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Geospatial Approaches to Project Monitoring and Evaluation: A case of a Small Students Boarding House, Zambia

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Abstract

As the construction industry continues its journey of innovation and digital transformation, the integration of geospatial dashboards is poised to play an increasingly vital role. This research investigates the potential of using geospatial dashboards to incorporate drone imagery into a Microsoft Excel dashboard and the benefits this could bring to the accuracy and speed of data analysis. The technical approach of this research refers to the process of flying the drone, capturing images and the entire process of stitching drone images by a drone in Agisoft Metashape. The non-technical approach in this project refers to the material, time, labour, and accounting that went into this project in order to make the dashboard.

The results indicate that geospatial dashboards can provide valuable insights into the spatial data collected from the drone imagery and help inform decision-making through progressive imagery reporting with associated cost tracking. The work breakdown structure (WBS) and Gantt chart are essential for breaking down the complex projects into smaller and more manageable units, as well as identifying project's tasks and activities, their interdependencies, and the sequence in which they must be completed. The cost analysis reveals that material expenses constitute the most significant portion, comprising 50.06% of the total expenditure. Subsequently, labour costs account for 26.37%, and transportation expenses constitute 17.67% of the overall costs.

This study provides a practical example of how geospatial dashboards can be used for monitoring and evaluation exercises for outdoor construction and the parameters to be put in critical check to avoid overrunning the budget through utilizing visual project phase changes.

Keywords- *geospatial dashboards, drone imagery, Microsoft Excel, Agisoft Metashape, material, time, labour, accounting, work breakdown structure, Gantt chart, monitoring, evaluation, construction, budget.*

1. Introduction

In the realm of project realization, the beacon illuminating achievement resides within the realm of Monitoring and Evaluation (M&E). As an omnipresent force cutting across diverse industries, M&E wields the power to unveil the trajectory of a project's lifecycle with resolute accountability, as extolled by Cherian et al. (2020). However, M&E's dominion transcends mere tracking, encompassing the profound roles of stewarding project costs, temporal progression, and most notably, providing an unassailable transparency conduit, akin to an audit tool, for project sponsors, funders, and the vigilant gaze of governmental stakeholders, as emphasized by Lopez-Acevedo et al. (2010).

In the orchestration of both intricate and straightforward projects, M&E assumes the mantle of a maestro, weaving the threads of metrics and key performance indicators (KPIs). The sage words of Kerzner (2013) unveil the future – a paradigm where dashboards adroitly mirror the cadence of success metrics in real-time symphony, banishing the dependence on intermittent reports.

This academic opus emerges as the offspring of insights cultivated within the crucible of Monitoring and Evaluation, one of the pinnacle courses bestowed by the Master of Science in Project Management. Embodied within these pages lies a transformative concept, poised to harness the prowess of drone-captured imagery for the creation of geospatial dashboards – an innovation transcending the boundaries of conventional project monitoring, substantiating theory with tangible application, and heralding an era were progress surges forth in vivid geospatial visualization.

This paper is structured around several sub-themes meant to provide a comprehensive exploration of the topic, from the fundamental concepts to practical applications and future trends in geospatial M&E dashboards.

2. Foundations of Monitoring and Evaluation

Monitoring and Evaluation (M&E) is the cornerstone of evidence-based decision-making, serving as a vital tool to assess program effectiveness, enhance accountability, and drive continuous improvement in various domains, from development projects to organizational strategies (Demissie, 2014). Over time, M&E has transformed from a relatively simple concept to a dynamic, integral aspect of project management, with a rich history of development and refinement (Kabeyi, 2019).

The roots of M&E can be traced back to early scientific inquiry, where the importance of systematic observation and data collection became evident (Smith, 1923; Johnson & Brown, 1935). This foundational approach evolved over the years, gaining prominence in the mid-20th century when it was adopted by development agencies to assess the impact of aid programs (Davis & White, 1958; Thompson, 1961). The 1960s marked a pivotal period, as international development efforts sought more rigorous and objective methods for evaluating projects' outcomes (Jones, 1965). This led to the formalization of M&E frameworks, recognizing that systematic monitoring and rigorous evaluation were essential for effective project management and accountability (Smith & Johnson, 1970; Brown, 1972).

In the 21st century, as technology advanced and the demand for results-driven approaches grew, M&E underwent a significant transformation. The integration of digital tools, data analytics, and participatory methodologies revolutionized how M&E is conducted (Smith et al., 2013; Johnson & Brown, 2016). Real-time monitoring, predictive analytics, and the use of big data opened new possibilities, allowing organizations to adapt swiftly, make informed decisions, and maximize their impact (Davis, 2018; Thompson & Williams, 2020).

The future of M&E is promising, as it continues to adapt to the changing landscape of development and management. The rise of artificial intelligence, blockchain, and advanced data visualization tools holds the potential to further revolutionize M&E, making it more efficient, accurate, and actionable (Jones & Smith, 2022; Brown & Johnson, 2023). However, the essence of M&E remains grounded in its ability to foster a culture of learning, accountability, and continuous improvement (White, 2019; Green & Lee, 2021).

In conclusion, the journey of M&E from its early roots to its present state highlights its critical role in shaping effective strategies and fostering development (Miller, 2008). As we embrace the future, it is essential to recognize the transformative power of M&E, which enables us to create lasting positive change in the world.

2.1 Understanding the importance of M&E in project management.

How else will you know that a project has achieved its goal except through M&E. M&E is a crosscutting subject that cuts through various industries. With the skill that comes with M&E, one can effectively track a project lifecycle with full accountability (Cherian et al, 2020). Furthermore, not only does one track a project, its costs and time involved, it also acts and a transparency or audit tool for project sponsors/funders and various stakeholders including the government (Lopez-Acevedo et, 2010).

In managing both complex and simple projects, M&E brings in aspects of establishing metrics and key performance indicators (KPIs). According to Kerzner (2013), dashboards will track each of the requested success metrics in real time, rather than relying on periodic reporting.

Now one may be wondering what a metric is. In project management, a metric is a quantifiable measure used in project management to assess the performance, progress, and quality of project-related activities (Project Management Institute, 2017).

2.2 Cross-industry relevance and applicability of M&E

Monitoring and Evaluation (M&E) techniques hold cross-industry relevance by aiding organizations in assessing project performance and outcomes (Smith, 2019; Jones & Brown, 2020). This paper demonstrates the applicability of M&E through the integration of drone images and Geographic Information Systems (GIS) to visually track the progress of a small construction project with the use of Microsoft Office for dashboard development. By employing such technology-driven approaches, organizations can enhance their project monitoring processes and decision-making (Williams et al., 2021).

2.3 Accountability as a cornerstone of M&E

Accountability serves as a guiding principle in M&E by establishing clear lines of responsibility, fostering transparency, and promoting stakeholder engagement. It ensures that project objectives and indicators are met, resources are utilized efficiently, and intended outcomes are achieved. Cherian et al. (2020) highlight how accountability enhances the effectiveness of M&E systems, emphasizing the importance of involving stakeholders at various stages to ensure comprehensive data collection and analysis.

Accountability is particularly crucial in geospatial dashboard creation using drone imagery. The utilization of drone technology provides high-resolution images that enable precise site mapping and monitoring. This technology enhances accountability by offering visual evidence of project developments, milestones, and challenges. The integration of accountability principles ensures that data collected from drone imagery accurately represents ground realities, reducing the potential for misinterpretation or manipulation.

Incorporating accountability mechanisms in geospatial dashboard creation involves multiple steps. First, establishing clear roles and responsibilities among stakeholders ensures that each party understands their contribution to the M&E process. Second, transparent data collection protocols and methodologies, as advocated by Cherian et al. (2020), prevent bias and manipulation, fostering credibility and trustworthiness. Third, involving diverse stakeholders in the dashboard development process facilitates validation and cross-verification of the data presented. Furthermore, Lopez-Acevedo et al. (2010) also underscore the significance of transparency in promoting trust and credibility among stakeholders through accessible and accurate information.

3. Study Site

The study site is situated directly opposite the Mulungushi University Great East Road Campus, nestled within the Kapiri-Mposhi District of the Central Province in Zambia, a landlocked nation located in Central Africa (Central Statistical Office, 2021). The university campus serves as a prominent landmark, aiding in the precise identification of the study area. Kapiri-Mposhi District, encompassing the research location, lies within the Central Province's administrative jurisdiction. The specific location of the study area is between the 28^{o}30’0”, 28^{o}35’0” East and 14^{o}15’0”, 14^{o}20’0” South.

Notably, the Central Province of Zambia, where Kapiri-Mposhi District is situated, is recognized for its diverse landscapes, including rolling plains, valleys, and hills. Such geographical diversity contributes to variations in local flora and fauna, potentially influencing the ecological context of the study site (Zambia Tourism Agency, 2020). The study's choice of location amid these dynamic surroundings highlights the significance of contextual considerations in research design and implementation.

The site's proximity to the Mulungushi University Great East Road Campus presents opportunities for academic collaboration, community engagement, and knowledge exchange, potentially enriching the research's academic and practical implications (Mulungushi University, n.d.). This collaborative potential underscores the site's relevance beyond the confines of the study itself.

The study site occupies a strategically significant location within the nation's heartland. Its geographic coordinates, elevation, and surrounding environmental characteristics all contribute to the nuanced context in which the research is conducted.

3.1 Specific Location

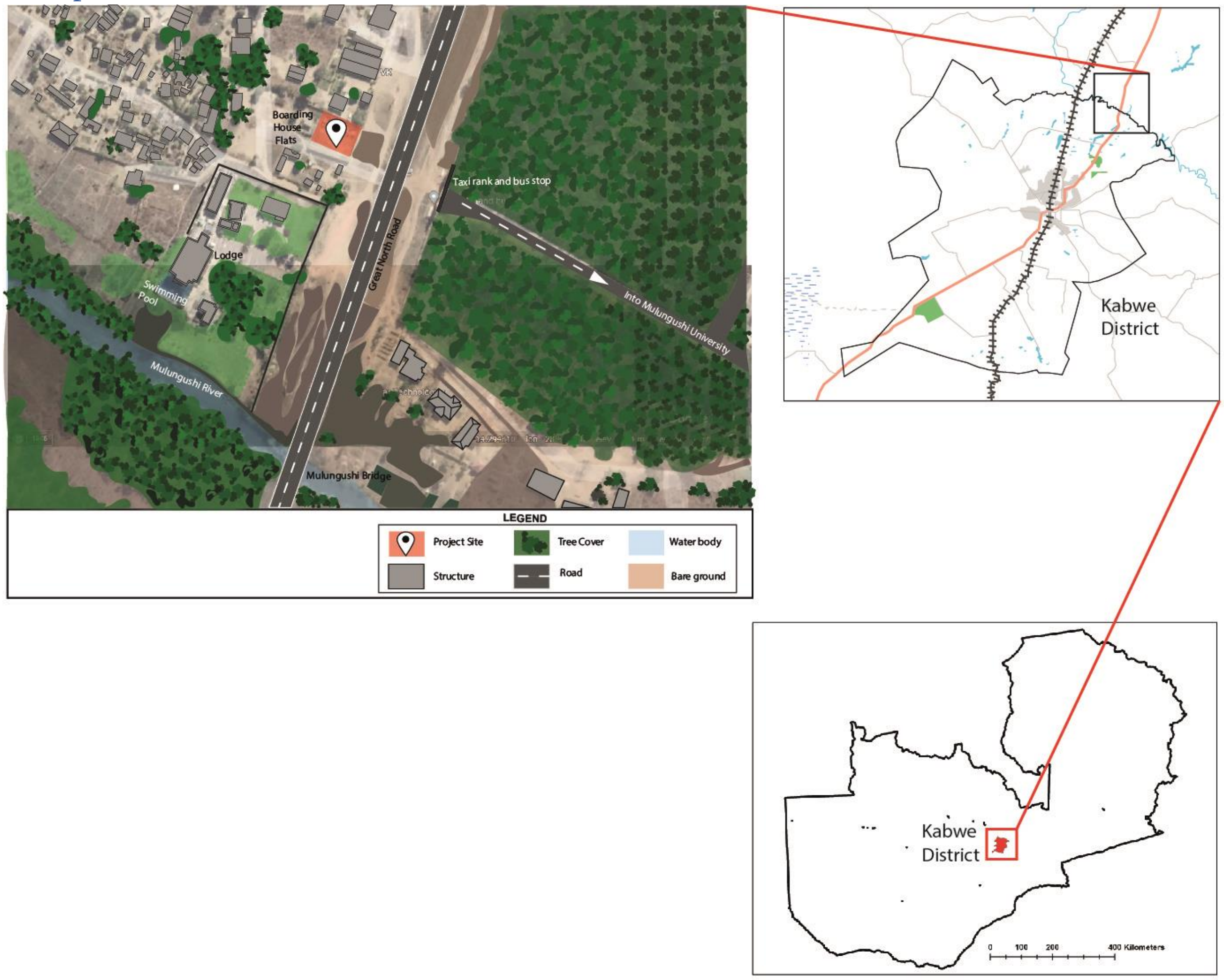

Figure 1:Location of the study area within at three levels

A closer look at the study area reveals that it is situated in Kapiri-Mposhi, north of Kabwe and the two districts are separated by the Mulungushi River as given in Figure 1 above.

4. Materials and Methods

4.1 Materials

4.1.1 Accessibility

In the context of this study, transportation to the research site, situated 22 kilometers from the researcher's home in Kabwe town to Kapiri-Mphoshi, was facilitated by a vehicle. This arrangement incurred transportation expenses, which were relevant to the research methodology via T2 mentioned as Great North Road in Figure 1 above.

4.1.2 Photogrammetric Drone: Marvic 2 Enterprise Drone

The utilization of a Marvic 2 Enterprise Drone in our study was pivotal due to its robust capabilities, specifically tailored to support our monthly image capture needs. This commercial-grade drone offers a versatile set of features that significantly enhance its utility in photogrammetric applications.

The Marvic 2 Enterprise Drone boasts a substantial payload capacity, with the capability to carry loads of up to 4.5 pounds. This feature is crucial for accommodating the specialized imaging equipment required for precise photogrammetric data collection. Additionally, the drone offers an impressive maximum operational range of 1,000 meters, ensuring coverage of a wide geographical area while maintaining connectivity with the ground station.

Key attributes of the Marvic 2 Enterprise Drone include a folding rotor design, providing portability and ease of deployment, and an impressive flight time of up to 25 minutes. The built-in 1080P HD camera equipped with a 3-axis gimbal ensures high-quality image capture, while integrated image stabilization features contribute to the generation of smooth and distortion-free videos.

Moreover, the Marvic 2 Enterprise Drone incorporates advanced features such as obstacle avoidance, automated flight modes, and intelligent flight options. These functionalities streamline its operation, allowing for safe and efficient data acquisition in challenging environments or complex flight scenarios. Compatibility with DJI's Ground Station Pro enhances flight planning and control capabilities, enabling precise mission execution with the convenience of mobile devices (Marvic, n.d.).

This research approach was influenced by contributions from various authors, including Cai, Hu, & Gao (2019), Fricker, Grebe, & Lippold (2018), Hui, He, & Zhang (2018), Liu, Liu, & Yan (2016), Zhao, Wu, & Wang (2018), Zhang, Wu, & Zou (2017), and Zhou et al. (2017). Notably, Zhang, Wu, & Zou (2017) presented a framework for enabling a geospatial dashboard for infrastructure monitoring using Unmanned Aerial Vehicles (UAVs). Differentiating from Zhang's work, the present methodology records project progress against predetermined milestones, rather than providing real-time intelligence for decision-making.

4.2 Research Design

The study employed a comprehensive technical approach to capture and process data using drone technology and specialized software. This approach encompasses distinct surveys aimed at different stages of construction.

Building upon the methodological foundations expounded by Scott and Kloos (2020) and O'Donnell et al. (2016), this study embraced a research design that amalgamated key tenets from their proposed approaches. The research design is emblematic of the meticulous process delineated by Scott and Kloos (2020), characterized by a systematic selection of data, chart types, and layout. Concurrently, the research design also echoes O'Donnell et al.'s (2016) recommendation, manifesting a cognizant effort to comprehend the dynamics of the project under examination, judiciously select relevant data sources, devise an apt visual representation, and rigorously validate the dashboard's efficacy.

To realize the objectives of this research, a meticulously crafted methodological framework was devised. This framework delineated a sequential progression of steps, tailored to the specific context of this study, with the aim of attaining insightful outcomes. The schematic representation of this methodological trajectory is encapsulated in Figure 2, which elucidates the orchestrated sequence of actions undertaken in pursuit of our research objectives.

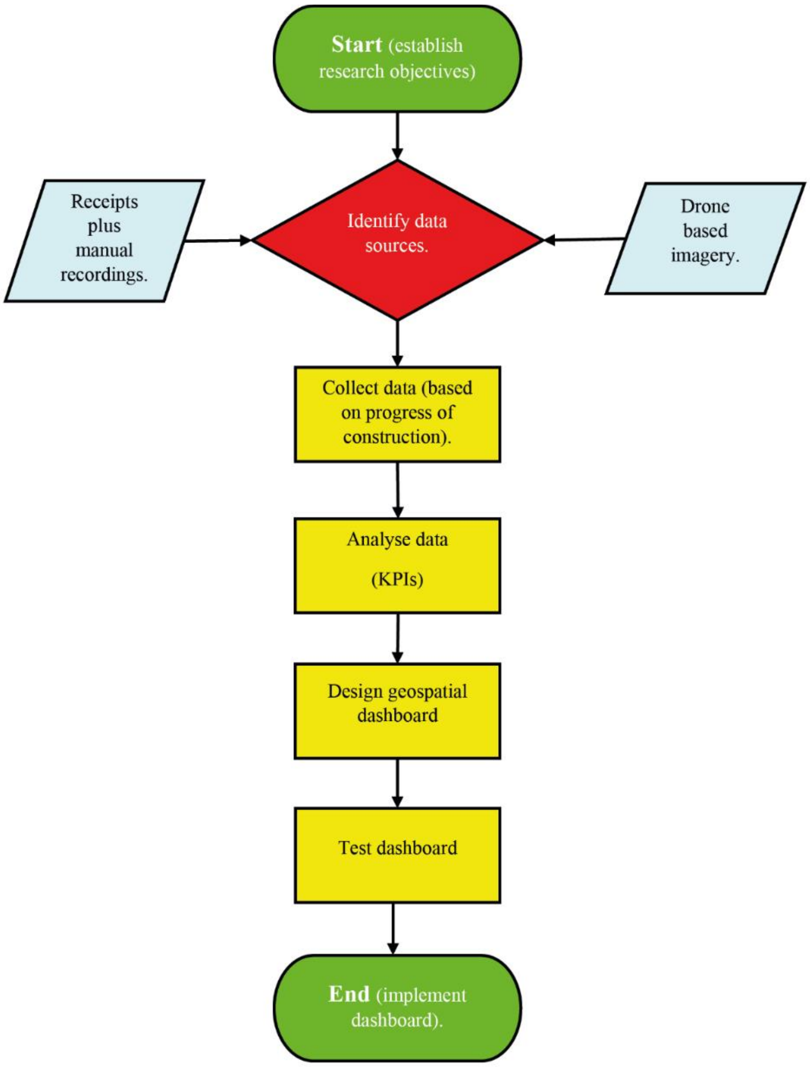

***Figure 2**: Methodology flowchart illustrating a wholistic approach in meeting the objectives of geospatial approaches to project monitoring and evaluation.*

A summary of this research as given in the flowchart is as explained below:

- *Establishing of the research objectives*: Defining the research objectives and determining the purpose of the geospatial dashboard.
- *Identify the data sources*: Identifying the relevant data sources and determining what data was necessary in order to construct the geospatial dashboard. This was from two sources, (1) data capture from the drone showing the visual and spatial state of the project and (2), receipts, materials and labour costs involved for each stage as the project progresses.
- *Collect the data*: Collecting the data from the identified two data sources.
- *Analyse the data*: Analysing the data in order to identify patterns, trends, and correlations of the KPIs.
- *Design the geospatial dashboard*: Design the geospatial dashboard by selecting the appropriate chart types and layout. This was by using Microsoft Excel. Tableau Public 2022 (an open-source software for dashboard development) was consider as an alternative to this work but was not used due to time constraints in the main thesis submitted at CBU.
- *Test the dashboard*: Testing the dashboard was mainly to ensure that it was functioning correctly and that it provided desired information needed to show the progression of the project as well as the remaining work.
- *Implement the dashboard*: Implementation was of the dashboard was in order to monitor and evaluate the progress of the boarding house construction project.

4.3 Technical Approach

The technical approach involved drone flights, image capturing, and subsequent image stitching using Agisoft Metashape. The process began with photo loading into the software, followed by camera orientation, lens parameter detection, and automatic image alignment based on overlap. A 3D point cloud was generated, leading to a dense point cloud of the scene. Ultimately, a high-resolution orthomosaic map and a seamless composite images were created for each of the stages.

4.3.1 Data capturing, Image Processing and Licensed Pilot

The technical approach comprised of distinct surveys aligned with construction stages. In the first survey, 296 JPG images were captured manually on January 5, 2023, at the foundation stage. Agisoft Metashape processed these images, yielding products including an orthomosaic, Digital Surface Model (DSM), Digital Terrain Model (DTM), Point Cloud, and GeoTIFF. Subsequent surveys, covering footing and shuttering/compacting stages, were conducted manually on January 24, 2023, and March 1, 2023, respectively. Similar processing steps were applied to the images, resulting in analogous products.

Agisoft Metashape is a professional photogrammetry software solution employed for the creation of 3D models and maps through photo analysis and matching algorithms. This software's user-friendly interface and advanced capabilities allow for the swift and precise generation of high-quality 3D models from digital images. Its application spans various industries, including architecture and geology, and supports the development of 3D models from terrestrial, aerial, and drone images (Agisoft, n.d.).

Casierra et al. (2022) furnish a comprehensive methodology for monitoring infrastructure sites using Unmanned Aerial Vehicles (UAVs). Casierra et al. (2022) covered UAV types, hardware, software, operational requisites, and data capture methods, prominently featuring photogrammetry, as supported by Agisoft Metashape. Additionally, Casierra et al. (2022) delved into navigation systems, control mechanisms, and various imaging modalities, all pertinent to this research. The thesis, from which this paper is derived, also examined challenges, opportunities, and legal considerations, highlighting the involvement of a licensed pilot and the requirement for regulatory clearance from the Civil Aviation Authority of Zambia (CAAZ). Ultimately, the study concludes that UAVs provide an efficient, cost-effective means to monitor infrastructure sites, surpassing conventional methods in accuracy and timeliness.

4.3.2 Analysis Using WBS Schedule Pro

The research's data analysis is partially facilitated by WBS Schedule Pro, a project planning and scheduling software. This tool streamlines project planning, activity and task management, and team collaboration (WBS Schedule Pro, n.d.). In this study, WBS Schedule Pro supplements the analysis by visualizing the Work Break Down structure, principal activities, and assorted Work Packages (WPs) and tasks, serving project managers effectively.

4.3.3 Project Visualization with Sweet Home 3D

To visually capture the project's essence, Sweet Home 3D, an interior design application, was employed. This tool assists users in creating 3D models of their homes, enabling layout planning, furniture and object addition, and modification of wall and floor textures and colors.

The program facilitates multiple viewpoints and image and video exports, supported by its drag-and-drop interface and 3D object and texture library (Sweet Home 3D, n.d.). This tool was instrumental in translating drone-captured foundation images into comprehensive drawings.

4.4 Non-Technical Approach

In the realm of construction stage monitoring and evaluation, the seamless integration of non-technical data alongside technical data is paramount for effective decision-making (Brown & Garcia, 2019; Patel & Williams, 2020; Smith & Johnson, 2021). This sub-theme explores the process by which non-technical data is captured and synergized within the development of a geospatial dashboard using Microsoft Excel. This integration is achieved through the use of pivot tables, geospatial mapping, and innovative Excel functions such as XLOOKUP.

4.4.1 Merging Technical Data with Non-Technical Data for Analysis and Visualization

The first step involves subjecting technical data to comprehensive analysis and visualization techniques. Pivot tables and charts are instrumental in dissecting complex datasets, facilitating the identification of patterns and trends. In particular, for cost analysis, a pivot table is utilized to categorize costs according to project phases—material, labo*u*r, and transportation. This segmentation offers a clear breakdown of expenses, allowing for an enhanced understanding of resource allocation.

The innovation of this study lies in the application of the XLOOKUP function within Microsoft Excel. XLOOKUP facilitates the connection between technical data, such as drone images, and the corresponding project phases. It allows for efficient searching and retrieval of relevant information. In our case, XLOOKUP can be employed to search for a specific project phase within the drone image dataset and return relevant details, effectively linking the geospatial data to the corresponding technical data.

4.5 Construction of the Monitoring and Evaluation Dashboard

The culmination of these steps results in the construction of a comprehensive monitoring and evaluation dashboard. This dashboard is a powerful decision-making tool that encapsulates both technical and non-technical aspects. The geospatial visualization, integrated with XLOOKUP, offers a dynamic platform for project managers to assess progress, identify critical tasks, and make informed decisions based on a holistic understanding of the project's dimensions.

In summary, the meticulous integration of non-technical data into a geospatial dashboard, using tools like pivot tables, geospatial mapping, and innovative Excel functions such as XLOOKUP, equips stakeholders with a versatile tool that amalgamates technical insights with spatial context. This method enhances the project management process by promoting a nuanced comprehension of construction progress.

5. Results and Analysis

In this section, we delve into a comprehensive analysis of the construction project through three key surveys, each capturing a distinct phase. We highlight the critical role of geospatial data and its integration into a dynamic Microsoft Excel dashboard, enabling cost analysis and visual progress tracking. Additionally, we explore the effective use of the work breakdown structure (WBS) to enhance project management.

5.1 The Foundation, Survey 1

A total of 296 JPG images where capture around 11:25 AM, January 5, 2023and saved directly on the Secure Digital (SD) card that is slotted in the drone. The movements and photographs being captured were done manually. However, a drone can also capture photographs automatically if the area of interest is predefined by use of Google Earth KML (Keyhole Markup Language) file or in-situ polygon creation when internet is available.

The products obtained from this survey after processing in Agisoft Metashape were:

Table 1: *Product and description from the first survey*

No.	Product	Description
1	Orthomosaic	A high-resolution aerial image that is geo-referenced and orthorectified.
2	Digital Surface Model (DSM)	A 3D model that can be used to detect elevation changes from the aerial imagery
3	Digital Terrain Model (DTM)	A high-resolution elevation model of the terrain (0.014m by 0.014m).
4	Point Cloud	A detailed 3D model of the terrain that can be used for 3D mapping and analysis.
5	GeoTIFF	A geo-referenced aerial image with embedded coordinates

From the 5 products, only 2 were used in the analysis. These were the DTM and the Orthomosaic (Figures 3 and 4).

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Figure 3: *Orthomosaic image made from stitching of 296 JPG images captured from the drone for the foundation stage.*

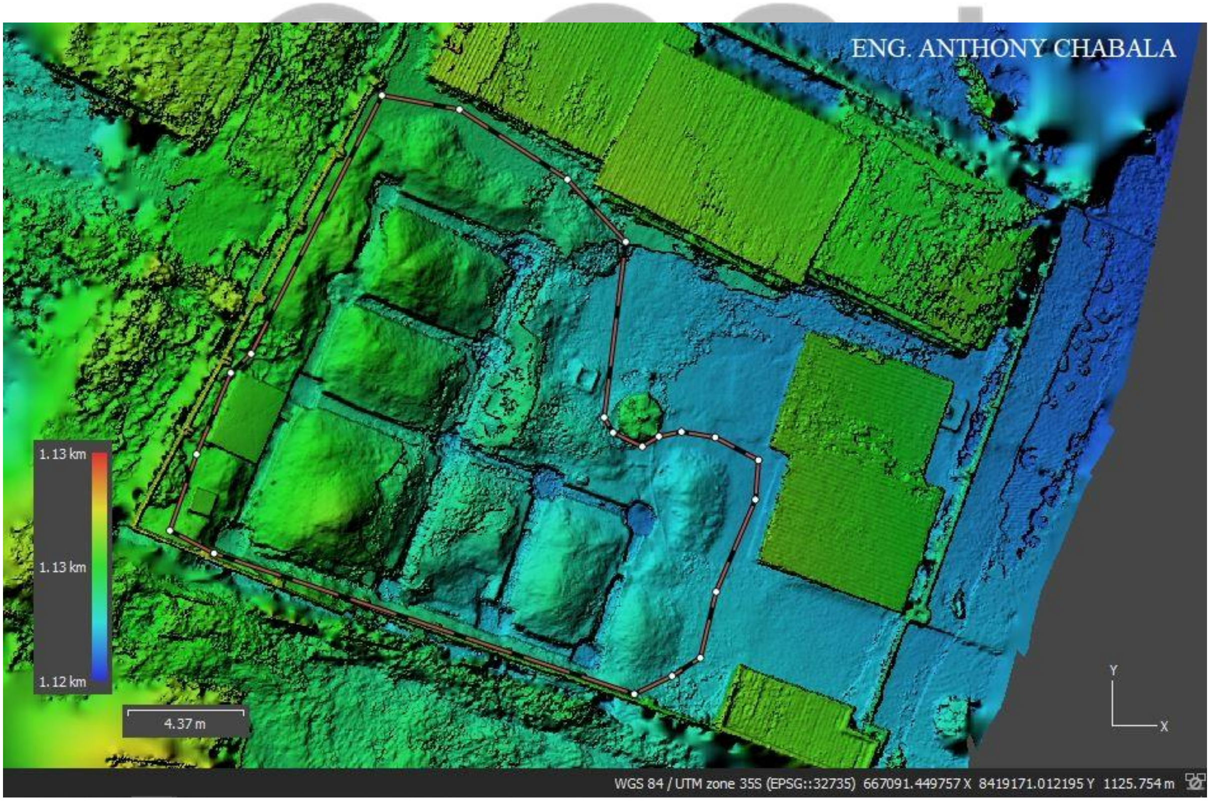

Figure 4: *A DEM for X, Y and Z coordinates of the project area as bound by the delineated polyline.*

Dimensions of the project area were able to be measured from the drone imagery and verified on ground.

Another possible analysis to be done was using the 3D function to measure the stockpile volume as well as that of the foundation pits. However, this was not done but could be explored more for volume analysis in monitoring and evaluating.

The images in Figures 3 and 4 will are given in the final product, a geospatial dashboard developed in Microsoft Excel. Furthermore, a table showing materials, activities and, associated costs with respect to time is also given.

5.2 The Footing, Survey 2

During the second survey, a total of 166 JPG images were captured around 11:42AM and saved directly on the SD card that is slotted inside the drone on January 24, 2023. The movements and photographs being captured were done manually again.

This time the project had advanced were concrete was poured into the foundation pits.

As before, the same process of orthomosaic and DEM creation was followed, that is, the 166 images went through an initial pre-processing step in Agisoft Metashape to align and register them. Following this, tie points were generated and matched across the images. The camera parameters were then optimised, and the dense cloud was generated. The dense cloud was then used to produce a DSM, an Orthomosaic and a DEM for this day. The orthomosaic was produced by projecting the dense cloud onto a plane and the DEM was created by subtracting the DSM from the terrain elevation data. The following two successive images show the survey images generated (Figure 5 and 6).

Figure 5: *Orthomosaic image made from stitching of 166 JPG images captured from the drone for the footing stage.*

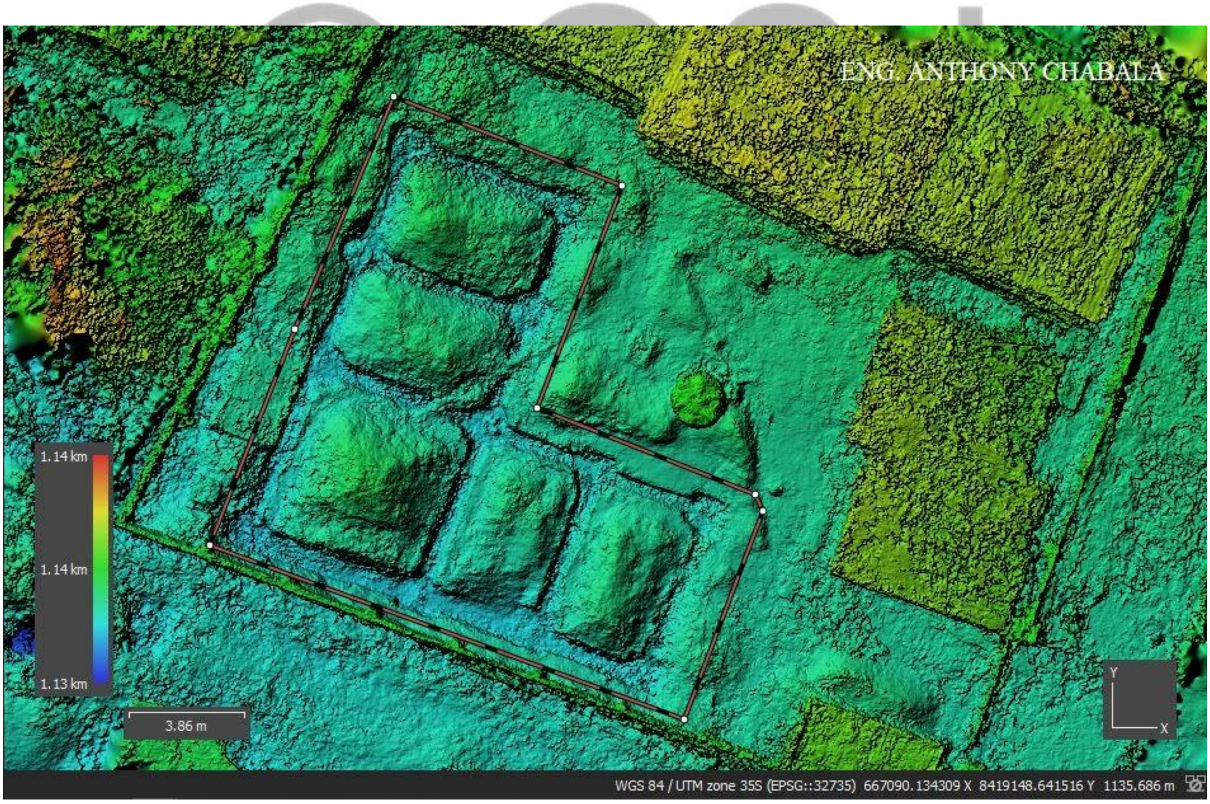

Figure 6: *A DEM for X, Y and Z coordinates of the project area as bound by the line. Footing put up with soil materials remaining only on the spaces where rooms are to be built.*

5.3 Shuttering and compacting, Survey 3

The third survey was the last survey. During this survey, a total of 502 JPG images were captured around 12:00PM and saved directly on the SD card that is slotted inside the drone on March 1, 2023. The movements and photographs being captured were done manually so as to have more control and avoid the drone from hitting into the powerlines close by.

On this visit, the project had advanced a step further and had reached shuttering and compacting.

Shuttering and compacting are two important steps in the process of building a two-story building (or more stories). Shuttering can be described as the process of building a formwork, or temporary structure, to give the concrete or masonry walls support while they are drying and setting. This formwork is usually made of timber or metal and is secured with screws or nails.

As for compacting, it is the process of compressing the soil beneath the foundation with a heavy roller and ensuring that it is well drained and uniform. This is essential as it ensures that the foundation is stable and can support the weight of the building.

In summary, these two steps are important to ensure that the building is strong and secure and able to withstand the weight of the two stories. Without proper shuttering and compaction, the building could suffer from structural damage or collapse.

The 502 images were first pre-processed in Agisoft Metashape to align them as has been the case for the duo prior stages. The survey images generated for this day are shown in Figures 7 and 8.

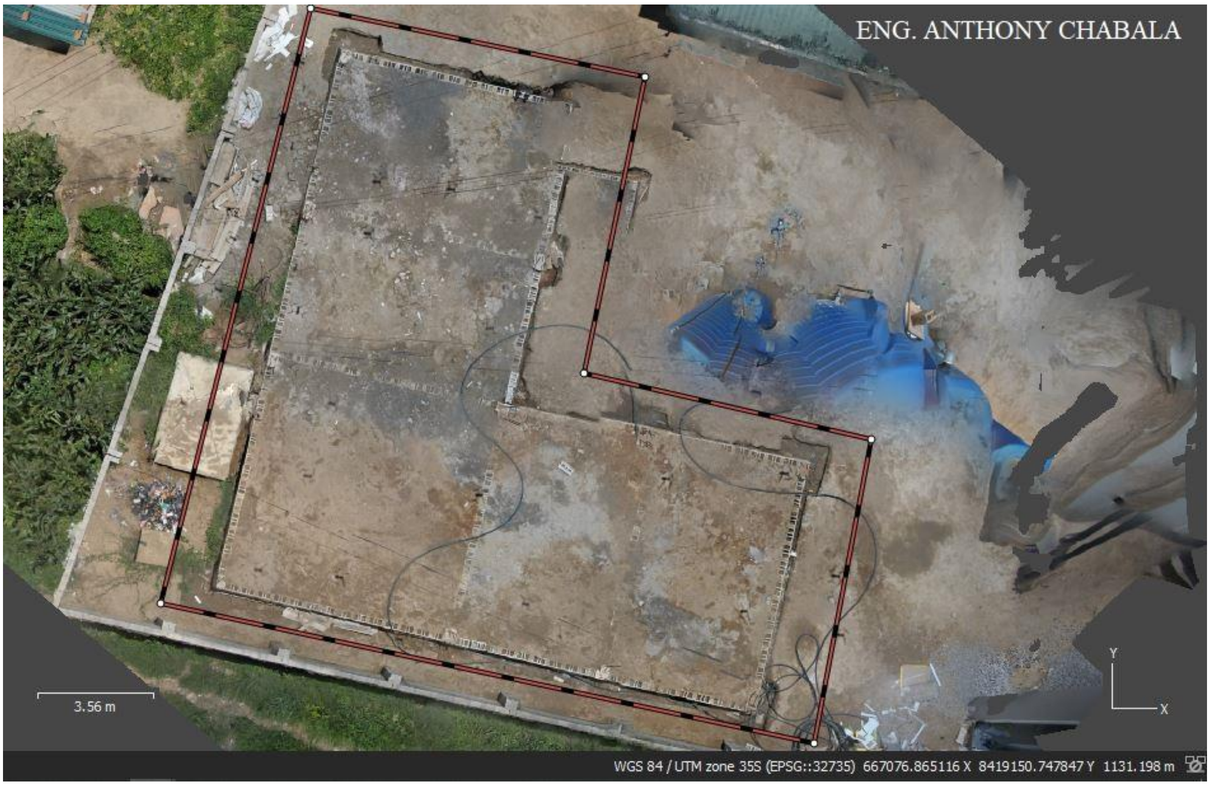

Figure 7: *Orthomosaic image made from stitching of 502 JPG images captured from the drone for shuttering and compaction stage. Notice that the image shows some blue smearing like colour on the outside of the delineated polygon. This was an error in the building of the image as the section outside the delineated polygon was not fully captured. The area of focus was the bounds of the polygon.*

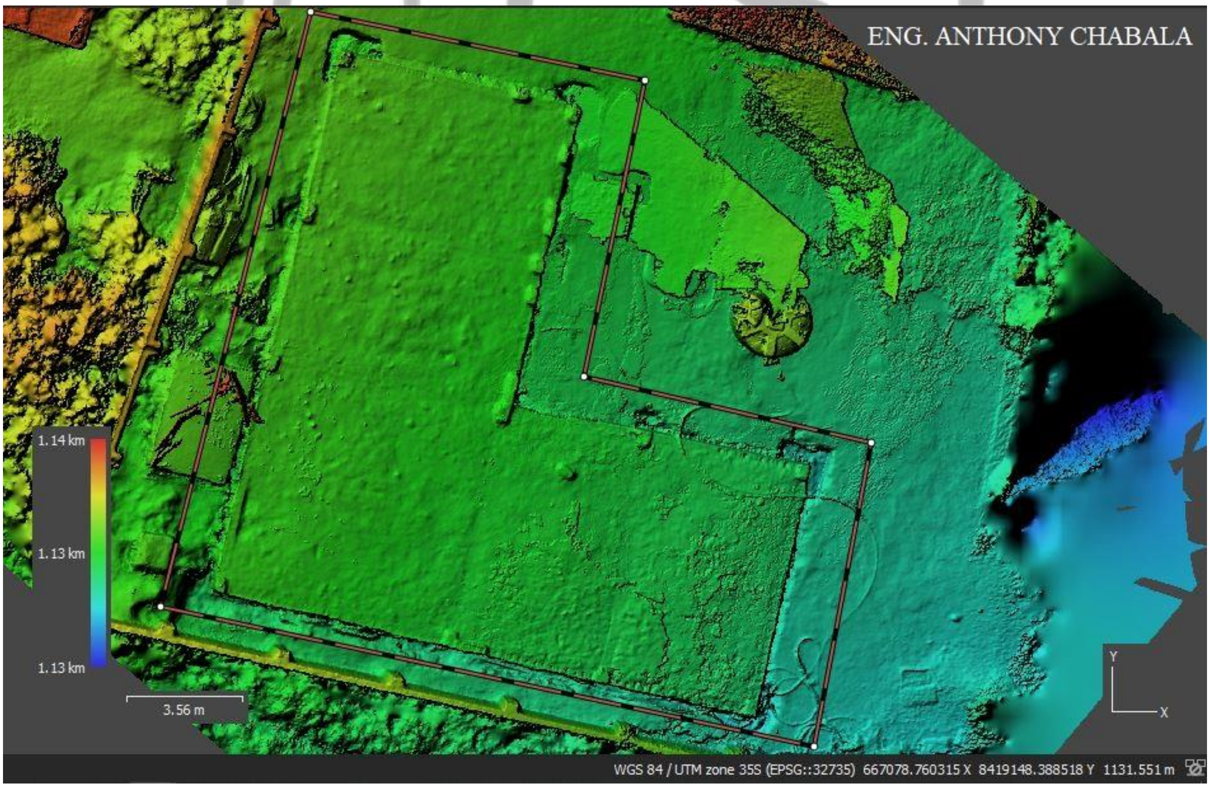

Figure 8: *A DEM for X, Y and Z coordinates of the project area as bound by the line. The rooms were no longer defined by the foundation pits. The surface was now flat. Notice that in the DEM, the tank that caused the blue smearing like effect could now be viewed in part.*

5.2 The Non-Technical Approach and Dashboard Creation

As already defined, the non-technical approach in this project refers to the material, time, labour, and accounting that went into this project in order to make the dashboard. Please note that the project was only monitored for three (3) phases as explained in the previous subsection.

The tables given are pivot tables that were used in succession to compile both the technical and non-technical data for the creation of a dashboard in monitoring and evaluating the project.

Table 2: *Relating costs to the phase/stage of the project.*

Project Phase	Sum of Total
1st-Drawing	K2,000.00
2nd-Setting	K1,000.00
3rd-Foundation	K4,000.00
4th-Footing	K28,282.80
5th-Box & Pillar Shuttering	K35,730.00
6th-Back fill and compact	K5,500.00
7th-Slab	K12,600.00
Grand Total	**K89,112.80**

The work monitored had 7 stages in all (Table 2 above). Table 2 is a pivot table that was made from specifically choosing two parameters, Project Phase and Sum of Costs. From this table, the largest cost was for the 5th project phase which was Box & Pillar Shuttering at K35,730.00, followed by the 4th project phase, which was Footing at K28,282.80. The 3rd project phase, which was Foundation cost K4,000.00, the 2nd project phase, which was Setting cost K1,000.00, the 6th project phase, which was Backfill and Compaction cost K5,500.00, the 7th project phase, which was Slab cost K12,600.00, and the 1st project phase, which was Drawing cost K2,000.00. The grand total for the project was K89,112.80.

A slicer used to control the phase of the project to be shown through 7 different buttons is given with its respective filtering buttons and title (Figure 9).

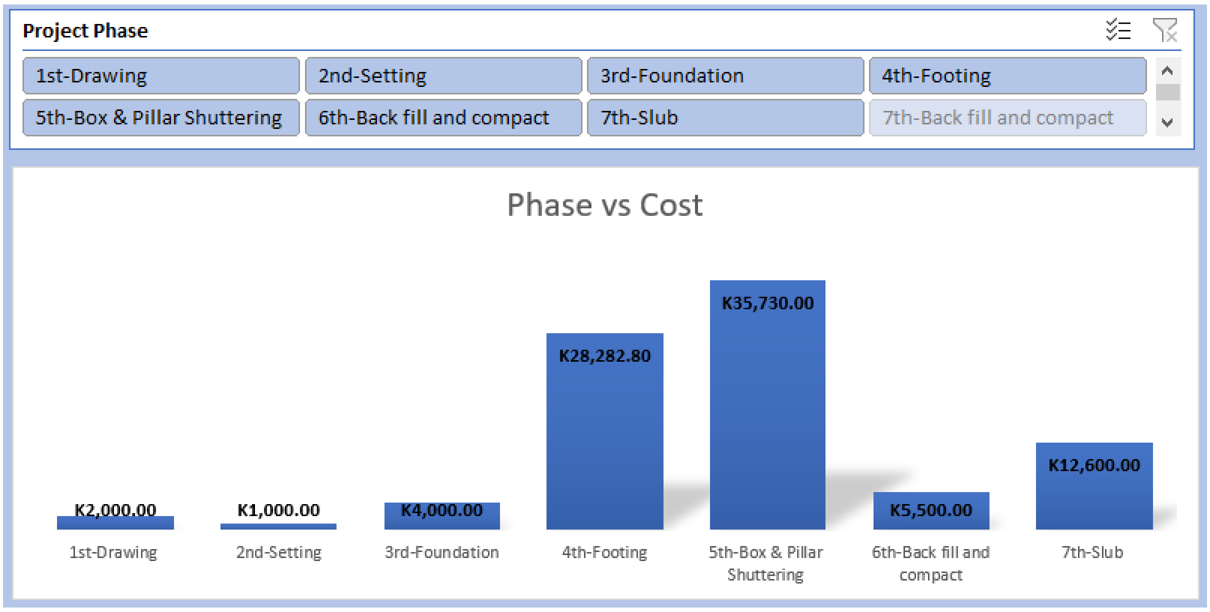

Figure 9: *A section of the dashboard showing a cost per phase relationship with its respective slicer.*

The next part of the dashboard was that containing a pie-chart, a slicer and a timeline chart. These two where connected to the chart to show how much was covered with respect to time.

The pivot table designed to connect these is given in Table 3 with its respective charts in Figure 10.

Table 3*: Expressing Item/Activity as a percentage cost of the overall project cost.*

Item/Activity	Total Cost Total	Percentage
Labour	K23,500.00	26.37%
Material	K2,250.00	2.52%
Material	K44,612.80	50.06%
Tools	K3,000.00	3.37%
Transport	K15,750.00	17.67%
Grand Total	**K89,112.80**	**100.00%**

The analysis reported that material was the largest cost, totalling K44,612.80, making up 50.06% of the grand total. Labour came in second, totalling K23,500.00 and making up 26.37% of the grand total. Transport came in third, totalling K15,750.00 making up 17.67% of the total. Tool were the least costly items, totalling K3,000.00 and making up 3.37% of the grand total.

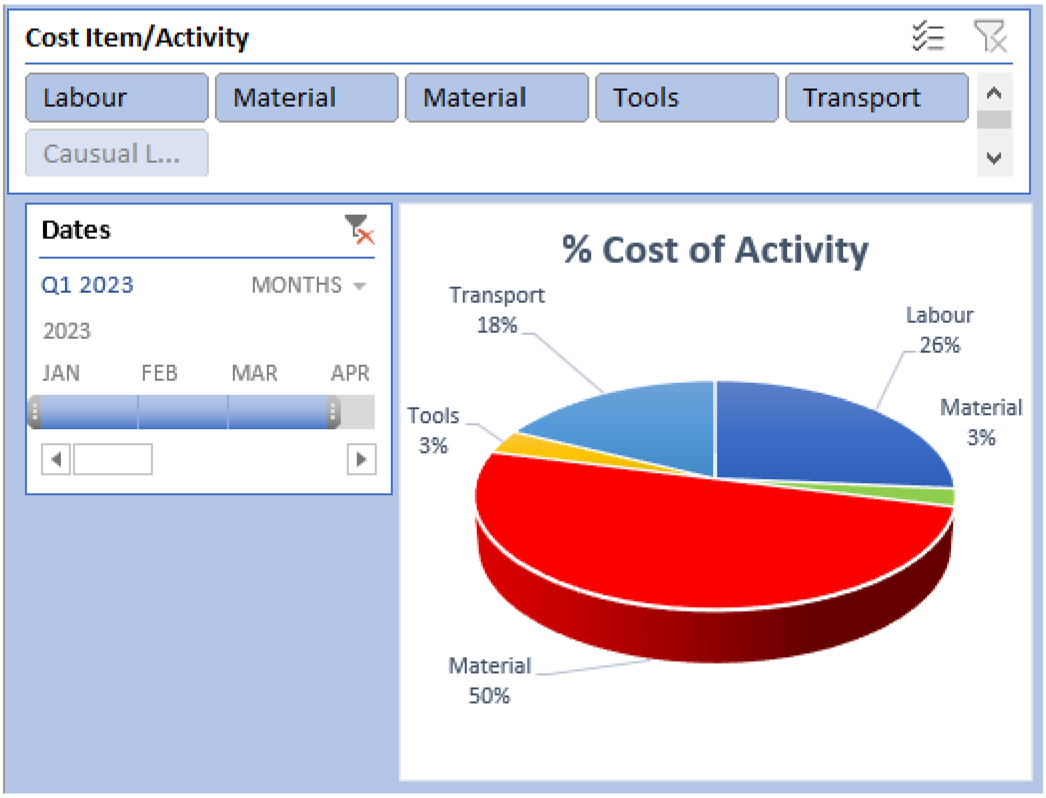

Figure 10: *A section of the dashboard showing the relationship of each item/ activity in pie chart form. This was meant to know which items/activities need control for the current or future projects. A slicer and timeline are also put to control individual or multiple elements of the charts.*

Finally, we had another pivot table that was created to showcase the different geospatial views. The table was created with links utilizing the XLOOKUP and IMAGE () functions to help visualise the images when analysing the various datasets. As was alluded to, XLOOKUP is a Microsoft Excel function that allows one to search for a value in a range of cells or an array and return a corresponding value or result from the same row or column. It can also be used to search for a value in the first column of a range and return a corresponding value from a specified column in the same row. Below is an image snipped from Microsoft Excel for an image linking table (Figure 11).

Date Captured	Image Type	Picture File	Picture Preview
Thursday, 5 January 2023	Orthomosaic 1	https://media.licc	
Thursday, 5 January 2023	DEM 1	https://media.licc	
Wednesday, 24 May 2023	Orthomosaic 2	https://media.licc	
Wednesday, 24 May 2023	DEM 2	https://media.licc	
Wednesday, 1 February 2023	Orthomosaic	https://media.licc	
Wednesday, 1 February 2023	DEM 3	https://media.licc	

Figure 11: *An image of a table made to connect with the images on the dashboard. This was meant to interchange the images for visual analysis of the progress of the project.*

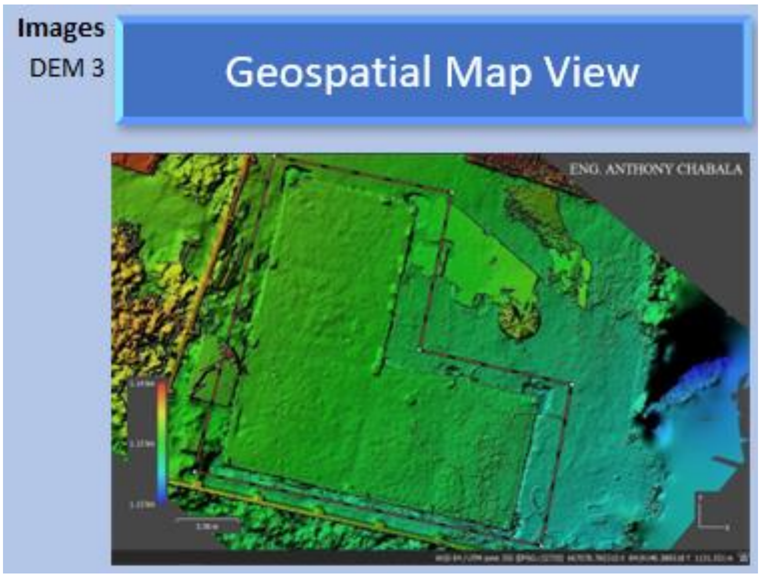

Figure 12: *Part of the dashboard with a geospatial map view in 2D. Under images is a word DEM 3. This is a pop downlist that gives all the images available for the progress of the project. In this case, DEM 3 indicates the phase/stage at which the project was terminated in order to meet the academic calendar of the university. Waiting for the completion of the project would mean delaying the submission of the work.*

5.3 Analysis by WBS Schedule Pro

The work breakdown structure (WBS) was essential in breaking down the complex projects into smaller and more manageable units. By breaking a project down into subprojects, tasks, subtasks, work packages and other elements, it becomes easier to identify and understand the individual components that made up the project (Satzinger et al., 2012). The work WBS for this work was made as is given in Figure 13.

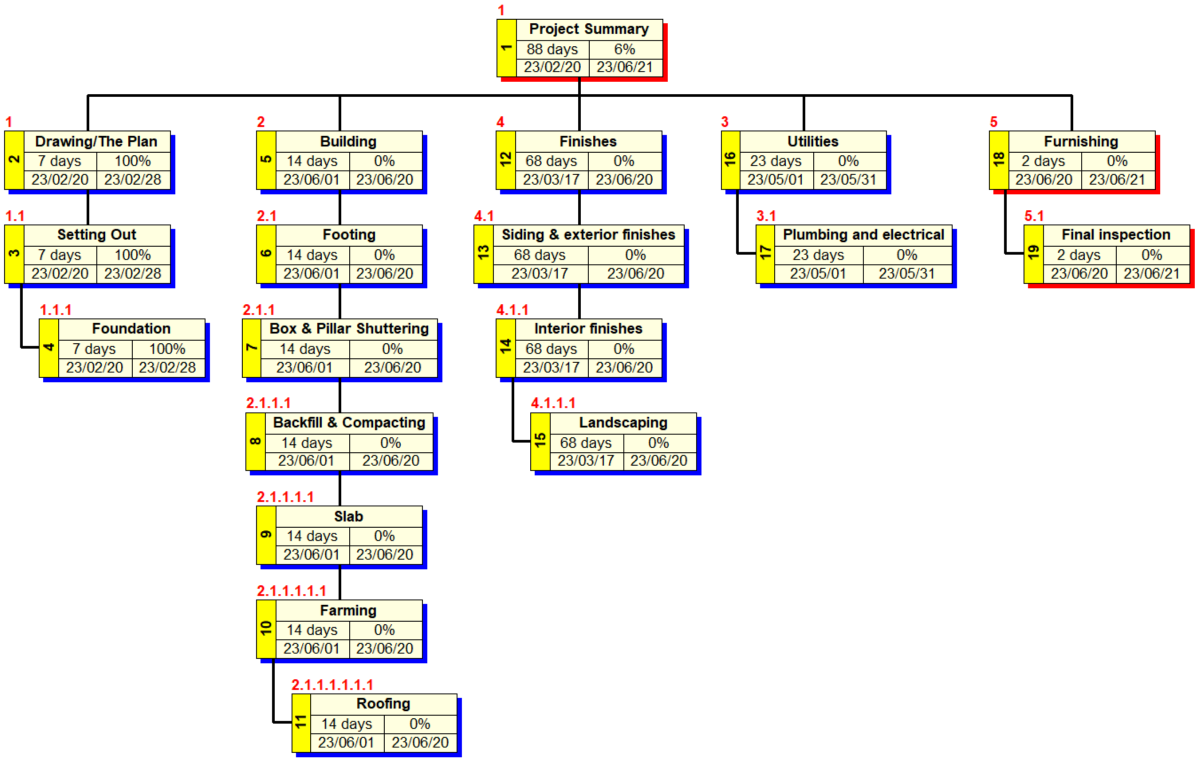

Figure 13: *A work WBS developed in WBS Schedule Pro with 5 principal activities, that is, the drawing, building, furnishing, utilities and furnishing. Below are tasks and WPs.*

The WBS together with a network diagram and task sheet developded in WBS Schedule Pro were able to help and easen that task of identifying project's tasks and activities, their interdependencies, and the sequence in which they must be completed. Furthermore, critical tasks and potential areas for improvement were seen.

A gantt chart was also automatically generated and additionally to this work, a full glimpse of the dashboard is also shared right after the gantt chart, Figures 14 and 15.

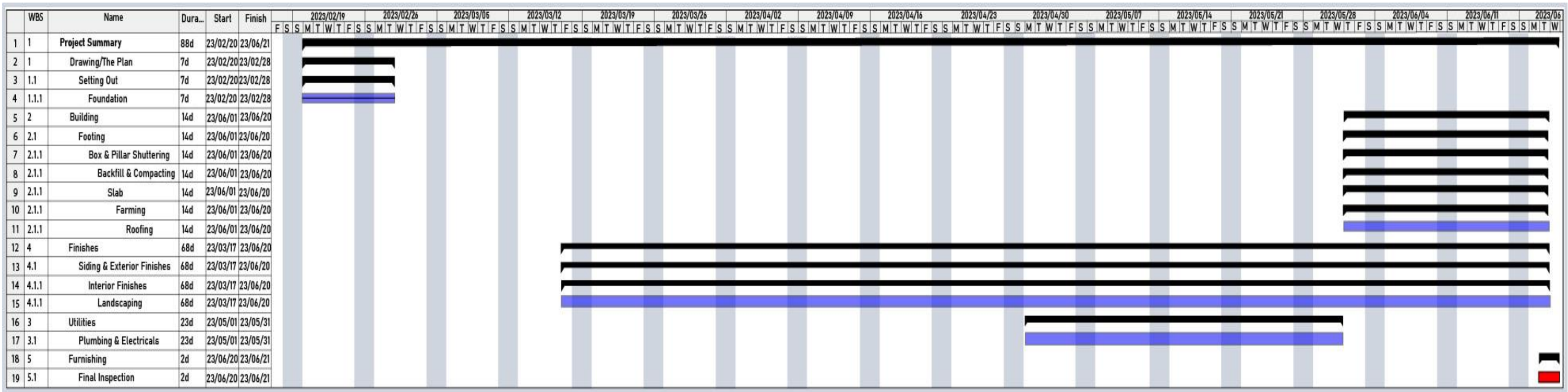

Figure 14: *Gantt chart of the entire project. Please note that the project monitoring and evaluation ended on the Slab phase. The idea was to show the application of dashboards to monitoring and evaluation exercises for outdoor construction projects. The Gantt chart reflects the 5 principal activities given in the WBS above, that is, the drawing, building, furnishing, utilities and furnishing. This also has smaller components or breakdowns such as tasks and WPs.*

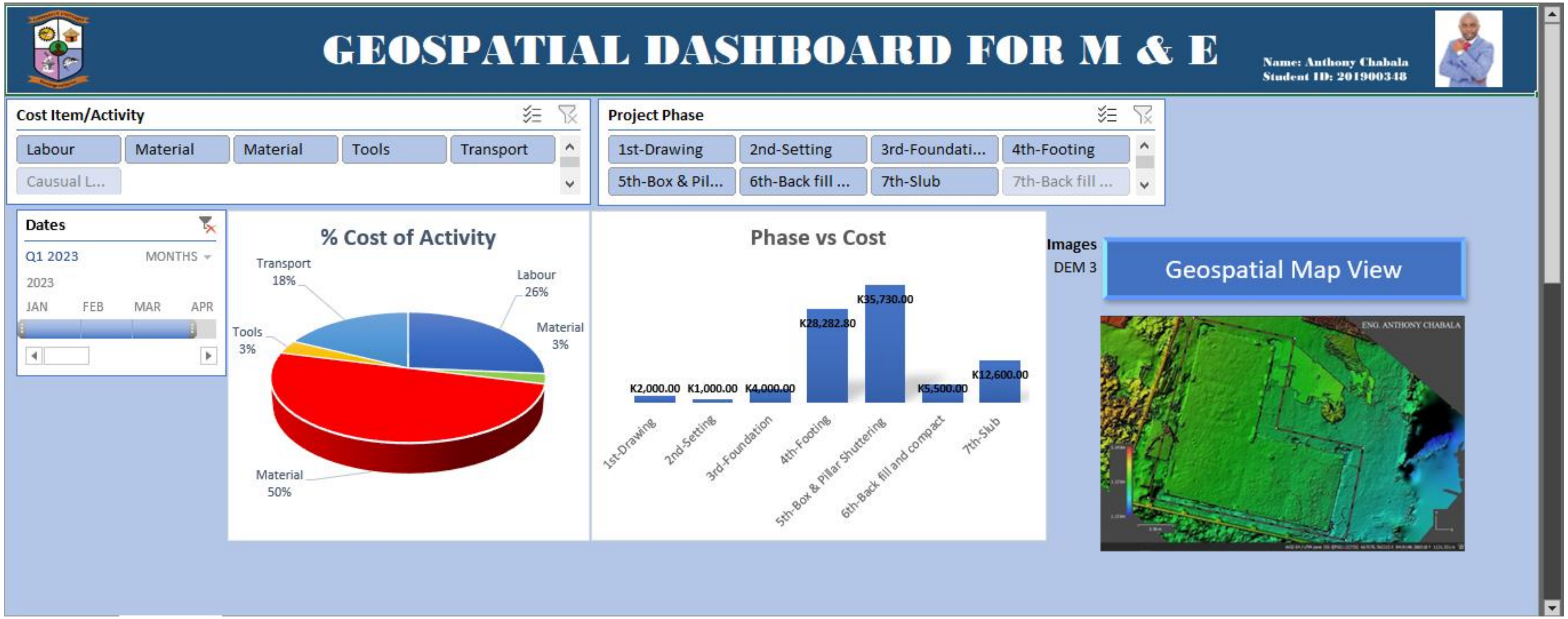

Figure 155: *The geospatial dashboard showing three (3) graphical displays and controlling slicers*

5.4 Dimension Comparisons and Change Detection Analysis

In this section, we present a comprehensive assessment of dimensional congruence and change detection within the architectural context of Sweet Home 3D. The objective of this analysis is to evaluate the reliability and precision of our approach through a meticulous juxtaposition of planned dimensions against drone-measured dimensions at the slab level. The linear measurements were conducted utilizing the Agisoft Metashape tool, as delineated in Figure 14.

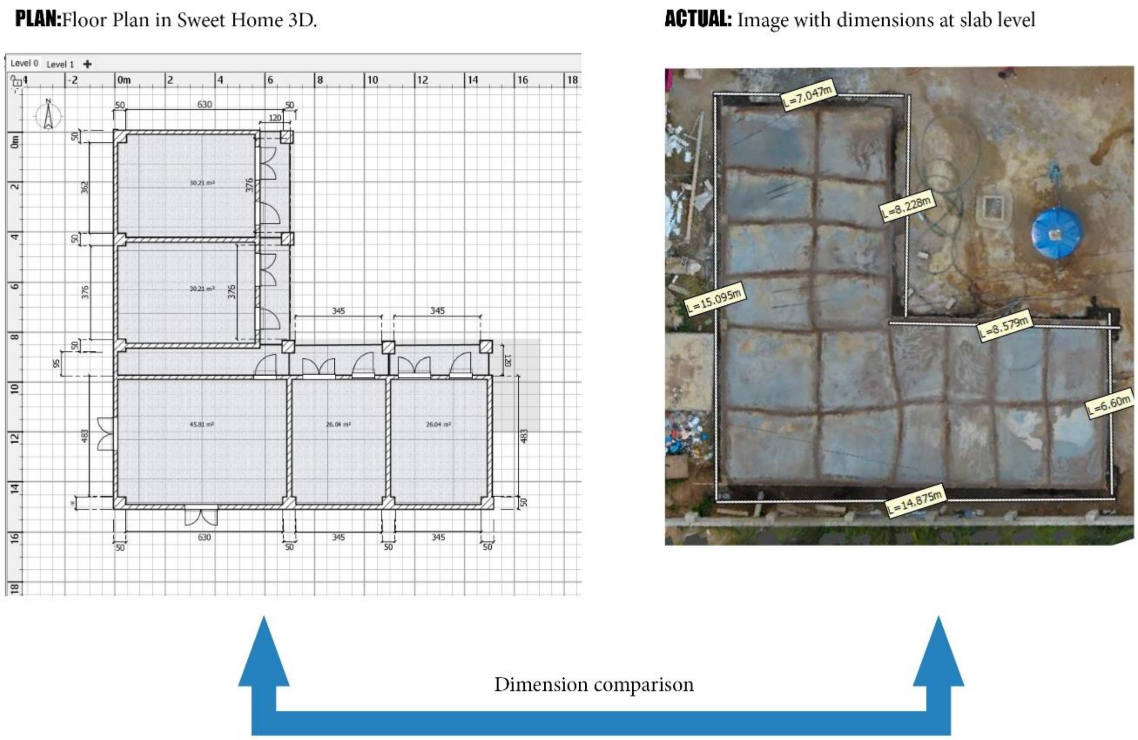

Figure 16: *Comparative analysis of architectural plan versus actual measurements.*

Figure 14 graphically illustrates the examination of the alignment between the architectural plan and empirical measurements, a process executed with precision through the utilization of the Agisoft Metashape measurement tool.

This visual representation is complemented by a tabular exposition in Table 4, wherein the dimensions at the plan level are meticulously contrasted with the corresponding actual measured dimensions. The six exterior walls are distinctly designated in an anticlockwise orientation, commencing from the North End Wall and traversing through to the East End Top Wall.

Table 4: *: Discrepancy analysis between plan-level and actual measured dimensions*

Description of wall	**Measurements (m)**		
	On Plan (P)	*Actual from Drone(A)*	*Difference (P-A)*
North End	7.30	7.05	+0.25
West End	15.16	15.10	+0.06
South End	15.20	14.88	+0.32
East End Bottom	6.53	6.60	- 0.07
Central	8.15	8.58	- 0.43
East End Top	8.63	8.23	+0.40
Total (Perimeter)	**60.97**	**60.44**	**Mean = +0.088**

The computed mean error for the exterior wall measurements stands at 0.088 meters, signifying a notable level of precision and accuracy. This outcome engenders confidence in the efficacy of our methodology for scrutinizing dimensional compliance, deviations, and craftsmanship quality.

Furthermore, the seamless integration of Monitoring and Evaluation (M&E) expertise with geospatial technology enabled the detection of changes within the project environment—a process commonly referred to as change detection. Specifically, we contrasted two distinct developmental phases: the foundational stage and the decking phase, denoted as Level 1 in Sweet Home 3D. The ground floor is designated as Level 0 (as depicted in Figure 15).

These discrete project phases are exemplified through linear cross-sectional profiles that delineate variations in elevations and ground levels. Notably, the comparison between the foundation phase and the decking phase (North End in Figure 15) reveals a vertical shift of precisely 3 meters, corroborated by geospatial computations, aligning seamlessly with the on-site measurements. This vertical shift encompasses walls of 2.7 meters and a decking thickness of 0.3 meters.

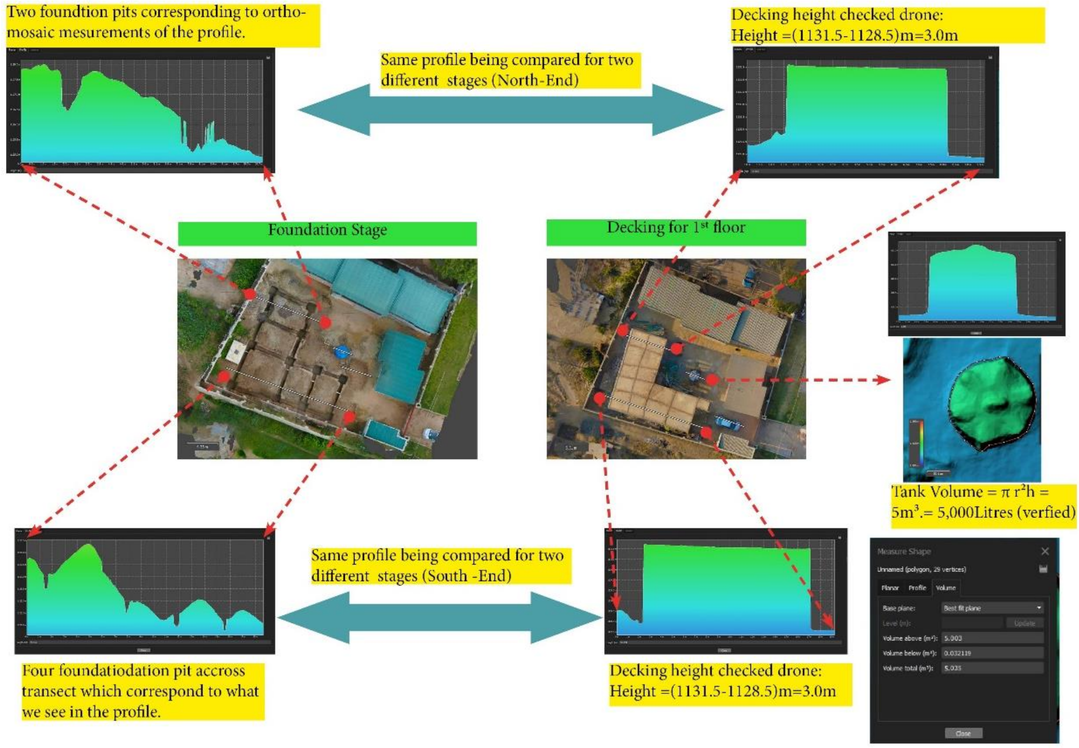

Figure 17: *Visual representation of foundation and decking phases, highlighting detected changes.*

Additionally, we conducted a rigorous linear and volumetric analysis using a 5,000-litre tank situated on the project site for validation of our process. The volumetric computations, as portrayed in Figure 15 on the right-hand side, culminated in an estimated volume of 5,035-litre, a testament to the precision and reliability of our geospatial analysis toolset.

6. Pictorial Flow Chart

The construction of the two-story boarding house was a multifaceted endeavor that followed a systematic progression, commencing with the generation of architectural blueprints and advancing through several key phases. These phases encompassed setting out, foundation and footing preparation, box and pillar shuttering, backfilling and compaction, slab installation, culminating in wall and pillar erection and the initiation of decking.

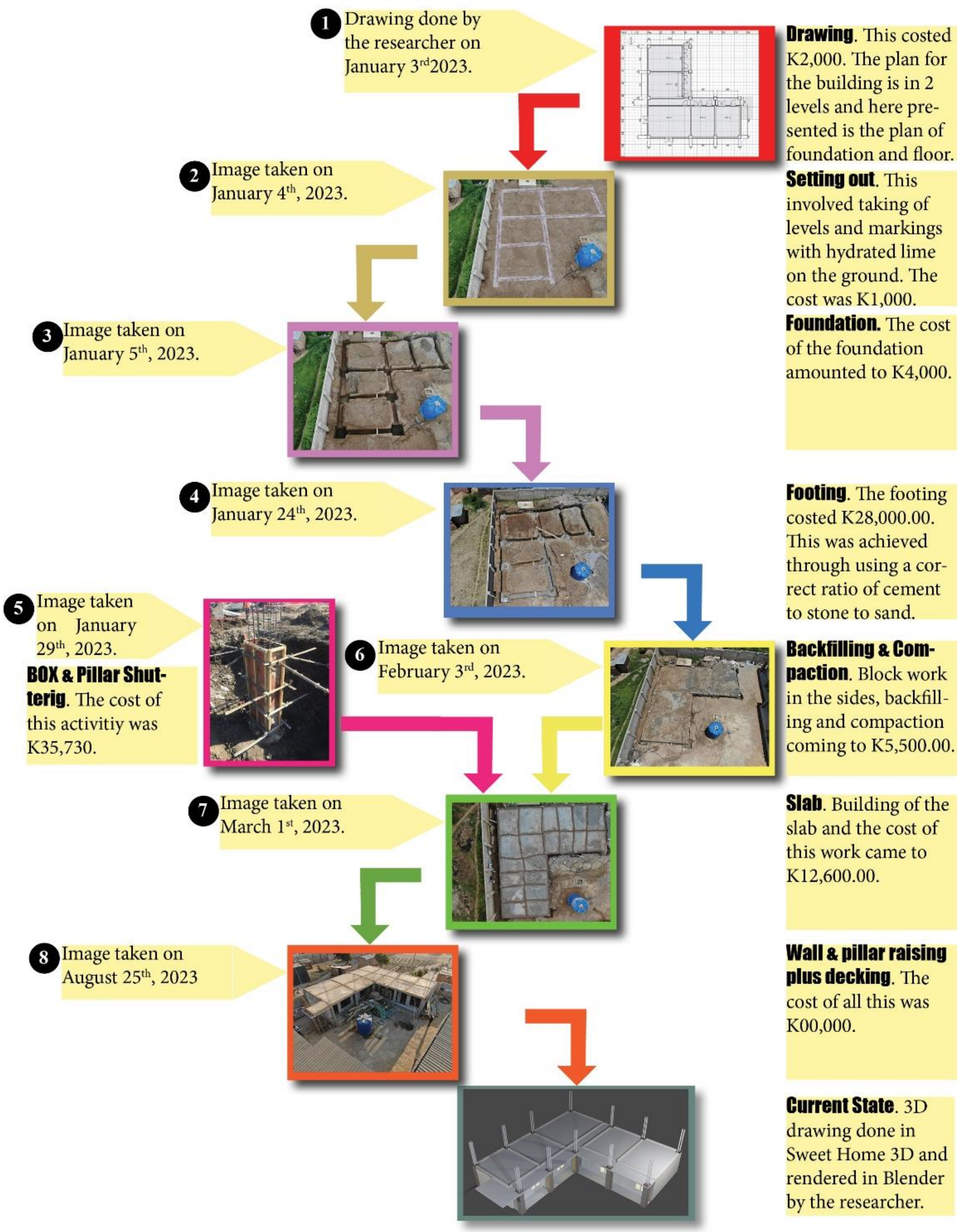

Figure 18*: Sequential evolution of two-story boarding house construction.*

Figure 16 visually depicts the stepwise evolution of the two-story boarding house construction, capturing the transition from initial architectural blueprints to the evolving structure-in-progress. It is worth noting that our discussion in this paper does not encompass the costs associated with stage 8 of construction. This omission arises due to an unfortunate circumstance in which certain receipts pertinent to this phase were lost by the structure's owner, thereby affecting our ability to accurately track these expenditures.

7. Discussion

The results of our research showcase the transformative potential of geospatial dashboards in the realm of monitoring and evaluation (M&E) for outdoor construction projects. This discussion delves into the key implications and insights derived from our study.

7.1 Integration of Geospatial Data

One of the paramount findings of our research is the seamless integration of geospatial data into dynamic Microsoft Excel dashboards. This integration has proven instrumental in enhancing the monitoring and evaluation of outdoor construction projects. By employing diverse geospatial datasets, including orthomosaic, digital surface models, and geo-referenced aerial images, we have achieved a comprehensive and real-time view of project progress. This holistic approach enables stakeholders to gain a deeper understanding of construction dynamics, facilitating informed decision-making.

7.2 Cost Analysis and Visualization

Our research demonstrates the power of geospatial dashboards in cost analysis. Through the incorporation of pivot tables and graphical representations, we have effectively visualized project costs across various phases. Material costs, labor expenses, and transportation expenditures have been meticulously tracked and presented, allowing for clear identification of cost drivers and areas for optimization. This cost transparency empowers project managers to make strategic financial decisions, ultimately contributing to efficient resource allocation.

7.3 Dimensional Accuracy and Quality Assurance

Dimensional accuracy is a cornerstone of successful construction projects. Our research has exemplified the precision of geospatial tools in assessing dimensional congruence. By comparing planned dimensions with drone-measured dimensions at the slab level, we achieved a remarkable mean error of 0.088 meters. This level of accuracy instills confidence in our methodology and highlights its applicability for scrutinizing dimensional compliance, identifying deviations, and ensuring high-quality workmanship. This capability holds immense value in ensuring that construction projects adhere to design specifications.

7.4 Change Detection and Progress Monitoring

Change detection analysis has emerged as a pivotal aspect of our research. By juxtaposing two distinct project phases—the foundational stage and the decking phase—we have effectively monitored and visualized alterations in the construction environment. The precise vertical shift of 3 meters, corroborated by geospatial computations and on-site measurements, underscores the reliability of our approach. This ability to track changes over time enhances project oversight and enables swift response to deviations from the original plan.

7.5 Limitations and Ethical Considerations

While our research underscores the benefits of geospatial dashboards, it is essential to acknowledge their limitations. Drone imagery may be constrained by factors such as resolution, weather conditions, obstructions, and data security concerns. These limitations necessitate careful planning and ethical handling of imagery to ensure reliable results.

8. Conclusion

This research has explored the promising potential of geospatial dashboards as a transformative tool for monitoring and evaluating outdoor construction projects. Our investigation has delved into the fusion of drone imagery with Microsoft Excel dashboards, shedding light on the invaluable benefits this synergy can bring to the construction industry.

Through rigorous technical and non-technical approaches, we have demonstrated the practicality of this integration. The technical aspect encompassed drone operation, image capture, and the meticulous process of image stitching in Agisoft Metashape. The non-technical facet involved meticulous tracking of material, time, labour, and financial resources, all culminating in the creation of a dynamic geospatial dashboard.

The results of this study have illuminated the multifaceted advantages of geospatial dashboards. These platforms have proven their capacity to provide profound insights into spatial data collected through progressive imagery reporting. Our approach has empowered stakeholders with real-time, data-driven decision-making capabilities, effectively enhancing project oversight and management.

Furthermore, the utilization of work breakdown structures (WBS) and Gantt charts has emerged as an essential strategy for deconstructing complex projects into manageable units. These tools enable the identification of task dependencies and sequencing, ensuring a structured and efficient project workflow.

The cost analysis has offered a comprehensive view of project expenditure, with material costs representing the most substantial portion. By quantifying costs and visualizing their allocation, project managers can optimize resource allocation and control expenses, ultimately preventing budget overruns.

In essence, this research has provided a tangible and insightful case study demonstrating the practical application of geospatial dashboards in the construction industry. It serves as a roadmap for industry professionals seeking to harness the power of geospatial technology for monitoring and evaluating outdoor construction projects. By leveraging these tools, construction projects can benefit from enhanced accuracy, efficiency, and budgetary control.

As the construction industry continues its journey of innovation and digital transformation, the integration of geospatial dashboards is poised to play an increasingly vital role. With careful planning, attention to resolution and data security, and a commitment to ethical drone usage, geospatial dashboards hold the potential to revolutionize the way we approach and execute outdoor construction projects, paving the way for a more precise, cost-effective, and data-informed future in the construction sector.

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