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GIBELA

2024 ANNUAL REPORT

Gibela Engineering Research Chair at Stellenbosch University


GIBELA
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CONTENTS

1 - EXECUTIVE SUMMARY

PROF ANNIE BEKKER
Chair
Gibela Engineering Research Chair

FROM THEORY TO THE TRACKS...

In 2024, the Gibela Engineering Research Chair (GERC) at Stellenbosch University continued to consolidate its niche in monitoring applications and asset management technologies for the Gibela X'trapolis Mega trains. This is achieved by combining the capabilities of sensors, data, models, and analytics into digital services that support modern railway operations.

A central theme guiding the work of the Chair has been the transition from **theory to the tracks**. The initiative seeks to enrich the academic environment with a practical school of engineering, where design solutions and research outputs are tested against the operational realities of the rail sector. Beyond technical proficiency, the research ecosystem fosters a culture that values safety, professionalism, disciplined scheduling, and clear communication hallmarks of engineering in the real world.

The X'trapolis Mega trainsets are modern, sensor-rich platforms capable of logging extensive operational and equipment data. In 2024, GERC explored these digital footprints to support predictive maintenance and improved asset management by delving into the data. Research efforts included the ingestion and structuring of central fleet management logs and the creation of data visualisation tools beyond proprietary systems. This work enabled the development of data-driven models to support the prediction of traction brake and door system failures. These efforts were further supported by the construction of a digital twin for lifecycle costing, allowing for comprehensive assessments of design configurations and maintenance scenarios.

While sensors on board the train provide rich operational insight, certain aspects of mechanical degradation remain beyond their reach. One such area is the condition of rail wheels, an aspect with significant cost and safety implications. Accordingly, GERC launched a dedicated focus on wheel profile measurements in 2024. This included both stationary and wayside laser-based assessments, as well as investigations into camera-based methods and local damage detection through trackside accelerometer and laser-based sensor systems.

The research also extended to the human experience in rail. Investigations into passenger comfort and fire safety formed part of the broader systems view. In the factory setting, a virtual reality welding simulator was developed to support skills development in a safe, immersive environment, bridging knowledge with practice.

As the Chair completes its third year, this report reflects on a maturing programme of research that advances from foundational inquiry to field deployment. The technical themes presented herein demonstrate the dual pursuit of real-world impact and academic excellence. At its core, the Chair remains committed to fostering meaningful partnerships with Gibela Rail Consortium and to developing engineering professionals equipped not only with theoretical knowledge, but also with the applied insight and discipline needed in industry. This annual report captures the progress and learning from the past year an effort aspiring to springboard our foundations in **theory to the tracks**.

2 - SPONSOR REMARKS

DR BUYISWA MNCONO-LIWANI
Corporate Services and Traction Motors Operation Executive
Gibela Rail Transport Consortium

The Gibela Rail Transport Consortium maintains a steadfast commitment to the Gibela Engineering Research Chair (GERC) at Stellenbosch University. The 2024 Annual Report reflects a narrative of meaningful growth, visionary leadership, and ongoing transformation. It is a testimony of how academic ideas, nurtured within university classrooms, evolve into practical applications that positively impact the day-to-day experiences of passengers, operators, and the broader rail community.

A closer examination of this report is a reminder that every railway innovation is the result of dedicated individuals. Students pose insightful questions, supervisors provide patient mentorship, and technicians confront and resolve real-world challenges. Additionally, industry colleagues offer critical opportunities for practical application. The GERC is not merely a research programme, it represents an enduring commitment to achieving safer journeys, more reliable rail services, and a transportation system that truly serves passenger's needs.

Over the past year, the GERC has excelled in merging theoretical knowledge with practical application. Their work on sensor data, analytics, and digital services goes beyond technical innovation, it enables tangible improvements in decision-making for rail operations. By transforming raw fleet data into clear visualisations and actionable insights, the chair has shifted maintenance and design decisions from guesswork to informed, strategic planning. Notably, the digital twin for lifecycle costing stands out as a significant advancement, allowing teams to evaluate design options and maintenance strategies before any physical implementation. This proactive approach safeguards both investments and passenger safety.

Projects related to wheel health and track interactions exemplify the importance of meticulous, incremental progress. The chair's emphasis on detailed wheel profile measurements using both stationary and wayside monitoring methods and exploring camera-based approaches demonstrates a commitment to a safety-first philosophy. These methodical steps are crucial in reducing risk and extending the lifespan of valuable rail assets.

Attention to the human aspects of rail travel, including passenger comfort and fire safety, reveals a holistic approach that looks beyond mechanics and systems. The GERC has developed a virtual reality welding simulator. This tool provides a safe, immersive environment for skill acquisition, ensuring that essential, potentially life-saving, competencies are developed without compromising safety.

Strong governance and collaborative partnerships underpin the success of the GERC. The Steering Committee, comprising representatives from both the university and industry, has offered stable and ethical guidance. Leadership transitions during 2024 were managed thoughtfully, ensuring continuity while also welcoming new perspectives. This blend of experience and innovation is vital for the ongoing relevance and adaptability of the chair in meeting industry needs and addressing real-world rail challenges.

The report details a vibrant and growing student pipeline, which brings fresh energy and renewal to the programme. In 2024, a total of 15 projects spanned undergraduate, master's, and doctoral levels, reflecting a nearly seamless progression from curiosity-driven inquiry to substantial industry contributions. The structured pathway from undergraduate research (Skripsie projects) through postgraduate and postdoctoral work, mirrors the lifecycle of rail projects, from concept, to testing, to deployment, and ongoing refinement. This approach steadily builds capability, resulting in a skilled, industry-ready workforce.

As we look to 2025, our shared ambitions remain both bold and grounded in achievable outcomes. Plans include deepening data-driven asset management, expanding the applications of digital twins, advancing diagnostics in wheel and track health, and enhancing human factors research. These goals directly support Gibela's mission to provide safer and more comfortable rail services. Further expansion of the Professional Development Programme and a smooth transition for graduates into Gibela facilities and field deployments will remain priorities. These initiatives are focused on creating real opportunities for students aspiring to become engineers, for researchers evolving into trusted advisors, and for technicians dedicated to keeping trains operating safely.

Heartfelt gratitude is extended to Professor Annie Bekker for her leadership and vision, the Steering Committee for their steadfast governance, and the entire GERC team for transforming ambition into meaningful impact. Appreciation is also owed to Gibela colleagues for their trust and partnership, and to the students and researchers whose curiosity, resilience, and spirit of collaboration drive ongoing progress. Their efforts today are paving the way for safer railways, more reliable services, and a thriving rail sector in the future.

The Gibela Engineering Research Chair exemplifies the powerful outcomes achieved when academia and industry collaborate with a shared purpose. By transforming theoretical knowledge into practical, track-ready solutions and maintaining a focus on people at every stage, GERC stands as a model for applied, human-centred research. We are proud to support this ongoing journey and look forward to deepening our collaboration in future, inspired by a renewed sense of purpose and commitment to positive change.

3 - STEERING COMMITTEE

The GERC is governed by a Steering Committee, which is a properly constituted governing body with fiduciary powers over the Research Chair. The committee comprises employees of Stellenbosch University and Gibela Rail Transport Consortium to advise on the strategy for the Research Chair and approve the strategic plans presented by the Research Chair Holder. The Chair agreement mandates quarterly meetings of the Steering Committee. Table 1 presents the members of the steering committee for 2024.

Table 1: Steering Committee of the Gibela Engineering Research Chair.

COMMITTEE MEMBERS	ROLE	ORGANISATION
Mr Sipho BAMBISA	Steering Committee Chairperson	Gibela Rail Transport Consortium
Mr Nitesh MUNILALL	Industry Technical Advisor	Gibela Rail Transport Consortium
Ms Karabo SERUNYE	Economic Development Advisor	Gibela Rail Transport Consortium
Prof Annie BEKKER	Research Chair Holder	Stellenbosch University
Prof Petrie MEYER *1	Vice Dean - Research and Industry Liaison	Stellenbosch University
Prof Herman ENGELBRECHT *2	Departmental Head	Stellenbosch University
Mr Pieter CONRADIE	Administrative Support	Stellenbosch University
Ms Tsholofelo MOKOLOPO	Scribe	Gibela Rail Transport Consortium

*1: Replaced by Prof Corne Schutte in September 2024
*2: Replaced by Prof Japie Engelbrecht in December 2024

The dates and locations of formal meetings are noted in Table 2. Figure 1 shows the visit of members of the Steercom to the High Voltage lab.

Table 2: Steering Committee Meeting Dates and Details

DATE	MEETING DETAIL	LOCATION
25 March 2024	Steering Committee Meeting	Online
4 July 2024	Steering Committee Meeting	Online
13 September 2024	Prof Corne Schutte was introduced to the team, replacing Prof Petrie Meyer as Vice Dean.	Online
6 December 2024	Dr Buyiswa Mncono-Liwani joined the meeting. Prof Japie Engelbrecht was introduced to the team, replacing Prof Herman Engelbrecht as Departmental Head (E&E)	Stellenbosch, Western Cape

Figure 1: Members of the December 2024 Steercom meeting at the High Voltage Laboratory with Mr Nelius Bekker

4 - GIBELA ENGINEERING RESEARCH CHAIR TEAM

4.1 - STAFF

	NAME	DESIGNATION	ROLE
	**Prof Annie Bekker**	**Research Chair**	Annie Bekker is a professor in the Department of Mechanical and Mechatronic Engineering (M&M). She is registered as a Professional Engineer with ECSA and is a NRF C2-rated researcher. She is responsible for the strategic and academic development of the GERC.
	**Mr Pieter Conradie**	**Chief Chair Engineer**	Pieter Conradie supports Chair activities through his earlier experience with the PRASA Chair in Rail Engineering at Stellenbosch University. As an internationally registered professional engineer with ECSA, he leads the GERC Professional Development Programme to foster the next generation of engineering professionals at Gibela.
	**Mr Michael Perumal**	**Senior Chair Engineer**	As a former employee of Gibela, Michael Perumal brings insight and relational knowledge of Gibela to the GERC. He is registered as a Professional Engineer with ECSA. His role ensures logistical, technical and practical support for student projects in terms of safety, equipment and expertise. Michael is also busy with his Masters with the GERC.
	**Dr David Ellis**	**Postdoctoral Fellow**	As a postdoctoral fellow, David Ellis is responsible for the research and academic depth of the GERC. This includes student mentorship, the in-depth pursuit of research questions, the development of practical rigs and writing articles for publishing in academic or industrial literature.
	**Mr Olabanji Asekun**	**Social Operations**	Olabanji Asekun assists with project management and undertakes the hosting and all organisational aspects of the GERC social impact events. He also uses his expertise to support the Gibela seminars.
	**Ms Susan van der Spuy**	**Finance & Admin**	Susan van der Spuy facilitates payments, financial reporting and travel bookings for all activities related to the GERC.

5 - GERC STUDENT PROJECTS

Through strategic project scoping and supervision, the Chair facilitates multi-tiered research engagement spanning undergraduate to postdoctoral levels. At the undergraduate level, final-year students undertake focused research projects (Skripsie) lasting either six months or one full academic year. Each student works closely with a dedicated academic supervisor on an individual project, ensuring rigorous scholarly mentoring while developing independent research capabilities.

The Chair's postgraduate research program encompasses both Master's and Doctoral studies. Master's candidates pursue two-year research projects which should solve advanced problems with technical depth, while Doctoral candidates engage in comprehensive three-year investigations which should contribute novelty to the field. These advanced studies contribute significantly to the Chair's research objectives and knowledge creation mandate. Postdoctoral research fellows, having completed their doctoral studies, conduct full-time investigations into sophisticated research areas.

Table 3 indicates that a total of 15 projects were in progress in 2024, with 6 final-year projects successfully completed. 2024 shows promising growth in postgraduate research, but further growth is required in the recruitment of PhD students. Additionally, focus could be afforded to increase faculty-wide participation from Skripsie level.

Table 3: Summary of final-year and postgraduate projects per Engineering department. Numbers in brackets indicate graduated students.

YEAR	FINAL YEAR		MASTERS			PHD	TOTAL
	M & M	Industrial	M & M	Industrial	Civil	M & M	
2022	3 (3)	3 (3)	1 (0)	1 (0)	-	-	**8**
2023	5 (5)	2 (2)	3 (1)	2 (1)	-	1	**14**
2024	5(5)	1(1)	5	2	1	1	**15**

5.1 - STUDENTS

Mr Luqmaan Ryklief

B.Eng Industrial

Ms Leane de Wet

B.Eng M&M

Mr Kyle Hurst

B.Eng M&M

Mr Keith Jonker

B.Eng M&M

Mr Xander Praetorius

B.Eng M&M

Mr Saieed Suleiman

B.Eng M&M

Ms Danielle van Nieuwenhuisen

B.Eng M&M

Mr Yoshua Becker

M.Eng Civil

Ms Nelisa Mabaso

M.Eng Industrial

Mr Stefan Knoblauch

M.Eng Industrial

Mr Daniel du Toit

M.Eng M&M

Ms Abbey Kirkman

M.Eng M&M

Mr Enrico Lubbe

M.Eng M&M

Ms Anique Phillips

M.Eng M&M

Mr Michael Perumal

M.Eng M&M

Table 4: A summary of academic projects with the GERC.

#	TITLE	STUDENT	SUPERVISOR	DEPARTMENT	FIRST YEAR OF REGISTRATION / (EXPECTED) COMPLETION
Final year projects					
1	Camera-based rail wheel wear measuring system	Ms Danielle van Nieuwenhuizen	Prof Kristiaan Schreve	M & M	2024/2024
2	Real-time Track Monitoring System	Mr Kyle Hurst	Mr Pieter Conradie	M & M	2024/2024
3	Development of a virtual reality TIG welding training simulator	Mr Keith Jonker	Mr Pieter Conradie	M & M	2024/2024
4	Investigation of vertical wheel-rail force and rail stress state: Wheel defects	Ms Leane de Wet	Prof Annie Bekker	M & M	2024/2024
5	Investigation of vibro-acoustic track signatures for train condition monitoring	Mr Xander Praetorius	Prof Annie Bekker	M & M	2024/2024
6	The Optimisation of Railway Operations – Developing a Performance Assessment Tool for Train Drivers	Mr Luqmaan Ryklief	Dr Philane Zincume	M & M	2024/2024
7	A vibration exposure calculator with subjective feedback for people in public transport	Mr Saeed Suleiman	Prof Annie Bekker	M & M	2024/2024
Masters' research projects					
1	A maintenance decision support digital twin for passenger trainset life cycle costing	Ms Abbey Kirkman	Prof Anton Basson & Prof Annie Beker	M & M	2024/2025
2	An on-board track monitoring system for modern railway vehicles	Mr Dániel du Toit	Prof Annie Bekker	M & M	2024/2025
3	Analysis and investigation of wheel loads using strain gauges and thermal imaging	Mr Enrico Lubbe	Prof Annie Bekker	M & M	2024/2025
4	Data mining for predictive rolling stock maintenance	Mr Stefanus Knoblauch	Mr Eldon Burger	Industrial	2022/2024
5	Dynamic rail wheel profile measurement utilising laser light technology	Ms Anique Phillips	Prof Kristiaan Schreve & Prof Annie Bekker	M & M	2024/2025
6	Fire modelling of passenger trains	Mr Yoshua Becker	Prof Richard Walls	Civil	2024/2025
7	Investigating machine learning solutions to aid in rolling stock predictive maintenance efforts	Ms Nelisa Mabaso	Prof Jacomien Grobler & Prof Annie Bekker	Industrial (Part-time)	2023/2025
8	Investigation of 2D multi-body track and train dynamics	Mr Michael Perumal	Dr Brendon Nickerson & Prof Annie Bekker	M & M (Part-time)	2023/2025

5.2 FINAL YEAR PROJECTS

5.2.1 CAMERA-BASED RAIL WHEEL WEAR MEASURING SYSTEM

This project focused on the design, development and validation of a camera-based system for train wheel wear measurement, offering a non-contact alternative to current methods. The system measures key wheel profile parameters, such as flange height, flange thickness, flange angle, and rim width, using high-resolution Basler cameras equipped with fixed focal lenses. The methodology includes calibrating the cameras with a checkerboard pattern to determine intrinsic and extrinsic parameters and a scale factor for pixel-to-millimetre conversion. The captured images of the train wheel profiles were processed using grayscale conversion, Gaussian blur, Canny edge detection, 2D homography, and edge alignment techniques to extract profile measurements.

The system was tested in a controlled laboratory environment using a stationary train wheel, as shown in Figure 2. The measurements were compared with those from an industry-standard non-contact system. The camera system demonstrated high precision in flange height measurements, achieving a standard deviation of 0.067 mm, outperforming the industry standard laser (0.077 mm). However, systematic errors in flange thickness, flange angle, and rim width measurements were observed, stemming from perspective distortions and the dependency on manual adjustments during processing.

To address these limitations, adjustments to the formulas were developed to correct the perspective bias introduced by angled camera setups. Despite these improvements, variability in rim width measurement and inconsistencies in flange thickness indicated areas for refinement.

The study concludes that the system is a viable non-contact solution for train wheel wear monitoring, with potential for real-world application after addressing current limitations. Future work will focus on integrating stereo imaging for depth analysis, automating measurement processes, and enhancing robustness under varying environmental conditions. This project lays a solid foundation for advancing rail maintenance practices with cost-effective, camera-based technologies.

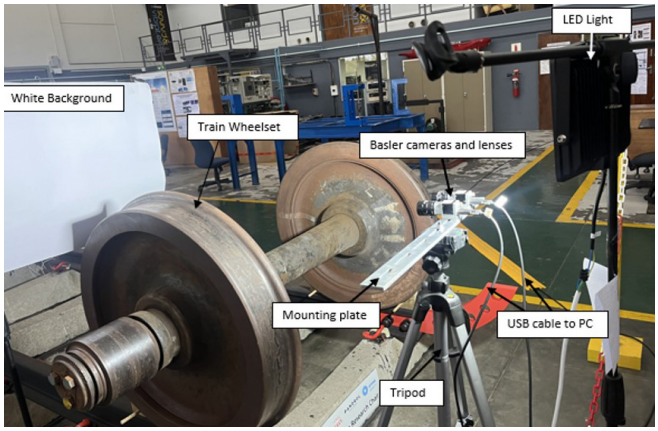

Figure 2: Laboratory setup of camera-based rail wheel wear measuring system

5.2.2 DEVELOPMENT OF A VIRTUAL REALITY TIG WELDING TRAINING SIMULATOR

This virtual reality (VR) simulator (shown in Figure 3) investigated the use of virtual reality for TIG welding training. The system addresses the need for cost-effective, accessible training solutions in the rail transport industry, particularly for stainless steel welding applications.

VR hand-tracking is enabled by the Leap Motion Controller 2 and is integrated with an HTC Vive Tracker mounted on a physical TIG torch. Virtual replication allows training of the complex ambidextrous movements required in TIG welding. The system implements real-time monitoring of eight critical welding parameters, including travel speed, work angle, and heat input, providing parallel feedback through haptic, visual, and auditory cues.

The simulator's requirements were determined in conjunction with professional welding instructors at Gibela's Welding Training Centre. The design of a specialised lap-to-groove joint makes it particularly valuable for rail industry applications.

Validation was conducted via a scoring system which evaluates welding technique. When a professional welder was able to create an accurate virtual 1G butt weld from intuitive use of the VR system, it reflected in high scores of their critical welding parameters for the process.

This research provides a low-cost, focused alternative to existing commercial welding simulators while maintaining essential training value. The system's ability to simulate custom weld positions, along with results obtained from validation, indicate that the simulator successfully balances cost, functionality, and training effectiveness for industrial skills development in TIG welding.

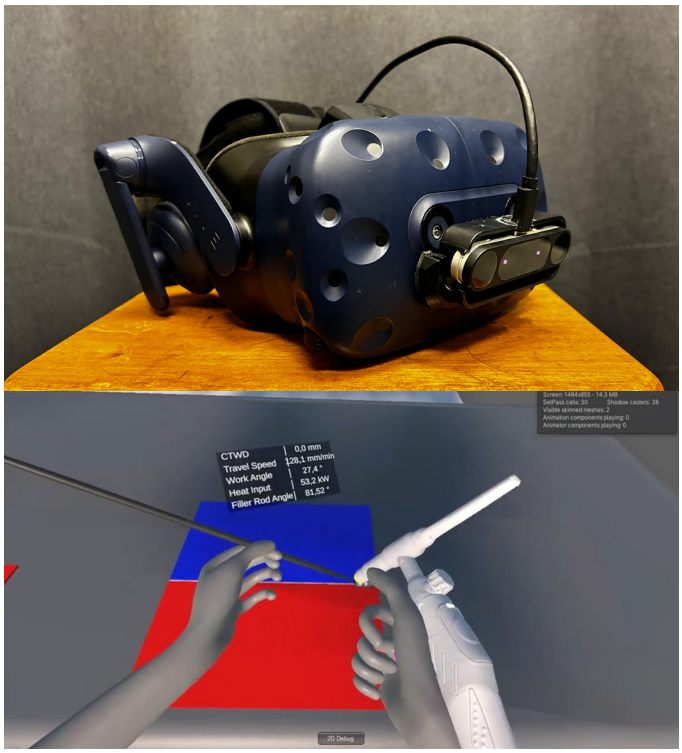

Figure 3: VR Headset used in welding simulator (top) and screenshot of user interface (bottom)

5.2.3 INVESTIGATION OF VERTICAL WHEEL-RAIL FORCE AND RAIL STRESS STATE: WHEEL DEFECTS

The reconstruction of the train vertical wheel-rail force using wayside monitoring was investigated. Wayside monitoring refers to the installation of sensors to assess the condition of the train wheels. This project focused on the application of strain gauges as a wayside monitoring method. A strain-based system with the correct configuration can act as a wheel impact load detector, indicating train wheel defects. The shear stress method was used to identify and quantify the relationship between train wheel loads and the beam stress and strain state.

An analytical investigation was performed into the shear stress measurement method, and a formula was derived for the measured bridge strain. An analytical model was created to mimic a laboratory measurement rig using the Macaulay beam theory. A finite element model of a laboratory measurement rig was developed to evaluate different load cases. A rail prototype measurement rig was instrumented with strain gauges according to the shear stress measurement method. The vertical wheel-rail force was approximated using a calibrated regression line and the analytical model. The results indicate that the analytical model has an accuracy of 88.4 % for an average wheelset test speed of 0.56 km/h.

A rail section at the Paarden Eiland depot was instrumented (refer to Figure 4) and strain measurements were obtained at train speeds of 0.5, 10, 20 and 30 km/h. The analytical model was used to predict the train vertical wheel-rail force and corresponding mass for each respective wheel axle at a train pass of 0.5 km/h. The strain data obtained at train speeds of 10, 20 and 30 km/h were used to determine the train dynamic load for each wheel axle. The results indicate that high dynamic loads correspond to documented wheel defects.

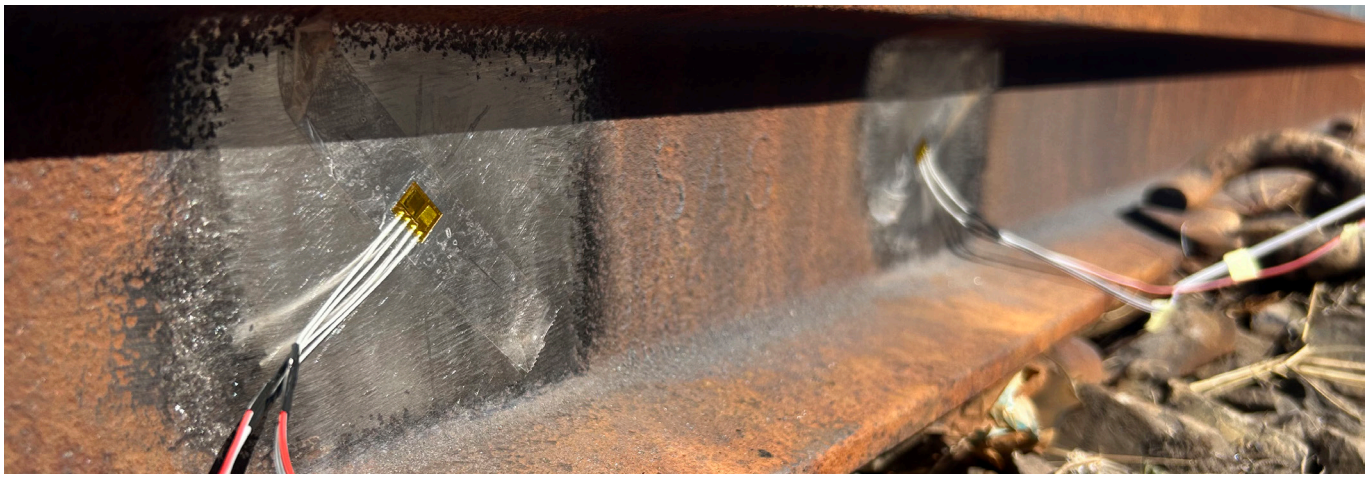

Figure 4: Section of rail instrumented with strain gauges to measure shear strain at the Paarden Eiland depot

5.2.4 INVESTIGATION OF VIBRO-ACOUSTIC TRACK SIGNATURES FOR TRAIN CONDITION MONITORING

Acoustic methods were explored for detecting wheel flats in trains. Wheel flats pose safety risks and incur maintenance costs. This research aims to establish a proof of concept for using wayside acoustic measurements to identify wheel flats, a novel approach for GERC at Stellenbosch University.

The project methodology includes designing an experimental rig with acoustic sensors placed along the track to capture the pass-by response of trainsets at varying speeds, as shown in Figure 5. Data from these experiments, taken from both defective and healthy trainsets, is analysed using signal processing techniques, including Fourier and short-time Fourier transforms. These techniques allow for characterisation of the unique acoustic signature of wheel flats, facilitating localisation to specific axles.

Acoustic sensors capture sound without a physical connection to the track, a method anticipated to provide more flexibility and reduced maintenance compared to conventional approaches, which can be a viable addition to Gibela's maintenance program.

Figure 5: Acoustic sensor used to detect the presence of wheel flats at the Paarden Eiland depot

5.2.5 THE OPTIMISATION OF RAILWAY OPERATIONS – DEVELOPING A PERFORMANCE ASSESSMENT TOOL FOR TRAIN DRIVERS

In South African railway operations, train driver performance significantly impacts overall operational efficiency despite modern control systems. This project addresses the need for a comprehensive performance assessment framework by developing a quantitative tool to evaluate train drivers using data from on-board sensors and the Central Fleet Management (CFM) system. The driver inputs are captured as shown in Figure 6.

A structured framework was developed encompassing key performance areas: Train Handling, Compliance with Rules and Safety, Vigilance and Attention, Passenger Comfort and Safety, Error Management, and Efficiency. Key Performance Indicators (KPIs) were established using the Analytical Hierarchy Process, with Average Master Control, Emergency Brake Rate, Average Speed, Maximum Speed and Temperature Violation Rate emerging as primary metrics.

The framework was validated using CFM data from November 2022 to January 2023. Analysis of 85 drivers revealed significant performance variations, with only one driver achieving a grade meeting the KPI. However, data quality issues limited the assessment's comprehensiveness.

The study concludes that while the developed framework provides a foundation for systematic driver assessment, its practical implementation requires addressing data quality challenges and refining benchmarks based on operational realities.

Figure 6: Driver performance can be evaluated by monitoring inputs

5.2.6 REAL-TIME TRACK MONITORING SYSTEM

This research explored the development of a real-time railway defect detection system using machine learning and sensor integration, tested on an HO (Half O) scale model train (Figure 7). The project builds upon previous research, aiming to enhance defect identification and blockage detection while the train is in motion. A custom You Only Look Once (YOLO)-based object detection model was developed,

Figure 7: Half O model track

alongside a LiDAR-based obstacle detection system. The system stops the train upon detecting obstacles or defects, using a camera and LiDAR as shown in Figure 8. The project faced challenges such as optimising the YOLO model, overcoming hardware limitations, and developing a solution for rotating the camera and LiDAR sensors to accommodate track curves. Technical innovations include the creation of a customisable defect detection system that is adaptable to various real-world conditions.

The study demonstrates potential for real-world application, showcasing the ability to improve railway maintenance practices and operational safety. Future commercial applications are discussed, highlighting the potential for implementation in large-scale railway systems to reduce unplanned maintenance and operational costs..

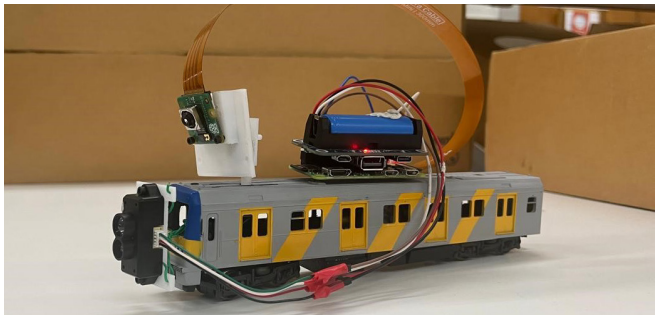

Figure 8: Model train instrumented with a camera and LiDAR

5.2.7 A VIBRATION EXPOSURE CALCULATOR WITH SUBJECTIVE FEEDBACK FOR PEOPLE IN PUBLIC TRANSPORT

Commuting is an essential part of the daily lives of people across the world, and comfort is one of the most important aspects considered when evaluating the quality of a commute. Impulsive vibrations largely impact the overall comfort of passengers. This project aimed to address the influence that impulsive vibrations had on the subjective comfort when travelling on a train and how this related to objective metrics of comfort presented standards.

An objective measurement system comprised of a triaxial seat pad accelerometer and GPS was implemented according to the ISO 2631-1 and EN 12299-2009 standards and was used to investigate whole-body and impulsive vibrations. A MATLAB application was designed to capture subjective comfort ratings and automatically process vibration measurements to quantify objective comfort measurements. The system was tested on a public X'Trapolis Mega train travelling from Newlands to Fish Hoek with 5 participants (see Figure 9).
The results showed that comfort is highly subjective

Figure 9: Passenger comfort measurement in progress

and that a definite correlation between the subjective ratings and objective comfort metrics could not be determined. The vibration dose value was found to be the best metric to determine the threshold of discomfort. The methods used during testing yielded the necessary results; however, further testing with more participants should be performed to obtain more concrete conclusions.

5.3 MASTERS RESEARCH PROJECTS

5.3.1 A MAINTENANCE DECISION SUPPORT DIGITAL TWIN FOR PASSENGER TRAINSET LIFE CYCLE COSTING

Digital twin (DT) technology has the potential to assist the rail industry through the data-driven optimisation of maintenance, thereby improving overall operational performance and reducing life cycle costs. However, little has been published on a comprehensive DT architecture that integrates data, such as life cycle costing (LCC), across the full life cycle of a fleet of rail assets.

This research aims to develop a proof-of-concept DT system to support LCC-related maintenance decisions for a fleet of passenger trainsets.

The DT system will accommodate the commonalities and differences of trainsets in multiple as-built and as-maintained baselines. The system will integrate LCC and related maintenance data collected throughout the trainsets' life cycles. Therefore, the DT system will provide an integrated platform for multiple trainsets, enabling the aggregation of data across various configurations for more comprehensive analysis.

The highly adaptable architecture for the DT system is being developed following the systems engineering approach. A context analysis informs the system requirements; therefore, adaptability, scalability and maintainability are prioritised in the architecture design.

This research shows the potential of a DT system that can accommodate the commonalities and differences of trainsets and integrate data across the life cycle of a fleet of trainsets. This DT system presents a step towards a comprehensive DT architecture for a rail asset's full life cycle, facilitating various applications within the rail industry.

5.3.2 AN ON-BOARD TRACK MONITORING SYSTEM FOR MODERN RAILWAY VEHICLES

This research presents a novel system for real-time railway track monitoring, addressing the limitations and costs of periodic inspections that rely on specialised measurement vehicles and extensive data post-processing. By utilising on-board sensors, including wireless tri-axial accelerometers on the axle-box (Figure 10) and an Inertial Measurement Unit (IMU), the system provides continuous, automated monitoring and rapid defect detection. Integrated with a Global Positioning System (GPS), the system not only pinpoints defect locations but also transmits data to a remote server for analysis. Machine learning, statistical methods, and time-frequency analysis work in tandem to identify track geometry defects.

The system's approach to vibration data processing through time-frequency domain analysis reveals key track geometry issues. It aligns with Industry 4.0 standards by introducing cloud-based data handling and reduced human intervention. The use of fused sensor data offers insights into both track and train dynamic responses, enhancing defect detection accuracy and providing valuable data on track degradation patterns.

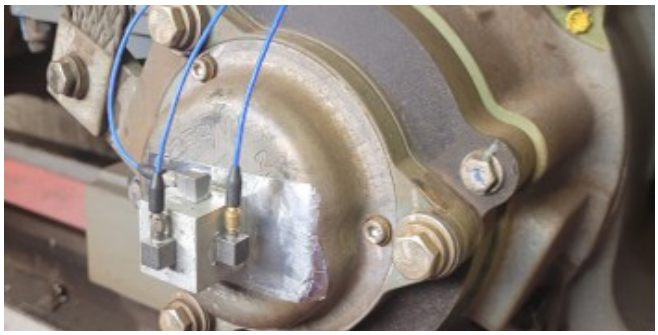

Figure 10: Triaxial accelerometer installed on axlebox of X"trapolis Mega

Early development phases show promising results in analysing axle-box acceleration data, with further field testing planned in collaboration with Gibela and the Passenger Rail Agency of South Africa (PRASA). These tests aim to refine the defect detection algorithms, making the system adaptable to various operational environments. Expected outcomes include a significant improvement in maintenance efficiency, transitioning from scheduled inspections to condition-based maintenance. This approach aims to optimise maintenance schedules, reduce track downtime, and minimise repair costs while enhancing safety.

Ultimately, this real-time monitoring solution is designed to benefit railway operators and maintenance teams by offering an efficient, reliable tool for continuous track condition assessment. The system's capacity for detailed defect mapping and real-time notification could play a crucial role in modernizing railway maintenance practices and improving the overall safety and reliability of railway infrastructure.

5.3.3 ANALYSIS AND INVESTIGATION OF WHEEL LOADS USING STRAIN GAUGES AND THERMAL IMAGING

Integrating strain gauges and thermal imaging offers an alternative approach to measuring vertical loads and analysing thermal wheel-contact patterns. This combination improves defect classification and assesses whether thermal imaging can be applied to moving trains, reducing operational disruptions.

The methodology integrates a Wheel Impact Load Detector (WILD) with a thermal imaging system. Strain gauges configured in a full-bridge setup were installed on the rail web to measure vertical loads. Laboratory tests validated the accuracy of the gauges, while field tests at the Paarden Eiland train depot involved static and dynamic measurements of wheel loads and flats at speeds from 4 km/h to 40 km/h. An Infratec 6300Z thermal camera recorded heat patterns on wheel treads exiting the WILD zone, as shown in Figure 11.

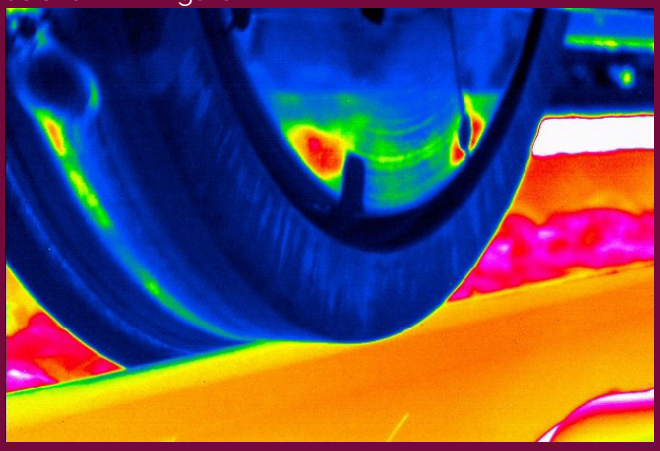

Figure 11: Thermal image showing potential to detect wheel flats

Machine learning is being used to distinguish between defective and non-defective wheels and correlate thermal data with load measurements.
Preliminary laboratory results show the WILD system achieves 99% accuracy in static load detection, with field data confirming the identification of wheel loads alongside wheel fats. Thermal imaging revealed localised cold spots at wheel-flat locations. Challenges include limited wheel capture in thermal imaging due to reduced resolution at higher frame rates and the WILD system's restriction to vertical load measurement within the instrumented section.

This research introduces the integration of thermal imaging with WILD systems. This dual-system approach provides earlier, more accurate wheel flat detection and new insights into defect analysis through image processing and machine learning.

5.3.4 DATA MINING FOR PREDICTIVE ROLLING STOCK MAINTENANCE OF PNEUMATIC BRAKES

Passenger rail services depend on reliable operations and strict adherence to schedules, requiring effective maintenance strategies to ensure passenger safety and minimise disruptions. Traditional preventive or fixed-interval maintenance practices risk repairing and replacing parts prematurely or after the occurrence of train failures. Condition-monitoring technologies allow trains, such as the X'Trapolis Mega trains operated by the PRASA, to transmit real-time subsystem data to centralised repositories. By analysing the condition of various components and subsystems in real-time, a transition to predictive maintenance can be accomplished by identifying and addressing potential faults before they occur.

This study focuses on predicting pneumatic brake defects using operational data collected through TrainTracer. The research addresses challenges such as high data volumes, noise, missing values, and variable data velocity by employing a data aggregation strategy that transforms event-driven data into fixed time windows. These windows allow for the prediction of pneumatic brake defects in future intervals, with response times exceeding 30 minutes to enable the isolation of faulty brakes without disrupting operations. Decision trees were selected for their ability to handle diverse data scales, outliers, and classification tasks while providing interpretable results. Models were evaluated using metrics such as recall, ROC AUC, and accuracy.

The study shows that decision trees provide a viable solution to predict the occurrence of pneumatic brake defects while providing sufficient response time for operators to isolate brakes. Additionally, the interpretability of decision tree models enables the derivation of business rules, offering maintenance teams actionable insights into the root causes of brake defects and improving maintenance strategies. The results show potential for the use of decision trees to predict other types of train faults, leveraging condition-monitoring technologies for scalable predictive maintenance approaches. This contributes to enhanced rail safety, reduced maintenance costs, and improved operational efficiency.

5.3.5 DYNAMIC RAIL WHEEL PROFILE MEASUREMENT UTILISING LASER LIGHT TECHNOLOGY

The reliability and safety of railway systems are critical to ensuring efficient and uninterrupted rail transportation. A key aspect of railway maintenance involves monitoring the condition of rail wheels. Current rail wheel inspection methods predominantly rely on manual, contact-based measurements using handheld devices. While effective under controlled conditions, these methods are labour-intensive, prone to human error, and require trains to remain stationary, limiting their applicability for real-time monitoring.

This research aims to design, develop, and implement a dynamic, non-contact rail wheel measurement system that operates in real time as trains are in motion. Using three strategically placed lasers (an example of which is shown in Figure 12), the system captures wheel profiles and merges the data into a common coordinate system, enabling accurate condition assessments. A stationary rig was developed as a precursor to the dynamic rig, allowing for laser calibration, angle optimisation, and the validation of profile merging algorithms.

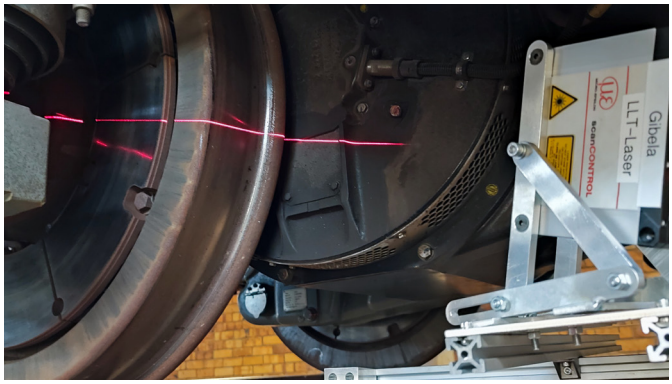

Figure 12: Single laser line capturing a static wheel profile of the X'Trapolis Mega in a pit lane at the Paarden Eiland Depot

The dynamic rig, currently under construction, is designed to account for the vibrational environment of operating trains. Future work includes vibration analysis of the dynamic rig, further refinement of flange and tread wear algorithms, and the development of a diameter calculation algorithm. Additionally, a trigger system for laser activation and a robust data storage framework are being implemented. This project ultimately seeks to enhance rail maintenance operations by providing continuous, automated, and accurate wheel condition monitoring, improving safety and reducing costs.

5.3.6 FIRE MODELLING OF PASSENGER TRAINS

The fire safety of passenger train components is crucial to ensure passengers' well-being and the train structure's integrity. This research investigates fire dynamics and safety in passenger trains, with a focus on the impact of materials, emerging fire risks, and occupant safety under various fire scenarios. Modifying specifications for improved fire resistance poses significant challenges as the material requires extensive and costly retesting. Each local product used must be tested and fire-rated before implementation. This restricts the localisation of materials and limits opportunities for innovation or geometric reconfiguration.

The study includes experimental testing and numerical modelling to assess time to flashover, evacuation tenability criteria, and the consequences of fires involving contemporary hazards such as lithium-ion batteries. Experimental testing involves cone calorimeter tests of train interior materials, which include finishes, walls, roofs, and floors, to determine ignitability and heat release rates under varied thermal flux conditions. These data form the basis for computational fluid dynamics (CFD) modelling using Fire Dynamics Simulator (FDS) and PyroSim. The models simulate a range of fire scenarios, including arson, accidental fires, and thermal runaway incidents in lithium-ion battery devices, examining critical factors such as heat release rates, toxic smoke generation, and evacuation times.

The research aims to investigate how long occupants have to escape under different fire conditions, the influence of material specifications on fire growth, and the localisation of materials. Also explored are future challenges posed by increasing passenger loads and emerging fire hazards, providing insights into proactive fire safety measures beyond current compliance requirements. By emphasising passenger safety and the performance of localised materials, the study seeks to advance international fire safety standards and support industry preparedness for evolving risks. Ultimately, this work provides a foundation for informed design and mitigation strategies, ensuring safer environments in an era of increasing passenger densities and novel fire hazards.

5.3.7 INVESTIGATING MACHINE LEARNING INVESTIGATING MACHINE LEARNING SOLUTIONS TO AID IN ROLLING STOCK PREDICTIVE MAINTENANCE EFFORTS

Door-related failures in train subsystems significantly impact operational reliability and performance. This study aims to develop interpretable machine learning models to predict door-related failures with high accuracy while preserving the temporal integrity of the dataset. Key objectives include identifying suitable predictive techniques, ensuring temporal alignment in predictions, and deriving actionable business rules to enhance subsystem reliability.

The dataset presented challenges such as missing values, redundancy, and class imbalance. Feature engineering efforts involved breaking down event codes, deriving temporal features, and incorporating event frequency metrics.

Initial modelling employed tree-based algorithms, Decision Trees, Random Forests, and Gradient Trees—alongside a Multi-Layer Perceptron (MLP). Models were evaluated using precision, recall, and F1-score, with Random Forests and MLP achieving the best performance, showcasing precision and recall exceeding 99%. Feature importance analysis guided the prioritisation of subsystem-specific features such as Traction and Emergency Braking. Domain feedback was integrated to refine feature selection and ensure relevance to operational contexts.

Future work involves refining the oversampling strategy to ensure temporal consistency, introducing additional time-aware features, recalibrating models, and exploring alternate interpretable techniques. The ultimate goal is to generate actionable business rules and insights, validated through collaboration with domain experts, to facilitate proactive maintenance strategies.

5.3.8 INVESTIGATION OF 2D MULTI-BODY TRACK AND TRAIN DYNAMICS

On-site experimental measurements capture real-world data and can assist researchers in developing an understanding of observed phenomena or validating theory, to name a few applications. Physical testing can uncover behaviour that is unexpected from theory and can lead to developments to bridge this gap. However, physical testing also introduces variables that cannot be controlled but may influence results significantly. In contrast to experimental measurements, simulations provide a controlled environment for investigating and probing observed phenomena.

This research focuses on developing a two-dimensional wagon track numerical model. The ability to control these parameters allows for comprehensive analysis of worst-case scenarios, which can be unsafe, costly, time-consuming or logistically challenging to execute experimentally.

The gains from the simulation can be used to inform maintenance scheduling, train/track design specifications and even train operation. The simulation will be validated against measured X'Trapolis Mega datasets and investigate contact forces due to wheel flats.

6 - RESEARCH INFRASTRUCTURE AND FIELD WORK

The GERC maintains a distinctive advantage through our capacity for independent, high-precision field measurements thanks to our sponsorship from Gibela. Rather than relying solely on literature data, simulations or third-party measurements, we conduct rigorous on-site testing using precision instruments. This self-reliant approach enables us to develop and refine custom testing methodologies tailored to our specific research needs.

The ability to perform our own measurements gives us complete control over data quality and experimental parameters. Our equipment allows us to capture detailed measurements in real-world conditions, while our iterative testing capability means we can verify findings, adjust methodologies, and explore unexpected results through additional testing campaigns. This hands-on approach not only ensures data integrity but also deepens our understanding of the physical phenomena we study. Our students are exposed to a school of practice through their immersion in an operational engineering environment.

By maintaining full control over our measurement processes, from experimental design to data collection, we can adapt our methodologies to address new research questions or accommodate challenging field conditions. This experimental autonomy has proven invaluable in advancing our research objectives and progress towards a high standard of scientific rigour.

6.1 SITE TESTING

Spanning from February 2024 to November 2024, two days per month (on average) were assigned to on-site instrumentation and measurement at the Metro Rail Depot at Paarden Eiland. The majority of on-site testing was conducted on Line 8 (see Figure 13), with measurements also occurring on pit lines and operational routes from the Paarden Eiland depot to Bellville station. Researchers are obliged to comply with depot regulations, which include background medical checks and safety inductions. GERC was reliably supported by the Gibela and PRASA staff at Paarden Eiland, namely, Mr Siya Xhosa and Mr Angelo Isaacs.

In addition to our existing toolbox, GERC experimented with the capabilities of the ImageIR 6300Z InFratec thermal camera thanks to a trial arranged by our measurement technology partner TANDM. The results of these extensive measurement campaigns are presently investigated in a postgraduate research project (as in section 5.3.3).

Figure 13: Students conducting on-site diagnostics of sensor connectivity on the fly


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6.2 LABORATORY TRACK RIG

The facilities of GERC were extended in 2024 with a new laboratory Track Rig. This laboratory rig comprises eleven P2 sleepers placed on a conveyor belt material spanning a length of 7.2 m supporting a 2x 48kg/m rail connected to the sleepers via 20mm anti-vandal Pandrol rail clips. The track gauge is 1067mm and thus utilises T17 Gauge Plate Insulators (GPI's) on the outer track with T11 GPI's on the inside of the rail. The setup was sponsored by PRASA, Pandrol, Gibela and Stellenbosch University. The laboratory rig introduces students to the rail installation process and provides a controlled environment to prepare for on-site testing and measurement. The laboratory rig facilitated research projects on both undergraduate and postgraduate levels. Figure 14 shows the assembly process of the test rig and Figure 15 shows the completed setup.

Figure 14: Assembly process and final result of the laboratory track

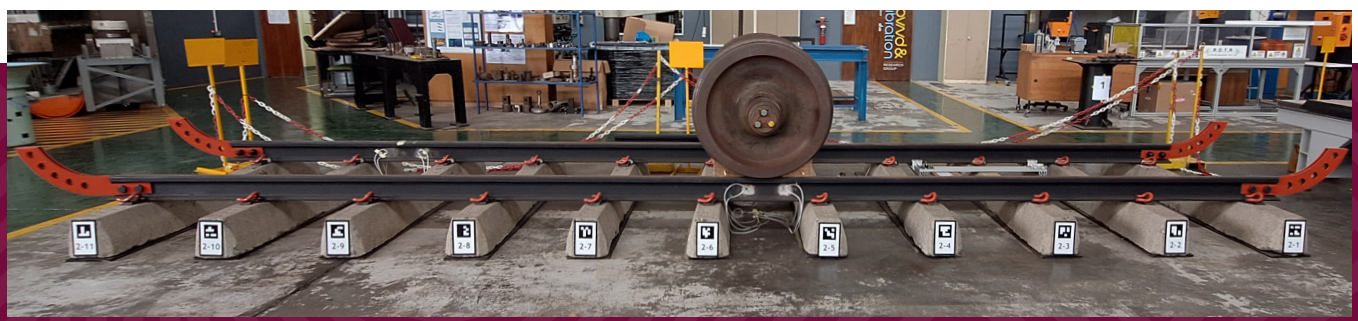

Figure 15: Lateral view of final track laboratory set-up with ArUco markers, single train wheelset and wheel stops

7 - ACADEMIC FOOTPRINT

Active participation in the rail engineering community is fundamental to the GERC's mission. Through strategic engagement in conferences, seminars, and technical workshops, the research group maintains direct connections with leading rail industry experts, practitioners, and researchers worldwide. This network of knowledge exchange ensures that our research remains aligned with current industry challenges while contributing to the broader advancement of rail engineering practices.

Our team members regularly attend and present at key industry events, bringing back valuable insights that inform our research directions and methodologies. These gatherings serve to share findings, validate approaches, and identify emerging trends in railway engineering. The bilateral flow of knowledge - from the field to research and back to the industry - strengthens the Chair's position as a bridge between academic research and practical implementation.

7.1 CONFERENCES

7.1.1 SAIMECHE POSTGRADUATE CONFERENCE

The South African Institute of Mechanical Engineers (SAIMechE) Annual Postgraduate Conference, held at the South African Renewable Energy Technology Centre at Cape Peninsula University of Technology, showcased GERC's significant contribution to railway engineering research. The conference, which offered professional development opportunities through its CPD accreditation, featured strong representation from our research group.

Two notable contributions highlighted GERC's presence. Prof Annie Bekker delivered the keynote address, reinforcing our Chair's leadership role in mechanical engineering research. Additionally, Mr Michael Perumal presented innovative research through his paper "Development of a 2D wagon-track multi-body simulation." His presentation focused on the mathematical fundamentals of rail implementation within simulation environments, contributing to the advancement of computational methods in railway engineering analysis.

7.1.2 TANDM COMMUNITY CONNECT

TANDM, a leading measurement and equipment supplier and valued partner of GERC, hosts an annual CPD-accredited symposium focused on advances in test and measurement. The event brings together industry leaders and TANDM's strategic partners to explore emerging trends, technological innovations, and their impact on the local market.

Figure 16: TANDM Community Connect hosted at Lord Charles Hotel, Somerset West

At this year's conference, Mr Michael Perumal delivered a keynote address, presenting a comprehensive overview of Gibela's operations and GERC's research initiatives, highlighting the relationship between the organisations. Figure 17 presents the highlights from Mr Perumal's address. The event was further distinguished by GERC team member Mr Enrico Lubbe receiving recognition for outstanding social media engagement (Figure 18).

Building on this successful collaboration, GERC aims to strengthen its presence at future Technical Conference and Convention (TCC) events.

Figure 17: Mr Michael Perumal presented an overview of GERC's strategy

Figure 18: Enrico won best "Social Media Post"

7.1.3 SOUTH AFRICAN COMPUTATIONAL AND APPLIED MECHANICS CONFERENCE 2024

The 13th South African Conference on Computational and Applied Mechanics (SACAM) took place at the STIAS Wallenberg Centre in Stellenbosch. Recognised as a leading international conference on the African continent, SACAM provides a platform for researchers and practitioners to present advancements in computational and applied mechanics. Held biennially under the auspices of the South African Association for Theoretical and Applied Mechanics (SAAM), the conference attracts both local and international participation.

The 2024 edition welcomed 62 delegates, including 6 industry representatives, with participants from 7 different countries. Dr David Ellis and Ms Anique Phillips represented GERC at the SACAM 2024. Dr Ellis presented a paper titled "Wheel Flat Detection Using Wayside Measurements and Hilbert-Huang Transform", while Ms Phillips presented "Optical Laser Rail Wheel Profile Measurement Unit". Both papers were well received, offering the presenters valuable experience in delivering technical content to a specialised audience.

7.1.4 INTERNATIONAL CONFERENCE ON RAILWAY TECHNOLOGY

Prof Annie Bekker and Dr David Ellis attended the Sixth International Conference on Railway Technology: Research, Development and Maintenance in Prague, Czech Republic, 1 to 5 September 2024. The conference comprised 215 attendees from 17 countries with approximately 30 technical sessions presented in four parallel tracks.

In their evaluation of emerging trends, GERC found that railway research is exploring the use of LiDAR in the automated detection of vegetation close to catenary wires and in obstacle detection using a combination of camera and LiDAR technology. Additionally, it was identified that a group at the University of Porto, Portugal, is very active in simulation approaches for wheel flat identification. Contributions at this conference related to multiple wheel flat identification in freight trains and machine learning methodologies for the identification of multiple out-of-round railway wheels from wayside monitoring systems. Several publications propose methodologies to estimate rail track geometry from inertial measurements on train bogies. Finally, studies on wheel-rail interaction, using thermal cameras, received high interest at the conference despite significant practical challenges with implementation.

Figure 19: Towers of Prague

Figure 20: David Ellis and Annie Bekker in Prague

7.2 EXPOSITIONS

7.2.1 ANNUAL RAIL SAFETY CONFERENCE

The Annual Rail Safety Conference (ARSC) serves as a key forum for rail industry professionals across Southern Africa to share knowledge, experiences, and best practices aimed at improving railway safety. The 2024 edition was held in Hazendal, Western Cape, and was attended by Mr Olabanji Asekun and Mr Pieter Conradie.

In addition to fostering valuable networks, their participation provided insights into the latest advancements in railway safety and performance across the region.

7.2.2 AFRICA RAIL

Africa Rail is the largest and most established rail event on the continent, serving as the key meeting point for stakeholders across the rail, freight, and transport sectors. The 2024 event was held in Sandton, Johannesburg, and attended by Mr Michael Perumal, Mr Olabanji Asekun, and Mr Pieter Conradie from the Gibela Chair. Figure 21 shows the GERC team at Africa Rail 2024.

The event provided valuable insights into the latest developments in the rail industry and facilitated the establishment of important networks. Following the event, it was agreed that the Chair will support Gibela at their exhibition stand during the 2025 edition of Africa Rail.

Figure 21: Mr Pieter Conradie, Mr Olabanji Asekun and Mr Michael Perumal at Africa Rail 2024

7.2.3 INNOTRANS

InnoTrans is the world's leading international trade fair for transport technology, held biennially in Berlin. The exhibition spans multiple segments, including Railway Technology, Railway Infrastructure, Public Transport, Interiors, and Tunnel Construction. With over 170,000 visitors across four days and occupying more than 40 halls at the Berlin Exhibition Grounds, InnoTrans is a key global platform for innovation in the transport sector.

Mr Pieter Conradie, shown in Figure 22, represented the Gibela Research Chair at the 2024 edition, gaining valuable insights into sustainable transport solutions, digital transformation, and forward-looking mobility concepts set to shape the future of global transport. The event also provided an excellent platform for building international networks.

Figure 22: Mr Pieter Conradie at Innotrans 2024

8 - "SKILL UP" WORKSHOPS

To date, the Chair has utilised ad-hoc workshops to upskill personnel and students through short-term training and development opportunities. These opportunities may be rail-specific or serve the general competency of staff and students in the group. Table 5 summarises the workshops conducted in 2024. Additionally, a year-round professional development programme is also conducted by GERC.

Table 5: A summary of workshops by GERC

DATE	TOPIC	# ATTENDEES	LOCATION	PRESENTERS
February 2024	Fundamentals of vibration	9	Gibela Corporate Office, Midrand	Prof Annie Bekker, Dr David Ellis
February 2024	Strain gauges and data acquisition: "(It does not) workshop"	6	Structural Laboratory, Stellenbosch University	Prof Annie Bekker, Mr Dylan Naidoo (TANDM)
April 2024	Final year student project presentations: Aims and objectives – speed talks	8	Stellenbosch University	Mr Nitesh Munilall (Head of Engineering, Gibela)
March 2024	Specialist course in signal processing and experimental modal analysis	27	Structural Laboratory, Stellenbosch University & Le Pommier Wine Estate, Stellenbosch	Prof Joerg Bienert (University of Applied Sciences Ingolstadt)
July 2024	Practical strain gauge application	32	Strain Gauge Laboratory, Stellenbosch University	Dr Brendon Nickerson, Mr Ferdi Zietsman
November 2024	"How to make an amazing presentation"	14	Stellenbosch University	Mr Eduard de Kock

8.1 FUNDAMENTALS OF VIBRATION

On 28 February 2024, Prof Annie Bekker and Dr David Ellis facilitated a Fundamentals of Vibration workshop for nine Gibela colleagues at the company's corporate office in Midrand. A pre-course survey indicated that most participants considered vibration-related topics highly relevant to their daily responsibilities, with particular interest in signal processing, practical vibration measurement, and the application of theory to real-world challenges. The post-course assessment demonstrated a satisfactory uptake of the presented material, with attendees reporting increased confidence in addressing vibration-related issues within their work environment. Participant feedback highlighted the value of the course and suggested the inclusion of additional content focused on rail-specific vibration and the interpretation of vibration reports in future sessions.

8.2 SPECIALIST COURSE IN SIGNAL PROCESSING AND EXPERIMENTAL MODAL ANALYSIS

From 11 to 15 March 2024, Stellenbosch University was treated to a lecture series by Prof Joerg Bienert, a specialist in acoustics and engineering mechanics, and the vice-dean of the Faculty of Engineering at the University of Applied Sciences, Ingolstadt, Germany.

Mr Teboho Ramothibe and Mr Gopolang Seyagodimo from Gibela joined about 25 final-year and postgraduate engineers and staff for the main lectures on signal processing, state-space models and practical experimental modal analysis. The schedule was extended to include specialist topics in structural modification and coupling, rotating machinery and vibro-acoustics. The presentation format varied between lectures, discussions and laboratory sessions. There was also an opportunity for lecturers and students to all be students in a classroom again and enjoy a social event at Le Pommier Wine Estate.

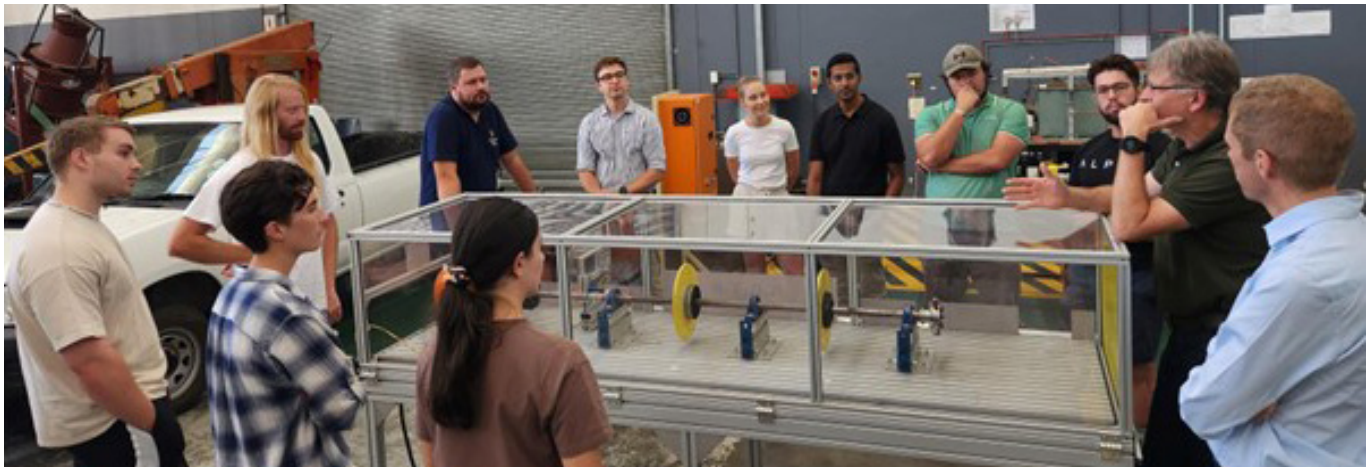

Figure 23: The format of the course included practical sessions in the Structural Laboratory.

Figure 24: Mr Teboho Ramothibe and Mr Gopolang Seyagodimo joined Prof Bienert and students and staff of GERC in Stellenbosch for a specialist course in Signal Processing, Experimental Modal Analysis.

8.3 STRAIN GAUGE PRACTICAL

The GERC hosted two strain gauge application practicals at Stellenbosch University's strain gauge laboratory on 3 and 5 July 2024, open to all persons, to expose the attendees to practical strain gauge installations. The sessions brought together a diverse group of 32 participants, including undergraduate students, postgraduate students, and lecturers. Dr Brendon Nickerson and Mr Ferdi Zietsman delivered a comprehensive refresher course on strain gauge theory and practical implementation. The hands-on component involved installing a quarter-bridge strain gauge on a mild steel beam, which encompassed cleaning the specimen, glueing the strain gauge, soldering the gauge, and testing the instrumented beam (Figures 25, 26 & 27).

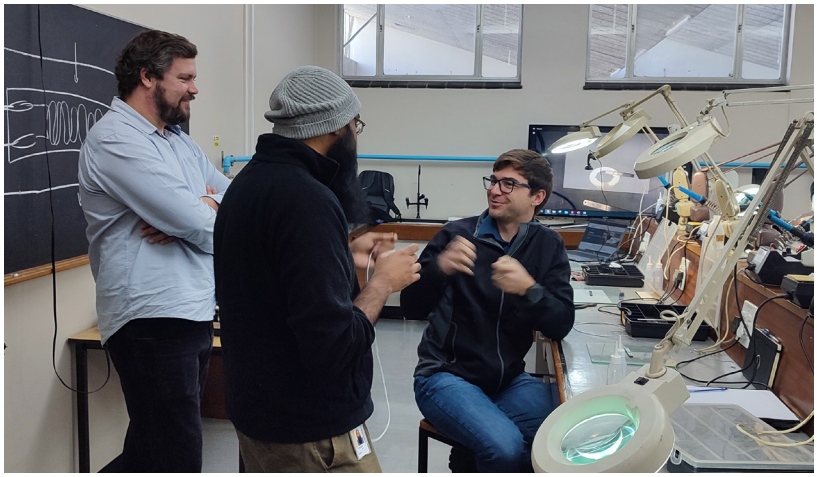

Figure 25: Dr Nickerson reviewing staff strain gauge installations

Figure 26: Attendees practising strain gauge installations

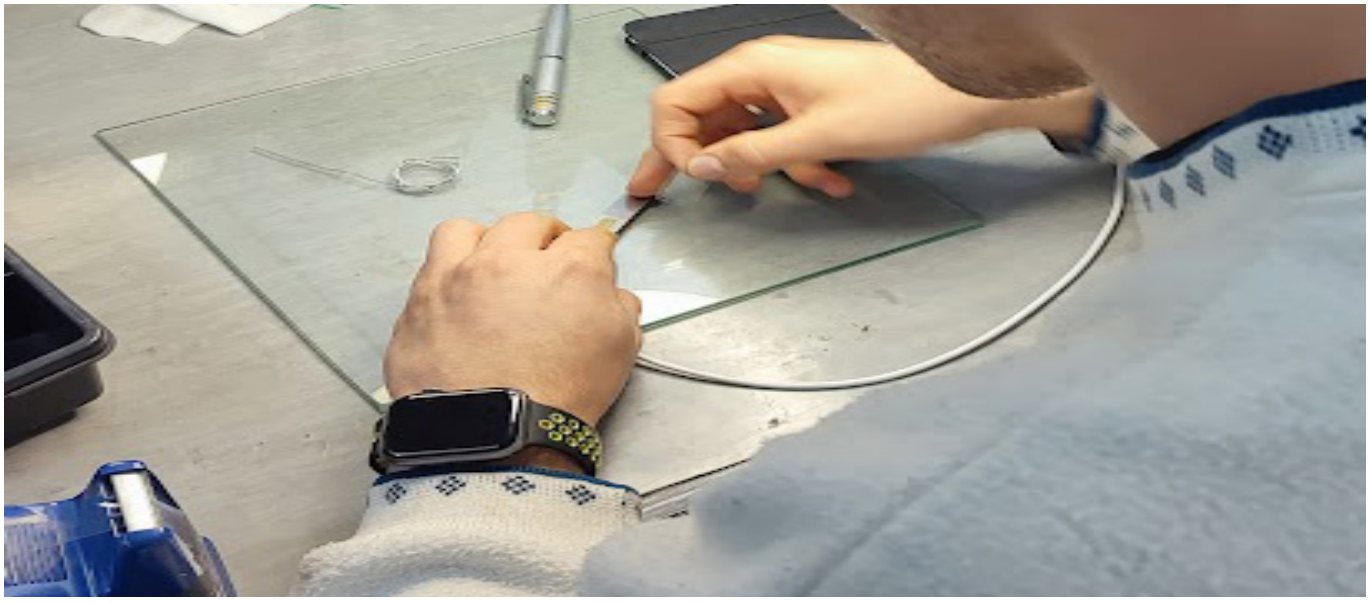

Figure 27: Close-up showing the dexterity required to install a strain gauge effectively

8.4 HOW TO MAKE AN AMAZING PRESENTATION

Building on the previous year's successful presentation skills initiative, the GERC continued its collaboration with Mr Eduard de Kock from the Stellenbosch University Language Centre. Mr de Kock provided specialised training to prepare GERC students for their oral examinations and presentations at the 2024 GERC Seminar. The training programme emphasised essential presentation competencies, including audience analysis, engagement techniques, and practical presentation skills. This investment in students' professional development demonstrates GERC's ongoing commitment to enhancing the communication capabilities of emerging researchers.

Figure 28: Mr Eduard de Kock provided yet another engaging presentation on how to make amazing presentations

8.5 GIBELA PROFESSIONAL DEVELOPMENT PROGRAMME

The Gibela Professional Development Programme (GPdP) was launched as a pilot initiative in 2023, aimed at mentoring and supporting engineering candidates on their path to registration with the Engineering Council of South Africa (ECSA). A total of seven practitioners were enrolled in the programme; two in Mechanical Engineering, three in Electrical Engineering, one in Industrial Engineering, and one in Computer Engineering, as shown in Table 6.

Table 6: A summary of the 2024 Gibela professional development programme outputs

	GIBELA				SU
	M & M	Industrial	E & E	Computer	M & M
ENROLLED	2	1	3	1	2
SUBMITTED	1	0	0	1	1
REGISTERED	0	0	0	0	1

One of the key challenges faced by candidates is understanding how to "write in ECSA language" and how to structure the required reports. To address this, the Gibela Chair provided targeted support to help candidates interpret ECSA requirements and develop their reports, offering both one-on-one guidance and general training sessions delivered either in person or online.

Through this interaction, one candidate successfully submitted their ECSA registration application while another candidate re-submitted their revised Engineering Report. The professional registration support was also extended to Stellenbosch University, resulting in Mr Michael Perumal (Chair Engineer) registered as a Professional Engineer and Mr Gerhard Durandt (Laboratory Engineer) submitted his ECSA application. The Chair provided guidance to

candidates in the Department of Mechanical and Mechatronic Engineering, helping them better understand the ECSA requirements.

To strengthen the focus on Professional Development, the Chair proposed establishing an independently funded GPdP enabling the training and resourcing of both internal and external mentors to support candidates effectively. In collaboration with the Gibela Training Centre, funding proposals were submitted to the Transport Education and Training Authority (TETA) and the Manufacturing, Engineering and Related Services SETA (merSETA) for special discretionary and project-based funding.

Furthermore, the South African Institution of Mechanical Engineers (SAIMechE) and the South African Institute of Electrical Engineers (SAIEE) visited the Engineering team at the Gibela factory. They expressed their commitment to providing support and mentors from their member networks, should additional support be required.

9 - SOCIAL RESPONSIBILITY

Initiated in 2022, the Rail Safety Education and Awareness Campaign for Primary Schools was developed to address the increasing need for vigilance around railway lines, particularly in light of the post-COVID resurgence in rail activity. The campaign has two key objectives: (1) to educate learners on rail safety, and (2) to introduce them to Science, Engineering, and Technology (SET). With financial and logistical support from Gibela and the Railway Safety Regulator (RSR), the initiative has completed 10 campaigns, reaching 820 learners from 13 schools across three provinces in South Africa. Two campaigns were held in 2024.

In April 2024, the rail safety campaign was held in the Western Cape, involving Grade 6 and 7 learners from St Vincent Primary and St Augustine's Primary Schools. At the Winelands Light Railway, learners participated in interactive sessions focused on rail safety, aimed at promoting responsible behaviour near railway tracks and on trains. Mr Loyiso Jiya from Gibela addressed the learners and encouraged them to study after school. To introduce them to SET, the learners visited the Civil Engineering laboratories at Stellenbosch University's Faculty of Engineering.

In July 2024, the rail safety campaign was held in KwaZulu-Natal for the first time, engaging Grade 6 and 7 learners from Emncgwini and Piet Retief Primary Schools. The event took place at the Pietermaritzburg Model Engineering Society's miniature railway yard, where learners were educated on rail safety. Mr Nkosiyezwe-Israel Makhanya from Gibela addressed the learners and explained the role of Gibela in the rail sector. They were also introduced to SET through an interactive "strongman" demonstrator. Laughter and excitement filled the air as learners, and even their teachers, competed in a friendly challenge to apply the greatest force to the device using their arms. Figures 31 to 35 capture the highlights from 2024 campaigns.

At Stellenbosch University, social impact is not merely a responsibility but a core value, grounded in collaboration and reciprocal engagement to help build a better society. In recognition of its meaningful contribution to social impact, the Rail Safety Campaign was honoured with a prestigious Stellenbosch University Social Impact Team Award in December 2024 (Figure 29). Originally funded by the University's Social Impact Department, the campaign has grown into a recognised, sustainable, and well-supported programme. The award, one of only nine presented, was conferred by the Deputy Vice-Chancellor: Social Impact, Transformation and Personnel, acknowledging the campaign's significant achievements and lasting impact.

Figure 29:The Rail Safety Education and Awareness Campaign received an award at Stellenbosch University Social Impact Awards 2024

The feedback from students, educators and funders has been overwhelmingly positive. This campaign has elevated rail safety awareness and sparked curiosity and ambition, encouraging young learners to dream bigger and explore possibilities within the SET fields.

The campaigns achieved the partnership's objectives and were well received, with positive feedback from the schools, stakeholders and partners. This campaign has elevated rail safety awareness and sparked curiosity and ambition, encouraging young learners to dream bigger and explore possibilities within the SET fields. A summary of the Rail Safety Campaigns in 2024 is shown in Table 7.

Table 7: 2024 Rail safety campaigns summary statistics

DATE	VENUE	SCHOOL	# LEARNERS
3 April 2024	Winelands Light Rail Stellenbosch University	St. Vincent Primary School	90
4 April 2024	Winelands Light Rail Stellenbosch University	St. Augustine's Primary School	95
10 July 2024	Pietermaritzburg Model Engineering Society	Emncgwini Primary School	75
11 July 2024	Pietermaritzburg Model Engineering Society	Piet Retief Primary School	80

The Rail Safety Campaign, led by Stellenbosch University through the Gibela Chair, is a powerful example of social responsibility and collaborative impact. In a sector often noted for challenges, this campaign focuses on positive change, uniting key stakeholders such as Gibela, RSR and SUN in a shared commitment to safety and education.

Figure 30: A group photo of learners at Winelands Light Rail

Figure 31: Mr Loyiso Jiya (Head of Communications at Gibela) engaging with learners

Figure 32: Captain Sporo teaching learners about Rail Safety

Figure 33: Learners testing their knowledge on Rail safety

Figure 34: Learners signing the Rail Safety Pledge

Figure 35: Mr Loyiso Jiya & Mr Nkosiyezwe Makhanya (KZN Depot Manager) with the Rail Safety Ambassadors

10 - INTERACTIVE ENGAGEMENT WITH GIBELA

10.1 GIBELA ENGINEERING RESEARCH CHAIR SEMINAR 2024

The Gibela Engineering Research Chair hosted its annual research seminar at the Lanzerac Wine Estate, continuing the Chair's tradition from previous years. The seminar, which afforded the participant one CPD point, was strategically structured to align with Gibela's research output requirements. The statistics and the programme for the seminar is shown in Table 8 & 9. The event drew diverse participation from academia, the PRASA, Gibela, and Alstom industry experts, as seen in Figure 36.

Prof Annie Bekker, GERC Chair, opened the proceedings with a keynote address (Figure 37) highlighting the research group's 2024 achievements. The seminar featured fifteen student presentations complemented by three industry presentations from Gibela representatives: Ms Dolly Mathebula, Mr Mahlori Chauke, and Mr Tebogo Tease. Dr. Buyiswa Mncono-Liwani, the Corporate Services and Traction Motors Operation Executive at Gibela, delivered the industry keynote address as seen in Figure 41.

Figure 36: Attendees ot the 2024 Gibela engineering research chair pose on the footsteps of the Cellar Hall at Lanzerac

To accommodate an expanded student cohort, the seminar program was organised into four distinct thematic sessions, each led by an appointed chair.

Dr. Brendon Nickerson presided over the *Track & Wheel Geometry and Human Element* session, while Ms Dolly Mathebula guided the Data Analysis track. Mr Gerhard Durandt chaired the On Track session, and Mr Tshepo Nkodi led the Off the Rails segment as shown in Figure 38.

Two awards recognised outstanding contributions: Mr Daniel du Toit received the Best Presenter Award, as seen in Figure 40, while Ms Leane de Wet earned the Best Poster Award as shown in Figure 39. A Kahoot quiz was conducted during the event based on the content of the day. The quiz was a group effort and was won by the team of Mr Tebogo Tease and Ms Anique Phillips.

Figure 37: Prof Annie Bekker presents the keynote address

Figure 38: Mr Tshepo Nkodi chairing the "Off the rails" session

Table 8: Summary statistics of presentations and attendees for the Gibela Engineering Reseach Chair seminar 2024

DATE	NUMBER OF GERC PRESENTATIONS	NUMBER OF INDUSTRY PRESENTATIONS	KEYNOTE SPEAKER FROM GIBELA	TOTAL NUMBER OF ATTENDEES	INDUSTRY ATTENDANCE
04 December 2024	15	3	Dr Buyiswa Mncono-Liwani	60	Gibela PRASA Alstom Industry Experts

Mr Nitesh Munilall provided closing remarks, offering guidance and expressing appreciation for GERC's research contributions (Figure 42). The formal proceedings concluded with a networking reception, fostering informal dialogue and professional connections in a collegial atmosphere.

This successful seminar exemplified GERC's commitment to advancing rail engineering research while strengthening industry-academia collaboration. The full-day event structure and execution demonstrated the Research Chair's mature understanding of industry requirements and its ability to showcase relevant, high-quality research outputs.

Table 9: GERC seminar 2024 programme

DESCRIPTION	PRESENTER	PROJECT TYPE
Opening		
Opening and welcome	Mr Pieter Conradie	-
Welcome from the Vice-Dean	Prof Corne Schutte	-
Keynote Speaker	Prof Annie Bekker	-
Keynote Speaker	Dr Buyiswa Mncono-Liwani	-
Theme 1: Track & Wheel Geometry and the Human Element Session Chair: Dr Brendon Nickerson		
Wheel profile measurements	Ms Anique Phillips Prof Kristiaan Schreve, for Ms Danielle van Nieuwenhuizen	Masters research project Final year research project
Track defect detection	Mr Daniel du Toit Mr Kyle Hurst	Masters research project Final year research project
Human cyber-physical system and train comfort	Mr Luqmaan Ryklief Mr Saeed Suleiman	Final year research project Final year research project
Theme 2: Delving in the Data Session Chair: Dolly Mathebula		
Lifecycle costing and LCC tool	Mr Mahlori Chauke	-
Data-driven problem solving	Mr Stefan Knoblauch Ms Nelisa Mabaso (online)	Masters research project Masters research project
LCC tools and digital twins	Ms Abbey Kirkman	
Theme 3: On Track Session Chair: Gerhard Durandt		
Equipment-based maintenance	Ms Dolly Mathebula	-
Wheel flat detection	Dr David Ellis Mr Michael Perumal	Post-doctorate project Masters research project
Load Reconstruction	Mr Enrico Lubbe Ms Leane de Wet	Masters research project Final year research project
Theme 4: Off the Rails Session Chair: Tshepo Nkodi		
Wheel wear prediction	Ms Tebogo Tease	-
Virtual welder	Mr Keith Jonker	Final year research project
Fire safety	Mr Yoshua Becker	Masters research project
Rail Safety and ECSA	Mr Pieter Conradie	-
Closing		
Closing remarks	Mr Nitesh Munilall	-

Figure 39: Ms Leane de Wet receiving the award for best Skripsie poster from Dr Buyiswa Mncono-Liwani

Figure 40: Mr Daniel du Toit receiving the award for best speaker from Dr Buyiswa Mncono-Liwani

Figure 41: Dr Buyiswa Mncono-Liwani presenting the keynote address on behalf of Gibela

Figure 42: Mr Nitesh Munilall providing concluding remarks at the 2024 seminar


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10.2 YEAR-END FUNCTION

The GERC concluded its year with a memorable function in the picturesque coastal town of Kalk Bay. Attendees had the option of enjoying a scenic train ride aboard the X'Trapolis, conveniently arriving within walking distance of the chosen venue. We were delighted to host members from the Gibela offiœs in Midrand, the Gibela factory in Dunnottar, along with our enthusiastic research group students and esteemed Faculty. This unique gathering fostered valuable interaction and socialising among all attendees. The scenic backdrop of Kalk Bay provided a delightful setting for this end-of-year celebration, making it a truly memorable occasion for everyone.

Figure 43: Gibela and Stellenbosch GERC pose at the Brass Bell restaurant

Figure 44: GERC students and staff at the seawall in Kalk Bay.

Figure 45: Mr Mahlori Chauke and Mr Keith Jonker recognised for a successful year at Gibela and Stellenbosch University, respectively

Figure 46: Ms Dolly Mathebula receiving an award from Prof Petrie Meyer and the GERC team (right)

11 - HIGHLIGHTS

11.1 DEPARTMENTAL YEAR-END AWARDS

The Engineering Faculty at Stellenbosch University continued its tradition of recognising outstanding student research in 2024. Through generous sponsorship from the Gibela Rail Transport Consortium, the Faculty presented two prestigious railway engineering awards. The "Best Final Year Railway Project in Mechanical and Mechatronic Engineering" was awarded to Ms Leane de Wet for her research titled "Investigation of vertical wheel-rail force and rail stress state: Wheel defects." Similarly, Mr Luqmaan Ryklief received the "Best Final Year Railway Project in Industrial Engineering" for his work on "The Optimisation of Railway Operations– Developing a Performance Assessment Tool for Train Drivers." Both projects demonstrated exceptional research quality and practical relevance to the rail transport sector, emerging as winners from a highly competitive year.

Figure 47: Award winners, Ms Leane de Wet and Mr Luqmaan Ryklief, receive prizes for "Best Final Year Railway Project" in Mechanical and Industrial Engineering, respectively

11.2 SOCIAL IMPACT AWARD

In December 2024, the Rail Safety Education and Awareness Campaign for Primary School Learners received the prestigious Stellenbosch University Social Impact Team Award. The award was presented during a ceremony at the Stellenbosch University Museum, where the campaign was recognised as one of the evening's highlights for its meaningful contributions to rail safety, education, and community engagement. The award was received on behalf of the team by Mr Pieter Conradie and Mr Olabanji Asekun from the Gibela Chair, along with Mr Loyiso Jiya from Gibela, who now proudly refer to the campaign as the "award-winning rail safety campaign".

Figure 48: Social impact award certificate (left), Mr Pieter Conradie receiving social media award (right)

12 - IN CLOSING

GERC extends its sincere appreciation to the Gibela Rail Transport Consortium, as well as to our staff, students, and all contributors who have enabled the work of the Chair. In a research environment that strives for real-world relevance, the sponsorship and collaborative openness of Gibela have been instrumental. Stellenbosch University is deeply grateful for this support, which has enabled the Chair to progress from establishment to tangible activity within just three years.

A defining highlight of 2024 has been the spirit of engagement that GERC has experienced through the encouraging and hands-on involvement of Gibela personnel. Their open willingness to participate in technical discussions, share operational insights, and provide practical feedback has meaningfully elevated the quality and relevance of our work and training. This collaborative approach has shaped the technical direction of many projects and created an immersive, applied learning environment for students.

GERC's student cohort now stands at 15, comprising a balanced mix of undergraduate and master's candidates. Undergraduate students engage in exploratory engineering projects that expose them to practical problem-solving. For GERC, this serves as an ideal platform to pilot projects with the potential to contribute meaningfully to Gibela. At the research level, the recruitment of a strong group of first-year master's students, each focused on advanced engineering challenges, has been a major success. As these students progress to the second year of their studies in 2025, they are expected to deliver outcomes at a more mature technical level.

The overarching theme of the Chair's work in 2024 remains the development of niche competencies in digital twin technology to support rail operations and asset management for the X'Trapolis Mega passenger fleet. Research into wayside measurement and monitoring technologies for rail wheel condition has advanced, alongside efforts to derive actionable insights from large volumes of operational data. Parallel work on passenger safety and comfort including fire risk mitigation and ride experience seeks to embed the perspective of the commuter within the broader context of rail digitalisation. Collectively, these projects mark GERC's transition from conceptual exploration at the desk to practical engineering research at the coalface of operations.

Beyond the university campus and factory floor, the Chair continues to promote rail awareness and STEM education through the Rail Safety Education and Awareness Campaign. In 2024, this initiative expanded to KwaZulu-Natal with its first school awareness event hosted in Pietermaritzburg. This milestone was made possible through the enduring partnership between Stellenbosch University, Gibela Rail, and the Railway Safety Regulator. The initiative was honoured with a prestigious Stellenbosch University Social Impact Team Award in recognition of its reach and relevance.

As the Chair reflects on its third year of operation, the trajectory is clear: 2024 was a year of meaningful progress from concept in theory to testing on the tracks. GERC has matured into a functioning, collaborative research group operating within the realities of the rail environment. With continued support, the next phase of the Chair's journey is poised to progress from theory to implementation. This demanding challenge reflects our commitment to delivering implementable solutions and skilled graduates who can respond to the evolving needs of Gibela and the wider rail industry.

GIBELA ENGINEERING RESEARCH CHAIR

Stellenbosch University
Department of Mechanical and Mechatronic Engineering

6th Floor c/o Banghoek & Joubert Str
Stellenbosch 7600

+27 21 808 4376

gibela@sun.ac.za

gerc.sun.ac.za

Stellenbosch

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