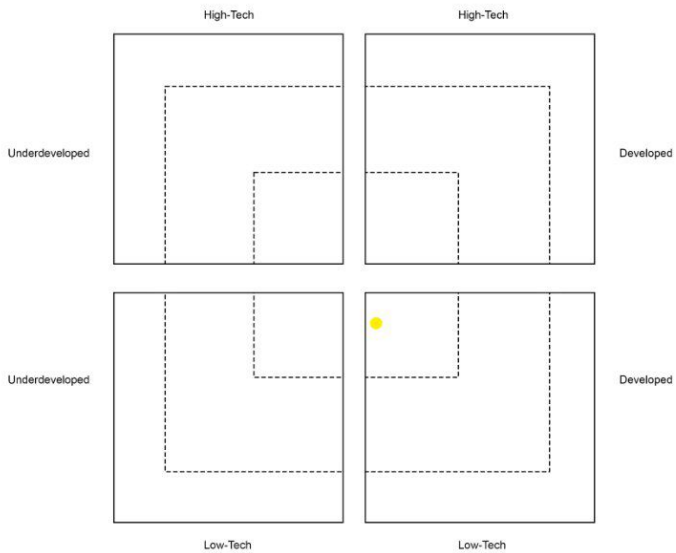

Figure 30: Project 45 - structural system (Author 2023).

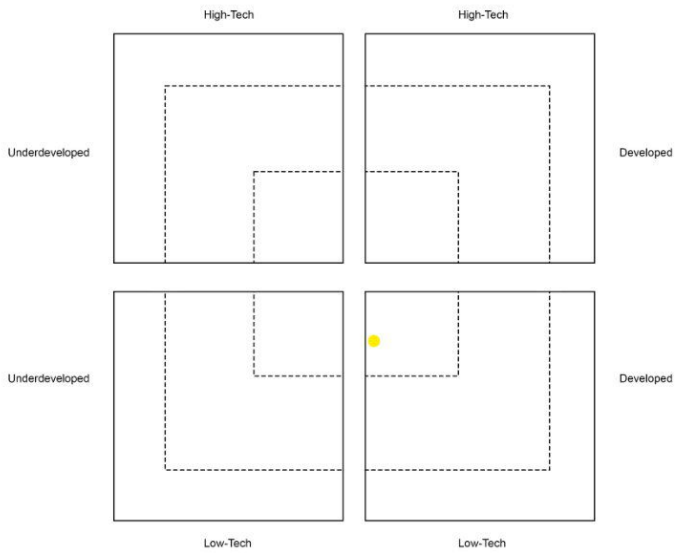

Figure 31: Project 49 - structural system (Author 2023).

On the other end, the projects that contained structural systems that are considered to be extremely emergent as building technologies in South Africa is project 6, KoSpaza Pop-up restaurant by Earthworld Architects, project 7, House Elliot by Elliot Paul, project 15 Witklipfontein Eco Lodge by GLH Architects, project 36, Mapungubwe Interpretation Centre by Peter Rich and project 40, Bosjes Chapel by Steyn Studio. These structural systems are EBTs that have not been widely adopted and implemented in South Africa, which places them in this category.

Project 6's structural system will be highlighted as it pertains to the study's interest. The KoSpaza shop designed by Earthworld Architects entails the use of a high-tech and underdeveloped structural system where interlocking plywood elements were used as elements of the structure. The interlocking elements of the plywood is high-tech due to the digital process of designing and manufacturing these precise joints that can be assembled without heavy machinery, additional fixtures or specialised skills. This particular structural system is under-developed in the country's context as plywood used for load-bearing elements in a structure is not commonly used.

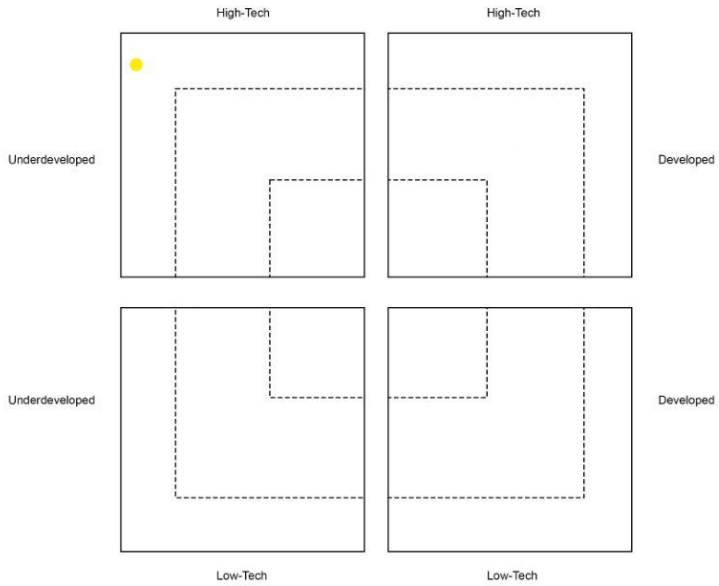

Figure 32: Project 6 - structural system (Author 2023)

The analysis of the data delivered a broad spectrum of results that can be discussed along with the literature review. This will aid in the goal of answering the research questions and eventually contributing to the theme of this paper within the broader built environment of South Africa.

5 Discussion

As mentioned, South Africa's built industry's dormant state in terms of its growth is due to the lack of innovation (Windapo, 2013: 65), which the author knew is not the case in architecture schools, rendering academia to be a viable solution due to the experimentative environment (Danaci, 2015: 1310). The importance of the process of making in the architectural profession, as highlighted by Loh (Loh, 2019: 34), comes to the forefront again as the data indicates that significant change in the industry is only possible by employing new ways of creating structures that do not carry the same negative effects into the environment as most conventional building technologies (Sebake, 2008: 490).

The data collected and analysed in unison with the literature review would indicate that the answer to the primary research question, "What building technologies can be considered to form part of current building practice in the South African built environment and which can be considered as emerging building technologies?" would be a positive and loaded one. The current building technologies in South Africa's practice mainly include brick, concrete, steel and stone as materials, conventional construction processes where trained labourers are employed to work on a low-tech basis, as well as structural systems where beam, column and exterior shell create the frame, which is held together by additional fixtures. These were predominantly the "not applicable" information that were evident in the selected case studies where some of the building technologies were not classified as EBTs.

Emerging building technologies in South Africa are present in completed projects included in the catalogue, with various materials and structural systems as EBTs. The construction process as an EBT, however, is the most common occurrence, as seen in figure 17, and can therefore currently be considered as the main driver of EBTs in South Africa. These will be focused on for the main research question as it provides the best-represented information set from the data. These construction processes include 3D printable concrete, CAD-designed premanufactured modules that can be assembled on site and the use of an independent CAD-designed frame that can act as a guide for masonry work as the most emerging building technologies. These construction processes are all high-tech and underdeveloped.

Examples of construction processes that are classified as medium-range EBTs due to their implementation are equally divided between being high- and low-tech with most of the processes being under-developed. The high-tech and underdeveloped examples include structural timber made with CNC techniques, CAD-designed metal cladding and rammed earth walls due to the pneumatic machines used during construction. The low-tech and underdeveloped examples include the prefabrication processes of constructing, dismantling and assembling a full structure, glued timber members that were bent with clamps, soil and cement-filled bags that are mixed on

site and fixed together as a structure by barbed wire. This last category is important information in order to answer the sub-question, “In what aspects can academia be valuable to the current industry’s practitioners regarding their knowledge on EBTs to become integrated in the built environment by implementing these technologies in practice?” as it is the most probable form of EBTs that could be implemented by students.

A project that will be highlighted for the sake of the discussion is project 13’s construction process, Walmer Creche by Simon Galland and LYT Architecture along with undergraduate architecture students from the University of Port Elizabeth. This project entailed a creche that was constructed by students on campus and then dismantled and re-assembled on site again - the building process continued for 10 weeks. Two medium-level emerging construction processes were involved, that are both low-tech and underdeveloped, namely the student participation and the prefabrication process where the entire building was constructed off-site and the reassembled on site by the students. This is low-tech due to the university students building this structure, making them part of the construction process, where skilled labourers would usually have this role. It can also be considered to be underdeveloped since this process of assembling the structure in an academic environment is not a developed process. The project also entailed prefabrication of an entire structure which is rare in the cases of South Africa.

Although the majority of architectural practices make use of current building technologies (Loh, 2019: 18), the data analysed from the catalogue proved that the majority of projects were executed by architecture firms in South Africa, not by academic initiatives. These include fabricators such as David Krynauw, involved with projects 22 and 23 in the catalogue, that worked with structural timber members cut out with CNC machines in a high-tech and underdeveloped manner, as well as Moladi Architects, involved with projects 28 and 29. These projects made use of reusable plastic formwork for the concrete that can be removed within 15 hours since the concrete has been poured. Both of these practices made use of construction processes that are classified as EBTs in South Africa, adding immense value to the built environment with specific focus on the time saved during construction, making these four projects more economically viable.

The author set out to find case studies that display the involvement of architectural academia that worked with EBTs, but the data only proves to have two projects where this occurred. Firstly, UJ’s Faculty of Civil Engineering and the Built Environment, in partnership with the KwaZulu-Natal Department of Human Settlements and AfriSam, project 18 in the catalogue, produced a 3D printed low-cost construction home. Here, university students were intricately involved in the project and gained experience of how their knowledge on EBTs could be executed in practice. The use of EBTs in this case study was a high-tech, but underdeveloped EBT that is extremely emergent in South Africa. The economic value that came from

this project was remarkable since the structure was produced in a shorter amount of time and with less construction materials.

To build on the success of what architecture schools can achieve with EBTs, a project that is similar to what has been included in the catalogue, is Creche X3 built by second year architecture students from the Nelson Mandela University in Port Elizabeth. (Studio Make, 2019: 5). This is significant to this report's discussion, as this project is an additional demonstration of what benefits architectural academia holds in the field of architecture and what values it adds to the built environment. The focus was placed on collaboration between students and the community as one of the project aims (Studio Make, 2019: 7). This project is also transportable, like the Walmer Creche done by Simon Galland in project 13, lending the construction process of prefabrication to be low-tech, but under-developed in South Africa.

This example, like project 18 and 13, can be considered as initiatives where architectural academia infiltrated the field, even on the fringes, and achieved outcomes that delivered more value than projects delivered by the conventional built material due to the use of EBTs, especially in the form of construction processes. Not only are these projects' multi-faceted values notable for the users and environment, but it deliberately goes against the current negative impacts caused by the majority of the built industry by acting as a fabricated solution that can act as a precedent for future built environment professionals.

The analysis concludes that within the projects that make use of EBTs in South Africa, few cases where academia is involved in the process, however when it is the case, the results/values are remarkable, yet, these projects are mainly classified as *emerging building technologies* due to the low-tech, underdeveloped construction processes.

Lastly, the final research question, "Can the inclusion of Emerging Building Technologies within the built industry contribute value to the environment such as being more versatile, economical, contextually responsive and socially responsible in the South African context? Can this cause the EBTs to be catalysts for the development of the current stagnant state of the tectonic trajectory in South Africa?" can be answered. The data in the catalogue indicates that some or multiple of these values appear in each project where an EBT was used, adding intrinsic value to the built environment, leaving it changed for the better. The most prominent values that are highlighted in the case studies when architecture schools are involved, are that these projects are contextually responsive, due to the extensive research done on the sites done by the students, who have more time to execute it, as well as the social responsibility that is established due to the involvement of the community members. These values remain significant in the industry as "architecture is an integral part of human activities," (Othman, 2009: 39) and will always have a great impact on its inhabitants (Schwartz, 2016: 66).

The contribution made by the Building Design Group can set expectations for what can be achieved when a model is followed where architecture students infiltrate the profession with knowledge from academia. This knowledge is generated through application and experimentation in the academic environment (Schwartz, 2016: 67), free from the business and time-related project restrictions in practice.

6 Conclusion

This study set out to investigate what EBTs are present and are being implemented by parties in South Africa, that could be causing positive change. A key point, namely the tectonic trajectory, was used as the inception for the rest of this report, that lead the study in a direction that situates the answers within the larger scale of the architectural history and future.The overall consensus of the published literature as well as the analysed data would reinforce the fact that the tectonic trajectory is of extreme importance to the build industry and that there are active key role players that contribute to this construction lineage by means of using EBTs.

The study found that projects that make use of one or more *emerging building technology* do create a positive impact on the built environment and its users. These technologies are found to be mostly under-developed, but well-divided between being high-tech and low-tech, indicating a balanced and growing industry.

The majority of the EBTs were, however, identified as construction processes, with the projects where architecture students were involved being low-tech and underdeveloped construction processes. These EBTs are thus highly labour-driven with community participation in the process of design and/or construction as key. The best EBTs to work with in South Africa's built industry in terms of the low level of technology required are the prefabrication projects done by students, that allows space for creative design solutions from academic minds without the constraints of high-tech modes of production, with hands-on opportunities for participation.

To conclude, although the specific direction of where the built industry is heading is not explicit, this study has provided evidence that the inclusion of each EBT with an intrinsic value, benefits the built environment. This indicates positive change, with change being the catalyst for any dormant state, creating a movement within the industry and ultimately, the tectonic trajectory of architecture.

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