FACULTY OF ENGINEERING
AND THE BUILT ENVIRONMENT

ENGINEERING PROJECT MANAGEMENT SPECIALISATION CENTER (EMSC)

RESEARCH ROADMAP
2020-2025

CARINBE

RESEARCH ROADMAP- EMSC

SUBMITTED TO | ESKOM-EPPEI

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CENTRE OF APPLIED RESEARCH +
INNOVATION IN THE BUILT ENVIRONMENT

ABBREVIATIONS

CARINBE	|	Centre for Applied Research and Innovation in the Built Environment
CBE	|	Council for the Built Environment
CIDB	|	Construction Industry Development Board
EMSC	|	Engineering Project Management Specialisation Centre
EPPEI	|	Eskom Power Plant Engineering Institute
SCEBE	|	School of Civil Engineering and Built Environment
UJ	|	University of Johannesburg

EXECUTIVE SUMMARY

In this document, we outline the research roadmap for the EPPEI's Engineering project Management Specialisation Centre (EMSC) based at the University of Johannesburg within the centre for Applied Research and Innovation in the Built Environment (CARINBE).

The document provides guidance to the centre and the stakeholders on research direction, key deliverables and the resources needed to deliver on the plans.

The research direction has been guided by needs within Eskom in project delivery and by the current and future key developments in the industry. Specifically, Eskom has many challenges in delivery of engineering projects, as they often do not meet project objectives efficiently and in an effective manner. Gaps have been identified in project integration and collaboration, project management structures, processes and systems and in the adoption of appropriate technology for information exchange and collaboration.

The research roadmap has also been shaped by key developments and direction of the construction and engineering industry. The UK government[1] in its "Construction 2025" publication, identified at least four focus areas namely, people, smart infrastructure delivery, sustainability and leadership. The National Research Council identified similar focus areas[2] in their study on how to improve construction productivity.

Based on the study within Eskom and literature, the proposed research roadmap has been drafted. Five research focus areas have emerged. As outlined in table 1.0, the focus areas include Building Information modelling and digital applications, integrated project delivery, managing projects, structures and systems, sustainability in project delivery and human factors.

[1] The HM Government, UK (2013), Construction 2025: Industrial strategy for construction – Government and industry in partnership.

[2] National Research Council (2009). Advancing the Competitiveness and Efficiency of the U.S. Construction Industry. Washington, DC: The National Academies Press. https://doi.org/10.17226/12717

Table 1: Research focus areas

ID	Focus Area	Vision
RF1	Building Information Modelling, and digital applications	Certainty of project outcome leveraging BIM and digital applications in all projects undertaken or commissioned by Eskom. BIM is the preferred and standard method for project delivery and have knowledge for improvement.
RF2	Integrated project delivery;	Project integration & digital collaboration is achieved from inception to operation in all Eskom projects, yielding high efficiencies in project outcomes
RF3	Managing projects, structures and systems;	The right project organizations, structures and systems are deployed on Eskom projects. Have developed intelligent systems to respond to any project requirements.
RF4	Sustainability in project delivery;	Eskom infrastructure is economically and operationally sustainable and does not contribute to environmental degradation as well as health and safety risk of workers.
RF5	Human factors – Health and safety management.	The construction and engineering project environments are safe for workers and users by partly leveraging artificial intelligence and predictive analytics to identify and manage risks in addition to cultural modification methods.

The research focus areas are elaborated on citing the key research topics, the drivers, barriers and the expected impact from the research. However, before the research focus areas are elaborated on further, the status on construction and engineering project management in Eskom and industry are presented.

Generally, the current performance on construction and refurbishment projects in ESKOM is reflective of the entire construction and infrastructure delivery sector. Projects are delivered late, budgets are usually overrun and the quality achieved is below expectations. The need for new approaches to project management and delivery is evident as can also be demonstrated by the rest of the industry and world. We too have recognised the need to improve through evidence based research and application, the construction efficiency, quality, timeliness, cost-effectiveness, and sustainability of construction projects.

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1.1| PURPOSE & STRUCTURE OF THE DOCUMENT

1.1.1 This document outlines the research roadmap for EPPEI's Engineering project Management Specialisation Centre (EMSC) based at the University of Johannesburg within the Centre for Applied Research and Innovation in the Built Environment (CARINBE).

1.1.2 The document provides guidance to the centre and the stakeholders on research direction, key deliverables and the resources needed to deliver on the plans.

1.1.3 The presentation of the rest of this document is as follows: the methodology of the research roadmap is discussed first followed by a presentation of findings from site visits and interviews within Eskom. The background and introduction to the research agenda is discussed in section two and three. Under these sections, the EPPEI, EMSC and CARINBE role and activities are discussed to inform stakeholders about the activities of the three structures.

1.1.4 The fourth section of the document elaborates on the research focus areas citing the key research topics, the drivers, barriers and the expected impact from the research.

1.2| METHODOLOGY

1.2.1 The roadmap has been guided by needs within Eskom in project delivery and by the current and future key developments in the industry. Specifically, Eskom has many challenges in delivery of engineering projects, as they often do not meet project objectives efficiently and in an effective manner. Gaps have been identified in project integration and collaboration, project management structures, processes and systems and in the adoption of appropriate technology for information exchange and collaboration.

1.2.3 This document has also been shaped by key developments and direction of the construction and engineering industry, globally. The UK government [3] in its "Construction 2025"

[3] The HM Government, UK (2013), Construction 2025: Industrial strategy for construction – Government and industry in partnership.

publication, identified at least four focus areas namely, people, smart infrastructure delivery, sustainability and leadership. The National Research Council identified similar focus areas[4] in their study on how to improve construction productivity.

1.2.4 Based on the study within Eskom and literature, the proposed research roadmap has been drafted. Five research focus areas have emerged. The focus areas include Building Information modelling and digital applications, integrated project delivery, managing projects, structures and systems, sustainability in project delivery and human factors.

2.0| BACKGROUND AND INTRODUCTION

2.1 ENGINEERING PROJECT MANAGEMENT SPECIALIZATION CENTER (EMSC)

2.1.1 As part of the EPPEI resolution, the EMSC was tasked with setting up a SC in engineering and construction project management. Preparations included attending meetings such as the workshop on Eskom New Build Coal – EPPEI Workshop on the 18th of April 2018 hosted at the University of Pretoria. Other meetings included two site visits to Kusile Power Station on the 19th of April 2018 and 17th of August 2018.

2.1.2 The outcome of various meetings and site visits yielded a formal establishment of the engineering and construction project management workgroup, constituting both Eskom and Academics with University of Johannesburg identified as the workgroup lead.

2.1.3 The workgroup was mandated to identify the key challenges facing Eskom on engineering and construction projects. Further mandate to the workgroup was to submit a proposal to establish the engineering and construction project management specialisation centre within EPPEI.

2.1.4 In November 2019, the Engineering project Management specialisation (EMSC) centre was set up at the University of Johannesburg in the Faculty of Engineering and the Built

[4] National Research Council (2009). Advancing the Competitiveness and Efficiency of the U.S. Construction Industry. Washington, DC: The National Academies Press. https://doi.org/10.17226/12717

Engineering within the Centre for Applied Research and Innovation in the Built Environment (CARINBE).

2.1.5 As with other specialisation centres, the objective of the EMSC is to assist ESKOM achieve its operational goals through training and postgraduate research[5]. In addition, the centre has the responsibility of establishing a consortium of institutions of higher learning that can participate in Engineering and Construction Project Management skills development.

2.2 EMSC WITHIN CARINBE

2.2.1 The Centre for Applied Research and Innovation in the Built Environment (CARINBE) is set up within the School of Civil Engineering and Built Environment (SCEBE), under the governance rules and structures of the University of Johannesburg (UJ). It is situated on the 6th floor, John Orr building, Doornfontein Campus.

2.2.2 CARINBE undertakes research and industry support to improve efficiency and effectiveness in project delivery. Other activities include postgraduate research and support in built environment and built environment professional skills development through offering short learning programmes (SLP).

2.2.3 The EMSC was mandated to focus in terms of training and postgraduate research on construction management, engineering project management, maintenance & operations engineering management and risk management.

2.2.4 This document presents plans on the research focus areas of the EMSC as mandated by EPPEI.

2.3 CURRENT ESKOM CHALLENGES

2.3.1 A 2017 report by KPMG estimated that through the construction of the five coal plants at Camden, Grootvlei, Hendrina, Komati and Kriel, the impact was a R32.8 billion per year in

[5] Eskom Power Plant Engineering Institute Phase 2 Enabling and Funding Agreement

economic activity, R9 billion Government revenue, R21.1 billion in household income per year and almost 93,000 jobs were sustained[6].

2.3.2 However, serious challenges have been experienced at the new build power stations being constructed at Kusile and Medupi power stations. Increase in cost, schedule delays and quality problems have been reported at both Kusile and Medupi power plants. According to a report by Moneyweb (Online), the cost to completion at Medupi has increased from R118.50 Billion to R160 Billion. The escalation in the projected cost to completion was in excess of R40 billion. At the other plant, Ingula pumped scheme, the increase in costs have reportedly been revised from R8.9 Billion to R36 Billion (fin24, online).

2.3.3 Complexity of the project resulting from multiple principal contractors, contracts and package interdependencies, need for an extensive front-end project planning, the social imperative of the project and the general governance of the project seem to suggest is the reason why the new build infrastructure performed poorly in view of the uniqueness of engineering projects and available capability.

2.3.4 Literature informs that such projects with scope and construction complexity largely influenced by the environment and institutional setting, often unfold differently from what was planned or envisioned[7].

2.3.5 Project outcome certainty is also a function of information availability. In complex projects, information availability, in the right format, from the right source, supplied at the right time and adequacy has an impact on project decisions. Project organisation on the other hand influences information flow and the quality thereof.

2.3.6 In addition, integration and interface management between different work packages can have a significant influence on processes and project outcomes. This was the case for the new build projects, which experienced difficulties interfacing and integrating the many different work packages and disciplines.

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[6] ESKOM Holdings SOC Ltd (2017). Economic Impact assessment of five of Eskom's coal power stations. KPMG

[7] Gerrits, Lasse & Verweij, Stefan. (2018). The Evaluation of Complex Infrastructure Projects: A Guide to Qualitative Comparative Analysis.

2.3.7 Undertaking complex projects, whether new-build, refurbishment or outage, demands capability in terms of competence of the people involved resources available and processes or management systems in place that can be deployed and the requisite knowledge held or shared in the organisation. In addition, project success depends on effective linkages between senior management and management of the project. The foregoing deals with project governance and leadership, without which, many mega projects experience serious challenges, which in some instances result in project failure[8].

2.4 ESKOM RESEARCH AGENDA AND DIRECTION

2.4.1 Eskom's research agenda is driven by its needs and therefore is aligned with the strategic organisational objectives.

2.4.2 Eskom's research agenda as captured in RaDaR 2019-2024[9], identifies Transmission build and refurbishment of current aging infrastructure as one of the grand challenges that it will face.

2.4.3 Refurbishment will have to be done without disrupting its customers and within the constraints of time, budget and resources.

2.4.4 Transmission build is necessary because of the aging infrastructure, increasing demand for electricity, new generation environment requiring bulk power from new sources and because of the need for regional integration.

2.4.5 Against this grand challenge of transmission build and refurbishment, Eskom indicates that it will need research that will provide technical knowledge for informed decision-making, for proactive management, lifecycle costing, effective use of resources and management of organisational risks.

2.4.6 Other research areas as presented by Eskom professionals in interviews and workshops include the following:

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[8] Morgan, A. and Gbedemah, S. (2010). *How poor project Governance causes delays.* A paper presented to the society of construction law at a meeting in London on 2nd February 2010.

[9] Eskom (2019), Eskom Research, Testing and Development Research Direction Report: a working document (RaDaR) 2019 - 2024

a) Improving design quality and sustainability;

b) Project contract administration;

c) Geotechnical and structural stability of ash dams and other civil engineering structures;

d) Productivity improvement;

e) Configuration Management;

f) Improving cost, time and quality performance in projects;

g) Engineering Project monitoring and Control.

3.0| EMSC RESEARCH OBJECTIVE

3.1| EMSC OBJECTIVES

3.1.1 The goal of the EMSC is to support and enable Eskom achieve its goals driven by its needs.

3.1.2 Collectively, the objectives of the Specialisation Centre are to:

a) Assist Eskom through postgraduate and applied research to develop capability to effectively and efficiently deliver Eskom's new build and refurbishment infrastructural projects;

b) Assist Eskom with knowledge on how to manage refurbishments and outages with minimal disruption to customers within constrained time and budget.

c) Generate knowledge from the new build projects for the benefit of future projects and expertise;

d) Produce Construction project management specialists through training in key areas relevant to Eskom;

3.2| RESEARCH OBJECTIVE – THE VISION

3.2.1 Our vision and as a product of our research in the SC, is collectively captured in the following statements:

a) There is certainty of project outcome leveraging BIM and digital applications in all projects undertaken or commissioned by Eskom.

b) BIM is the preferred and standard method for project delivery and have knowledge for improvement;

c) The right project organizations, structures and systems are deployed on Eskom projects. Have developed intelligent systems to respond to any project requirements;

d) The right project organizations, structures and systems are deployed on Eskom projects;

e) Eskom infrastructure is economically and operationally sustainable and does not contribute to environmental degradation as well as health and safety risk of workers;

f) The construction and engineering project environments are safe for workers and users by partly leveraging artificial intelligence and predictive analytics to identify and manage risks in addition to cultural modification methods such as the LIP+3C model[10].

4.0| RESEARCH FOCUS AREAS

4.1| BUILDING INFORMATION MODELLING AND DIGITAL APPLICATIONS

4.1.1 Vision

a) Most projects, suffer delays, cost overruns, are of poor quality and rarely satisfy client needs. The new build projects within Eskom have also shown that it is not immune to the problems that projects world over face in the construction of infrastructure.

b) Building information modelling as a process to deliver projects has shown to deliver positive project outcomes. Consequently, many governments across the world have recognized the

[10] Musonda, I., Haupt, C.T. and Pretorius, J.H.C., 2013, December. Improving health and safety culture–a guide for construction clients. In Challenges in innovation, integration and collaboration in construction & engineering. Proceedings of the 7th International conference on Construction in the 21st Century, Bangkok (pp. 19-21).

value of BIM as a critical requirement to meet project goals[11]. BIM is now a standard project delivery methodology in many countries including the United Kingdom, United States and Scandinavian countries notable Finland, Denmark and Norway[6].

c) Therefore, our vision is that there is certainty of project outcome leveraging BIM and digital twin in all projects undertaken or commissioned by Eskom. BIM is the preferred and standard method for project delivery and have knowledge for improvement.

4.1.2 Key research topics

a) Information technologies integration

b) Integration of design, construction & operations

c) 4D & 5D building information modelling – Construction simulation

d) Site to office digital applications- Drones and laser scanners for monitoring and control

e) Workflow and resource optimization

f) Transforming traditional project controls

g) Project transparency

4.1.3 Drivers, barriers and impact

a) The driver for adopting and exploring the benefits of BIM is the push to leverage tools and technology enabled by the fourth industrial revolution. Specifically, the need to improve efficiency, effectiveness and sustainability of constructed facilities in the wake of constrained resources has meant that new technology-based solutions are needed to deliver or execute projects better. Project delivery inefficiency, ineffectiveness and unsustainable solutions result in cost escalations, delays, poor handover data sets, high health & safety risks and significantly reduced project value.

b) The barriers are primarily associated with the fact that BIM and digital twin is at a very low level of adoption in South Africa and Africa in general. Further, the lack of standards and

[11] Sarvari, H., Chan, D.W., Rakhshanifar, M., Banaitiene, N. and Banaitis, A., 2020. Evaluating the Impact of Building Information Modeling (BIM) on Mass House Building Projects. *Buildings*, *10*(2), p.35.

willingness to adopt BIM may limit data source for research. The initial high cost of implementation of building information modelling and other technology tools in project delivery, has proved to be a barrier to its adoption.

c) BIM has a positive influence on a project in terms of meeting the project goals such as cost, time, quality, safety, sustainability and value throughout the project life cycle.

4.1.4 Research roadmap

The roadmap as envisaged now is shown in table 2.0.

Table 2: BIM research roadmap

Best practice	Eskom /Industry status	Gaps	Required Action	Period	Resource
Plan – accurate information available enabled by BIM & digital applications to aid decision making, project conceptualisation, risk identification, estimates, organisation, resourcing & structures	None at the moment	Digital intelligence enabled project planning	To investigate and generate solutions for BIM adoption, To evaluate BIM performance and needed improvements	5 years	1x Research Professor 2x Post-doc fellow 3x PhD candidates 6x Master Students
Design – coordinated digital models, in 4D & 5D, simulated construction towards certainty of project goals and sustainability, analytics optimised design		Coordinated design solutions from different disciplines Project outcome certainty Digital rehearsals			
Build – processes, systems and tools for scheduling, monitoring and control of projects. Site to office reports & real-time issue resolution	No BIM scheduling and monitoring	Site-to-office digital reports Real time issue resolution Email based communication of issues.	To investigate appropriate efficiency and effectiveness enhancing digital applications, data exchange methods in projects to achieve optimal		
Operate – Data source for virtual handover and commission, data platform for condition monitoring and predictive maintenance	Isolated facilities management	None data informed maintenance	Configuration management & Enhanced project handover of systems and data. Drones and laser scanners for monitoring and control	5 Years	

4.2| INTEGRATED PROJECT DELIVERY & DIGITAL COLLABORATION

4.2.1 Vision

a) An integrated project delivery (IPD) system aims to collaboratively involve key project participants very on at the beginning of the project[12]. IPD leverages partnering contractual arrangements resulting in greater project efficiencies. Key considerations and factors affecting project success are team cultures, owner business objectives and project goals.

b) Therefore, our vision is that through our research outcome, project integration & digital collaboration is achieved from inception to operation in all Eskom projects, yielding high efficiencies project outcomes. Have developed intelligent systems to respond to any project requirements.

4.2.2 Key research topics

a) Achieving project Collaboration;

b) Evaluating optimal project delivery systems;

c) Assessing software interoperability for effective collaboration;

d) Integration of design, construction & operations;

e) Optimizing project performance;

f) Preparing for the digital age; and

g) Innovation in IPD and team communication;

4.2.3 Drivers, barriers and impact

a) The driver of IPD has been the fact that the concept has proved to be an effective way of project delivery. Further, the use of BIM, especially the advances in 4D and 5D, has also made it possible to implement IPD. Moreover, the realization by clients and professionals

[12] El Asmar, M., Hanna, A.S. and Loh, W.Y., 2013. Quantifying performance for the integrated project delivery system as compared to established delivery systems. *Journal of Construction Engineering and Management*, *139*(11), p.04013012.

that design, construction and facilities management will function better in a multi-disciplinary environment has driven the concept for implementation.

b) The barriers include the contractual arrangements that do not support IPD. The procurement system, the fragmented nature of the built environment industry and the silo approach to design of systems further inhibits the implementation or adoption of IPD in projects.

c) The positive impact of IPD has been noted and documented. Integrated project delivery has emerged as a new delivery system with the potential to provide better performance through a more supply chain integration[13]

[13] Mesa, H.A., Molenaar, K.R. and Alarcón, L.F., 2016. Exploring performance of the integrated project delivery process on complex building projects. International Journal of Project Management, 34(7), pp.1089-1101.

4.2.4 Research roadmap

The roadmap as envisaged now is shown in table 3 below.

Table 3: IPD research roadmap

Best practice[14]	Eskom / Industry status	Gap	Required Action	Period	Resource
Teams - Integrated team composed of key project stakeholders put together early in the process is open and collaborative	Follow traditional approach to project organisation.	Early contribution to project by all team members, none concurrent sharing of knowledge & expertise	Investigate ways to encourage early participation of all team members to project & implications	3 years	1x Research Professor 2x Post-doc fellow 3x PhD candidates 6x Master Students
Process – Are Multi-level and concurrent, early contribution of knowledge and expertise, information openly shared, stakeholder trust and respect.	The approach is linear, segregated, and distinct. The knowledge is gathered just as needed. The information is hoarded and builds silos of knowledge and expertise				
Risk - Risk is managed collectively and appropriately shared	Risks are individually managed. They are transferred or attempt to transfer to the greatest extent possible.	Equitable risk sharing, stakeholder mutual respect and collective responsibility	To investigate IPD implications on risk management		
Compensation/reward - The team success is tied to the project success. It is based on value derived from the project.	Achievement is individually pursued and individuals assert minimum effort for maxim reward.		To investigate incentives and barriers to collaboration , team success and collective value creation, to establish key issues in inter-disciplinary / organisation networks impacting on value creation at front-end of projects	3 years	1x Post-doc fellow 1x PhD candidates 3x Master Students
Communication / technology - Communication is digitally based, virtual and is based on nD BIM	Paper based contract document share, emails	Digitally based, common data environment	To investigate adoption of digital communication and use of common data environment, contractual implications and training.	3 years	1x PhD candidates 3x Master Students
Agreements - The agreements encourage, foster and support multi-lateral open sharing and collaboration. It is about risk sharing.	Allocate and transfer risk. Little risk sharing	Open sharing and collaboration	To investigate contractual and legal implications on risk. Understand and promote project collaboration	3 years	1x PhD candidates 3x Master Students

[14] Guide, A.I.A., 2007. Integrated project delivery: A guide. *American Institute of Architects, California*.

4.3| MANAGING PROJECTS, STRUCTURES AND SYSTEMS

4.3.1 Vision

a) Projects are a complex and open system. Literature suggest that projects are not entirely and always unique. However, projects can be influenced by different contextual factors and to different degrees at different stages of the implementation process[15]. Understanding project characteristics according to Hussein[10] is critical in order to comprehend the challenges that the project characteristics contribute to project execution as it influences how information should be shared & managed, choice of the implementation methodology, project structure and systems. Project success is influenced by project characteristics, which include organizational complexity, projects as transformation agents, impact on business and strategy, project constraints and uncertainty.

b) Through the right characterization of projects, the right project organizations, structures and systems are deployed on Eskom projects.

4.3.2 Key research topics

a) Project characterisation and project performance

b) Project organisation complexity determinants

c) Establishing key project constraints

d) Understanding the transformative nature of projects and impact on business and strategy

e) Characterizing and management of project uncertainty

f) Integration and management of culture, structures, systems and organisational behaviour

g) Managing project actors and their environments

h) Scientific study of project delivery and management process

i) project leadership and improvement of project effectiveness

[15] Hussein, B., 2019. The influence of project characteristics on project success factors. Insights from 21 real life project cases from Norway.

j) Project success measures, value enhancement and benefits management

4.3.3 Drivers, barriers and impact

a) The frequent failure in meeting project objectives in the industry in project execution has led to rethink the management of projects. Recent enquiry into project organization, structure, systems, and the fact that projects are not unique from the technical point of view, has led to enquiry on other factors that influence project performance. Focus on the technical system only has often led to projects being treated as an effort that should be completed within agreed time, budget and scope regardless of context in which projects are located[10].

b) Traditional project management practices cannot adequately cater for increased complexity of projects in planning[16].

c) Projects executed in South Africa, have diverse contexts. Understanding the social-technical environments that give rise to the project organization complexities, constraints and uncertainties will greatly improve project performance.

[16] Lenferink, S., Tillema, T. and Arts, J., 2013. Towards sustainable infrastructure development through integrated contracts: Experiences with inclusiveness in Dutch infrastructure projects. *International journal of project management*, *31*(4), pp.615-627.

4.3.4 Research roadmap

The road as envisaged now is shown in table 4.0.

Table 4: Roadmap on managing project structures and systems

Best practice	Eskom / Industry status	Gap	Required Action	Period	Resource
Project technical characterisation	Main focus in project definition but less on context evaluation	Social-technical evaluation of projects	To investigate project characterisation and impact on performance of projects in different contexts	3 years	1x PhD candidates
Project social characterisation					
Evaluation of Project organisation complexity	Focus on project and not as a system	Project system evaluation	To investigate various project characteristics and influence on structure, processes, resources and systems	3 years	1x Research Professor 1x Post-doc fellow 3x PhD candidates 6x Master Students
Assessment Project uncertainty and constraints					
Projects as transformation and value creation agents					

4.4| SUSTAINABILITY

4.4.1 Vision

a) Built infrastructure can be harmful to the environment. It displaces people, exposes construction workers to hazardous conditions, cause pollution and environmental damage[17]. Apart from the construction methods and materials used, sustainability outcomes of infrastructure are also dependent on how infrastructure is implemented.

b) Our research outcomes and that of our network partners, is that Eskom infrastructure is economically and operationally sustainable and does not contribute to environmental degradation as well as health and safety risk of workers. This is achieved with the appropriate construction methods and materials and how infrastructure is implemented.

4.4.2 Key research topics

a) Project management factors to aid delivery of sustainable infrastructure

b) Construction Methods and Materials to achieve highest sustainability levels in buildings

c) Fly ash and construction waste utilisation

d) Efficient use of resources to optimize construction operations and project success

e) Challenges of sustainability and regeneration

f) Barriers and drivers of sustainable infrastructure

g) Project cost and value optimization

h) Sustainable finance mechanisms

i) Project supply chain management

j) Sustainability and project contracts alignment

[17] Thacker, S., Adshead, D., Fay, M., Hallegatte, S., Harvey, M., Meller, H., O'Regan, N., Rozenberg, J., Watkins, G. and Hall, J.W., 2019. Infrastructure for sustainable development. *Nature Sustainability*, *2*(4), pp.324-331.

4.4.3 Drivers, barriers and impact

a) South Africa and Africa in general needs new infrastructure to cover the existing backlog and to replace the aging one. The needed infrastructure is almost the same in quantity as the current stock. Therefore, doing it sustainably can save money, generate economic returns and significantly reduce health and safety risks.

b) A number of barriers to adoption of sustainability methods have been noted. They include inter alia, procurement systems, underpinning knowledge, stakeholder participation, lack of transparency and high initial cost associated with sustainability programmes.

c) Research on sustainability of infrastructure will contribute positively and influence construction methods, materials and general implementation of projects leading to better returns from the constructed facilities.

4.4.4 Research roadmap

The road as envisaged now is shown in table 5.0.

Table 5 : Sustainability research roadmap

Best practice	Eskom / Industry status	Gap	Required Action	Period	Resource
Assessment of project management factors to aid infrastructure sustainability	Partially done. New build and refurbishment focused research to enhance sustainability is inadequate.	Sustainability project deliverables	To investigate project management factors to improve sustainability of infrastructure	3 years	1x Research Professor 1x Post-doc fellow 2x PhD candidates 4x Master Students
Sustainable construction methods and materials		Use of alternative sustainable methods & materials in construction and refurbishment projects	To investigate alternative materials, use of fly ash and construction waste materials	3 years	
Capability development for sustainability	Being done	Continuous capability development in view of new challenges	To investigate capability requirements for sustainability needs	3 years	

4.5| HUMAN FACTORS

4.5.1 Vision

a) The health and safety of workers in the engineering and construction sector has received much attention in recent years. However, accidents resulting in fatal injuries, lost-time-injury-frequency-rates and associated costs are still very high.

b) Worker health & safety and productivity are linked to the environment created by the facility. The nature of the facility is determined by decisions made during the entire project development cycle. It should be noted that the engineering and construction responsibility does not stop with the hand-over of the project but rather extends to the operation or use of the facility[18].

c) Our vision is that through research and training, the construction and engineering project environments are safe for workmen and users by partly leveraging artificial intelligence and predictive analytics to identify and manage risks in addition to cultural modification methods such as the LIP+3C model.

4.5.2 Key research topics

a) Organizational culture and H&S performance;

b) Using artificial intelligence to identify and predict occupational accidents in engineering and construction projects;

c) Addressing the needs and abilities of humans involved in the construction process;

d) Health and safety improvement in civil engineering and construction industry;

e) Future skills of the engineering and construction management professionals;

[18] WEF (World Economic Forum), 2016. Shaping the Future of Construction: a Breakthrough in Mindset and Technology.

4.5.3 Drivers, barriers and impact

a) The need to continue prioritizing the health and safety of workers in the engineering and construction remains critical and important.

b) According to the World economic Forum[19] Health and safety remains a critical area of improvement for the industry throughout the whole of its project life cycle. Although it has made significant progress the industry, remains one of the most dangerous industries to work in. therefore efforts must continue to be made to reduce the risks and hazards that are prevalent in the construction industry.

c) The engineering and construction sector is often impacted by the changes in health and safety requirements, regulations and environmental standards[13]. The recent Covid-19 in particular calls for new ways of organizing work and therefore affecting significantly on productivity.

d) Research in health and safety in the industry will result in Eskom remaining current and comply with relevant regulations and standards. Further, currency on health and safety knowledge and capability will inform the improvement of management of projects needed. This will ensure that productivity, budget, quality and environmental thresholds are met.

[19] WEF (World Economic Forum), 2016. Shaping the Future of Construction: a Breakthrough in Mindset and Technology

4.5.4 Research roadmap

The road as envisaged now is shown in table 6.0.

Table 6: Research roadmap on human factors and health & Safety

Best practice	Eskom / Industry status	Gap	Required Action	Period	Resource
Leadership- Visible and committed Involvement – All stakeholder involvement Processes – H&S as a key performance indicator. Influence project management	evident	Remaining current with new developments in H&S. H&S culture development	To investigate key strategic factors for H&S improvement in projects	3 Years	1x Research Professor 1x Post-doc fellow 2x PhD candidates 4x Master Students
Communication – Appropriate digital H&S communication	Not available	Improved risk identification and visual communication of risks	To investigate appropriate digital platforms, tools and techniques for best H&S communication results	5 years	1x Research Professor 1x Post-doc fellow 2x PhD candidates 4x Master Students
Competence – organisational capability to identify and manage risks leverage AI, BIM & digital technology. Current organisational knowledge		No initiative at the moment on H&S digital applications	To investigate extent and how to improve H&S using AI, BIM and other digital technologies to improve risk management. To track and remain current on trends and key requirements for H&S		

5 | EMSC CAPACITY

5.1| CENTRE FOR APPLIED RESEARCH AND INNOVATION IN THE BUILT ENVIRONMENT (CARINBE)

5.1.2 CARINBE is a University of Johannesburg senate approved research centre, which draws its expertise from departments within the School of Civil Engineering in the Faculty of Engineering and the Built Environment. The departments in the faculty of engineering and the built environment that will participate in the research programmes and capacity development include:

a) Civil Engineering Technology;

b) Civil Engineering Science;

c) Construction Management and Quantity Surveying;

d) Operations management;

e) Post-graduate school of Engineering management;

f) Regional and urban development.

5.2| ESTABLISHED RELATIONSHIPS WITH OTHER UNIVERSITIES

5.2.1 University of Johannesburg, has established and good working relationships with all the universities in Gauteng namely; University of Witwatersrand, University of Pretoria and Tshwane University of Technology.

5.2.2 A memorandum of understanding between the University of Johannesburg and Wits University is in place to collaborate on research and other initiatives. Relationships between staff members at various levels from these institutions are in place and collaborate on programmes such as the one proposed in this submission. Moreover, the proposed programme will accord the mentioned institutions to develop closer ties and collaborate more on research for the benefit of institutions such as Eskom and the wider society.

5.3| RELATIONSHIPS WITH GOVERNMENT DEPARTMENTS

5.3.1 The University of Johannesburg through CARINBE has signed a memorandum of agreement with the council for the built environment (CBE) to collaborate and undertake research on issues relating to the built environment. Through this agreement, UJ and CBE have undertaken research projects on Skills development for infrastructure development, transformation and strategic Infrastructure programme.

5.3.2 Another memorandum of agreement is with the Gauteng Province's department of infrastructure development (GPDID) to use innovative digital technology to monitor and control infrastructural projects. Drones and building information modelling have been used in order to improve project delivery efficiency and effectiveness in the use of constrained resources.

5.3.3 Other relationships exist with the Development Bank of Southern Africa (DBSA) on research to do with Building Information Modelling for which an MOA has been signed.

5.3.4 UJ has strong links with Government departments and is eager to add value to the services that the state provides to its people. Similarly, the University benefits from its interactions with industry and government departments.

5.4 | RESOURCES AND PERSONNEL

5.4.1 The Centre has an established and operational office with the entire communication infrastructure in place. However, the centre will need the following resources to execute on the research agenda it has set for itself.

5.4.2 Staff

a) Principal Coordinator x 1 no.

b) Research Professors (part-time) (PhD) x 5no.

c) Research associates (Post Doctorate fellows) x 10no.

d) Postgraduate students (M&D) x 52no.

5.4.3 Office

a) The Centre has an established and operational office with all the communication infrastructure in place. However, the allocated space will need slight improvement to accommodate the research agenda, as it is currently suitable for administration only.

b) The office will need partitioning, furniture and branding to reflect Eskom and UJ's values.

5.4.4 Small Equipment

a) Laptop computers x 5No.

b) Table and chairs x 5No.

c) Desktop Data storage x3No.

6| BUDGET

6.1 A budget of ZAR 1 833 171,90 for the first year has been determined in order to establish the programme team and implement it.

6.2 A breakdown of the amount is provided below and a detailed estimate is attached. The University of Johannesburg rates have been used to estimate the cost of each resource.

6.3 The budget will cover running costs and equipment associated with the programme.

7.0| CONCLUSION

7.1 The Centre for Applied Research and Innovation in the Built Environment (CARINBE) as the Engineering project Management Specialisation Centre (EMSC) has outlined the research roadmap that it would like to implement for ESKOM's EPPEI programme. Five key research areas have been proposed in which training and postgraduate research will be undertaken. These key areas include:

a) Building Information Modelling, iTwin and digital applications in engineering and construction industry;

b) Integrated project delivery approach;

c) Managing projects, structures and systems;

d) Sustainability in project delivery; and

e) Human factors – Health and safety management.

7.2 The research programme will run for a maximum period of five years.

7.3 The overall objective of the programme is to capacitate Eskom with advanced engineering and construction project management expertise. The research will benefit Eskom by leveraging the opportunities presented by the planned energy new build and refurbishment programme of aging facilities and therefore attain sustainability in current and future projects.

7.3 Specifically, the benefits of the programme include:

7.3.1 Credible research data becoming accessible to the academic researchers for the benefit of Eskom, the public and academia in general;

7.3.2 Development of a knowledgebase of lessons learned through scientific study of problems encountered in the execution of the projects;

7.3.3 Enhanced collaboration between Eskom and academia;

7.3.4 Established and trusted link for knowledge exchange and optimisation between Eskom and academia for the benefit of sustainable infrastructure development.

7.3.5 Eskom will continue to position itself as a leader in knowledge generation through research in the energy sector, professional skills development and contribute to the government's effort to address the problem of scarce skills in South Africa.

7.3.6 Increase in the number of capable construction project managers able of delivering complex projects within the set objects;

7.3.7 Improvement in the efficiency and delivery of energy infrastructure;

7.3.8 Developed future capacity to deliver complex projects without entirely relying on expatriate expertise;

7.4 The objectives of the research programme will be achieved through the following:

7.4.1 Capacitating the specialisation centre to organise, co-ordinate, monitor and control the research agenda and professionals' development program;

7.4.2 Identifying suitable candidates from within Eskom and outside of Eskom to enrol in built environment postgraduate degree programmes at the University of Johannesburg and other identified universities;

7.4.3 Eskom providing part or full bursaries for the identified postgraduate students to enable them undertake research in the chosen area from the programme;

7.4.4 Conducting research and practical assignments on Eskom's unique infrastructure development programmes;

7.4.5 Eskom and the identified host university providing mentorship and supervision of the candidates' research projects where necessary;

7.4.6 CARINBE as the EPPEI EMSC, coordinating with other identified universities and ESKOM to ensure a proper management of the research programme outlined in the roadmap.

ANNEXURE 1 | BUDGET

Table 7: Budget

ID	DESCRIPTION	2,020	2,021	2,022	2023	2024
1.0	**OPERATIONAL STAFF**					
1.1	Programme coordinator x 1 no. @ R56, 622.85 per month (100% contribution)	679,474.20	733,832.14	792,538.71	855,941.80	924,417.15
1.2	Administration assistant x 1no. @ R16,292.45 per month (50% contribution) for 6months in 2017 to administrate & coordinate activities	97,754.70	105,575.08	114,021.08	123,142.77	132,994.19
	Subvention allowance for UJ researchers and facilitators x 4No. @ R15,000,00 for maximum of four months per year	240,000.00	259,200.00	279,936.00	302,330.88	326,517.35
1.3	Teaching buy-out x 4no. @ R11,100,00 per reliever for maximum of three months per year	133,400.00	144,072.00	155,597.76	168,045.58	181,489.23
	Sub-total	1,150,628.90	1,242,679.21	1,342,093.55	1,449,461.03	1,565,417.92
2.0	**SMALL EQUIPMENT**					
2.1	Laptop computers x 5No.@ R12,000.00	60,000.00	-	-	-	66,000.00
2.2	Table and chairs x5No @ R7,000.00	35,000.00	-	-	-	38,500.00
2.3	Desktop Data storage x1No. @ R5000.00	2,500.00	-	-	-	2,750.00
	Sub-total	97,500.00	-	-	-	107,250.00
3.0	**CONSUMABLES**					
3.1	Stationery @ R5,000.00 per year	5,000.00	5,400.00	5,832.00	6,298.56	6,802.44
3.2	Miscellaneous office tools @ R1,000.00 per year	1,000.00	1,080.00	1,166.40	1,259.71	1,360.49
3.3	Printing @ R3,000.00 per year	3,000.00	3,240.00	3,499.20	3,779.14	4,081.47
	Sub-total	9,000.00	9,720.00	10,497.60	11,337.41	12,244.40
4.0	**TRAINING**					
4.1	***Programme design workshop***					
4.1.1	Eskom in-put (workshop)	3,500.00	-	-	-	-
4.1.2	Development and preparation of PSDP protocols @118.75/hr for 8 hrs for 30 days by material developer	28,500.00	-	-	-	-
4.2	***Administration Infrastructure***					
4.2.1	Operating space	150,751.00	-	-	-	-
4.2	***Professional Development Courses***					
4.2.1	Research methodology and Professional Development Courses @ R53,500.00 (Presenter & materials) per two day event for 4 events in a year held at UJ	214,000.00	235,400.00	258,940.00	284,834.00	313,317.40
	Sub-total	396,751.00	235,400.00	258,940.00	284,834.00	313,317.40
5.0	**RESEARCH**					
5.1	***five programes as per roadmap***					
5.1.1	Bursaries	90,000.00	99,000.00	108,900.00	119,790.00	131,769.00
5.1.2	Research equipment	270,000.00	297,000.00	326,700.00	359,370.00	395,307.00
	Sub-total	360,000.00	396,000.00	435,600.00	479,160.00	527,076.00
Total		**2,013,879.90**	**1,883,799.21**	**2,047,131.15**	**2,224,792.44**	**2,525,305.72**

ANNEXURE 2 | CARINBE KEY STAFF

Table 8: Staff members from SCEBE (Members of CARINBE)

Title	Name	Availability	Skills or strengths
Director	Prof I. Musonda	Available	Project management and research More than 20 years' experience. Registered Engineer and Professional Construction Manager.
Principal Researcher	Prof S Ekolu	Available	Senior academic. NRF rated researcher. More than 20 years experience
Principal Researcher	Prof F. Okonta	Available	Senior academic. With more than 20 years experience in research and teaching
Principal Researcher	Dr T. Gumbo	Available	Knowledge of key research methods. Extensive experience in research and management. More than 10 years of experience.
Principal Researcher	Dr J. Mahachi	Available	Senior academic and practitioner with more than 20 years experience in research, teaching and consulting. Professional Engineer
Principal Researcher	Dr S. Ramabodu	Available	Senior academic and practitioner with over 20 years of experience. Professional Quantity Surveyor
Senior Researcher	Dr C. Okoro	Available	Knowledgeable in property economics
Principal Researcher	Prof M. Ferentinou	Available	Knowledgeable and expert in geotechnical engineering.