PAPER 9

FROM THEN TO NOW: A VIEW OF NMBM'S PROJECT MANAGEMENT ADVANCEMENT SINCE THE 1800'S

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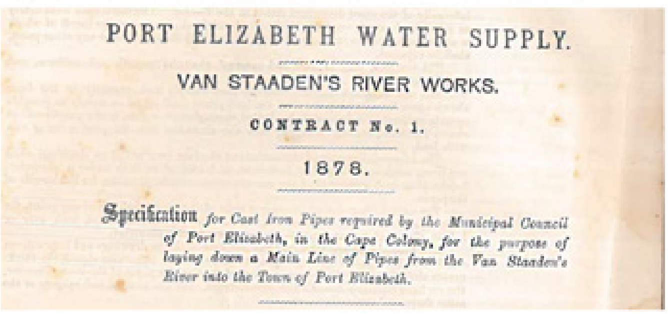
ABSTRACT

Shortly before 1880, the city engineer of the then Port Elizabeth, now Gqeberha, would set off on a three-day horse ride to get to the construction site of what would become the city's first proper source of water. It would then make sense that the contract document includes specifications and items in the bill of quantities for stabling and feed for the engineer's horse. Similarly, in modern documents you can find accommodations for the engineer's vehicle in a construction contract.

This paper will explore how project management has progressed within the municipality. It will also discuss how contracts have evolved or in some cases stayed the same, by comparing modern practices to actual contract documents from the 1800's. It will highlight how NMBM has since applied pioneering approaches to deal with the challenging, high-collaborative interaction required between all stakeholders involved in professional services. In recent years, innovative technologies have since revolutionised and been introduced in the Architecture, Engineering and Construction (AEC) industry. With these developments, there have been advancements in contract administration and management of projects within the built environment.

An example of the successful integration of Industry 4.0 technologies by the municipality was the VR experience used for the Coegakop Water Treatment Works. The technologies used played a fundamental part of the municipality's submission for securing funds from national government. It facilitated by enabling decision-makers to have a walkthrough and understand the proposed facility. It was used in the initial tender briefing for prospective bidders, which was a first for the municipality. The simulation helped refine complex parts of the design, undertake clash detection, and enhanced the design in terms of constructability considerations. Opportunity exists to further extend the uses of this technology by the integration of building information modelling (BIM). The 3D BIM model acts as a common portal where all stakeholders can work simultaneously and share information, and the changes are updated in all domains automatically. This paper will explore the almost inexhaustible list of functionalities this technology has throughout the project and asset life cycle.

Finally, all the above information is fed into a water management system and a newly developed Scada system that enhances operational efficiencies and network control.


PORT ELIZABETH WATER SUPPLY.

VAN STAADEN'S RIVER WORKS.

CONTRACT No. 1.

1878.

Specification *for Cast Iron Pipes required by the Municipal Council of Port Elizabeth, in the Cape Colony, for the purpose of laying down a Main Line of Pipes from the Van Staden's River into the Town of Port Elizabeth.*

FIGURE 1: *Cover page of Contract No. 1 for the Van Stadens River Works.*

1. INTRODUCTION

There is ample evidence, spanning many centuries, that displays the human's ability to execute complex construction projects. Crafting potential accelerated through the development of hand tools, unlocking more building materials.

One could assume that it would have been impossible to place the tip on the Egyptian pyramids if there had been no specifications for the building blocks used all the way from the foundations. Like the Great Wall of China, these projects were executed with limited resources available at the time, mostly relying on manual labour or animal powered machinery. These projects required the organisation of labour, management of resources, time, and cost, whilst applying mathematical principles as well as basic surveying skills. This laid the groundworks for modern construction management.

More complex structures followed. Curves, beams, columns, domes, and cantilevers required some structural analysis. Teams became more complex as carpenters; glass makers and other disciplines joined the construction team.

Later practices would continue to be standardised and even regulated by professional bodies. Construction management would become a defined profession with specialised tertiary education available globally.

2. EARLY DAYS

During the late 1800's the fast-expanding town of Port Elizabeth was desperately seeking a reliable source of water. With no engineer employed to the council, they sought assistance from the local colony hydraulic engineer. He would investigate possible proposals and submit his feasibility report. This report would then enable the town council to prospect for a suitable engineer back in England. This engineer would then be shipped to the town to complete the proposed designs and oversee the implementation of the project.

The entire Van Stadens River Works Contract No. 1, as indicated by Figure 1, was handwritten by the appointed engineer. This included the specifications, Bill of Quantities (BoQ), drawings, and general conditions of contract. Figure 2 indicates how complex the content of the contract document already was during the 1800's. It included multiple topics that are still essential today like contract duration, quality control, clarifies liability and risk, describes limits of responsibility. There was a clause that deals with the "interference with traffic" during a time when everyone on site used ox wagons or horses. Even some topics like the preservation of game, which has become a lot more specialised. The first few contracts would have specific purposes and didn't necessarily conform to a bigger holistic view, water was needed to keep the city alive. Extra water would provide security for the city to grow.

The town council would then advertise the project, where contractors would complete a form of tender and schedule of quantities as indicated by Figure 3. Once again laying the groundwork for the way the city would manage contracts from that point onwards.

At NMBM today, large developmental projects are typically still conceptualised by municipal engineering staff. The development of infrastructure is guided by multiple avenues of information or requirements. For instance, water infrastructure is developed based on the Water Master Plan, which in turn is informed by the Water Services Development Plan (WSDP). This document must follow the Spatial Development Framework (SDF) which through the town planning division guides total development proposals holistically. This process can also be altered when the municipality must react to external risks like drought or other natural disaster. Usually, the next step is appointing a Professional Service Provider (PSP) to formulate the concept into a practically executable project whilst ensuring it conforms to all applicable standards and regulations. The project tender will then be advertised for a contractor to make an offer on. The appointed contractor executes the project under the watch full eye of the project engineer and NMBM engineer.

Up until the late 1990's Nelson Mandela Bay municipality's water division would still execute large scale projects with internal engineering staff managing all administrative, engineering and procurement aspects including construction supervision.

3. HISTORIC CONTRACTS

Life has drastically changed since 1878 for any role player in the construction industry, including the clients or beneficiaries. Technological advancements have seen exponential growth, and no construction project seems unattainable if the resources match the ambitions.

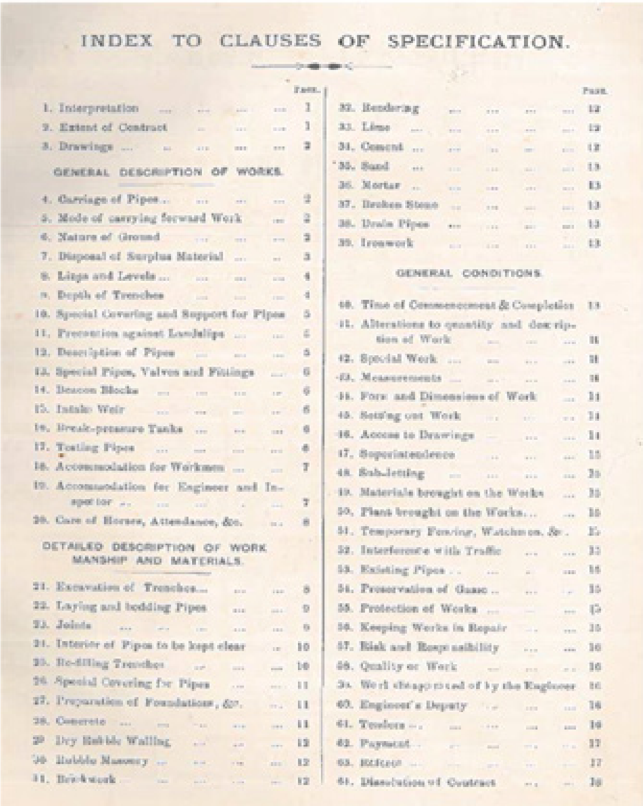


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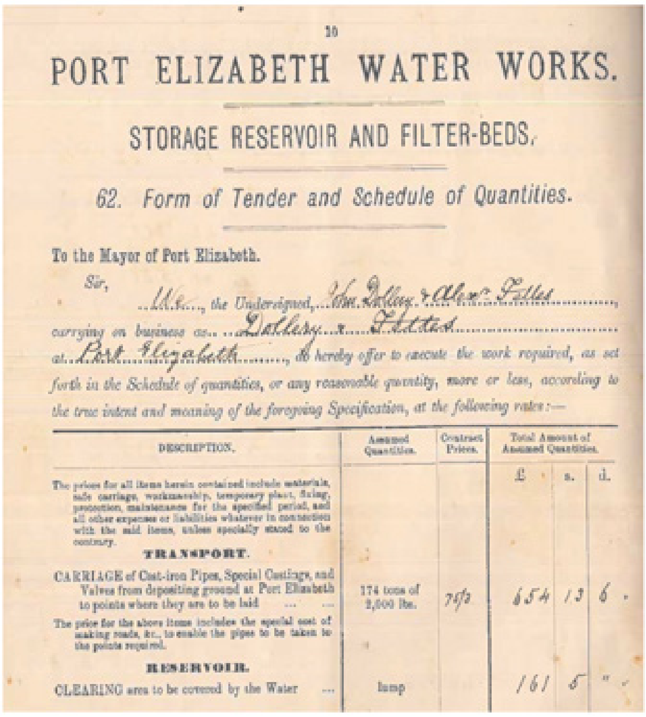
FIGURE 2: *Index page of Contract No. 2 Van Stadens River Water Works 1878.*

One would then think that there would be a drastic difference when comparing a construction contract from a 150 years ago to a modern one. However, Figure 2 indicates that during the late 1800's the Council contract documents already satisfied many of the fundamental first principles of construction management. Of course, every aspect has become more specialised and regulated but it is an evolution based on these core fundamentals. The importance of foundational knowledge is highlighted by the practise of teaching mathematics manually before using the aid of calculators or computers.

The historic contract document included specifications, a Bill of Quantities, drawings, and general condition of contract. Some other interesting clauses that have slightly changed are indicated below.

"20. Care of Horses, Attendance & c. – All horses whether belonging to the Council or other parties, used by the Engineer or Inspector in travelling to or from the works, shall, while off-saddled at the works, be under the care of the Contractor, who shall be responsible to the Council or other owners thereof for their safe keeping and proper and sufficient feeding and grooming". It continues "The horses shall have the best forage and water, proper litter, and every requisite attention. The Contractor shall see to the transport of all food and other necessities required to be sent up from Port Elizabeth for the personal use of the Inspector or Engineer, provided such shall not require special means of conveyance."



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PORT ELIZABETH WATER WORKS.

STORAGE RESERVOIR AND FILTER-BEDS.

62. Form of Tender and Schedule of Quantities.

To the Mayor of Port Elizabeth.

Sir,

...We..., the Undersigned, ...[illegible]...

carrying on business as ...[illegible]...

at ...Port Elizabeth..., do hereby offer to execute the work required, as set forth in the Schedule of quantities, or any reasonable quantity, more or less, according to the true intent and meaning of the foregoing Specification, at the following rates:—

DESCRIPTION.	Assumed Quantities.	Contract Prices.	Total Amount of Assumed Quantities. £	s.	d.
The prices for all items herein contained include materials, safe carriage, workmanship, temporary plant, fixing, protection, maintenance for the specified period, and all other expenses or liabilities whatever in connection with the said items, unless specially stated to the contrary.					
TRANSPORT.					
CARRIAGE of Cast-iron Pipes, Special Castings, and Valves from depositing ground at Port Elizabeth to points where they are to be laid ...	174 tons of 2,000 lbs.	75/3	654	13	6
The price for the above items includes the special cost of making roads, &c., to enable the pipes to be taken to the points required.					
RESERVOIR.					
CLEARING area to be covered by the Water ...	lump		161	5	"

FIGURE 3: *Form of Tender & Schedule of Quantities 1878*

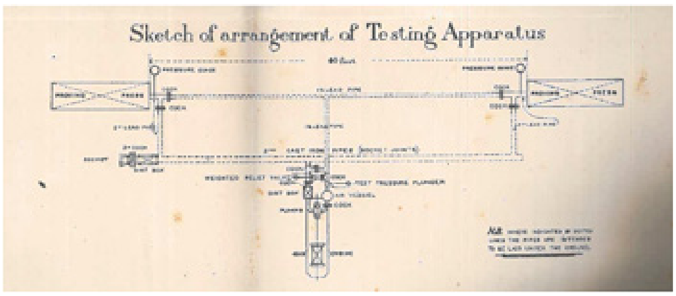

FIGURE 4: *Testing apparatus indicating the importance of quality control in 1878*

Modern contracts also have allowances that provide some necessary accommodations for the day-to-day site staff. Site offices and parking for vehicles, these can even be more specified to include air-conditioning, internet services and a cell phone. In most of the early contracts the contractor was also responsible to immediately start the construction of a telephone line from the construction site that went straight to the city engineer's office. This was implemented to ensure that the engineer could immediately be notified of any on site challenges. The telephone line would then remain in place for the municipality's operational staff who would phone the engineer with any concerns identified while inspecting the pipeline on horseback. Communication is another critical aspect of project execution that has never disappeared. Nowadays it is not uncommon to have a communication expert in project meetings, especially if the project affects service delivery. Social media is a powerful tool when effectively utilised.

Quality control already featured in the 1800's contract specifications and it is obvious that it was a very important topic for the engineer at the time. Quality of workmanship, materials and procedures were clearly defined as well as with whom the responsibility lies. At the time of the first major construction contract, the absence of a harbour in Port Elizabeth presented significant risk to safely transport the cast iron pipes onshore from the ships who were anchored out in the bay. Then followed additional risks to transport the pipes to site over mountains and through streams via ox wagon. Manhandling of the pipes could no be hidden as a testing apparatus, as per Figure 4, was to be constructed to ensure the pipes were not cracked and could withstand the operational pressure. All this risk was clearly made the responsibility of the contractor in the contract specification.

By 1965, the quality control specification would include testing by an independent person. During recent bulk water pipeline construction projects, NMBM appointed an independent PSP specifically qualified to execute stringent quality control on important elements of pipeline construction. For instance, the approving of welding procedures, welds and pipe fabrication, approving coating systems and applications thereof as well as approval of cement mortar lining. A unique quality management system is developed for each project.

Some components have even come and gone like in the second Churchill bulk water pipeline contract specifications in 1965 where it was necessary for the following clause, "48. Prison labour – Prison or convict labour shall not be employed on the works or engaged thereon in any capacity or manner whatsoever". So growing pressure to align with international human rights standards could affect some components of the contract document. There are actually numerous factors that have contributed to the evolution of the contract document over time.

4. WHAT DRIVES CHANGE?

So, it's clear that some of the important fundamentals have been established for a very long time. However, they never remained the same. Some aspects that influence the evolution of construction management are:

a) Regulation changes

As previously mentioned, the development of water related infrastructure is guided by the WSDP. The Water Services Act 108 of 1997 mandates that the Water Services Authority develop WSDP's. This act together with the National Water Act of 1998 provides a regulatory framework that establishes national standards as well as provides for the management and conservation of water resources. Regulatory requirements like water use licensing can affect a project's commencement date and as such must be sufficiently considered to ensure efficient project execution.

a) Environmental considerations

The historic contracts did address environmental issues, however, they focused more on poaching of local game. In modern times the environmental impacts of projects are regulated, and noncompliance can result in serious consequences. This component has become a critical part of modern construction and has the potential to make a project unfeasible. There is also an increasing consideration for sustainability, energy efficiency, green practices, and waste reduction in modern projects.

b) Standardization

Standardization has multiple benefits; it allows for repeatability in processes and reduces the likelihood of inconsistencies. Standardized templates emerged that sought to streamline the contractual process. The construction industry in south Africa is regulated by the Construction Industry Development Board (CIDB) and companies that are registered with the CIDB receive a grading. Registration is mandatory if they aspire to participate in the construction of public sector projects. The CIDB limits the choice of forms of contract to the following recommendations to ensure standardization.

- International Federation of Consulting Engineers (FIDIC)
- General Conditions of Contract for Construction Works (GCC)
- JBCC series, and
- NEC family of standard contracts

The GCC is the most used form of contract in South Africa and plays a major role in defining responsibilities, rights, and risk allocation.

Many municipalities have developed a comprehensive set of municipal standards or building codes. These regulations are mandatory for developing services or property that fall within the area of authority of the said municipality. This will prescribe acceptable practices as well as approve materials for use, aiming to ensure efficient operations of municipal services as well as safeguarding the wellbeing of the residents.

c) Health and safety

There have been remarkable improvements to health and safety considerations from the 1800's to today, driven by increased awareness of workplace hazards, legislative changes and technological advancements. Historically workers had to sometimes endure hazardous conditions with little to no protective equipment and no proper safety protocols in place. Today it is considered an integral part of the construction project and requires the appointment of a specialist who is responsible for developing a project specific Health, Safety and Environmental (HSE) plan as well as monitoring compliance of the plan throughout the construction activities.

d) Risk allocation

As indicated previously with the transportation of pipes on the Van Stadens River project, a great amount of risk was placed on the contractor. Modern contracts aim for a fair distribution of risk.

One of the key features of the GCC is to apportion the risk based on the party best suited to deal with it. It also addresses liabilities and latent defects periods, which are important to clearly define before project commencement so that the risk can be allocated to the responsible party.

e) Legal precedents

Sometimes the unforeseen can only be addressed upon their emergence. When the relevant parties cannot come to a common agreement it could be settled by a court decision. These legal precedents, which clarify risk allocation and contract interpretation, subsequently shape the contract documents that ensue.

All these changes have created very complex project teams and innovative solutions are required to deal with the high-collaborative interaction required between all stakeholders.

5. INDUSTRY 4.0

Industry 4.0 (4IR) is the rising trend in integrating technologies which lead to increased automation, predictive maintenance, and self-optimisation of process improvements. In the built environment, it mainly centres on the physical-to-digital transition and then digital-to-physical transition to help coordinate, design, and execute built environment infrastructure more effectively and efficiently (Dallasega et al., 2018). There are various technologies under the 4IR umbrella such as Artificial Intelligence, Augmented Reality, blockchain technology, Building Information Modelling, Internet of Things, machine learning, Virtual Reality, etc. The Municipality ventured into 4IR through the integration of virtual reality (VR) in the design stage of the construction of Coegakop Water Treatment Works. The decision to use VR in the project demonstrates the municipality's commitment to innovation and modern technology by integrating innovative solutions to address essential infrastructure needs.

FIGURE 5: *Virtual Reality simulation inside Coegakop Water Treatment Works.*

Virtual Reality is the simulation of certain aspects of the real world, enabling real-time interaction with each other. The advanced abilities of the immersive and interactive visualisation help facilitate the design, engineering, construction, and management in the built environment. Recently, the advancement of VR technology enables for client-walkthroughs, review, and construction sequence visualisation. This is advantageous in terms of facilitating construction planning and scheduling, project collaboration, and the allocation of resources. VR has the potential to streamline project execution and enhance project efficiency.

Traditional drawings often lead to errors and misunderstandings. The virtual environment created through VR provides a clear scope and specifications of the project, reducing the chances of disputes. It provides an understanding of the layout of the facility, operational procedures, and the functionality of the proposed facility. Key components can be easily identified. In addition, the simulation provides an understanding of how the different systems work together to treat and distribute the water, and sheds light on the operational efficiency – Coegakop WTW in our case.

6. COEGAKOP WTW VIRTUAL REALITY

Due to the complexity and operator-centric design of the Coegakop Water Treatment Works, the highly collaborative interaction between the various stakeholders involved in the design of the plant required a more streamlined approach. The stakeholders involved were the client, engineers, architects, geohydrologists, environmental practitioners, 3D software modellers, VR programmers and other professionals. As a result, a 3D model of the plant was developed. The model helped to facilitate continuous simultaneous collaboration between the various professional stakeholders (Hills, 2020).

A step further was taken, the model was transformed to virtual reality. This was advantageous as it enabled visualisation of the plant processes during operation. This was achieved successfully by simulating the operating procedures for an electrical switch station and a backwash amongst others. The VR experience proved to be beneficial as it enabled fast and informed decision-making by providing a walkthrough of the plant

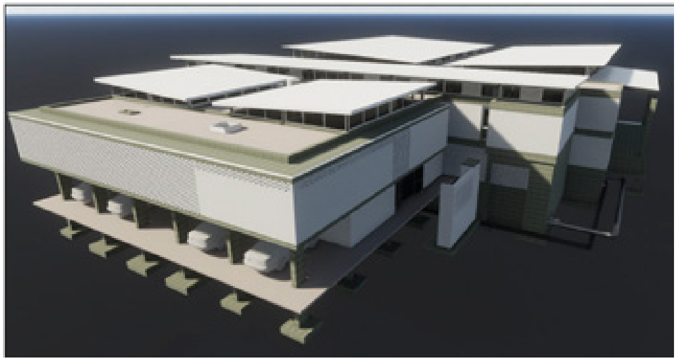

FIGURE 6: *Coegakop Water Treatment Works simulation in the design stage.*

FIGURE 7: *Coegakop Water Treatment Works completed.*

The design of the plant is operator centric. Due to the complexity, integrated nature, and the dense design required to achieve the desired operator-centric plant, the VR experience assisted with factors such as clash detection and space optimisation thus improving the design in terms of constructability. The ability to refine complex parts of the design, which are typically noted during construction, helped reduce issues such as construction delays, claims and variations.

Securing funds for an infrastructure project of that magnitude tends to be challenging for municipalities. Effective and comprehensive communication of the project goals, benefits, impacts and integration with the existing infrastructure was important when convincing the funding bodies. The VR experience proved to be beneficial in securing funding from national government. The detailed visualisations and walkthrough helped explain the complexity and significance of the project (du Toit et al., 2018).

7. BUILDING INFORMATION MANAGEMENT (BIM)

There has been a noteworthy acceptance and increase in Building Information Modelling (BIM) within the built environment. The Architectural, Engineering and Construction (AEC) industry is shifting towards 3D BIM-models for infrastructure and construction projects. BIM is a digital representation of the physical and functional properties of a facility. It

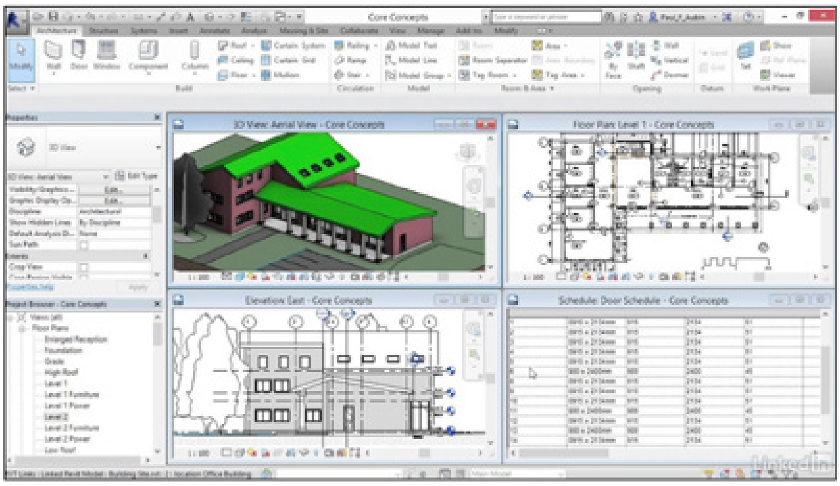

FIGURE 8: *3D BIM Model of a building.*

serves as a shared and reliable resource for information to facilitate decisions throughout the lifecycle, from inception to operation and maintenance. BIM has a plethora of benefits. In this article, the focus is more on its ability to improve project visualisation, facilitate collaboration, ensure accurate documentation, and facilitate compliance and auditing processes. BIM integration enhances efficiency and has the potential to reduce disputes and optimise the management of resources.

BIM creates a 3D model that provides a comprehensive view of the project, providing an improved understanding of the scope, design, and specifications of the project. BIM facilitates effective collaboration and communication by providing a centralised database where all the information is stored and accessible for all stakeholders. The information is updated in real-time therefore it has the most recent information, enabling for effective collaboration and decision-making. The compiling of documentation is automated, which ensures a consistent, accurate and up-to-date status of the project. The automation of processes helps reduce time and effort required for documentation, reduces errors and ensures access to accurate and reliable information at all times.

Contract management entails ensuring that all aspects of the project comply with the relevant regulations, standards, and contractual duties. Compliance is facilitated through BIM by generating a comprehensive and detailed record of the project, including design, construction, and operational information. Based on the BIM dimensions employed on the project, the report generated entails the relevant information of the project for auditing purposes. The detailed record streamlines the auditing process, which makes it simpler to show compliance and identify any areas of non-compliance.

BIM enhances risk management through detailed analyses and simulations of the overall project. Potential risks and issues are discovered early which enables proactive risk mitigation. Conflicts in the different building systems are identified before actual construction through clash detection, which in return reduces the risk of costly rework and delays. Detailed information on the materials, labour and equipment required for the project is contained within the model, which assists with efficient resource planning and allocation. This advanced resource management tool helps to ensure that the project is on schedule and within budget, reducing the risk of delays and cost overruns.

The 3D model created for the Coegakop Water Treatment Works was developed in detail through Autodesk Revit, one of the numerous software applications that fall under BIM. Revit is an application for BIM with features for the three main disciplines of AEC (architectural, MEP – mechanical, electrical, and plumbing, and structural engineering). BIM has been widely recognised for its capabilities in the advancement of the creation and management of infrastructure projects throughout the entire lifecycle. The use of BIM could have been further explored within the Coegakop WTW project as it is a beneficial tool throughout the project lifecycle.

8. BIM AND VR INTEGRATION

There are added benefits to BIM-use which add to the capabilities of VR. As previously mentioned, errors in construction are detected early. VR helps facilitate risk management by exposing potential issues such as design faults or safety hazards before they even occur or escalate. Early detection of risks helps mitigate costly delays and disruptions. In the case of contract management within the built environment, VR can be used as a tool for training. The virtual environment allows for practical experience without the possible risks associated in training within the real world.

VR can be integrated with BIM for real-time progress monitoring of the construction. This enables visualisation of the as-planned in contrast to the as-built progress and identify any deviations. This ensures prompt decision-making when issues arise and help to keep the project on schedule and within budget. BIM can be used to create virtual models of construction projects. However, its main purpose is to provide real-time data on project progress and cost.

VR is primarily a tool used for visualisation, while BIM incorporates visualisation with detailed project data and analytics. VR is effective for design reviews and presentations, while BIM is excellent in continuous project management and coordination. VR can help designers detect errors before they occur and become costly problems, and BIM can help contractors avoid costly mistakes by providing a clear and concise model of the project. In addition, VR can be used to provide clients with a better understanding of the project, while BIM can provide the detailed information about the construction process. As a result, these technologies have the potential to make construction projects more accessible to an audience of a wider range.

9. FUTURE IS NOW – SMART CONTRACTS

Traditional contract administration and management procedures often involve tedious paperwork, manual processing, and a lack of transparency, which leads to inefficiencies and disputes. Smart contracts are contracts which self-execute with the terms and conditions written directly into code. Smart contracts offer a promising solution by taking advantage of blockchain technology. Smart contracts can automate and streamline various aspects of contract administration and management, therefore enhancing efficiency, transparency, and trust among stakeholders.

In contract administration, smart contracts can automate the execution of an agreement and ensure that all stakeholders are immediately assured of the result, without any involvement from negotiators/mediators/arbitrators or loss in time. The workflow of the project can be automated, initiating the following activity when the programmed conditions are met. Payment terms programmed in a smart contract automatically activate payments once specific conditions are met, such as the completion of a construction activity or phase. Smart contracts provide a transparent and permanent record of all transactions and alterations made to the contract. This transparency minimises the possibility of disputes and fraud, as all parties have access to a single, unalterable, and trusted source.

Errors in contract administration can lead to significant delays and major cost overruns in projects. Smart contracts reduce human errors by ensuring that the contract terms are executed as per the contract, mitigating the possibility of misunderstanding and misinterpretation. In addition, the immutability of the blockchain records ensures that disputes can be resolved promptly by referring to the exact terms and conditions encoded in the smart contract.

Contract management involves supervision of the entire lifecycle of a contract, from negotiation and execution to monitoring and renewal. Smart contracts facilitate this process through the automation of many aspects of contract management. Not only does it accelerate contract execution, but it also reduces the associated administrative costs. Monitoring compliance with contract terms can be automated, ensuring timely and accurate performance assessments.

Security is a major concern. Traditional contracts are prone to altering, manipulation and unauthorised access. Smart contracts take advantage of the security features of blockchain technology, such as cryptographic encryption and decentralised storage. These ensure that contract data is secure and accessible only to the authorised stakeholders, therefore reducing the risk of data breaches and unauthorised modifications.

Compliance with regulatory requirements is a critical aspect of contract management in the built environment. Smart contracts can be programmed to include compliance checks by ensuring that all contract activities adhere to the relevant regulations. Additionally, the transparent nature of blockchain records simplifies the auditing process. Auditors can easily access a comprehensive, untampered history of all the contract-related activities, therefore streamlining the audit procedure and reducing costs.

10. WATER MANAGEMENT SYSTEM'S

Another phase of the modern contract that is receiving increasing attention is the close out of projects. This goes beyond verifying the completion of the works and the financial closure of it. NMBM has developed a stringent list of requirements before the close out of a project can be considered. This ensures that there is a smooth transition from the project phase to the operational phase by capturing all relevant project information to maximise the institutional knowledge gained.

NMBM have been utilising a comprehensive water management system since 2008 where information from all interventions is integrated. For instance, after the close out phase of the project, documents like the drawings and Operating & Maintenance (O&M) manuals are captured in the system. This then allows for the creation of scheduled maintenance based on the recommendations from the O&M manual. Automated job cards will then be raised and will be emailed directly to relevant role players for execution and closure.

The system supplies the data necessary for input into the WSDP and Infrastructure Development Plans (IDP), data on costing of different capital and maintenance work and it links the GIS with the billing system. This system also provides the information required for annual audits, questionnaires, complaints statistics, Council reports, asset management as well as Blue Drop, Green Drop and No Drop requirements.

11. CONCLUSION

Modern construction procedures and the management thereof is based on historic documents and practises. Forever adapting to the legal, regulatory, and technological changes of the world.

Over time we have learnt from our mistakes, sometimes the hard way when it comes to health, safety, and the environment. All these advancements seek to increase the efficiency of project execution, reduce risks and extend the infrastructures maximum useful life.

Further technological advancements are ready to be explored for even more growth. Even though in most cases the end user is oblivious to all the background happenings and simply require their needs to be fulfilled.

12. REFERENCES

A history of prison labour in South Africa (no date) South African History Online. Available at: https://www.sahistory.org.za/article/history-prison-labour-south-africa (Accessed: 15 June 2024).

BIM Modelling Services – Outsourcing BIM Specialist Company (2023) QTO Estimating. Available at: https://www.qtoestimating.com/bim-modeling-services/ (Accessed: 20 June 2024).

cidb. Available at: https://www.cidb.org.za/ (Accessed: 15 June 2024).

Construction safety evolution: Past, progress, and future: Owen Construction Consultancy, Owen Construction Consultancy Ltd. Available at: https://owenconstructionconsultancy.co.uk/news/history-safety-construction-industry (Accessed: 18 June 2024).

Dallasega, P., Rauch, E. and Frosolini, M., 2018. A lean approach for real-time planning and monitoring in engineer-to-order construction projects. Buildings, 8(3): 1–22.

Du Toit, G., Theunissen, B., Petrie, D., van Jaarsveld, M., Verserput, E. and Murray, R. (2018). 'Coegakop Biofiltration Plant', *2018 IMESA Conference*. Port Elizabeth, 31 October – 02 November 2018. 96-99.

Hills, M. (2022) 'Meet South Africa's largest Bio Filtration Plant', Water & Sanitation Africa, pp. 16–20.