COMMERCIAL VIABILITY REPORT

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PROSPECTOR
ROBOTICS

EXECUTIVE SUMMARY

Prospector Robotics Limited (PRltd) is a UK-based start-up revolutionizing the mining industry with cutting-edge autonomous robotic solutions.

The geochemical sampling process allows mining companies to collect and analyse soil samples to identify potential mineral deposits. The latest creation is the robot ROMIE which is an autonomous sampling robot designed to operate on prospecting land, making geochemical sampling processes faster, safer and more efficient than ever before.

The era of manual labourers drilling fields and collecting soil samples is a thing of the past with the introduction of ROMIE. ROMIE performs drilling, and soil analysis and stores the results in the database at desired sampling point with ease.

The company aims to facilitate cost-effective, efficient, and safer mining practices using advanced robotic technology and predictive algorithms. The mining equipment industry is a lucrative market, with the potential for sales reaching billions of dollars annually and tapping into an unrivalled growth market.

PRltd has raised £1.9M in the Dragons' Den competition to fuel their mission of impacting the mining industry. The funding will be allocated towards the design, development, testing, and production of the autonomous robotic solution, as well as the establishment of a subsidiary in South Africa (SA).

The company is led by a highly experienced and skilled team with backgrounds in engineering, robotics, and business management. The employees have a track record of successful product development and commercialisation, providing confidence in their ability to deliver results.

Based on market research, the demand for autonomous robotic solutions in the mining industry is growing, with an estimated market potential of $8.6B [1] in revenue in the next 7 years. PRltd's autonomous robotic solution is expected to generate revenues of £46M in the first year, with projected growth of 25% annually.

PRltd offers an attractive opportunity for investors seeking high returns in a rapidly growing market. The company's unique product, experienced management team, and strong growth potential make it an appealing investment opportunity.

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LIST OF ACRONYMS

AI	Artificial Intelligence
ANC	African National Congress
B	Base case
B2B	Business to Business
BoP	Beginning of Period
BS	Blue-Sky case
CAGR	Compound Annual Growth Rates
CAPEX	Capital Expenditure
Co	Company
DDP	Development Delay Protocol
EBITDA	Earnings Before Interest Taxes Depreciation Amortisation
EIS	Enterprise Investment Scheme
ESG	Environmental, social, and governance
FCF	Free cash flow
GBP	the British Pound sterling
GDBP	Group Design Business Project
GDP	Gross Domestic Product
GPS	Global Positioning System
HR	Human resources
IoT	Internet of Things
IP	Intellectual Property
IPO	Initial Public Offering
M&A	Merger and Acquisition
ML	Machine Learning
OPEX	Operating Expenses
PGM	Platinum Group Metals
PRltd	Prospector Robotics limited
Q1	quarter 1
R&D	Resource and Development
ROMIE	Robotic Ore Mineral Identification and Exploration)
S	Standard case
SA	South Africa
SEIS	Seed Enterprise Investment Scheme
TBReAI	Team Bath Racing Electric Artificial Intelligence
UKRI	UK Research and Innovation
UN	United Nation
UoB	University of Bath
USD	United States dollar
V1	Version 1
V2	Version 2
V3	Version 3
VC	Venture Capital
XRF	X-Ray Fluorescence Spectroscopy
YoY	Year on year
ZAR	South African Rand

1 BACKGROUND

1.1 History and position to date

PRltd was founded in February 2023 by a group of seven engineers from the Electronic and Electrical Engineering Department at the University of Bath (UoB). One of the co-founders, who grew up in a mining family, identified a gap in the market for automation and sampling processes. The team shared the vision and thus the idea for an automated sampling robot called ROMIE (Robotic Ore Mineral Identification and Exploration) was born.

Before undertaking any kind of mining activities, the site's mineral potential needs to be determined. As mentioned during an interview with Gerard De Hert [2], a geologist at La Mancha Capital Advisory and Endeavour Mining, mining companies need to follow a variety of phases as follows:

Table 1: Phases of Mining Operation

Phase	Characteristic
Reconnaissance phase	Examine geological maps
Mapping phase	Produces a geological distribution of the earth
Geophysical surveys	Provides a variety of data of the land
Geochemical sampling	Involves sample collection and analysis
Target selection	Choosing the appropriate tools and equipment based on minerals available

PRltd's first product, ROMIE, is focused on geochemical sampling, which up until now has been done through human labour. Currently, human labour presents an issue for the sampling processes regarding; time, cost, work conditions and sustainability. The process is cumbersome and requires a large workforce, which burdens companies. PRltd will reduce the prospection process time and cost by a factor of six and two respectively. It will highly reduce human involvement and improve sustainability.

PRtld enters as a unique player in the South African market due to the innovative nature of ROMIE. An attractive global mining industry customer market of $2T [3] is targeted, refining its focus on the global mining and autonomous mining equipment market, respectively valued at $170B [4] and $2.6B [5].

To date, PRltd pitched their idea to a group of industry leading experts and secured an investment of £1.9M at the beginning of the third quarter of 2023. In addition, the UoB is granting £500 to develop the first version (V1) of ROMIE and a full access to their facilities and equipment. The company is looking at a valuation of £19M (in a standard case), generating £47M over nine years.

PRltd is focused on expanding its product line and increasing its market share in the automated agricultural and military industries. The company is also exploring new partnerships and collaborations to accelerate the growth and development of ROMIE's technical features in different continents, including South America, North Africa, and Oceania.

Through a combined enthusiasm for automation systems and interest in the mining industry, PRltd was founded on the mutual belief in the team's expertise to solve a global problem benefiting our close partner: Team Bath Racing Electric Artificial Intelligence (TBReAI) and the UoB.

1.2 Objectives

The mining industry has undergone an automation revolution in recent years, with major players automating stages like excavation and haulage. However, the prospection stage has remained technologically stagnant, aside from advances in sample analysis methods in laboratories. PRltd seeks to provide a bridge between the underutilised new sampling technology called X-Ray Fluorescence Spectroscopy (XRF) and the existing automation opportunities in the prospection stage of mining, which is still dominated by outdated manual labour.

The company's short-term goals are focused on the first stage of revolutionising the industry standards by developing an autonomous, electric-powered, rugged robot that can prospect a grid of customer-defined plots. It utilises proprietary real-time path planning and machine learning, equipped with state-of-the-art sensors and on-board sample analysis. This technology is the unique autonomous sampling capability of extracting soil information by drilling into the ground and testing samples using a custom onboard XRF analyser.

The product will also provide an in-depth mapping service of the area along with a heatmap indicating mineral-rich areas of interest to the customer, eliminating the need to send off samples to Europe and wait for costly analysis and data processing. ROMIE intends to become the go-to solution for new prospecting endeavours.

The company's long-term goals include upgrading ROMIE with autonomous fleet capabilities to further distinguish its speed and cost advantages compared to human labour. The company aims to utilise the knowledge gained through this product development to expand into new market and application ventures, as aforementioned.

2 MANAGEMENT

2.1 Management Team

When PRltd was created, one of its first priorities was to create a competent management team, in order to assign tasks effectively and ensure projects are completed. Consequently, the founding employees discussed their individual achievements and experience to determine which roles within the organisation most suited them. Additionally, a skills matrix was created to investigate which qualities and attributes are missing from the employee skillset and as such require external hiring. The matrix can be seen below and full Curriculum Vitae (CVs) for each employee can be found in the Appendix 2.1.

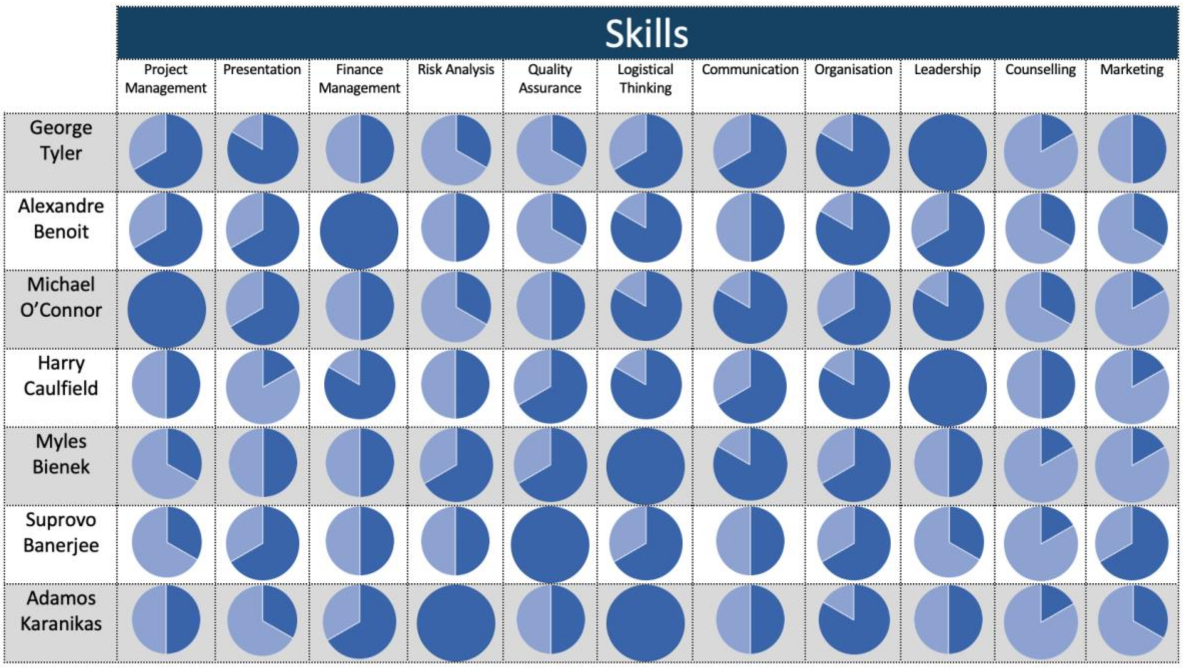

Figure 1: Skill matrix displaying the attributes and qualities for the founding employees

As shown in the skill matrix, George Tyler has a strong overview in multiple managerial abilities, in addition to soft skills in leadership and organisation. He also has industrial experience, through assessing priority projects and adjusting business strategy due to customer demands and external requirements whilst working at Semtech. Therefore, Mr. Tyler was assigned the role of Business Manager. Moreover, he is responsible for developing the local path planning algorithm, due to his work in previous robotics projects and experience in developing a ROS1 system for object avoidance.

Alexandre Benoit has a strong background in financial services and demonstrates a high level of logistical thinking and organisation. He is accredited with an Advanced Level 6 Diploma in Trading and Financial Market Analysis issued by the London Institute of Banking and Finance, and as such is the most suitable choice for Financial Manager. Furthermore, his knowledge of machine learning developed through foundation and advanced courses qualified him to write the global path planning integration algorithm.

Michael O'Connor has led a variety of diverse groups and teams during his industrial experience at BAE Systems, liaising with a variety of departments and senior stakeholders. Paired with his leadership and communication skills, he was chosen to be Project Manager. Additionally, his knowledge of motors and batteries for electric vehicles supports his development for the drive system.

Harry Caulfield exhibits a strong skillset in leadership, finance management and logistical thinking. In addition, he has real-world mining machinery experience through working as a Product Development Engineer for Caterpillar. This involved communicating with operational engineers to design new parts and systems for the existing production line. Consequently, he was selected as Operational Manager. Moreover, he is developing the drill and sensor system for the product, due to his strong technical knowledge demonstrated through designing excavation machinery.

Myles Bienek displays a variety of hard skills developed through industrial experience. His previous employment at PragmatIC Semiconductor provided him with the opportunity to participate in rigorous testing and troubleshooting sessions. Additionally, he has detailed insight into the full engineering process, as he designed the digital blocks for two Near-field Communication Integrated Circuits through concept, implementation, simulation, and fabrication. Therefore, he was assigned the role of Product Manager. He also has previous work experience with TBReAI, allowing him to both develop the object detection system for our product and improve their software.

Suprovo Banerjee has proficient skills in quality assurance, presentation and sustainability marketing. Furthermore, he has industrial experience as an Electronics Technician Intern at Metric Group Ltd. Stationed in the development team, Mr Banerjee participated in carrying out quality and environmental tests on new prototypes. As a result, he is the most suitable choice as Quality Manager. Furthermore, using his experience in simulation and CAD software for commercial products, he will design the PCB schematics.

Adamos Karanikas was formerly involved in a technology start up called Aegis Rider. During his time at the company, he was involved in risk identification and mitigation during their initial development period. Combined with his strong soft skills in logistical thinking and organisation, he was chosen to be Risk Manager. Moreover, his previous work using ROS2, microcontrollers and sensor programming allows him to develop the sensor fusion integration.

The founding team lack marketing and counselling skills; therefore, the company will hire external applicants to set up both the marketing and sales team to sell the product and Human-Resources (HR) department to oversee internal matters with employees. For the marketing roles, the company would look for individuals with existing sales experience and connections and networks within the mining industry. For HR, it is essential that employees have strong communication and confidentiality skills, as well as cultural awareness and sensitivity. All legal services would be outsourced. The following organisational chart shows the management hierarchy for the company.

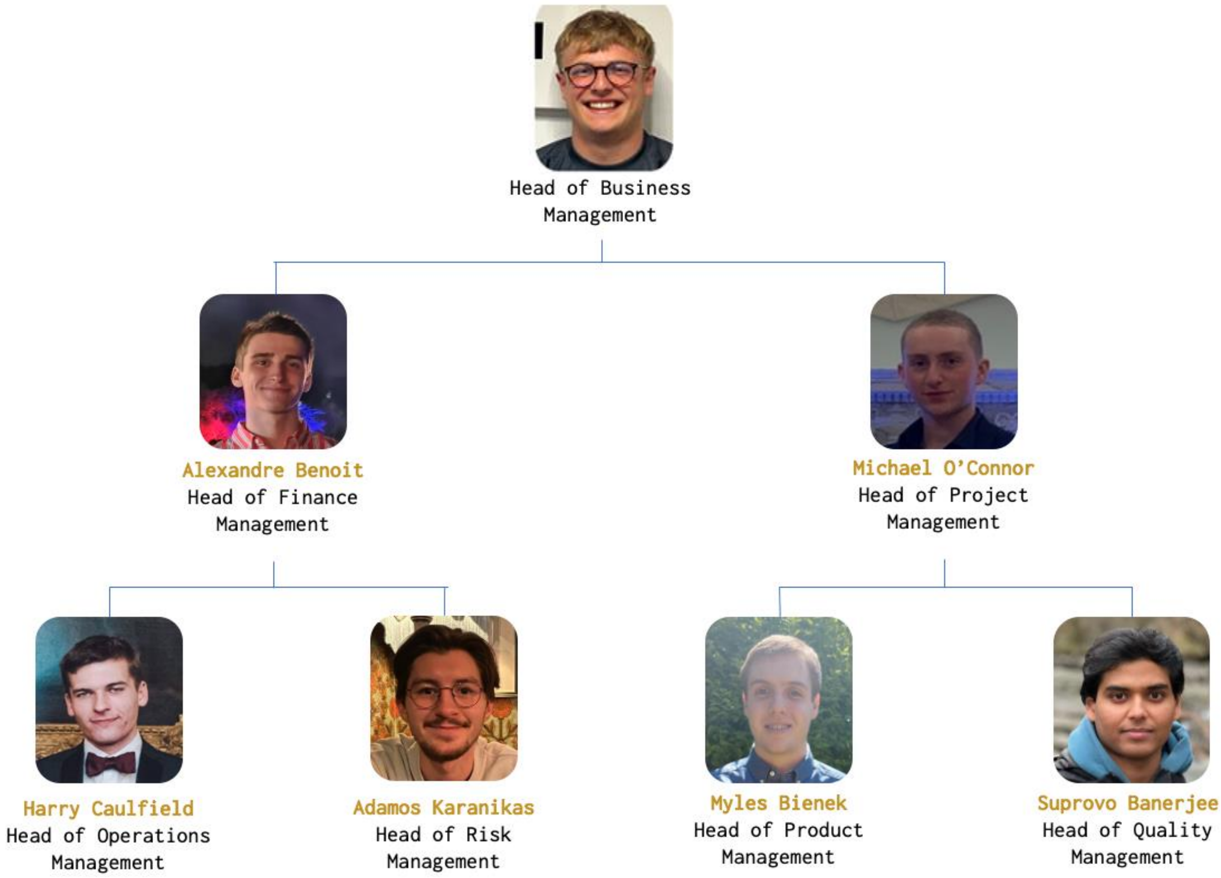

Figure 2: Organisational chart for the company

2.2 Organisation:

At the beginning of the project, PRltd (set up as a Limited UK-based company) is using facilities supplied by TBReAI and the UoB. This process involves a detailed legal protocol the company must undergo (Appendix 2.2.1). As George Tyler is already Head of Business Management and aware of the legal obligations and responsibilities the company will need to follow, he will be assigned the role of Director for PRltd. He is responsible for maintaining company records, establishing articles of association, and paying Corporation Tax [6].

Additionally, all the founders will complete a Founders Agreement Form, which will document; their individual roles and responsibilities, salary and work schedule, equity compensation and founder restrictions [7].

Following the investment period, the company plans to build facilities in Johannesburg. In order to achieve this, PRltd will establish a South African Subsidiary. Like before, the set-up of the subsidiary is broken down into several steps (Appendix 2.2.2). The most notable measures include: investing 2.5M ZAR (£110k) in the company, employ South African citizens and complete a Notice of Incorporation to verify the business [8]. The founders will apply for Business Visas (Appendix 2.2.3).

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3 PRODUCT

3.1 Description

ROMIE is an autonomous robot of length 1.5m with width and height of 1m. It is designed to survey a defined plot of land and test samples in the ground at equidistant points from each other. The resolution is set by the customer, but a typical case is 200m from each other. Figure 3 below shows a CAD model of ROMIE.

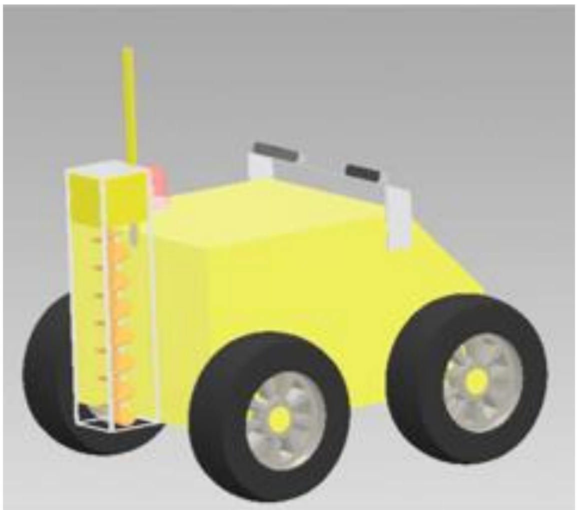


Figure 3: Concept design of ROMIE

The robot uses an earth auger connected to a 150W motor to drill a hole 30cm deep with a diameter of 10cm. [2] After this, a scanner is lowered into the hole and obtains data of the composition of the ground by using XRF technology to identify the elements in the soil. This data is stored locally in the robot with the GPS location of the test. The robot then navigates to the next point of surveying to repeat the test at this new location. In 43 days, the robot generates a comprehensive map of mineral abundances in a typical 100km² land for the customer (Appendix 6.1.3). Mining operations can then begin with this information. A detailed description and parts list of the robot can be found in Appendix 6.1.7.

On-site testing removes costs and time taken for sample shipping to Europe. The robot also can effectively work 24/7 with breaks for charging. Currently, no other automated solutions for this sampling stage exist in the market. Each robot is leased at £95k/month. ROMIE's value proposition offers a more cost effective and faster prospection per plot of land than any human method. Further details are presented in the competition sub-section.

3.2 Standards

The initial market ROMIE will enter is the mining industry in South Africa, this means it is essential that the robot and the business meet the standards set by the country. ROMIE must comply with the Mine Health and Safety Act 1996, particularly Chapter 8 which focuses on Machinery and Equipment [9]. An NCRS Letter of Authority must be given for the robot [10] as well as having valid electromagnetic compatibility certificate, which are all recognised by the South Africa Bureau of Standards [11].

For quality control purposes, the company needs to follow a set of procedures and guidelines set internally outside of government standards (Appendix 3.2.3). All robots will undergo basic testing and inspection checks once assembled, but a chosen number will be tested vigorously to ensure that they meet internal standards such as performance, reliability, safety and build quality. The results and the product's documentation, including parts adhering to military specifications, should be maintained for information to be easily traced.

Regarding sustainability, when determining the materials for the Prototype Phase, the robot must not contain any substances considered hazardous waste [12] (Appendix 3.2.2). There must also be a partnership with a licensed recycler of electronic waste equipment for disposal of the robot at the end of its life such as AST Recycling [13]. Additionally, the company must follow GRI standards of section 301-2 which states: "The reporting organisation shall report the percentage of recycled input materials used to manufacture the organisation's primary products and services." [14]

ROMIE can potentially completely remove the CO_2 produced during the geochemical sampling process. The CO_2 from the current method of sampling using a human workforce is mostly released from the transportation of samples to a European lab for analysis. Calculations in Appendix 3.2.4 show that approximately 1300kg of CO_2 is produced when using the current method. ROMIE will not produce any CO_2 during its operations; only the charging of its battery can be considered for any greenhouse gas emissions. However, the power source used to charge the robot is the customer's responsibility.

3.3 Readiness for the Market

Currently a materials and parts selection has been made and ordered, and designs of the subsystems have been created, with the aim for a prototype to be ready by the end of May. This will lead to a prototype showcase for investors which will allow the company to enter the next phase and further develop the robot. (See timeline section)

At the end of March, PRltd received feedback from our initial Dragon's Den pitch. The investors liked the design but had a suggestion for improving the cooling of the electronics inside the robot. Considering high temperatures in South Africa (between 15°C and 36°C) [15], good temperature regulation must be achieved to not damage any components. The current design is a passive cooling method by having an insulating plastic case sealing off the air of the inside from the outside. The investors suggested a more active cooling method such as fans with vents at the bottom of the robot. A possible further improvement to cooling is using batteries developed by SCHARF as part of a collaboration with the company. These batteries have very good temperature control by using thermal dampening between the cells, reducing the heat produced and improving safety. Another technique by SCHARF is water cooling on the electric motors. [16]

3.4 Applications

Typical features of the land in SA are flat and arid [17]. The customer will input a list of GPS coordinates for an area to be defined. After this, the robot will generate a grid of points for where sample testing will take place. Figure 4 below shows an example grid map with the movements of the robot defined.

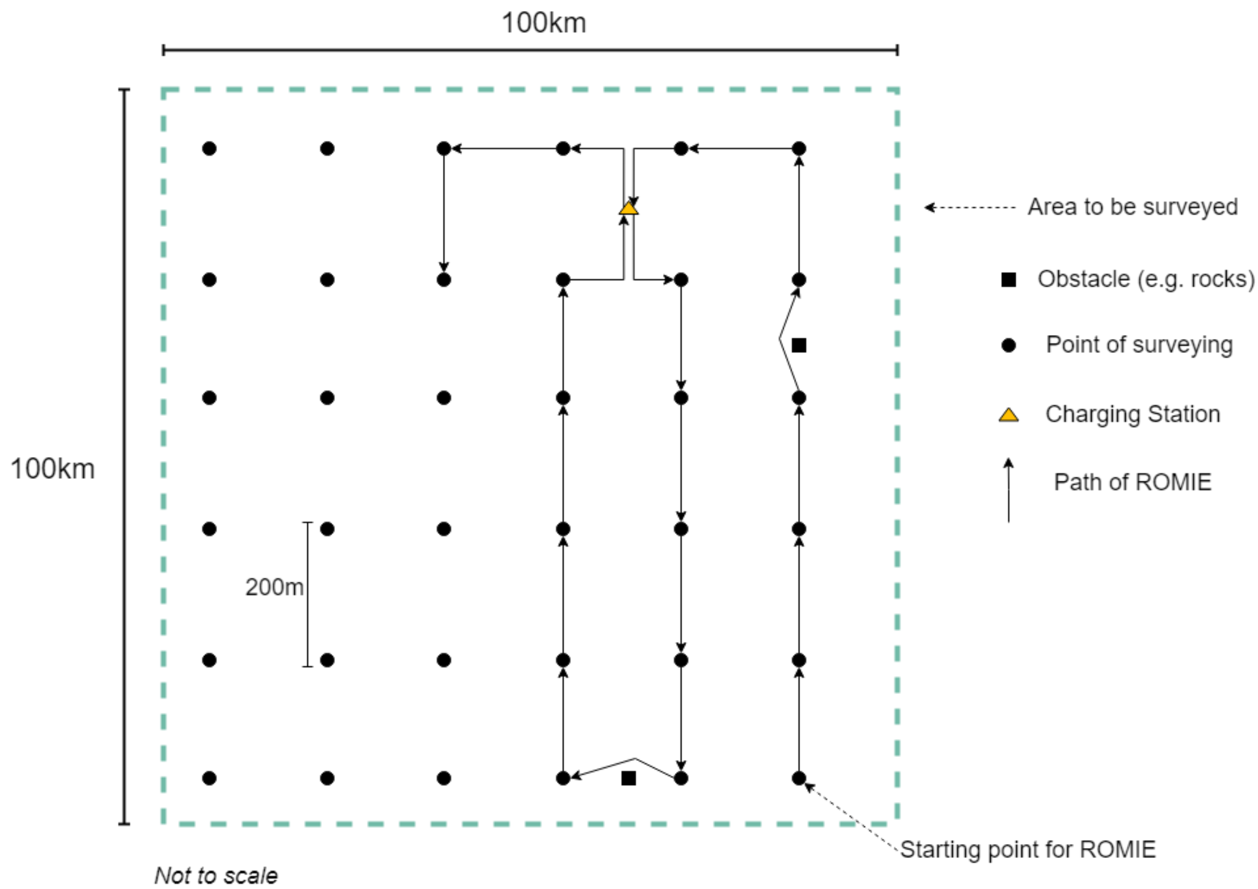


Figure 4: Example operation of ROMIE in a land to be surveyed.

ROMIE will begin at a corner of the area of prospection to then move optimally through the land to cover all the points for surveying. Between points there may be obstacles such as trees or rocks, the sensors and mapping software will guide the robot around them to the next point.

When the hole has been drilled, the scanner emits X-rays into the surrounding walls. These X-rays excite the electrons in the atoms which releases energy back to the scanner, each element has a unique energy. The results from the scan contain the percentages of each element found in the ground. This allows the customer to see if areas of the land have higher concentrations of desired minerals [18].

3.5 Service and Support

Customers will have access to PRltd's service and support throughout their leasing contract. This support includes dedicated employees at the company for training customers and providing any help with the robots. This gives the customer quick access to help and maintenance whenever needed.

Faulty robots will be inspected by trained employees of the customer or engineers of the service team, and light repairs can be carried out on-site where possible. Robots that require heavy maintenance will be taken back to the production site where they can be repaired in a timely manner. Being centralised allows for quick access to replacement parts as well as improving sustainability by recycling replaced parts where possible. While robots are in heavy maintenance, replacement robots are given to the customer to prevent further delays in surveying.

3.6 Proprietary Position

As of April 2023, no designs of ROMIE are patented yet. As shown in the timeline, patents are planned to be filed at the end of the development of the V2 prototype. Outside XRF scanning used in surveying only exists in a handheld form which requires a human to be operated. [19]

The software created by PRltd will be proprietary and the source code will only be available to engineers of the company. However, the robot will also contain open-source software vital for its operation. These include: the operating system Ubuntu which will be running on the robot's computer, and ROS2 with the ROS2 Wrapper created for the ZED2 Camera. This software is all free for commercial use, but copyright notices must be listed in the source code. There is also no liability nor warranty provided by the developers of each software. [20] [21] [22]

3.7 Comparison with Competition

In the mining industry, there is currently little to no competition for an automated surveying vehicle operating in the geochemical sampling stage of prospecting. However, the direct alternative ROMIE is competing against is human labour as previously mentioned, and the accuracy of lab testing compared to XRF technology. Figure 5 below shows the different types of sample preparation before chemical analysis as well as direct analysis.

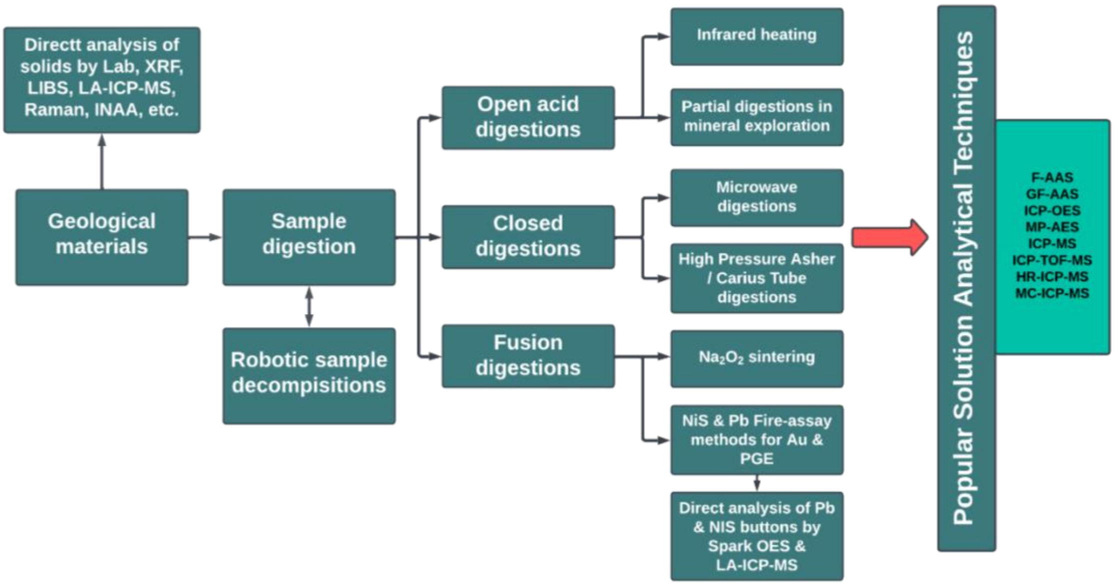


Figure 5: A schematic diagram showing the different types of sample preparations in geochemical analysis [23]

XRF is not as accurate as solution analytical techniques. Particle sizes and roughness of surfaces can affect the results. Sample preparation in the lab removes these problems as they are usually ground into fine powders or pellets, leading to a consistent accuracy [23]. However, the time taken to ship the samples to Europe for preparation and analysis is far longer than conducting the tests on-site. Although the data for each sample point would be less accurate, a very similar end result heatmap of minerals will be achieved by both methods. For the typical case, the human prospect process takes approximately 250 days and costs more than £530k. For a land of the same size, ROMIE will be able to complete a survey approximately 6 times faster than the current method and have a cost of £380k for the 2 months taken. (Appendix 6.1.2 and 6.1.3).

In Europe, a 2020 research project called UNEXMIN developed a robot designed for autonomous exploration and mapping of flooded mines. The project was a success resulting in the company UNEXMIN GeoRobotics being formed [24]. The design is of a multi-robot platform which consists of 3 spherical robots with a diameter of 0.6m.

The robots each have a power consumption of 250-400W and have an autonomy of up to 5 hours [25]. Although the environment is different, these specifications can be compared to the power consumption of ROMIE, which is calculated to be 1300W and has a battery capacity that allows for 12 hours of autonomy (Appendix 3.7). As ROMIE is to cover a much larger area than the UNEXMIN robots, it is ideal for the autonomy to last as long as possible.

3.8 Future Developments

In 2031-32 PRltd aims to reinvest 15% of its profits into Research & Development (R&D). This is to improve the product as well as to be able to modify its payload to enter different markets. A further development for ROMIE is for wireless communication between robots. This enables the sharing of live data while surveying the land. This would allow for a fleet of robots to work together efficiently which makes the process of prospecting even faster for the customer. A similar system already exists with Caterpillar's MineStar Solutions. Thanks to the Internet of Things (IoT), it connects all machines to a network for live monitoring of an entire fleet and increases efficiency by giving automatic assignments to vehicles. [26]

Additionally, ROMIE's payload modification would enable it to undergo different tasks in other markets. One example would be to replace the drill and scanner with high quality cameras for agricultural surveying and plant identification. With the modular design, the rest of the robot such as perception and local path planning would be able to remain the same.

4 BUSINESS DEVELOPMENT

4.1 Description of Customers

Target customers are companies carrying out mining operations in SA. The nation finds itself as home to 547 active mining projects, with a little over a third of these being focused on gold mining and platinum-group-metals (PGMs) alone and 152 of these being known to be open-topped mines [27]. In 2022 PGMs and gold contributed collectively to more than 70% of the total market capitalisation of mining companies in SA. The price of these commodities has fluctuated over the past year with a fall in the prices due to production recovery and semiconductor shortages placing pressure on industrial vehicle supply [28].

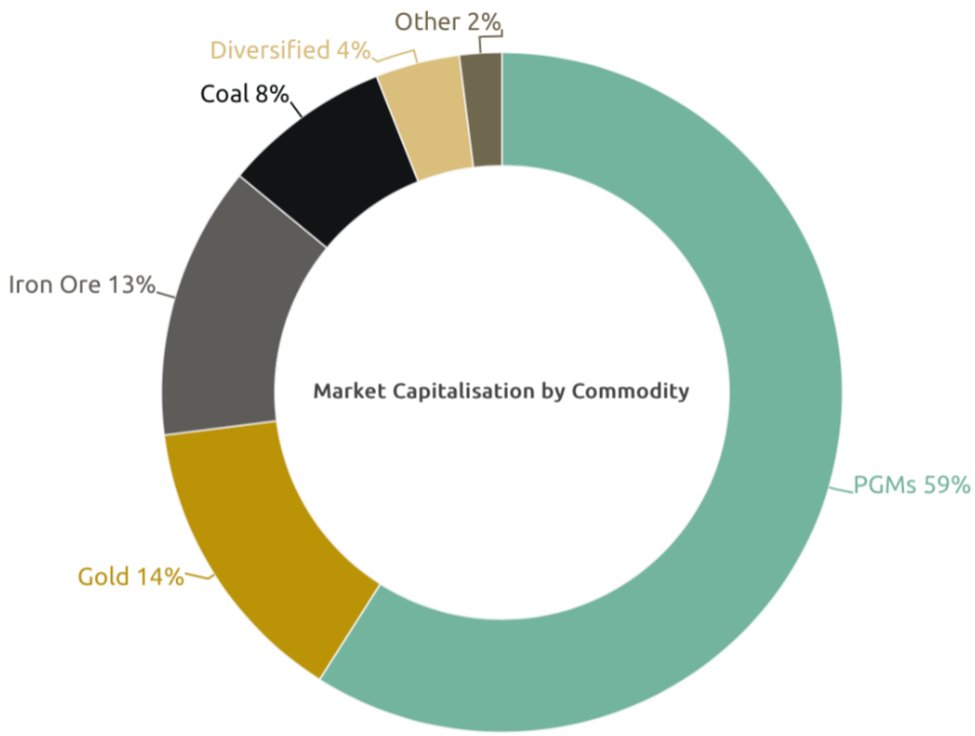


Figure 6: Graph of Market Capitalisation by Commodity of Mining Companies in South Africa [28]

Despite commodity price fluctuations, most companies in SA still target PGM and gold mineral deposits, and it is these firms who dominate the nation's mining industry and, therefore, would be those who are target customers.

The customer profile (size, location, and industry segment) is a key factor for business development. Initially, larger mining companies in the sector are targeted. These include Anglo American Platinum, Gold Fields, Impala Platinum, and other firms of comparable size. Plans are to advertise ROMIE at conferences such as the African Mining Indaba [29] and the World Robot Conference [30].

4.2 Customer Needs and Benefits

ROMIE's financial gains when compared to human labour come in a variety of areas. Currently in the South African mining industry, 38% of operating expenses (OPEX) are on employee benefits and salaries. Integration of autonomous technologies such as ROMIE into operations would cut down on this spending. Additionally, 6% of OPEX in the industry is on transportation [28]. Thanks to ROMIE's autonomous running and onboard testing capability, expenses in transportation during the prospecting process could be cut significantly. Further benefit could soon be added as the South African government looks to introduce tax reliefs for mining investors willing to inject funds into the exploration segment of mining operations [31], of which prospecting is a part.

Environmental, social and governance finds itself at the heart of the conversation about the future of the mining industry and are highly scrutinized by prospective investors [32]. ROMIE can carry out the prospecting process in a more carbon efficient manner than the current method thanks to the low level of sample and worker transportation required, among other factors. This is beneficial as it allows companies to reduce funding into decarbonising current methods and enables them to meet sustainability goals.

Introducing ROMIE reduces the chances of injury and illness to workers in the sector. ROMIE's ruggedised design and object detection software allows it to operate in harsh environments, which may be dangerous for human workers. Whilst the number of deaths in the sector fell year-on-year (YoY) between 2021 to 2022 to a record low of 49 fatalities, Mineral Resource and Energy Minister Gwede Mantashe still places emphasis on redoubling efforts to ensure there is no loss of life. Additionally, occupational disease and injury cases remain at fairly constant levels YoY, with both reducing by just 4% across the aforementioned period [33]. This may indicate that the industry itself is not becoming safer, rather, the healthcare provided to prevent death from these injuries and illnesses. The introduction of the autonomous ROMIE increases safety by reducing the requirement for human labour. Significant investment is also required into security for workers and assets on mining sites, costing mining companies an estimated $2.5B [34] annually.

4.3 Market Size and Growth

As of 2022, the top 10 most valuable mining companies in SA were worth a collective $83B with the largest of these, Anglo American contributing $24.27B to this sum [35]. The mining industry itself continues to show strength nationally, generating revenue of $41.2B in 2022, more than double the value ten years prior [36]. SA finds itself as home to 32 active mining companies with hundreds more registered [37].

The initial target market will be the mining machinery industry in SA which as of 2022 finds itself valued at an estimate $290M, a 7% increase on the valuation the year before [38]. The wider markets, of which this is a subset, also show growth with the global mining machinery market worth $170B [39] and the global mining market worth $2.02T [40] as of 2022. These markets show compound annual growth rates (CAGR) of 11.1% and 6.1% respectively. A further influential market, the autonomous mining equipment market, is worth today $2.6B and is growing at a rate of 6.4% per year [41], driven by rising concern for mine worker safety and hence a requirement for solutions requiring less human intervention.

As stated, the large majority of ROMIE customers will operate in PGM and gold mines where conditions tend to be similar topographically, so customers will require robots with mostly the same physical capabilities. Difference in requirement between customers will come from the service offered rather than the product itself since this is affected by the number of robots required, the level of technological support needed, the length of contract, etc. These will all be accounted for in the price of the contract offered.

Primarily, larger mining companies will be targeted. It is felt that these companies will be easier to gain support from, since adopting recent technology is less of a risk for them as any fluctuations in productivity based on this is unlikely to greatly affect their revenue.

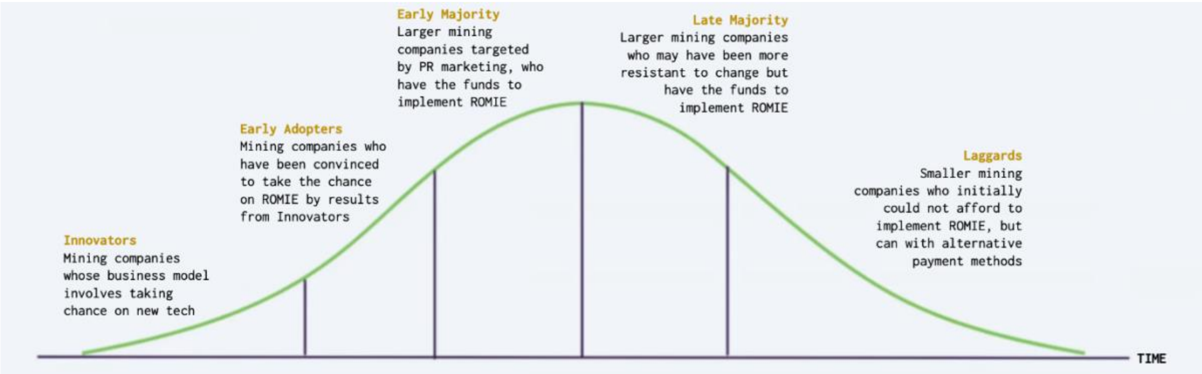


Figure 7: Graph of adoption of technology

Additionally, they may be interested in the health and safety benefits of ROMIE as, due to their larger public presence, serious cases of employee injury or death could be far more widely publicised and be more damaging from a brand image perspective. Innovator firms whose business strategies largely involve taking on new-to-market technology will also not be hard to convince as they will be attracted in large part by the nicheness and novelty of ROMIE.

Early adopter type companies would be slightly more challenging to gain trust from, with some level of demonstration of the financial and productivity benefits of ROMIE being required before full support is gained. Smaller mining firms may also be harder to target as introduction of the innovative technology could be outside of their budget. To eventually target these companies, further proof of the benefits of the service and alternative payment arrangements such as financing could be proposed.

Challenges could be encountered by some who are resistant to change from well-established methods. Again, to counter this, further demonstration of the operational benefits of ROMIE would be required. Introduction of regulation may limit areas in which the robot can be used in which case changes may be needed to the machine itself before gaining these customers.

4.4 Competition

At present, there are no robots like ROMIE available on the market for prospecting in SA mines. Consequently, the only direct competitor to ROMIE is human labour. Per unit 100km^2, ROMIE is cheaper and faster than this current method thanks to its onboard testing and automation. Additionally, during the process of prospecting, ROMIE is more environmentally friendly. Moreover, ROMIE is not limited by the same legislation [42] as human workers, meaning it can work longer hours and in harsher conditions, further increasing productivity. The workers displaced from prospecting by the introduction of ROMIE could then be redistributed into other roles or retrained to operate as service support for autonomous machines on site, in accordance with the requirements outlined by Chapter 100 of the Mineral and Petroleum Resources Development Act (2002) [43] which necessitates the training and employment of those people local to where the mining operation will take place.

Indirect competition comes from multiple areas, one being major mining machinery manufacturers such as Caterpillar, Komatsu, Sandvik and more. Komatsu and Caterpillar currently dominate the mining machinery market, collectively holding almost a quarter of the total global market capitalisation [44]. These companies have begun to venture into the autonomous mining machinery market by introducing Sandvik's 'AutoMine' (Figure 8) and Caterpillar's "MineStar' (Figure 9) ranges, providing autonomous solutions to processes in mining operations such as haulage and excavation.

Figure 8: CAT Mapping Software showing location of machines in operation [45].

Figure 9: Sandvik AutoMine® [45]

Whilst such companies have a high level of integration into the mining industry, they have focused their efforts on automating processes on larger-scale tasks for which they already have much of the technology. This may mean their ability to react quickly to ROMIE is inhibited, with the development and release of rival prospecting machines taking years. In this time, ROMIE will be adapted and improved based on customer feedback, giving the advantage of greater flexibility than established global manufacturers.

Indirect competition also comes from companies who produce similar autonomous robots but in different applications such as solutions in Figure 10.

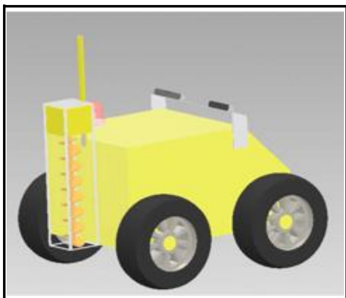
			
Product	ROMIE	Husky	HEROS
Manufacturer	Prospector Robotics	ClearPath Robotics	Innok Robotics
Price	£95k/month	£80k (most basic model capable of mapping)	N/A (Prototype)
Industry	Mining	Agriculture, mapping, surveying	Agriculture, industry, mining, surveillance
Application	Prospecting	Large scale mapping and localisation, outdoor autonomous navigation	Seed sewing, sewer rehabilitation, fertiliser distribution, snow ploughing, transportation
Mining industry integration	Very high - applacation specific design	Little - few uses for general mine mapping	Some - uses in general mine mapping and some material transportation
Product flexibility	Highly flexible - early entry into niche market	Some - modular payload can be desinged for prospecting, may however lack expertise in designing this	Some - modular payload can be desinged for prospecting, may however lack expertise in designing this

Figure 10: Comparison of ROMIE with competitors [45] [46]

These products could therefore be adapted for the purpose of prospecting, as much of the technology could be carried forward with the payload being the only major redesign required. Reaction times may vary based on the competitor's level of industry integration. ROMIE's early entry to the market and application specific design are expected to allow PRltd to gain a foothold before competitors are able to produce a rival robot.

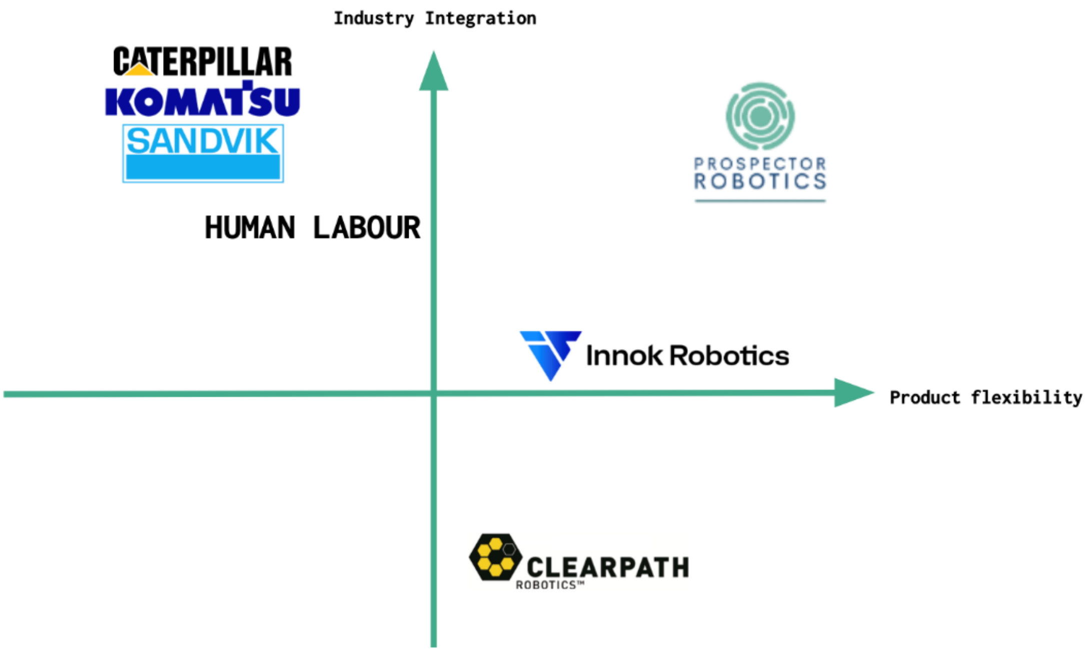


Figure 11: Competitor matrix

Potential competition could also come from R&D projects such as the UNEXMIN UX range out of the University of Miskolc (Hungary) (Figure 11) [47].

Figure 12: UX-1 submersible [50]

Whilst this product carries out the same task as ROMIE, it does so in a vastly different environment so significant redesign would be required to almost all areas of the robot before it can be considered a direct competitor to ROMIE. This sort of change of application would not be anticipated as the project is currently in R&D rather than being commercially available.

4.5 Economic, Social, Political and Legal Factors Affecting the Market

Whilst there is strong evidence to suggest the target market for ROMIE and its wider associated markets will continue to grow, economic, social, political, and legal factors could all be at play in influencing future behaviour of the landscape.

Economically at present SA finds itself in a stable position having recovered to pre-pandemic GDP (Gross-Domestic-Product) levels [48]. Whilst ROMIE itself could be a solution to this, in general, investment into new mining machinery would be anticipated to slow down with investors instead opting to invest in second-hand machinery. This could lead to a reduction in the size of the mining machinery market in SA and, therefore, the size of the ROMIE customer base since fewer companies have the available free funds to invest in new equipment.

Socially, in the nation, there is some level of apprehension in the acceptance of autonomy into key industries from the public and those working at lower levels due to lack of trust in the ability of autonomous technology to adapt to unprecedented situations when compared to human workers [49]. Introduction of smarter technologies such as Artificial Intelligence (AI), ML and IoT, however, will look to solve this problem further and build public confidence. A factor driving the potential growth of the mining machinery market is the requirement of many major mining companies to meet new sustainability goals. One example of such is Anglo American's Sustainable Mining Plan which looks to meet UN Sustainable Development Goals of operating in carbon neutral mines [50]. To meet these, fossil fuel powered machinery will need to be replaced with electrically powered solutions, driving the market to grow, and thus encouraging investment into solutions such as ROMIE. A factor driving potential growth of the autonomous machinery sector is the increase in wages and retirement and resignation numbers. Over the past decade the mining labour force in SA fell by 11.5% but employee earnings increased by 91%, showing the vast expense human labour is becoming [32]. Introduction of autonomy provides a solution to this reliance on expensive human labour.

Global and national political factors can both have significant effects on all global markets. Conflict in Ukraine has caused price rises, inflation, and exchange-rate fluctuations worldwide. In SA this has left the Rand weakened and led to less disposable income in many sectors. This may lead investors to apprehension when investing in potentially risky new-to-market technology. Further to this, conflict within the African National Congress (ANC) has led to failure to run state-owned enterprises. This has had knock on effects such as unreliable energy supply which has led to estimated losses of up to $241M/day to the nation's economy [51] affecting the mining sector again leaving less available funds to invest in new machinery.

A piece of legislation that could be key in driving the growth of the mining machinery market in SA is the proposed introduction of tax incentives for investors who inject funds into the exploration stages of mining operations [31]. If such legislation is passed, an increased investment into the equipment required to carry out these processes would be expected and would drive growth of the mining machinery market. Currently there is little legislation on use of autonomous machines in SA. If this were introduced the autonomous mining machinery market would be affected.

4.6 Development of the Company

Completion of the product's development allows for the intended service to begin marketed and put into operation. As a stable customer base is built up in SA, ROMIE can then be marketed to mining companies in other mineral-rich countries in Africa for which its technology is suitable such as Sudan and Egypt. Once profits from the leasing contracts to customers begin to be made, these can be reinvested into R&D to further the product such that it carries out the prospecting process more effectively and can do so in even more rugged terrain. Furthermore, development could be made to the product so that ROMIE can be marketed to mining companies in nations such as Australia, Brazil, and Canada where the environment in which it operates will have different requirements due to its hostility and topography. Development of the product could also trigger competitors to react to ROMIE and begin development of technologies to act as a direct rival.

By improving the service further, demand for ROMIE would grow thus leading to further profits and hence the next stage of development into a fleet-based model allowing for contracts to be signed for several robots which will implement IoT technology so that they can be greater integrated into the smart workspace. This would take a similar model to Hexagon's 'SwarmFleet' robots, which currently operate in the agricultural sector and look to optimise efficiency in farming [52].

Further R&D would then take ROMIE into entirely new sectors requiring ruggedised autonomous solutions such as agriculture, general mapping, and surveying and possibly into military operations, viable thanks to military specification components comprising ROMIE. This would open entirely new customer bases and markets potentially larger than those within the mining industry. For example, expansion into automation in agriculture and military would give access to markets currently worth $841.9M [53] and $18.8B, [54] respectively.

5 OPERATIONS

5.1 Make or Buy Considerations

Manufacturing parts, assemblies or entire products externally or internally can have significant impacts on the operational requirements and needs of the company. Different methods are considered which include licensing, sub-contracting, and machining in-house.

In-house fabrication would give the company the most control over the production process and manufacturing as many parts as possible would reduce the price of the robot and allow for the machine to stay competitive in the market in the future [55].

Licensing is based on granting a third party the right to use the technology or intellectual property (IP) in exchange for royalties. The company would still retain the IP, however, there would be a loss of control over quality assurance and the engineering team would like to remain heavily involved in the production process [56].

Sub-contracting would involve hiring a third-party manufacturer to produce parts for the machine. The company would retain ownership and IP of the product and have control over the manufacturing process and quality control [57]. To retain more flexibility over the product, all outsourcing needs will be met by sub-contracting.

To decide which components would be manufactured in-house, every level of the machine was passed through the flow chart shown in Figure 13 below which shows the decisions and requirements to make in-house manufacture viable. Appendix 6.1.7 shows a breakdown of every assembly that is outsourced or manufactured in-house.

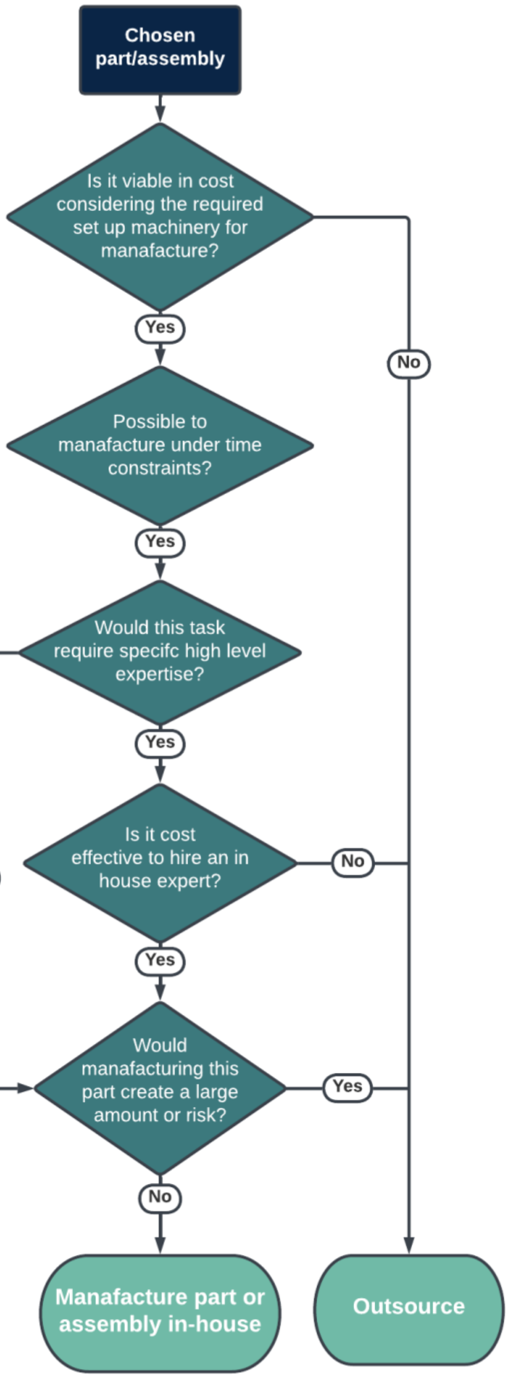


Figure 13: Path of parts to decide on production means [55]

The main driving factor for outsourcing is the initial set up costs. In Appendix 5.1, a breakdown of costs for different potential manufacturing methods is shown for the worst case of the facility. The manufacturing process of using temporary fasteners would cost £73,500, which despite being substantial, is justifiable due to the gain in control, cost reduction, and the ability to repair machines in-house.

Welding, metal fabrication and painting for metal or plastic parts are processes deemed to be unfeasible. The lack of a paint facility on-site would require all fabricated metal parts to be shipped to an external painting facility in Johannesburg or further which would be logistically difficult and costly. Therefore, a paint facility would also need to be included if these were chosen as options. It would cost the facility an extra £221,500 and £246,000 for welding and metal fabrication respectively. Metal parts only make up a small percentage of the cost of the robot and are also logistically low risk components offering little gain to manufacture in-house.

5.2 The Manufacturing Process

A table of every construction phase on the assembly line can be seen in Appendix 5.2. The maximum and minimum time for manufacture denotes completion times for one operator compared to multiple employees.

Figure 14 shows graphically how this time varies for manufacture on each process. The plan for how to spread operators across each operation for the base, standard and blue-sky cases to ensure the most efficient manufacturing process are shown in Figure 15. The addition of an extra person to a section is presumed to reduce the difference in time between the maximum and minimum values linearly. There will be 11 manufacturers in the base case and 22 for the standard and blue-sky. The production line has been designed with Lean development in mind. Operators are assigned to ensure every stage can completed in similar timings and operate concurrently reducing idle times, except for the charging station which can be made independently [58]. As each timing is based off estimations, the first 'test' run of the factory line will be timed on each section to allow for corrections before full production begins.

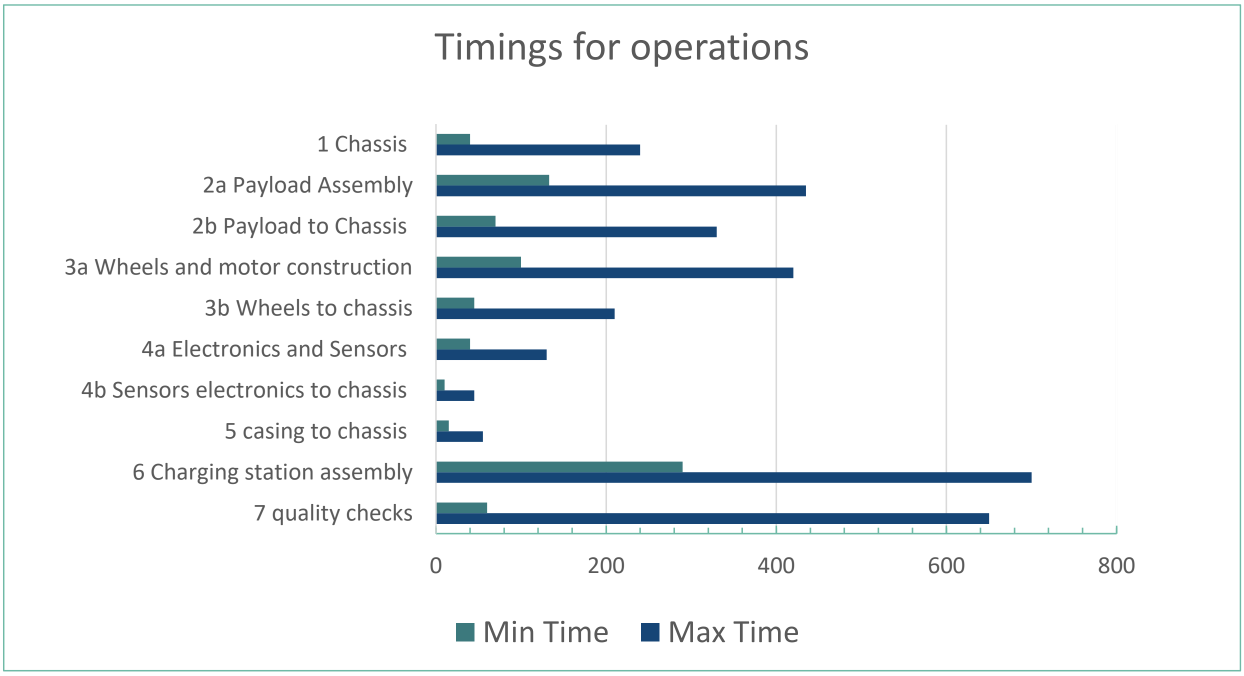
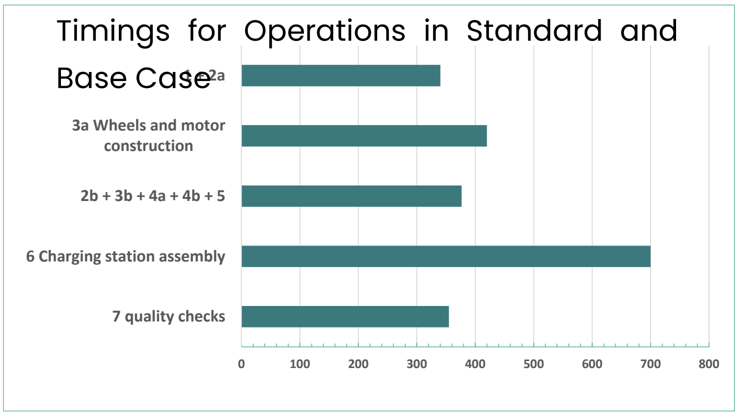
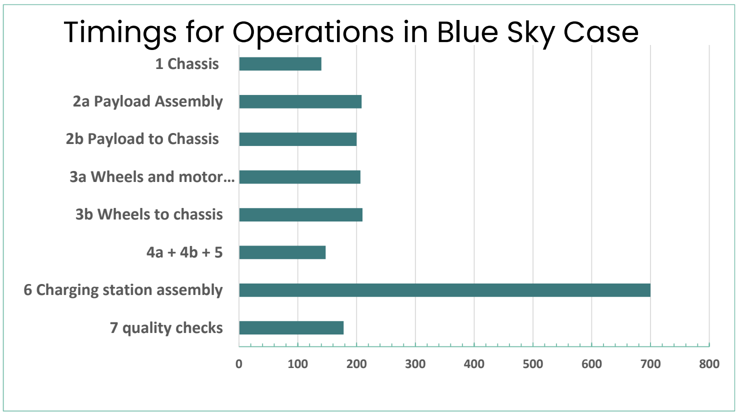


Figure 14: Graph of operations on the factory line and the expected maximum and minimum time for assembly





Main Process	Max Time	Min Time	People	Time
7 quality checks	650	60	2	355
6 Charging station assembly	700	290	1	700
2b + 3b + 4a + 4b + 5	770	180	3	377
3a Wheels and motor construction	420	100	1	420
1 + 2a	675	173	3	340
Parts stocking			1	
		people	11	

Main Process	Max Time	Min Time	People	Time
7 quality checks	650	60	5	178
6 Charging station assembly	700	290	1	700
4a + 4b + 5	230	65	2	148
3b Wheels to chassis	210	45	1	210
3a Wheels and motor construction	420	100	3	207
2b Payload to Chassis	330	70	2	200
2a Payload Assembly	435	133	4	209
1 Chassis	240	40	2	140
Parts stocking			2	
		people	22	

Figure 15: Tables and Graphs for operation times for base, and standard/blue sky

5.3 Base of Operation

For the Prototype Phase, being based in university laboratories allows the company to operate without any facility related expenses, allowing funds to be focused on prototyping and preparing for the move to SA. In exchange for using the facilities at the UoB, TBReAI will gain access to all software that would be beneficial to modify their systems. Anything containing valuable or private information will require a confidentiality agreement.

PRltd will rent a facility in SA rather than remain in the UK, as there is considerable local expertise in the mining industry. This facility allows PRltd to access this resource and build closer relationships with various industry contacts [59]. ROMIE will be leased to the customer, making communication and contact with operators of the product crucial to the company's success.

Deciding where to move the facility within SA can greatly impact the supply chain's efficiency, ability to hire manufacturers and engineers, and accessibility to the available market. Johannesburg was selected as the most suitable location for the company to be compared to 3 other suitable regions due to their significant existing industrial presence [60]. Figure 16 shows a comparison of the regions on various statistics and Figure 17 shows existing mining sites across the country overlayed with how far a vehicle could drive in 6 and 10 hours from each location. A more accurate map of these mines and how the data was collected can be viewed in Appendix 5.3.

	Cape Town	East London	Durban (eThekwini)	Johannesburg (Gauteng)
Population	3,433,441	478,676	3,120,282	2,026,469
Distance to the nearest port (N/A if port is within region)	N/A	N/A	N/A	Durban - 572km Richards Bay port - 603km
Relevant industries within the region	• Steelworks • Automotive • Tyre manufacturing	• Automotive	• Steelworks • Automotive • Tyre manufacturing, • Aluminium Production	• Automotive • Steelworks • Metalworking • engineering
Ranking in the potential for development in manufacturing	Joint 2nd	4th	Joint 2nd	1st
Ranking in cost of facilities	4th	1st	3rd	2nd

Figure 16: Table of comparisons of regions in South Africa [95]

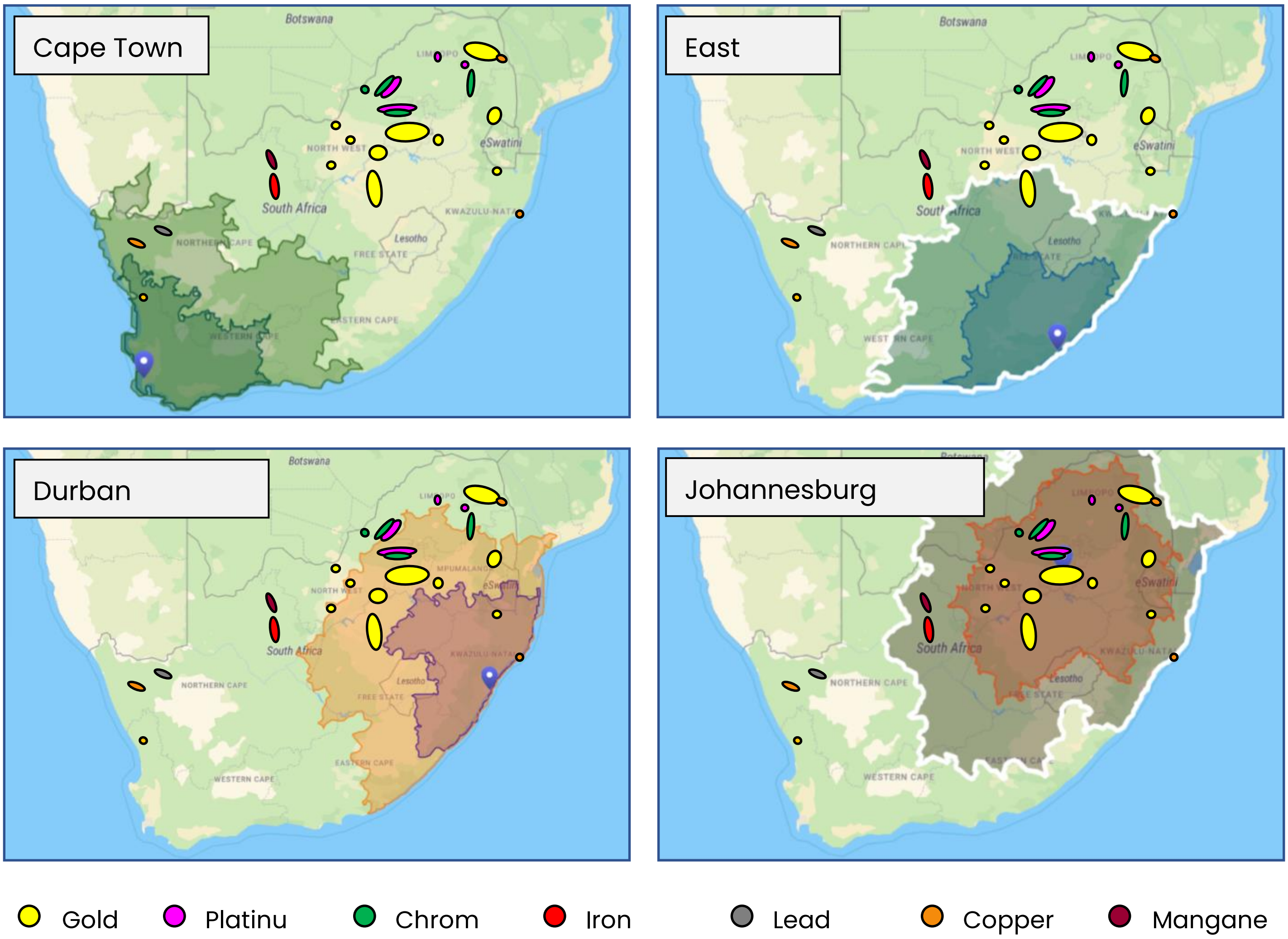


Figure 17: Map of four regions, existing mines for metals and minerals, and how far from each location you could drive across South Africa in 6 and 10 hours.

Gauteng is the only non-coastal region researched which could cause more difficulty in acquiring parts internationally. Arguably, this is unimportant compared to the benefit of being in the middle of the mining cluster allowing for quicker servicing of robots. As there is such a large existing industry for Engineering and Metal working, there are many potential local suppliers which could allow for cheaper parts as the transportation and supply chain costs would be very small. This would also reduce the company's carbon footprint of each machine produced.

5.4 Supply Situation

For V1, the Electrical Engineering Department has offered use of all hardware from previous electrical engineering projects.

Prototype V2 parts will not be scalable to production as they will be made from cheaper materials and lower tolerances. This is done to ensure parts arrive in time to meet the tight time constraints. The exception to this would be the XRF scanner, as it will need to be designed to specifications early to decide if it is viable to manufacture in-house.

Prototype V3 will be exclusively made from parts ordered from the suppliers intended for production. This will open communication to ensure a smooth transition into manufacturing as quality checks can be finalised before the Production Phase.

V3 will determine the availability of parts as some electrical components may not just have an unpredictable lead time, but also shortages that could last many months. For example, the Jetson Orin Board over the last year has had a lead time of around 8 weeks as a minimum with potential to be much longer than this [61]. Risky parts will be shipped to the UK before moving to SA in enough quantity to support the initial manufacturing requirements for the facility. At risk parts will aim to maintain a 2-month cushion, with 1-month for other parts, to account for any unforeseen delays or shortages.

To further counter the risk for these parts, the battery, XRF scanner module, microcontrollers, electronic boards will all be designed to fit into incomplete machines allowing parts to be added quickly and efficiently once they arrive.

To reduce risk in supply chain issues, all custom sheet metal parts will come from two separate suppliers, with both having access and capabilities to manufacture every required metal plate. Splitting the production of these parts allows for one manufacturer to account for disruptions from other contractors [62]. This approach will be applied to every metal part, fastener, and plastic part.

5.5 Delivery Logistics

Whilst occupying space in the UoB, parts would be ordered by a third-party courier to the University addressed to the Head of Operations, Electrical Engineering Department, or to individual specific engineers on the team as needed.

All parts sent from PRltd for testing, customers, or anything else, would be done using the faculty mail services DHL account. Every shipping order requires a courier request form found on the UoB department website. A customs invoice will be required to ship internationally.

For the Production Phase, all international parts will be shipped by sea rather than by air. This will increase delivery times from approximately 4 days to up to 2 months, however, it will be 5 to 6 times cheaper for delivery and considerably more environmentally friendly [63]. Any parts needed promptly to fix logistical issues will be ordered by air freight. Except for the stand-alone Lithium-ion batteries due to UN regulations UN3090 [64] [65].

The logistics of shipping parts by freight can be complicated and requires international relations, adequate documentation, licensing, and communication across potentially many countries and different time zones. Figure 18 shows a flowchart of required logistics operators and tasks required at each stage. Freight forwarders ensure the shipment of goods, and can be involved with the storage, transportation, and documentation of supplies. Clearance agents manage the clearance of the product from the country ensuring every item meets required local and international standards and legislation [66]. It will be required for all found suppliers of parts to have their own logistical capabilities of shipping the part to Port Durban.

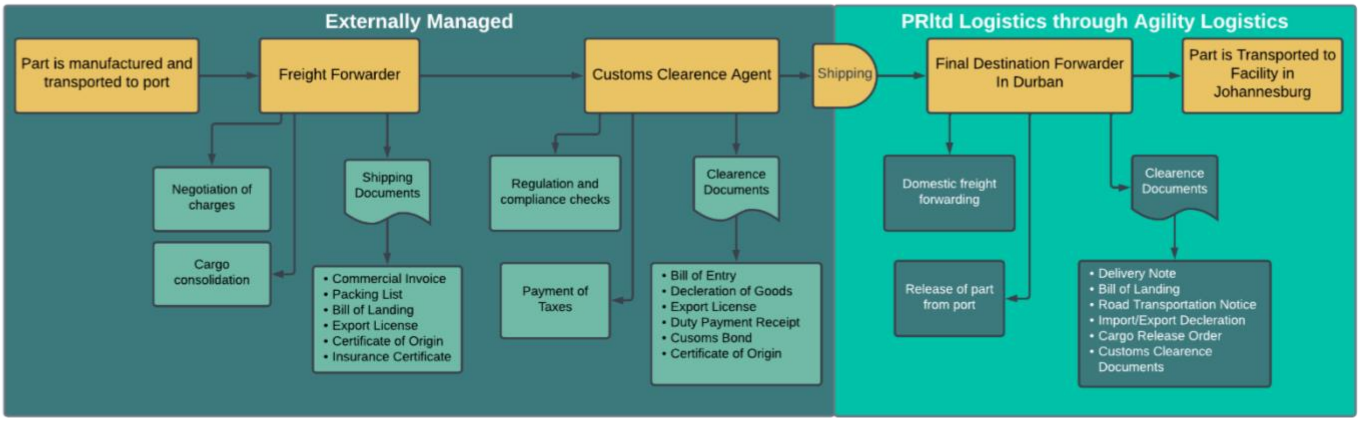


Figure 18: Flowchart of operational logistics for importing parts internationally.

Once the part arrives in Port Durban, a third-party Final Destination Forwarder will be employed by PRltd to release the parts from the port and manage the clearance documents [67]. Outsourcing the management of the delivery of parts to Durban and managing local delivery logistics allows the company to benefit from economies of scale as these large shipping companies can transport many items to Johannesburg. This leads to cheaper transport costs, and less greenhouse gases released from trucks.

Agility Logistics based in Durban, will be the chosen logistics consultant for importing material, and in the future for exporting products internationally. This is due to their presence in SA and established network of partners. They also have a base of operations in Durban and Johannesburg, creating simple and easy logistics for the delivery of parts [68].

ROMIE will be driven by engineers to each location to aid in the setup process and help with any issues that may arise. Transport for delivery of the product is shown in the facility cost in Appendix 6.1.6. Any servicing and product support will be performed out of the company vehicles by engineers.

6 FINANCIAL

6.1 Summary

PRltd's financing requirements will be met through a combination of grants, equity financing, and government schemes.

To start, PRltd has received a grant of £500 from the UoB, which will cover the initial prototyping costs of ROMIE V1. Any additional expenses, such as salaries and trips, will come from PRltd's start-up financing fund, which consists of savings from the co-founders.

PRltd plans to avoid debt financing in the early stages. Instead, £1.9M is raised through equity financing in return of 9% PRltd's stake using the Seed Enterprise Investment Scheme (SEIS) and Enterprise Investment Scheme (EIS), attracting early-stage investors from the mining and robotics industry.

The major risk is a decline in the mining industry, which would impact the customer base and revenue. However, the company plans to mitigate this risk by expanding the product line and seeking opportunities in other industries.

The long-term strategy may involve an Initial Public Offering (IPO) to finance the operations at a larger scale, pay off possible debts, and expand further plans. Although this would require the founders to give up some control over the company. An IPO would: attract more investors and customers, provide stakeholders with dividends over time, or sell or merge the company to a larger corporation.

A cash flow, balance sheet, and profit and loss forecast are available for the next nine years, showing the company's positive results and growth potential.

The model relies on different cases that change the output:

- Base (B): the pessimistic case scenario
- Standard (S): the realistic business scenario
- Blue-Sky (BS): the most optimistic business scenario

The following financials would only discuss the standard case (other cases can be found in the *Appendix 6*)

6.2 Summary of the forecasts and key assumptions

6.2.1 Forecasts Summary (Appendix 6.1.9)

PRltd has developed a leading model for ROMIE, which is expected to generate steady revenue over the nine years forecast period as shown below with their first profit performed in 2026:

Forecasts Summary - Standard Case				
Feature's type	**Total over 9 years**	**Year - 2023**	**Year - 2026**	**Year - 2030**
Sales revenue	72,960,000	0	4,560,000	12,160,000
Total OPEX	-7,421,508	-139,204	-903,435	-903,435
Total CAPEX	-7,880,568	-224,929	-1,196,303	-1,196,303
Net Income	49,193,310	-159,676	2,703,407	8,538,341
Capital Raise	1,900,500	1,900,500	0	0
Total Assets	577,166,701	5,387,529	10,387,844	96,237,369
Total Liabilities	577,166,701	5,387,529	10,387,844	96,237,369
FREE CASH FLOW	46,950,301	1,536,367	1,784,410	7,925,677

Figure 19: Forecasts Summary - Standard Case

The definition of the terms stated in Figure 19, can be found in Appendix 6.1.1.

6.2.2 Assumptions

The following list of assumptions is broken down into type of cost, scenario cases and periods. Some parameters are hardcoded depending on the case selected and will be shown as followed: “name of the parameter” (Scenario=number chosen); for example, in a base case scenario, the number of “Production Workers” is 11 (i.e., “Production Worker” (B=11)).

6.2.2.1 Employee Cost (Appendix 6.1.4)

Table 2: Employee cost assumptions

TYPE	ASSUMPTIONS		
PROTOTYPE PERIOD	7 engineers are not getting paid.		
	7 of PRltd employees play 14 roles		
	Only labour cost is paid		
INVESTMENT PERIOD	7 engineers are getting paid		
PRODUCTION PERIOD	Role	Scenario	Number
	Production	B	0
		S	11
		BS	11
	Technician	B	0
		S	0
		BS	11
	Janitor	B	0
		S	0
		BS	2
	Employee benefits considered		

6.2.2.2 Business organisation's cost (Appendix 6.1.5)

They represent all the overheads and non-fixed assets.

Table 3: Business Organization cost assumptions

TYPE	ASSUMPTIONS
PROTOTYPE PERIOD	Cost covered by the UoB
INVESTMENT PERIOD	Cost covered by the UoB
	Trip covered by PRltd
PRODUCTION PERIOD	Cost covered by PRltd
PHONE AND MICROSOFT	One/employee
MARKETING AND ADVERTISING	As stated in Section 4.1 [69] [70]

6.2.2.3 Facility Cost (Appendix 6.1.6)

Table 4: Facility cost assumptions

TYPE	ASSUMPTIONS
RENT	Includes water, electricity and gas bills.
	Rent increase depending on the scenario as more employees enrolled
PROTOTYPE PERIOD	Cost covered by the UoB such as materials and workshop access
INVESTMENT PERIOD	
PRODUCTION PERIOD	Cost covered by PRltd

6.2.2.4 Robot Hardware Cost

All prices have been assumed from websites stated in the references list in the Appendix 6.1.7.

6.2.2.5 Robot Software Cost (Appendix 6.1.8)

Assume that not every engineer has access to all the software to save money.

6.2.2.6 Leasing Model

The Prototype and Investment periods have no leasing. The leasing price was determined by comparing the operational costs of the human and ROMIE models. It was also set to cover the business operational costs. Hence, a leasing price of £95k/month was calculated (20% more than monthly OPEX).

6.2.2.7 Prospection Human Model (Appendix 6.1.2)

Assumptions need to be made to determine the price of our robot by analysing the prospection labour cost. Based on Gerard de Hert's interview [71], the company was advised on all the input parameters needed to build a comparison model on a typical area of land. The total cost of these operations is assumed to be £530k.

6.2.2.8 Prospection ROMIE Model:

Regarding the performance of the battery discussed in Section 3.7, this model calculates the cost/quantity benefits of ROMIE against the human model.

Table 5: Human vs ROMIE Specification comparison model

MODEL	PROSPECTION PERIOD (DAYS)	NUMBER OF ROBOTS	PRICE (£)	TIME RATIO	PRICE RATIO
HUMAN	250	0	530,000	NA	NA
ROMIE CASE 1	86	1	285,000	2.9	46%
ROMIE CASE 2	43	2	380,000	5.8	28%
ROMIE CASE 3	17	5	475,000	14.5	10%

Assuming leasing 2 robots/contract, with contract modifications based on customer requirements. Details of the calculation in Appendix 6.1.3.

6.2.2.9 PRltd Valuation Model (Appendix H.1.10)

Assuming Weighted Average cost of capital of 25% and perpetual growth rate of 3%.

Table 6: PRltd's Valuation Model

CASE SCENARIO	VALUATION	DRAGON'S STAKES
B	**£5.4M**	**26.3%**
S	**£19M**	**9%**
BS	**£25M**	**7%**

Valuation's calculations can be found Appendix 6.6.1.

6.2.2.10 Contract model (found in summary):

For different scenarios, the number of contracts varies. Contracts are assumed to be signed when PRltd is implemented in South Africa.

Table 7: Contract model

TYPE	ASSUMPTIONS
CONTRACT RATE	25%/year
B CASE	1 contract/quarter (times 1.25^n over the years with n representing the increase in years)
S CASE	S case: 3 contract/quarter (same increase as above)
BS	BS case: 4 contract/quarter

6.2.2.11 R&D tax reliefs:

PRltd is eligible for a project-specific notified state aid tax relief scheme, saving 15% in R&D tax credit rate [72]. The input is not displayed in the financial model but will be included once the scheme is granted.

6.2.2.12 Estimated cost and expenses for the project within the GDBP timeline:

Table 8: Cost Breakdown for GDBP

Part Name	Quantity	Unit Price (£)	Total Cost (£)
Drill	2	68	136
Electric Actuators	2	118	336

The total expenses for the GBDP timeline are £472.

6.2.2.13 Summary

Table 9: Summary table

TYPE	ASSUMPTIONS
LEGAL ADVICE	Third party accountant for every annual report
	For moving to SA and a fill out legal paperwork.
RESCUE FLEET	1.5 times the number of operational robots would cover potential damages

6.3 Cash Flow Forecasts (Appendix 6.2)

The current cash flow forecast is the sum of all the parameters in the Cash Flow Summary: Earnings-Before-Interest-Taxes-Depreciation-Amortization (EBITDA), Tax, Capital-Expenditure (CAPEX) and Capital Raised. The Cash Beginning-of-Period (BoP) and End-of-Period (EoP) were added.

Cash Flow Summary	Total	Y - 2023	Y - 2024	Y - 2025	Y - 2026	Y - 2027	Y - 2028	Y - 2029	Y - 2030	Y - 2031	Y - 2032
EBITDA	65,538,492	-139,204	-210,472	-747,785	3,656,565	5,176,565	6,696,565	8,216,565	11,256,565	14,296,565	17,336,565
Tax (20%)	-12,608,123	0	0	0	-675,852	-967,598	-1,259,345	-1,551,092	-2,134,585	-2,718,079	-3,301,572
CAPEX	-7,880,568	-224,929	-40,894	-343,421	-1,196,303	-644,905	-706,172	-767,438	-1,196,303	-1,318,836	-1,441,369
Capital Raise	1,900,500	1,900,500	0	0	0	0	0	0	0	0	0
FREE CASH FLOW	**46,950,301**	**1,536,367**	**-251,366**	**-1,091,206**	**1,784,410**	**3,564,061**	**4,731,048**	**5,898,035**	**7,925,677**	**10,259,650**	**12,593,624**
Cash Beginning of Period	**455,475,715**	**3,441,775**	**5,730,918**	**4,343,348**	**3,057,352**	**13,783,466**	**29,790,191**	**50,464,864**	**76,638,968**	**111,842,636**	**156,382,198**
Cash End of Period (Cummulated FCF)	**502,426,015**	**4,978,142**	**5,479,552**	**3,252,142**	**4,841,762**	**17,347,527**	**34,521,239**	**56,362,899**	**84,564,645**	**122,102,286**	**168,975,822**

Figure 20: Cash Flow summary yearly - S case

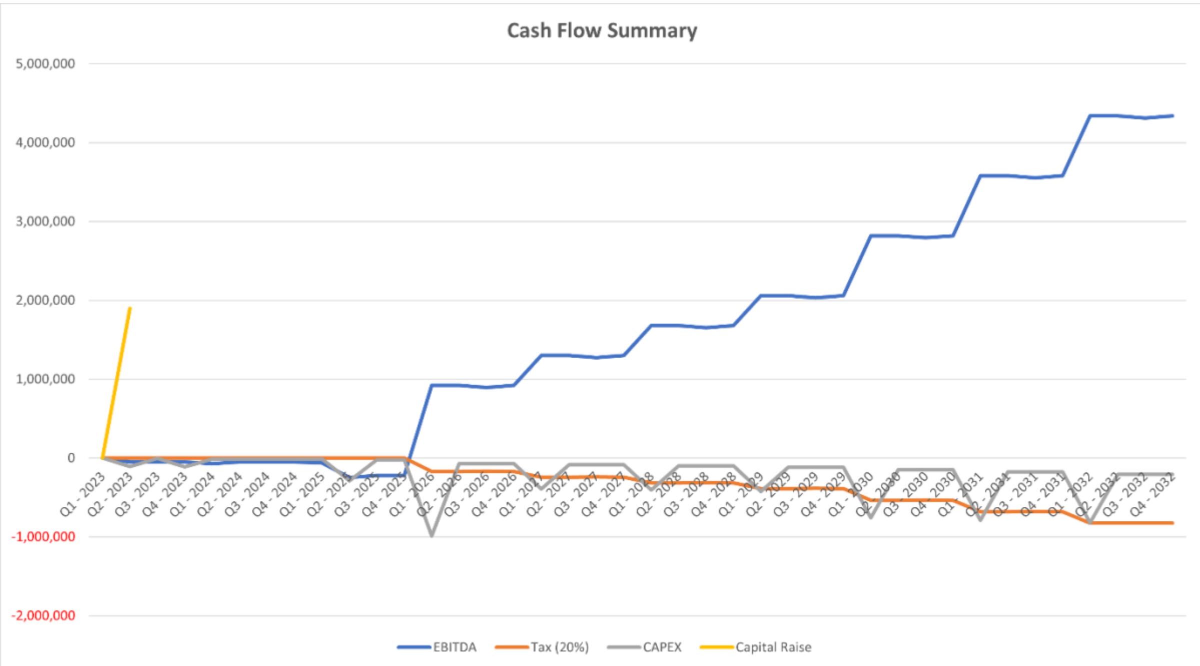


Figure 21: Cash Flow summary projection quarterly

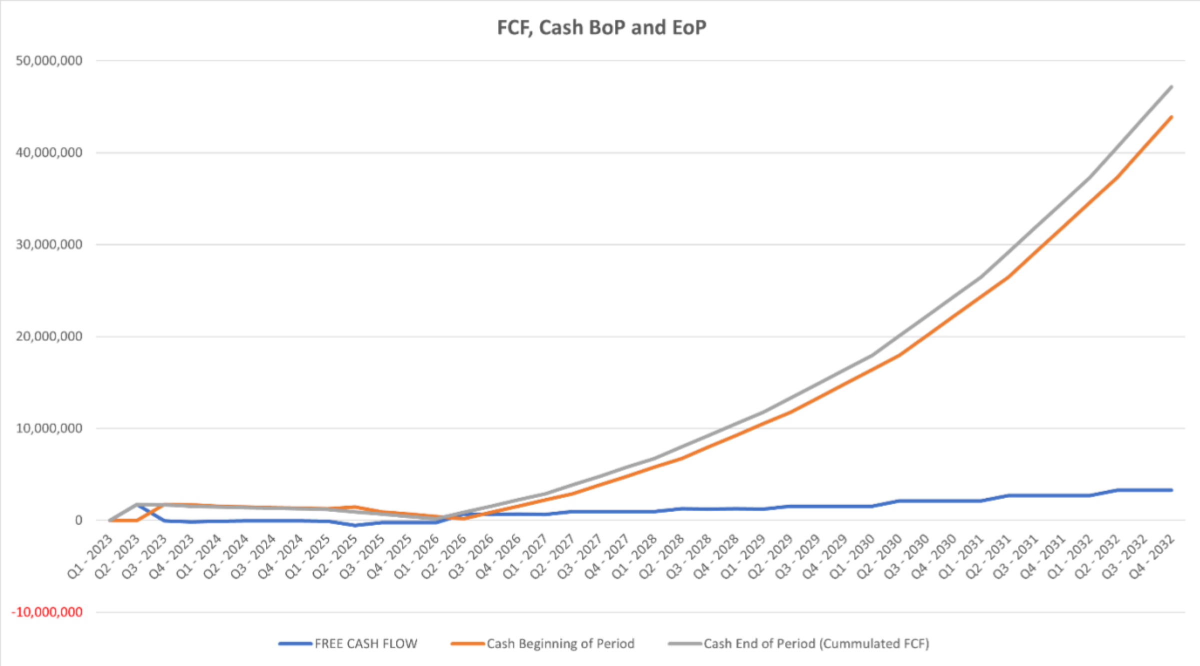


Figure 22: FCF, Cash EoP and Cash BoP graph - S case

6.4 Projected Profit and Loss Accounts (Appendix 6.3)

The current projected profit and loss model generates the Net Income output which is the Operating income before tax (sales revenue + operational cost + amortisation) plus the Tax. The graph below shows the detailed profit and loss breakdown.

Profit & Loss	TOTAL	Y - 2023	Y - 2024	Y - 2025	Y - 2026	Y - 2027	Y - 2028	Y - 2029	Y - 2030	Y - 2031	Y - 2032
Sales revenue	72,960,000	0	0	0	4,560,000	6,080,000	7,600,000	9,120,000	12,160,000	15,200,000	18,240,000
Operational cost	-7,421,508	-139,204	-210,472	-747,785	-903,435	-903,435	-903,435	-903,435	-13,036,146	-903,435	-903,435
Amortisation (20%/year)	-3,737,059	-20,472	-40,894	-80,354	-277,307	-338,573	-399,839	-461,106	-5,939,242	-706,172	-828,704
Operating income before tax	61,801,433	-159,676	-251,366	-828,139	3,379,258	4,837,992	6,296,725	7,755,459	93,504,612	13,590,393	16,507,860
Tax (20%)	-12,608,123	0	0	0	-675,852	-967,598	-1,259,345	-1,551,092	-19,196,595	-2,718,079	-3,301,572
Net Income	49,193,310	-159,676	-251,366	-828,139	2,703,407	3,870,393	5,037,380	6,204,367	74,308,017	10,872,315	13,206,288

Figure 23: P&L Projection - S case

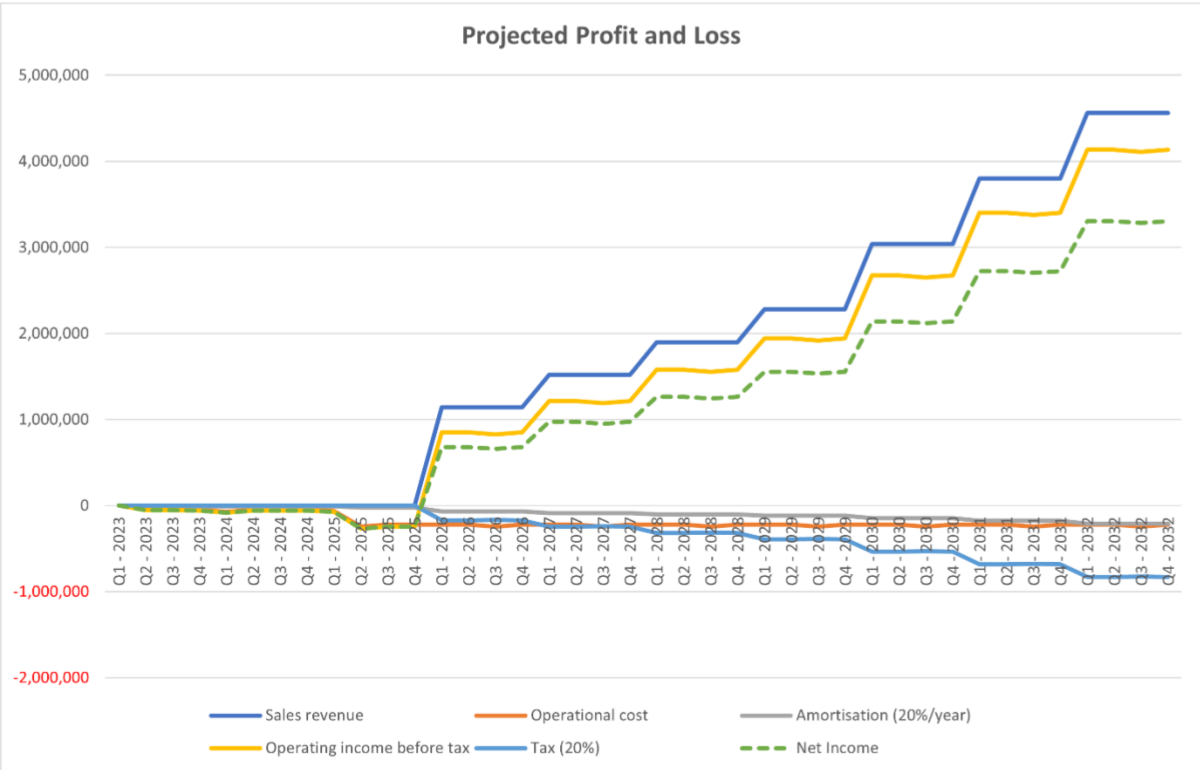


Figure 24: Overall projection per quarter graph - S case

6.5 Projected Balance Sheet

A balance sheet reporting PRltd's assets, liabilities and shareholder equity is given in Appendix 6.4.

PRltd shows a perfect balance sheet with a check line to make sure that the total asset minus the total liabilities is equal to zero.

Balance Sheet (at end of period)	Total	Y - 2023	Y - 2024	Y - 2025	Y - 2026	Y - 2027	Y - 2028	Y - 2029	Y - 2030	Y - 2031	Y - 2032
Asset	74,740,686	409,387	817,830	1,607,030	5,546,082	6,771,410	7,996,739	9,222,067	11,672,724	14,123,380	16,574,037
Cash	502,426,015	4,978,142	5,479,552	3,252,142	4,841,762	17,347,527	34,521,239	56,362,899	84,564,645	122,102,286	168,975,822
Total Assets	577,166,701	5,387,529	6,297,382	4,859,172	10,387,844	24,118,937	42,517,978	65,584,966	96,237,369	136,225,666	185,549,859
		0	0	0	0	0	0	0	0	0	0
Capital	74,120,000	5,702,000	7,602,000	7,602,000	7,602,000	7,602,000	7,602,000	7,602,000	7,602,000	7,602,000	7,602,000
Net Income	503,046,701	-314,471	-1,304,618	-2,742,828	2,785,844	16,516,937	34,915,978	57,982,966	88,635,369	128,623,666	177,947,859
Debt	0	0	0	0	0	0	0	0	0	0	0
Total Liabilities	577,166,701	5,387,529	6,297,382	4,859,172	10,387,844	24,118,937	42,517,978	65,584,966	96,237,369	136,225,666	185,549,859

Figure 25: Balance Sheet Projection - S case

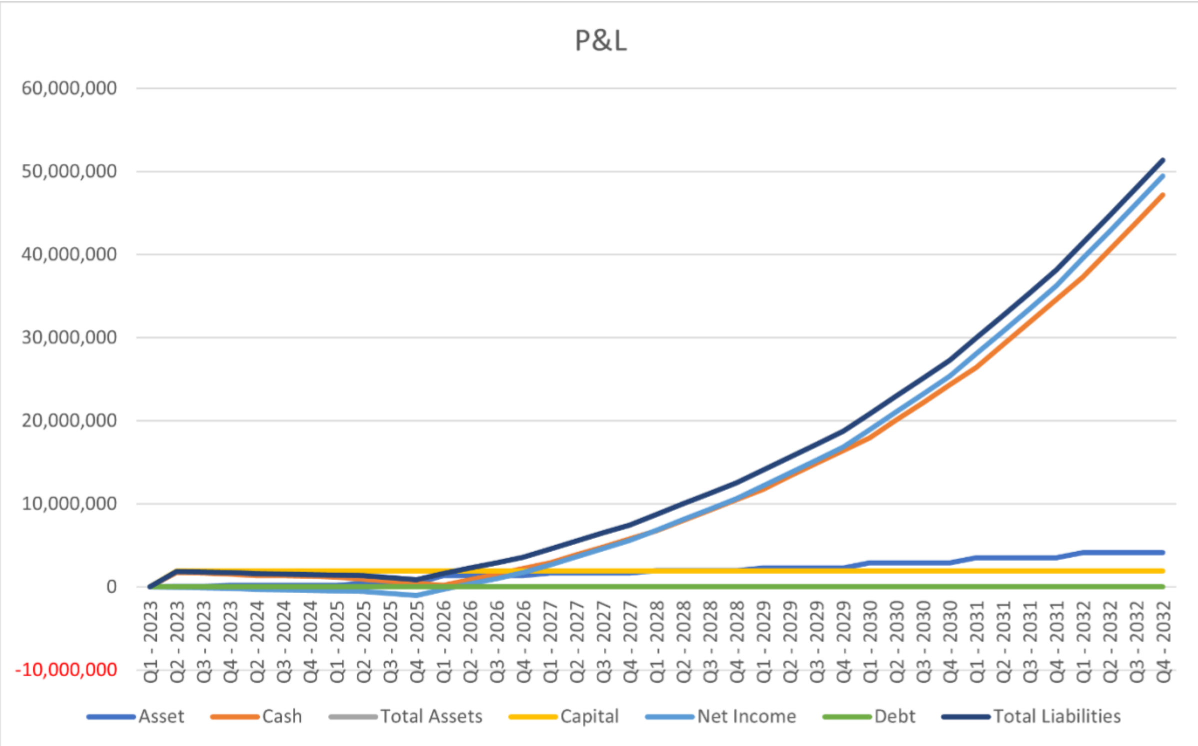


Figure 26: Overall projection per quarter graph - S case

6.6 Principal Risks and Sensitivity

The risks the company faces can be categorised under the following banners: Market, Liquidity, Credit, Strategy, Legal Risks and Operational Risks which are mostly covered in the Implementation Section. The following sections discuss what the risk involves and how it affects the financial as well as discussing mitigation measures.

6.6.1 Market Risks

There are multiple risks categorised within Market Risks, each of which could potentially affect the sales and revenue.

6.6.1.1 Competition

The entry of new competitors or a substitute product would negatively affect PRltd's market shares and revenue. Section 4.4 fully identifies any threats from existing companies or fellow start-ups. It was found that there exists no direct competition to threaten PRltd's potential market share and determined that any indirect competition like Komatsu or Caterpillar would not be able to match the rate of technological development before PRltd manages to secure the desired South African Market share.

6.6.1.2 Consumer Demand

Consumer's behaviour could lead to a possible decrease or increase in demand for ROMIE. The risk of incorrectly identifying the consumer demand has a direct effect on the revenue. The financial modelling covers three different levels of demand to account for this potential risk which tries to anticipate the consumer trends. The effects of consumer demand on FCF are covered in depth in the rest of this section.

6.6.1.3 Supply Chain Disruption

Supply chain delays and/or shortages of parts directly impact the production and therefore the sales. An example of this would be the GPS which in the past has seen its price fluctuate to 6 times the base price due to extreme demand. This risk is planned to be mitigated by following the ordering procedures covered in Section 5. This helps avoid possible high prices and extensive lead times on components. As stated above, the financials introduce a contingency factor covering this kind of inconvenience.

6.6.1.4 Currency Fluctuation

Changes in exchange rates has a direct impact on the cost of importing or exporting goods and therefore affecting profit margin. PRltd's nature involves dealing with multiple currencies (USD, GBP, ZAR), introducing loss of value risks based on currency pair fluctuations. Some losses in value are expected as both economies (GBP, USD) have shown varying inflation rates in recent periods [73]. Operating with ZAR may introduce further loss in purchasing power, as it has seen poor performance in the past years. Not much can be done to mitigate the risk of currency fluctuation except for trying to maintain a minimum amount of FCF by following the organic growth of the company's expenses and reinvesting into the operations costs associated with this growth (i.e., hiring of new engineers, development, etc.).

6.6.1.5 Regulatory changes

The changes in laws, regulations or policies from different entity ruling the mining industry has an impact on financial projection and assumptions in the model. PRltd's plurilateral relationship with the mining industry involves being up to date with mining regulations such as The World Gold Council [74] or environmental regulations. Consequently, to mitigate this risk, a good lawyer and accountant are needed.

6.6.1.6 Technological development

The rapid change in technology can lead to the obsolescence of ROMIE or alternatively create a great opportunity. Even if there are benefits and drawbacks, they both constitute a risk as PRltd needs to rapidly adopt new technologies reducing operational cost and maybe capturing new market opportunities. However, if PRltd fails to adopt, it will lose on market share. However, the unique market position and the R&D investment means that there is a good overview of what is possible in the field.

6.6.8 Credit Risks

PRltd risks customers not paying the lease on time which can have an obvious impact on the operations and the revenue generated leading to a potential bankruptcy of the company. To mitigate this risk, PRltd is only accepting upfront payments. That way, PRltd don't need to analyse the counterparty credits. However, some collateral or credit insurance can be implemented. This is easily mitigated through legal action through the International Court of Arbitration.

6.7 Liquidity Risks

6.7.1 Cash flow shortages

The most prevalent liquidity risk is failing to secure adequate funding during the first fundraising round. The Dragon's Den investment allows the company to operate with little to no debt for the first fiscal year and turn a healthy profit with its first projected contract in Q1 2026. To mitigate the consequence of cash flow shortage, there are other paths explored to finance the first two phases (Prototype and Investment) such as private grants and governmental tax credit grants. Applications to governmental grants would be made to further hedge the risk of not securing an investment.

A linked risk to the liquidity of the company is the sum of capital that must be invested into tools and machinery necessary for development. In the financial analysis this is mitigated by categorising these costs under amortisation, operating under the understanding that they will return equal or greater value to the company over time.

6.7.2 Credit denial

If PRltd's credit rating is downgraded, borrowing money might be denied by financial institutions making capital access difficult. To mitigate this, clear payment documentation will be kept in the company records.

6.7.3 Market conditions

A downturn in the economy can lead to a drop in demand and therefore in PRltd's FCF. These risks can be mitigated by maintaining, diversifying and managing adequate cash reserves.

6.7.4 Legal Risks

These include all the losses regarding any legal or regulatory actions that has been taken against PRltd. It can involve fines, penalties or unpaid expenses. These can affect the financials through fines or interest rates for late payments. As mitigation, PRltd needs to ensure records of their spending by establishing a strong compliance program and have legal support.

6.7.5 Strategy Risks:

The strategy risks involve considering market disruption, innovation in PRltd's R&D and regulation changes. They also involve understanding brand perception and a potential future Merger and Acquisition (M&A) which in the worst case, affects the market position.

6.7.6 Brand perception

PRltd's product demonstrations can fail and therefore give a bad perception of the brand. However, the company's commitment to compliance with ESG regulations should reflect positively on PRltd's image.

6.7.7 Mergers & Acquisitions

Undertaking an acquisition or a merger in the best case would be very beneficial for the company's reputation and valuation. However, it can present some downside effects such as integration challenges and work-culture differences.

These risks can be mitigated by diversifying the business environment. Keeping a multicultural environment will help with conflict resolution between teams, a strong governance, and risk management framework.

6.7.8 Research & Development

There is significant risk when developing both hardware and software. The risk that technical development of either pipeline does not meet deadlines can be mitigated by prioritising the software pipeline to meet the needs of the TBReAI partnership. This could allow income to be generated through software leases/sales to companies already delving into the automation sector of mining like Caterpillar or Hexagon AB, while hardware is still in development.

6.8 Financing Requirements

PRltd has various financing requirements, which depend on the approach and the financial strategy desired.

PRltd wants to start its financing rounds by adopting an equity scheme. As stated before, the Dragons' Den event allowed a £1.9M investment in return for shares of PRltd, thanks to angel investors or Venture Capital (VC) representatives from the mining and robotics industry. SEIS and EIS UK government initiatives are designed to attract early-stage investors to invest in 'high-risk' companies [75] (Appendix 6.6.2). These strategic investors have industry expertise where they can provide guidance on strategy, management, and other critical areas of the business. They have networking opportunities which contribute in increasing PRltd's customer base, marketing and business development and help introducing new partners. Incorporating any angels or VCs will help validate the project and bring credibility to the company. Angel investors are more prioritised than VC or Incubators/Accelerators as they tend to take a lot more equity stakes. Another type of financing that could be considered is crowdfunding. However, PRltd's business nature is Business-to-Business (B2B) and therefore does not present any advantages for random individuals. It will be adopted as a backup plan basing the fundraising theme on R&D.

PRltd is also eligible to grant schemes and R&D tax reliefs [76] which will highly improve the financing requirements. Entering funding competitions such as: "Made Smarter Innovation: Industry ready Robotics and Automation" [77] or government (UK) schemes will grant resources to further develop the product. PRltd can obtain grants in a range of £25k to £10M through UK Research and Innovation (UKRI), Research England and Innovate UK [78].

7 IMPLEMENTATION PLAN

7.1 Implementation

An implementation plan is necessary in tracking project activities throughout the design life cycle and effectively divide resources. The strategy planning timeline is split into three different phases: the Prototype, the Investment and Production Phase.

Figure 27: Company timeline phases

The Prototype Phase (Figure 28) encompasses: the initial inception of the product, research into the market and feasibility of the design and the development of the showcase prototype.

To meet the prototype deadline, resources have been divided amongst the different subsystems to allow different manufacturing processes to work concurrently. Smaller, team-set deadlines occur throughout the build phase for each sub-system to ensure they are running to schedule. Additionally, customer interaction with the geologist will occur throughout the timeframe to ensure the product viability is complying with industry needs.

An integration time slot has been included towards the end of the build phase, to bring the different subsystems together and ensure they work cohesively with one another. During this time the company will also be legally established as Prospector Robotics Limited.

Prototype phase

Monthly view

SUMMARY OF MOST IMPORTANT MILESTONES		Feb-23	Mar-23	Apr-23	May-23
Inception of product product	**Create an initial idea for product**				
	Develop a needs analysis				
	Design specification				
	Customer interaction with South African Geologist				
	Feasibility study for product				
Market research	**Gather information of current markets**				
	Research into market competitors				
	Determine how our product addresses market gaps in South Africa				
	Create business strategy to differentiate the company from competitors				
Establish	**Perform legal requirements to set up a Limited Company**				
	Elect a company director				
	Assign company shareholders and identify people with significant control				
	Finalise company agreement documents				
	Establish a record keeping system				
	Register the company				
Development of Version 1 prototype	**Hardware manufacturing**				
	Initial concept design				
	Breakdown of parts				
	Chassis and motor design				
	Drivetrain development				
	Drilling and sensing design				
	Full sub-system assembly				
	Risk mitgation factor				
	Software programming				
	Initial concept design				
	Breakdown of parts				
	Sensors decision				
	Software development				
	Camera object detection				
	Global path planning				
	Local path planning				
	Circuit Design				
	Odometry				
	Full sub-system assembly				
	Risk mitgation factor				
	System Integration				
	Integrate all sub-systems together				
	Risk mitgation factor				
	Review of the protoype				
Initial investment to continue project	**Pitch prototype to potential investors**				
	Pitch to Dragon's Den board				
	Demonstrate to TBRe AI mapping functionality				
	Showcase prototype				

Figure 28: Prototype phase Gantt chart

Investment phase

Quarterly view

Figure 29: Investment Phase Gantt Chart

Beyond that, during the Investment Phase (Figure 29), further alterations are made from additional testing and customer feedback before the final design is mass-manufactured.

V2 will undergo field testing on SA sites to ensure it is resilient to the different environmental factors, whilst V3 will endure lifecycle testing to gauge its reliability. After both testing sessions, the data will be used to redevelop the robot. The prototypes built throughout the investment phase will be used to showcase the product to investors. Once full functionality can be shown, the business will start to contact manufacturing facilities, using accurate sub-system design documents and Bill of Materials for costing quotes. Furthermore, the company will also set up Prospector Robotics South African Subsidiary and begin ordering equipment for the warehouse in Johannesburg. The timeline has now been increased to a 2-year timeframe rather than 1-year period initially proposed, due to feedback and concerns given by investors.

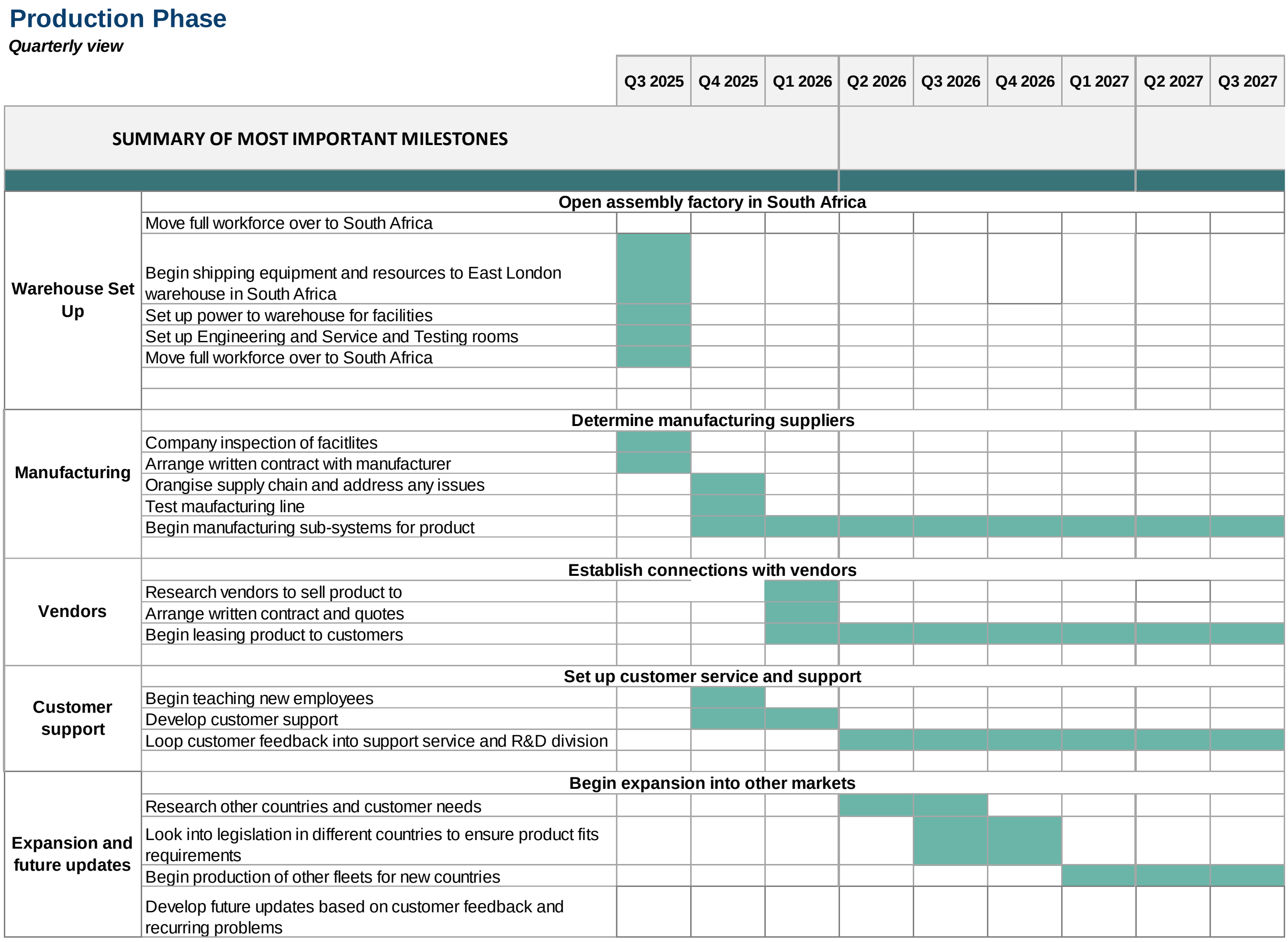


Figure 30: Production phase Gantt chart

The Production Phase includes the back end of the design process, focusing on setting up facilities in SA wide scale manufacturing and customer service.

The main priority at the beginning once stationed in Johannesburg is setting up the warehouse to assemble and store the fleet of robots.

Additionally, during this time the company will also begin exploring potential vendors, establishing 'Customer Supplier Relationships' with Mining Corporations, as well as plan logistics for shipping and delivery.

Throughout the Production Phase, resources will be used to train the customer support and service division on how to use and fix the equipment, to meet quality and maintenance standards.

Finally, beyond the scope of the design life cycle, the company will undergo further continuous research into vendor satisfaction and market analysis. This will help develop smaller updates for the existing product and potential areas to diversify into with further upgrades. The business will also begin to investigate other countries and markets to expand into.

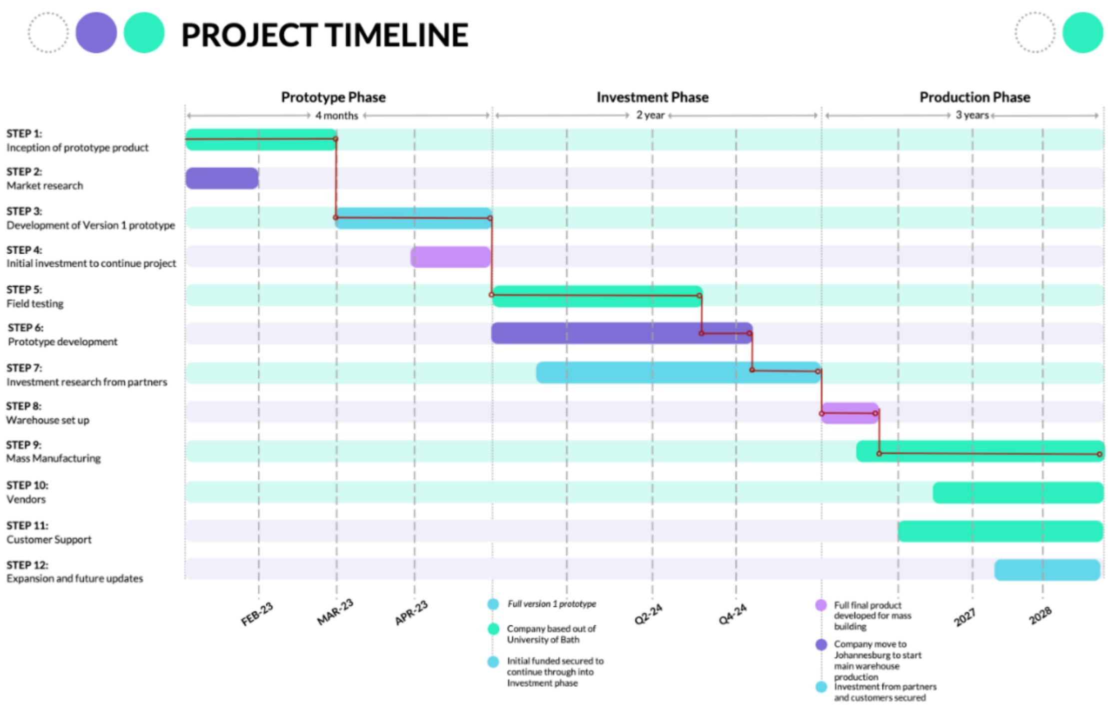


Figure 31: Full project timeline

7.2 Risk Analysis

An analysis was conducted for each phase to determine the largest risks and their effect on the expected timeline. Strategies to mitigate these risks are defined below. The risks are identified as Technical and Operational.

The major risks for each phase are outlined. During the Prototype Phase the most consequential risks are setbacks in technical development. A delay in the V1 Prototype development carries the risk of pushing the entire timeline back. In the Investment Phase, the two most important risks to be considered are negative results from lifetime testing and delays in V2 development. In the Production Phase, operational risks are the most prevalent when setting up the South African warehouse, component sourcing issues, and of course possible delays in V3 development.

Table 10: Risk Mitigation Strategies

Phase	Risk Type	Identification	Effect	Mitigation
Prototype	Technical	V1 Software Development Delay	Pushes back project timeline	Engineers follow the **DDP** for any possible internal delays
			Risks project viability	
		V1 Hardware Development Delay	Delays timeline	Hardware iused from old University projects to expedite development
		XRF hardware minimisation issues	Delays timeline	If PRltd engineers fail to achieve this task deadline, task will be outsourced to
			Affects overall hardware design	
	Operational	V1 Assembly Delay	Hard deadline missed	See Figure 10 for Assembly
			Financial and Operational costs	Large time bandwidth allocated as mitigation
			Reduced available testing time	
Investment	Technical	V2 Software Development Delay	Delays timeline	Engineers follow the DDP for any possible internal delays
				Focus only on expansion of existing features
			Decreases integration period	Critical systems will always keep one stable version to fall back onto if needed
		V2 Hardware Development Delay	Delays timeline	Hardware parts ordered ahead of time
			Decreases integration period	Minor design changes, only quality improvements
	Operational	Critical Failures during Testing	Immense timeline delays	Testing and development parallelised on a subsystem basis
			Possible product redesigns needed	
		IP not adequately protected	Risks of IP theft and copycat products	Patent portfolio is filed for sub-systems
			Possible loss of market share	Risk of any single patent falling through is mitigated by portfolio
Production	Technical	V3 Software Development Delay	Delays timeline	Engineers follow the DDP for any possible internal delays
				Focus only on bug fixes and production-level code changes
		V3 Hardware Development Delay	Delays timeline	Focus on finalising the hardware to a commercial quality using test results
				Engineers follow the DDP for any possible internal delays
	Operational	Assembly and Manufacturing Delays	Increases time needed for number of deployment-ready ROMIE	See Figure 10 for Assembly time considerations
				Allocated time is calculated on worst-case values from Figure 10 to mitigate unforeseen delays
		Lack of Hardware Components for Assembly	Stalls Assembly Possibly delays deployments	See Section 5.4 for stocking of components
		Lack of Electronics Components for Assembly	Stalls Assembly Possibly delays deployments	Regarding component
				Hardware design allowing all the hardware to assembled without any electronics components until available (Section 5.4)

Development Delay Protocol (DDP): A two-step strategy, involving a reassessment of allocated resources and skills between engineers. After a given period, evaluation of progress is made after new engineer allocation. If this has proven productive, maintain project structure until completion, else extend deadline or shift project aim to become achievable within allocated time.

7.3 Prospects

7.3.1 Hard Exit Strategy

The hard exit strategy would be a complete sale of the business and all its property (production facilities, product, IP etc.) to a larger corporation, most likely a pre-existing larger firm in the mining industry such as Caterpillar or Komatsu, for cash. This would involve no further involvement in management or business operations of ROMIE and associated products and services after the sale. This may be beneficial for employees and the business itself as from a low-level little change will occur initially.

7.3.2 Soft Exit Strategy

A soft exit strategy would most likely involve a partial sale of the business followed by a more gradual transitional passing of ownership and management. A soft exit may also constitute the sale of the entire business but with partial responsibility in management or operations being held still by the initial business owners. This can be beneficial for both parties as it ensures a smooth transition of operations to the new owner with lower risk of the business collapsing after sale as management with knowledge of the business are still in place for a period. This however does garner a lower fee for the selling party. Again, this sale would be expected to be to a larger firm in the mining industry.

APPENDIX

2.1 Founding employees CVs:

GEORGE TYLER

Home address: 16 Stacey Road, Tonbridge, Kent, TN10 3AR
Term address: 72U Lower Oldfield Park, Bath, Somerset, BA2 3HP
LinkedIn: linkedin.com/in/george-tyler-3258961b8
Email: gdt27@bath.ac.uk
Mobile: 07540 337398

Education

University of Bath | 2019 - 2024
MEng (Hons) Robotics Engineering (with Industrial Placement)
Year 1 Average - 75% | Year 2 Average - 74% including:

Mathematics 2	97%	Digital Electronics	87%
Electromagnetics	88%	Power Electronics & Drives	80%
Signal Processing	87%	Digital Systems Design	79%
Signals, Systems & Communications	87%	Mathematics 1	78%

The Judd School, Tonbridge | 2012 – 2019
A-level Results

Mathematics	A	Further Mathematics	B
Physics	A	German	B

GCSE Results
9A* 2A 1B including:

Maths	9	Physics	A*	Product Design	A
Additional Maths	A*	German	A*		

Engineering Experience

Semtech EMEA, Bristol | July 2021 – July 2022

During a year-long industrial placement, I involved myself in many areas of a market-leading semiconductor manufacturer, allowing me to gain greater insight into commercial and technical aspects of the business. Through liaising with the product engineering team, I developed communication and team-work skills whilst projects developing data analysis tools in JSL furthered my analytical skills and developed my technical abilities such as learning a new scripting language whilst carrying out the task.

Year 3 Project | September – December 2022

Developing an integrated system programmed on a Nucleo Board capable of controlling the speed of a fan based on user input from an encoder. The integrated nature of this project allowed me to develop technical skills from software and electrical areas. Meeting the strict deadlines of the project developed further the ability to work effectively to a deadline.

Year 2 Project | September – December 2020

The components of a microcontroller were programmed at a low-level using hardware description language to be combined into a functioning combined system. Learning a new language as the project was ingoing allowed me to further problem-solving skills whilst balancing multiple aspects of a project which had to be able to work together reinforced my time-management skills.

Year 1 Project | March – April 2020

In this project I programmed an Arduino to act as a PID controller to regulate the angle of a propeller attached to an arm. As this was an individual project, this allowed me to develop technical and problem-solving skills as well as creativity in finding an inventive lower friction pivot design.

KFZ-Meisterbetrieb, Heusenstamm | June 2018

Stripping a 2-stroke scooter engine allowed me to gain greater insight into how individually engineered components work together in a system. I supported colleagues in the repair of a pneumatic brake system developing technical skills. Working in a team in a second language developed my communication and linguistic skills.

Computing Skills

Microsoft Office (Highly competent)
Especially Word, PowerPoint and Excel which I have often used to create reports and presentations, and for data analysis tasks.

Python (Competent)
Experience in creating various AI applications such as a search algorithm capable of solving sudokus and a simulation of a robot whose direction is controlled by real-time image recognition.

MATLAB (Competent)
Experience in MATLAB used for data processing (video compression) and data presentation.

Autodesk Inventor (Competent)
Used to model components from technical drawings and assemble modelled components.

C (Competent)
Used to create an integrated system capable for control of speed of a fan, including PID control, LCD displays and colour changing LEDs.

JMP Scripting Language (Competent)
Writing of GUIs and programs for PCM data analysis to make more efficient the drift analysis process in mass production.

Arduino/C++ (Basic)
Used to create simple mechatronic systems such as a PID controller for motor position.

Assembly Code (Basic)
Able to interpret code and programme basic operations for PIC16F series.

Work Experience

Sevenoaks Swimming Club, Sevenoaks | January 2018 – September 2021
Part-time work as a coach. I was responsible for my own squad which improved my communication and planning skills via writing and delivering sessions to help swimmers improve across the season.

The Little Brown Jug, Chiddingstone Causeway | May 2020 – September 2020
Working part-time in front-of-house allowed me to develop teamwork skills. Interacting with customers and any problems they may have had developed my communication skills and an understanding of customer demands.

Hobbies & Interests

Swimming
I swim competitively for the university and Sevenoaks SC. I have won multiple county, regional and national medals including a national gold medal. My dedication and hard work earned me the role of club captain allowing me to develop further leadership qualities.

Other sports
Playing six-a-side football recreationally at university allowed me develop teamwork and communication skills whilst captaining school rugby teams developed these along with leadership qualities

Languages
Studying German at A-level gave me a high competency in and passion for the language which has led me to continue my study via online courses. I also understand French from GCSE.

Additional Information

Driving License
Full clean UK driving licence

Senior Prefect Role
This experience improved my organisational and teamwork skills as I organised charity events, assemblies and sporting fixtures for other students alongside a team of my peers and teachers.

Swimming teaching qualification
In order to improve my coaching ability and understanding of a sport I was passionate about, I undertook the SEQ Swimming Assistant (Teaching) Qualification.

Alexandre BENOIT

: 4 Thornbank Place, BA2 3HH, Bath, UK | 9-11 Manson Place, SW7 5LT, London, UK

: +33631045318

: amgb20@bath.ac.uk or alexandre.benoit4000@gmail.com

: https://www.linkedin.com/in/alexandre-benoit-belieth/

EDUCATION

2019 – Present | MENG INTEGRATED MECHANICAL AND ELECTRICAL ENGINEERING | University of Bath, Bath, UK

1st year: Upper 2.1 – 66% - GPA: 3.7

2nd year: Upper 2.1 – 66% - GPA: 3.7

3rd year: First 1.0 – 74% - GPA 4.0

2017 – 2019 | FRENCH SCIENTIFIC BACCALAURÉAT | Lycée Français Charles de Gaulle, London, UK

Lower 6th in Science section, focusing on Maths A, Physics (A), Chemistry (A) French scientific Bac with Honors

2012-2017 | FRENCH BREVET | Saint Jean de Passy School, Paris, France

French Brevet certificate with Honors.

ENGINEERING PROJECT & TECHNICAL SKILLS

- **Dragster Challenge:** Part of a team designing a dragster car for competition in the first year of University. It was 30cm long, made of a carbon fibre tube and a pulley system. We were awarded by the University of Bath and the lecturer for its original design.
- **Arduino project:** Optimization of a DC Actuated controlled arm assimilated to a levitation system. The use of PID control was used in order to levitate the arm to a parallel position to the ground. The sensor will allow the control system to self-correct thanks to the gyroscope IMU Sensor. Error correction was the main challenge resolved by removing mechanical noise and implementing physical bandpass filters. Everything has been computed thanks to the Arduino software.
- **Mouse design:** Using an embedded control system with ultrasound, a car was able to follow a line producing a magnetic field.
- **Shuttle tile:** Modelling the Thickness of Heat Resistant Tiles During Atmospheric Re-entry. Minimum tile thickness and research on heat-resistant tile were conducted. The spaceship was in a re-entry to earth's atmosphere. A MATLAB program was developed to approximate numerical methods derived from Partial Differential Equations. A GUI was developed to show the simulation of re-entry on earth with dynamic data and animation displayed.
- **Google machine learning foundational and advanced courses**

KEY SKILLS: Language

- **Microsoft Software:** proficient
- **Autodesk Inventor:** designed industrials components
- **OrCAD:** proficient
- **COMSOL:** project on a capacitive pressure sensor
- **Coding languages:** C++, C, Arduino, Python, HTML, CSS, JavaScript, Solidity, MATLAB, MBED and React js (to add in the future: NumPy, Pandas
- **MATLAB:** proficient
- **French:** Fluent
- **English:** Fluent
- **Spanish:** Intermediate B1

EXPERIENCE

Feb 2022 – Present | CO-FOUNDER | Belieth LTD

Belieth brings local charities to a global community via WEB3.0. Belieth solves many of the problems facing modern charities today. NFTs represent a donation through investment, creating a potentially profitable donation. A win-win for charities and donors. Community building in the Metaverse builds donor-to-charity trust and makes the participants feel included. NFT owners can also allocate the community fund within the charity, giving owners a real impact on the beneficiaries.

Sept 2021 – May 2022 | VEHICLE DYNAMIC ENGINEER | Williams Advanced Engineering and Jaguar TCS Formula E

- **DIL Operator:** Simulator driver for Formula E car test session. Setting up the car model by doing different Lap test. Operating the DIL Formula 1 or E's driving session.
- **DIL Sound System Improvement:** Improvement of the DIL Audio software. Pulling out Data from the dSpace (the internal brain of the car) via the local network and inputting the data to the relevant sounds. Each sound had some form of equation purely based on each physical component's behavior. Implementation of new realistic sounds helping the driver to be immersed in a real-life environment. Involving a very good comprehension of libraries, how executable services work, computer interactions on a local network and debugging on visual studio.
- **State-of-the-art report on torque vectoring/direct yaw moment**: wrote a report on the different and most advanced control systems for torque vectoring as well as mechanical improvements.
- **Push To Talk Application**: re-creating the well-known racing radio that allows engineers to communicate during a race in a web-application. This is used as a racing simulation tool in order to communicate to the specific engineer.

Sept 2022 – Present | VEHICLE DYNAMIC LEAD ENGINEER | Team Bath Racing Electric, Bath, UK

In charge of the vehicle dynamic team. Supervising the suspensions, brakes, hubs, tyres, steering and simulation section of the car. Involving a general comprehension of the sub-systems as well as managing a team of 15 people.

Sept 2020 – June 0221 | POWERTRAIN AND AERODYNAMIC ENGINEER | Team Bath Racing Electric, Bath, UK

Helping design the accumulator battery cooling system. Implementation of new powerful fans and study of optimization of air flowing in the accumulator in order to get as much clean air as possible.

July 2020 – Present | ENGINEER FUN CUP RACES (French GP – Paul Ricard, Magny-Cours, Belgium GP – Spa-Francorchamps) | Motorsports-Marketing-Management M3M, Belgium

Managing a team of four drivers and two mechanics. Developing my own GUI strategy model for endurance racing.

Doing a lot mechanic on the car.

Sept 2020 | SUMMER INTERN | Amplify Trading, London, UK

Developing my knowledge in the world of finance studying the buy and sell side via lectures and simulations. (I came second to the trading live simulation); rotating through roles in finance including market making, sales trading, investment banking, asset management and trading.

Sept 2020 – Present | TREASURER | University of Bath Skydiving Society, Bath, UK

Management of society's money. I am responsible for business expenses for a budget of GDP 1000.

July - August 2020 | MECHANIC ASSISTANT | Cycle Neaud Morind, Ile de Ré, France

Repairing clients' bikes and was responsible for renting and sales. I sore a little of how a small company works and learnt something about how to manage customer's behavior. I was doing a stock inventory by the end of each day.

July 2018 | RESEARCH ASSISTANT | Imperial College, Dpt of Electrical and Robotics Engineering, London, UK

Working with Dr. Antoine Cully. Coding in C++. Helping to solve coding issues of an Artificial intelligence program called PAL; a medical program which helps children with a range of medical issues. Patients were interacting with the robot (the initial AI) which learns patient behaviour and knows how to detect the patient's feelings. Key tasks where: i) manipulating PAL app and running fake users that interact with the robot, ii) going through error messages in the code which lead to the app crash, iii) report and solve programming issue.

April 2018 | MECHANIC ASSISTANT | Garage du Moulin Bleu, Ile de Ré, France

Studying the basics of cars functioning. Worked on cars and learned mechanical skills relevant to car repair.

July 2017 |TEACHER ASSISTANT | L'Ecole des Petits, London, UK

Teaching assistant and event organizer for a month. Helped organize the end of the year show for the school.

2013 – 2017 | OFFICIAL FRENCH HANDBALL REFEREE | Handball Federation

Referee for competitions in the region of Ile de France.

May-July 2014 |FRENCH OPEN « ROLAND GARROS » BALL BOY | Stade of Roland Garros, Paris, France

Ball boy at Roland Garros 2014. One of 200 successful applicants selected from 4,000.

ACCREDITATIONS

- **Jan.2023 | Google machine learning foundational and advanced courses**
- **Sept. 2020 | Distinction Level 6 diploma in Trading & Financial market analysis | London Institute of Banking & Finance**
- **2016 | Official French Handball Referee | French UNSS**
- **2015 | First Aid Certificate, level PS1 | International Red Cross**

ACTIVITIES & INTERESTS

- **Car and karting race driver:** Doing multiple tracks and test days as well as two kart championship in England
- **Blog Author:** Currently writing articles about Tesla and study Tesla’s technology in order to write technology essays.
- **Tennis:** Ranked 3.2 in the English system and won more than 10 local tournaments in France
- **Skateboarding for 5 years.** Made videos with a crew of 11 people in Paris. Received sponsorship.
- **Golf:** Handicap 14. Winner of 10 local tournaments including ORPI, Veuve-Clicquot and HERMES competitions.
- **Handball:** 3 times champions of Paris, came twice 3rd in the championship in Ile de France, represented the University of Bath in the English championship.
- **Societies**: Member of the IET, Bath Electronical and Mechanical Engineer, Bath Computer Science, Bath entrepreneurs and Bath finance.

CHARITIES

2017-2019 | VOLUNTEER CHEF ASSISTANT | Notre Dame De France Church Charity, London, United Kingdom

Prepared sandwiches for homeless people every Saturday twice a month.

February 2017 | VOLUNTEER | Mama Love’s Childcare Centre, Cape Town, South-Africa

Worked for the charity in Cape Town for a month, helping member of staff to take care of orphans aged 3 to 7.

Michael J.S. O'Connor

Electrical and Electronic Engineer

I am a highly driven and productive engineer with a passion for programming, strategic planning and problem solving. Seeking opportunities to enhance my existing skillset and abilities whilst also progressing my career ambitions. From previous work experience, university projects and sporting accomplishments, I have developed strong organisational and time management skills and I am driven in both my professional and personal life.

Education:

University of Bath September 2019 - Present
MEng Electrical and Electronic Engineering

Emanuel School September 2011 – June 2019
A-Levels: Mathematics, Physics, Drama, Extended Project Qualification
10 GCSEs Grade A*-B; Mathematics (8), Triple Science (A*A*A*), English Literature/Language (A*A*)

Work Experience:

BAE Systems Summer Internship June 2022 – September 2022
Maritime Services Software Engineer – *Exceptional Performance Rating*

- **Researched and investigated FPGA technology and capabilities for future simulation projects using the PYNQ Z2 board by TUL:**
  - Documented a walkthrough with clear and concise instructions on how to set up the board and connect to a computer.
  - Worked through the system Jupyter Notebooks, completing the tutorial on how the program operates and its capabilities.
  - Created programs to run from board boot up and control the on-board peripherals using the bit file.
  - Utilised Python's async library to run different modules concurrently.
  - Started a UCP program for the board and computer to communicate with one another.
  - Prepared a clear supporting document containing handover notes, outlining; which directories contained key files, issues that were discovered throughout the project and the functionality of the newly written code.
  - Developed Python and Linux programming skills throughout

- Stretch assignments:
  - **Educational Outreach:**
    - Presented an Industrial Placement talk and involved in a 'Board Games Career event' at the University of Portsmouth, allowing students to ask questions about the application process
    - Delivered a 'Life Modules and Future Aspirations' as part of a virtual work experience to a range of year groups, illustrating my journey through education and employment.
    - Partnered with the NHS and Y12 students at UTC Portsmouth to create a project focused on upcycling inhalers to reduce environmental hazards and emissions.
  - **Graduate forum representatives:**
    - Communicated with senior stakeholders to deliver presentations from different areas within the business unit, allowing the graduate community to gain exposure to different projects.
    - Created icebreaker and networking activities to bring together the different Early Careers cohorts
    - Developed business cases to visit other offices and sites to showcase company products and talk with senior engineers.

BAE Systems Industrial Placement June 2021 – June 2022
Maritime Services Electronic Engineer – *Exceptional Performance Rating*

- **Provided Electrical and Electronic Engineering support to resolve technical issues on Underwater Weapons**
- Worked to help drive improvement within the Torpedo Repair and Maintenance Team:
  - Attended weekly progress meetings to assess individual projects and overall team

Personal Info

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Email

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Key Skills

- Advanced numerical skills
- Logical approach to problem solving
- Excellent communication skills, both verbal and written
- Presentational experience from educational opportunities and work-experience
- Pro-active in liaising with other teams and employees
- Strong cultural and diversity awareness through charitable and volunteering work
- Realistic goal setting through evaluating progress and success criteria
- Creative and imaginative vision

Training

Electricity at Work Regulations
Certificate of Achievement

Awarded by Technical Training Solutions (2021)

Live Working
Certificate of Competence

Awarded by Technical Training Solutions (2021)

Export Control practices

Regularly assessed at BAE Systems

performance.
    - Assisted in routine testing through operating laboratory rig and followed procedure to ensure the equipment passed the necessary requirements to be used in service.
    - Worked reliably and effectively without close supervision and using own initiative to progress tasks
- **Followed company procedure to design certify a pre-built piece of support equipment:**
    - Liaised with original design engineers to ensure the equipment conformed to the test specification despite amended user requirements due to laboratory relocation.
    - Worked collaboratory with senior team members to guarantee documents underwent necessary approval and authorisation.
    - ***Team nomination for Chairman's Award***
- **Designed and manufactured an attenuator switchbox to be used in testing:**
    - Involved in ordering appropriate components through certified suppliers, whilst managing cost, quality and environmental impacts.
    - Soldering skills learnt at university were further developed.
- **Manufactured a pre-designed fusebox for use in laboratory testing:**
    - Communicated with the drilling office and manufacturing teams to build the required fusebox, in compliance with safety regulations.
- **Created digital Electrical drawing documents for an existing piece of support equipment:**
    - Used Cadence System Capture to design schematic drawings, utilising technical knowledge developed at university.
    - Completed Allegro Cadence SPB 17.4 QIR4 Online training course, focusing on the creation of new schematic symbols and PCB footprints.
    - Produced a worksheet of problems encountered and solutions from the course which was then distributed to other departments.
    - Researched and investigated different data sheets to determine suitable replacements for outdated and obsolete components.
- **Researched and documented the functionality of Cadence for future design tasks:**
    - Developed problem solving and troubleshooting skills through exploring the software's capabilities.
    - Enhanced presentational skills through demonstration of the program to a group of senior engineers to illustrate how the program worked and address the issues discovered.
- **Participated in an electric propulsion testing project:**
    - Checking the status of equipment, the work environment and facilities before commencing work by 'testing for dead' the propulsion battery to ensure it was safe to connect to.
    - Learnt how to use the testing software and control the electric motors and load bank, as well as approach a High Voltage area in a safe and professional manner.
- **Involved in a 'slow run through' of bespoke custom cable:**
    - Follow a detailed assembly document which outlined the steps required to manufacture a new cable, focusing on how the procedure could be altered for improved clarity.
- **Participated in an assurance check on board UK in-service submarine:**
    - Worked closely with the Royal Navy personnel on a testing assignment

- Stretch assignments:
    - **Immersion Organising and Hosting the January, June and September intakes for Early Careers new starters:**
        - Developed leadership skills by managing different teams and delegating work for an efficient process.
        - Enhanced project management skills by; creating a structured timetable of guest speakers, networking with senior stakeholders and liaising with other leads at different sites.
        - Improved presentational skills by being Master of Ceremony for an Immersion Day, acting as continuity announcer and support for new graduates.
        - ***IMPACT award for contribution to Immersion***
    - **Organising a graduate networking event with Naval Ships Business Unit:**
        - Planned and presented a business case to senior stakeholders for funding
        - Liaised with Naval Ships graduates prior to the event to ensure no technical issues and safety guidelines were being met, such as COVID-19 restrictions
    - **Maritime Service Early Careers Long Term Social Committee Chair:**
        - Responsible for arranging large events for graduates, industrial placements, summer interns and apprentices.
        - Opportunity to demonstrate my team-building ethos through running events and improve cross-scheme engagement.
        - Aimed to collaborate with other business units and create an inclusive environment for the Early Careers community.
        - ***IMPACT recognition award for welcoming attitude to new starters***

Programming skills

MATLAB
●●●○○
Intermediate

Python
●●●○○
Intermediate

C++
●●○○○
Developing

Assembly
●●○○○
Developing

SystemVerilog
●●○○○
Developing

Circuit drawing skills

Cadence packages
●●●●○
Competent

Allegro PCB editor
●●●●○
Competent

LTspice
●●●●○
Competent

Office IT skills

Microsoft Office packages
●●●●●
Highly Competent

Skype for business
●●●●●
Highly Competent

WebEx meetings
●●●●●
Highly Competent

Harry Caulfield

Personal Details:
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Education

University of Bath **2019-2025**

MEng (Hons) Integrated Mechanical and Electrical Engineering (sandwich)

Year 1 Modules and Grades:

Semester 1:		Semester 2:	
Solid Mechanics 1	54	Solid Mechanics 2	45
Thermodynamics	51	Digital Electronics	77
Mathematics 1	61	Mathematics 2	73
Robotics Design	56	Robotics and Mechatronics Systems	59
Circuit Theory	45	Integrated Design and Materials	67

Dulwich College **2013-2019**

A Levels:

Mathematics A Physics A Design and Technology A

GCSE's:

8 A*'s and 3 A's including:

Mathematics A* Physics A* Spanish A*

Engineering Projects & Technical Skills

First Year University Projects **2019-2020**

As a group we had to create a miniature dragster powered by a single spring. This involved working to maximise its efficiency by improving the design and by balancing different elements such as decreasing its weight whilst maintaining structural strength. In the electrical department I designed a self-hovering fan with a gyroscopic sensor which greatly built my confidence in coding and creating electronical devices.

Lockdown Projects **2020**

Under Government Lockdown I designed and made my own project. A football table where I am still constructing a scoreboard using infrared sensors. This enabled me to independently deepen my understanding of my newly learnt knowledge by putting it into practice. It also helped to maintain my ability for craftsmanship and design.

CAD Society **2017-2019**

At Dulwich I founded a society for people interested in a career in engineering or product design, which allowed students to develop their skills on CAD software. It aimed to give students a head start into universities or other career options.

Weizmann UK Safecracking competition **2017-2018**

In Year 12 I joined a small group within my school to compete in a Scientific safe cracking competition. Unlike conventional safecracking, you aim to beat other teams by constructing a safe that can only be cracked with physics principles. Ours used a combination of Brownian motion with rice and siphoning water to correct levels.

Computing Skills

Microsoft

I have extensive knowledge with Microsoft Office programmes such as: Word, Excel, Publisher and PowerPoint for writing reports and documenting data.

Engineering Specific Software

I am knowledgeable of Arduino software and C++ which I use for programming robotics and sensors. I have a deep understanding of Inventor from creating CAD models in university and school. At university I learned to use COMSOL Multiphysics and OrCAD for modelling electrical and mechanical components.

Design and Presentation

For creating videos or images I am also aware of how to use Adobe programmes including Photoshop, Premiere and After Effects. This can helpful for marketing or creating presentations.

Work Experience

Construction Work - Urban Additions **2017-2020**

I worked with a building company on multiple projects, helping with a variety of tasks including painting, interior decorating, brick laying and tile cutting. I learnt skills such as working efficiently with a large variety of people and, also how to talk to clients to identify their wants and needs.

Rowing Coach - Dulwich College **2019**

During a summer rowing camp, I trained students entering Year 9 on how to row for the first time on the tideway on the River Thames. I had to take the role of an authoritative figure and I gained a lot of confidence being a leader and taking all the responsibilities that come with this position.

Teaching Assistant - City Heights **2018**

I acted as an assistant teacher for Science and Maths classes ranging in years 8-11. I learnt how to structure my lessons to best integrate my passion for engineering into my teaching. I had to teach a group of children, of varied abilities, thus my organisation skills as well as my ability to explain concepts from multiple angles has developed greatly.

Structural Engineering Consultants - Barnard and Associates **2017**

I have shadowed engineers on a variety of different jobs, for example adding a mezzanine floor to a Louis Vuitton store. For the first time I could apply knowledge I had learned within a classroom, greatly improving my confidence in tackling non-theoretical problems. Even more importantly, I gained business and management skills which I hope to carry forward into my future career.

Interests

Rowing

I had the role of Captain of Boats in my final year of Dulwich College which I am incredibly proud of as I worked very hard to improve from the bottom boat in year 9 to racing in the Henley Royal Regatta twice.

Lamda

I received a distinction for my Silver Lamda performance in acting. I worked hard for this award to push myself out of my comfort zone and make me more confident in my public speaking skills. I now feel much more capable to give presentations and to talk to people with clarity and enthusiasm.

Myles Bienek

Address:	2 Percheron Close Impington Cambridge CB24 9YX	Telephone:	mobile: 07587 026676 home: 01223 561776
Nationality:	British	Email:	mb2638@bath.ac.uk

Qualifications:-

University of Bath studying for a Masters Degree in Integrated Mechanical and Electrical Engineering.

Average Scores

Year 1 -	77.5%
Year 2 -	72.3%

Hills Road Sixth Form College – A Level Results: 2017 - 2019

Maths -	A	Further Maths -	A	Physics -	A
Chemistry -	A				

Impington Village College - GCSE Results: 2012 - 2017

Maths -	9	Biology -	A*
Additional Maths -	A	Chemistry -	A*
Astronomy -	A	Physics -	A*
Computing -	A	French -	A
History -	A*	English Literature -	6
English Language -	7	European Computer Driving Licence - Distinction*	

Work Experience:-

Pragmatic Semiconductor **June 2021 – August 2022**

For my university year in industry, I worked at Pragmatic in the ICDE team. The role involved maintaining the DRC system by fixing bugs and adding new rules. I also designed the digital blocks of two NFC ICs through concept, implementation, simulation, and fabrication.

University of Cambridge Department of Engineering **July 2018**

One week at the Cambridge University Engineering Department where I was tasked with converting database data format from Bitbucket to Jira using Python.

CRFS Limited **July 2016**

One week at CRFS Ltd in Cambridge where I worked on the design of a logarithmic spiral antenna circuit board. CRFS design and manufacture high-end RF spectrum monitoring equipment for civilian and military use.

Engineering Education:-

Third Year University Projects **September 2022 – June 2023**

During the first semester I designed a PID system to control the speed of a CPU fan using an SMT32 microcontroller. It was written in C++ and used interrupt control and pulse width modulation. A tachometer input was used as part of the feedback loop.

Second Year University Projects **September 2020 – June 2021**
In the first semester I learnt how to code in MATLAB and completed a project which involved writing code to simulate a spacecraft entering the orbit of Venus while considering the effects of the atmosphere. I also learnt SystemVerilog and wrote and tested the components of a RISC processor for an FPGA. Another project reinforced my skills in Autodesk Inventor by designing a shaft for a wind turbine. In the second semester, I designed a control circuit using op-amps for a small vehicle to follow a wire with a current flowing through it.

Personal Projects **July 2020**
I used 3D CAD and a 3D printer to develop an adapter for a pressure washer attachment. This expanded my knowledge on the University provided software Autodesk Inventor. I also expanded upon my work in first year to display graphically the output of the Inertial Measurement Unit on a mini OLED screen.

First Year University Projects **September 2019 – June 2020**
In the first semester I learnt how to use an Arduino to control the speed of a motor by sampling the voltage from a potentiometer. This was expanded on in the second semester through adding an Inertial Measurement Unit to create a control system written in C++.

Hills Road Robotics Club **October 2017 – April 2018**
I am interested in robotics and during my time at Sixth Form I joined the robotics club. I was involved with helping the club launch a robotics design competition for local schools. While there I learnt to write control software for the robots in C++.

Suprovo Banerjee

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Email: sb2754@bath.ac.uk
Mobile: 07594539459

Education

University of Bath (September 2019 – Present)
MEng (hons) Electrical and Electronic Engineering

University modules:

- Year 1:
  - Introduction to programming in MATLAB; Electronic laboratory techniques & professional engineering practice; Circuit theory; Engineering physics; Mathematics 1; Signals, systems and communications; Digital electronics; Mathematics 2; Electronic systems design and manufacture 1
- Year 2:
  - Electronic devices & circuits; Digital systems design; Signal processing; Electromagnetics; Electronic systems design and manufacture 2; Communication principles; Structured programming; Electrical systems & power electronics; Group design and professional engineering practice 2; Control systems
- Year 3:
  - Industrial Placement
- Year 4:
  - Fundamentals of visual computing; Digital networks and protocols; Digital communications; Power system plant; Power system fundamentals

Reading School, Reading, Berkshire (September 2014 – July 2019)

- A-Level: Mathematics - A, Physics - B, Chemistry - B, Further Mathematics - C
- GCSE: English Language - 8, English Literature - 6, Mathematics - 9,
  Physics - A*, Chemistry - A*, Biology - A, Religious Studies - A
  Geography - A*, German – A, Computer Science: A*, Electronics: B
  Additional Mathematics - A

Engineering Experience

Projects at University of Bath (2019-2020):

- Dyson Workshop – proposed a solution to reduce the number of microplastics/plastics on clothes that goes into oceans by designing a filter for a washing machine
- Microprocessors – assembled a working stopwatch and digital lock using PIC microprocessor
- Electronics systems design and manufacture – designed and soldered different PCBs

Computing, Electronics and Robotics Course (Smallpeice Trust) at University of Southampton (August 2018)
Designed and developed a technical solution to a challenge involving computing, electronics and robotics as a part of a team, and competed against other teams to deliver the best solution.

Summer Computer Science Course (Debate Chamber) at Birkbeck, University of London (August 2017)
Explored both the foundations of Computer Science and its potential to produce transformative innovations by using programming languages such as Java.

Aerospace and Rocketry (Techcamp) at Sparsholt College/Wessex Conference Centre (August 2015)
Built a working drone and designed a rocket with optimum aerodynamics using my knowledge of mechanics and electronics

ECITB Engineering Experience (Smallpeice Trust) at Harper Adams University (April 2015)
Worked in teams to design a bridge and provide cost-effective solutions to deliver such a project on time

Space School at University of Leicester (August 2014)
Attended lectures and workshops – building rockets, scuba diving, stargazing, etc.

Computer Skills

- Experience in using Windows, macOS and Linux operating systems
- Knowledge in Microsoft Office programs such as Word, PowerPoint, Excel, Outlook and also alternatives including Apple's Pages, Keynote and Sheets, and Google's Docs, Slides and Sheets
- Understanding in using CAD software such as OrCAD
- Programming skills including MATLAB, Visual Basic and Python (completed Python Mega Course from Udemy in summer 2020)

Work Experience and Employment

Electronics Technician Intern at Metric Group Ltd (August 2021 – August 2022)
Industrial Placement in the development team to improve the current car parking machines such as fixing existing electrical and design issues, testing parts and embedded software, as well as contribute to the design and manufacture of brand-new machines by conducting tests to check whether new prototypes could work in different environments; suggested and amended designs to initial prototypes originally created by the mechanical team

Performance Support Officer at Wokingham Borough Council (June 2020 – August 2020)
Used Microsoft Excel extensively to analyse social care data, identify trends and patterns, predict demand, and provide data visualisation

STFC Rutherford Appleton Laboratory - ISIS Neutron and Muon Source (July 2018)
Effectively used CAD to design a specific lifting bracket, presented my design to a team of engineers with Q&A session

Laing O'Rourke, Wimbledon, London (October 2017)
Produced a report to identify the use of sulphur hexafluoride as an arc-quenching medium for an electric switchgear while being on site with the engineers where a new substation was being built using new electrical switchgears instead of traditional transformers

Lloyds Bank, Wokingham (August 2016)
Acquired new skills such as cash handling, risk management, sorting and filing, public interaction and general task management as well as shadowing the staff of the bank

MISSION YOU at TCS, London (July 2016)
Provided technological solutions to overcome problems of clients

Customer Assistant at Vue Cinemas, Reading (December 2017 – July 2018)
Worked with people as part of a team using my communication and problem-solving skills to deliver fantastic customer service and shared a passion for film with customers

Hobbies & Interests

- Cricket – I have been playing since I was 8 years old. It developed my teamwork skills. I became captain of my cricket club team in 2016 which improved my leadership skills.
- Music – I started playing the piano when I was 6 years old and started playing the violin when I was 8 years old. Music increasingly became a hobby and playing both instruments helped me to be disciplined and improve time management.

Additional Information

- Bronze and Silver Duke of Edinburgh Awards
- ABRSM Piano Grade 6, Violin Grade 8
- Bronze and Silver RSCM Chorister Awards
- LAMDA Speaking in Public Grade 6 (Bronze Medal)
- Silver Medal at Marlow Music Festival 2015
- Bronze and Silver Certificates at UKMT Mathematical Challenges
- Industrial Cadet Level 2 (Silver) at Tata Consultancy Services
- Best Bowler 2012 and Best Batsman 2016 at Wokingham Cricket Club
- Vice Chair of Bath Indian Society 2020-2021
- Full UK Driving License

ADAMOS KARANIKAS

3rd year Integrated Mechanical & Electrical Engineering Student at University of Bath

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EDUCATION

MEng Integrated Mechanical & Electrical Engineering [Year 2: 69.6%]

University of Bath [2019 – 2024]

Modules

- *Electrical and Electronic*:
  Circuit Theory, Digital Electronics, Digital Systems Design, Electromagnetics, Electronic Devices & Circuits, Electrical Systems Power Electronics, Signals Systems and Communications
- *Mechanical*:
  Solid Mechanics, Thermodynamics, Modelling Techniques, Design & Materials, Fluid Mechanics
- *Integrated Application*:
  Integrated Design & Materials, Robotics Design, Robotics & Mechatronic Systems, Design & Manufacturing of Electromechanical Systems, Integrated Control Systems Design, Mathematics

Academic Projects

Electrical:

Circuit and PCB Design for various applications taking into consideration thermal management and physical space limitations.

Robotics:

Design, C++ development, assembly, and testing of PC fan controller based on an STM microcontroller. Produced analytical report from results.

Design:

Full design process for a shaft for a domestic wind turbine. Using MATLAB and Inventor with an iterative method for optimisation. A technical report was made to cover the process and results. Executive decision making and workload management were key to keep the group on track.

Aerospace:

Modelled aerocapture and thrust procedure of a spacecraft to be placed in orbit around Venus using MATLAB. Involved numerical model methods like Runge-Kutta and Euler. Clean programming practices were important for all group members to successfully understand the code implementation. (1st)

International Baccalaureate [35/45]

Zurich International School [2012 – 2019]

- Higher Level Subjects: Maths **6**, Physics **6**, Chemistry **5**
- Extended Essay on the effect of operating frequency of transformers on their efficiency. **[22/24: B]**

EXPERIENCE

Engineering Intern

Aegis Rider AG **-** Zurich, July 2021 – July 2022

Internship focusing on microelectronics and embedded systems development.

- Development of wireless communications between microcontrollers.
- Sensor control programming using communication protocols like I2C, SPI, UART.
- Microelectronics systems development of prototypes and further versions, which are implemented in current product.
- Developed critical systems independently within a fast-paced environment of a start-up.
- Participated in product demonstrations to potential investors.
- Experienced how a technical product is built from concept to pre-production level [Research & Development]

Design Engineer

Team Bath Racing Electric **-** Bath, Sept 2020 – May 2021

Part of the Formula Student TBRe Team, working in the AI group. Specifically, the sub-division designing and manufacturing the autonomous steering actuation module.

- Review and optimisation of previous design.
- Designing new autonomous steering module package using Inventor, constrained by FS regulations.
- C++ and Python programming on Raspberry Pi and Arduino microcontrollers controlling steering servo motor.

Assistant Mechanic

Kaelin Motos - Zurich, Summer 2020

Unpaid work at a local motorcycle garage.

- Learnt how to interface with clients and adapt based on their requirements.
- Appreciated the importance of good design and its influence on product performance.

Bioinformatics Intern

Roche Glycart AG - Zurich, Summer 2019

Developed Single Cell Sequencing plot generator using R and R Shiny for internal web-tool.

- Self-taught R to improve data visualisation based on user needs.
- Created function to adapt plots to accommodate any sized dataset to be visually optimised.
- Participated and presented in team meetings across multiple sub-groups.

Student Tutor

Voluntary Role – Zurich, January 2018 - April 2019

- A focus of the *IB Diploma* on community, decided to tutor in Maths and Physics
- Helped students comprehend concepts through analogies to connect with their strengths.

SKILLS AND LANGUAGES

- Programming [C, C++, Python, MATLAB, R]
- Linux OS proficiency [Ubuntu CLI]
- Circuit and PCB Design
- CAD Design [Inventor]
- SystemVerilog HDL Digital Circuit Design
- Electronic circuit simulation [PSpice]
- ROS and ROS2 [C, C++, Python]
- Microsoft Office Suite proficiency
- Greek, English [Native proficiency]
- German [Intermediate proficiency: B2]

INTERESTS AND ACTIVITIES

Motorcycles

Passionate about all aspects of motorcycling, from the vehicle design to the riding experience. Experiencing new places through riding is one of my favourite pass times.

Rugby

I have played for my school and region as well as being included in the Swiss national U18 team. I competed within the University system during my first year. Learning to follow strict training schedules and the work ethic required to train properly was extremely valuable and easily transferable to my academic life.

Water Sports

I engage in various water sports like kitesurfing (beginner), white-water kayaking (up to Level 4 rivers) and scuba diving (PADI open water certified). Through these sports I have learnt how to perform in a calm and collected manner when put in a high-stress environment.

Rock Climbing

Started as a means of physiotherapy from previous injuries but developed a passion for the problem solving and critical decision-making that it requires.

2.2 Legal

2.2.1 Legal stipulations to set up a limited company:

Elect a company director

↓

Assign company shareholders and identify people with significant control

↓

Finalise company agreement documents

↓

Establish a record keeping system

↓

Register the company [6]

2.2.2 Legal stipulations to set up a South African subsidiary:

Complete South African work visas for all employees

↓

Register the company using an Articles of Incorporation

↓

Complete a Memorandum of Incorporation and Notice of Incorporation

↓

Open a South African bank account and register for VAT and taxes

↓

File with the Department of Labour for unemployment insurance

↓

Register for Diseases Compensation and Occupational Injuries

↓

Apply with the District Council [8]

2.2.3 Business Visa Requirements:

In order for an applicant to be granted a South African Business visa they must adhere to the following requirements (taken from the Republic of South Africa Department of Home Affairs):

- Complete Form BI-1738
- Submit a certificate issued by a chartered accountant registered with the South African Institute of Chartered Accountants to the effect that you have:
    - At least an amount in cash to be invested in the Republic as determined from time to time by the Minister, after consultation with the Minister of Trade and Industry or
    - At least an amount in cash and a capital contribution as determined from time to time by the Minister, is available.
    - An undertaking by the applicant that atleast 60% of the total staff complement to be employed in the operations shall be South African Citizens or permanent residents, permanently employed in various positions.
    - An undertaking to register with:
        - The South African Revenue Service
        - Unemployment Insurance Fund
        - Compensation Fund for Occupational Injuries
        - Companies and Intellectual Properties Commission, where legally required and
        - Relevant professional body, board or council recognized by SAQA, where applicable.
    - A police clearance certificate from each country where you resided since the age of 18 years, including the Republic of South Africa A letter of recommendation from the Department of Trade and Industry regarding –
        - the feasibility of the business
        - and the contribution to the national interest of the Republic.
    - A yellow fever vaccination certificate if you have travelled or intend travelling through a yellow fever endemic area Medical and radiology reports

[79]

3.2 - Regulations to adhere to:

3.2.1 Mine Health and Safety Act: Regulations: Machinery and Equipment:

Table 11: Design Regulations

Regulation:	How the product meets the requirement:
(8.10.1) The employer must take reasonably practicable measures to ensure that pedestrians are prevented from being injured as a result of collisions between trackless mobile machines and pedestrian. At any mine where there is a significant risk of such collisions, such measures must include at least the following:	Every engineer on site must ensure pedestrians are stood at least 5m away from product whilst in operation.
(8.10.1.1) At any mine where there is a significant risk of such collisions, such measures must include that all electrically or battery powered trackless mobile machines, excluding shovels, bucket wheel excavators and overburden drills, must be provided with means to automatically detect the presence of any pedestrian within its vicinity. Upon detecting the presence of a pedestrian, the operator of the trackless mobile machine and the pedestrian must be warned of each other's presence by means of an effective warning. In the event where no action is taken to prevent potential collision, further means must be provided to retard the trackless mobile machine to a safe speed where after the brakes of the trackless mobile machine are automatically applied without human intervention.	Avoid obstacles and audible warning if a person is detected.
(8.10.3) The employer must take reasonably practicable measures to prevent trackless mobile machines running uncontrolled.	Product will have a kill switch operated by on site engineers.
(8.10.4) The employer must take reasonably practicable measures to ensure that persons are prevented from being injured as a result of overturning of any trackless mobile machine. Roll overprotection structures must be fitted on trackless mobile machines if required in terms of the mine's risk assessment.	Employees are not allowed within 5m of the product whilst it is running
(8.10.7) The employer must take reasonably practicable measures to ensure that persons are prevented from being injured as a result of brake failure.	Product will have a kill switch operated by on site engineers.
(8.10.7.1) Trackless mobile machines are operated with adequate and effective braking systems	Braking system to stop from any obstacle detected

(8.10.7.2) All braking systems are adequately and routinely tested for intended functionality	Calibration test to include a brake test upon start up to ensure the braking system is functioning
(8.10.7.3) All braking systems are regularly maintained	Product checks must be completed both before and after use of customer.
(8.10.7.4) That where a combined braking system is used, the design of the braking system is such that it complies with the requirements for the separate systems and that it fails to safe.	Test braking system during the system integration design phase to ensure it fails to safety
(8.10.14) The employer must take reasonably practicable measures to ensure that trackless mobile machines, skid mounted machinery and trailers are visible to persons in their vicinity.	Lights attached to product to ensure clear visibility with person
(8.10.16) The employer must take reasonably practicable measures to ensure that procedures are prepared and implemented for the safe isolation and lockout of trackless mobile machines.	Circuit breakers including within design to ensure electrical safety is maintained. Programme to display fault and error within the product
(8.10.18) The employer must take reasonably practicable measures to ensure that procedures and standards are prepared and implemented for maintaining trackless mobile machines in a safe operating condition.	Quality and maintenance checks carried out both before and after operation
8.10.21 The employer must take reasonably practicable measures to ensure that procedures are prepared and implemented for the safe recovery and towing of trackless mobile machines.	Product includes space to attach a towing hook on the vehicle.
(8.10.24) The employer must take reasonably practicable measures to ensure that procedures are prepared and implemented for inspecting trackless mobile machines immediately prior to use	Quality and maintenance checks carried out both before and after operation
(8.10.24.1) The operator of the trackless mobile machines physically inspects and ensures that the brakes, lights and any other defined safety features and devices are functioning as intended prior to setting such trackless mobile machines in motion;	Calibration documentation created and test procedure and visual inspection to be carried out before use.
(8.10.24.2) Pre-use check lists that have to be completed by all operators of trackless mobile machines at the beginning of their shift. Such check lists must clearly identify all the components, features and functionalities to be inspected by the operator. For each component, feature or functionality, the check list must clearly indicate the pre-established criteria under which the trackless mobile machines may or may not be put in motion.	Calibration documentation created and test procedure and visual inspection to be carried out before use.
(8.10.25) The employer must take reasonably practicable measures to prevent any trackless	Avoid large changes in elevation

mobile machine reversing over the edge of a stockpile or dump.	
(8.10.26) The employer must take reasonably practicable measures to prevent inadvertent movement of any trackless mobile machine whilst parked.	If product is stationary during sample taking or rest, power to wheel motors will be switched off to ensure it cannot move.

[9]

3.2.2 Annex 1 of The Basel Convention for the Control of Transboundary Movement of Hazardous Waste:

(Y19) Metal carbonyls
(Y20) Beryllium; beryllium compounds
(Y21) Hexavalent chromium compounds
(Y22) Copper compounds
(Y23) Zinc compounds
(Y24) Arsenic; arsenic compounds
(Y25) Selenium; selenium compounds
(Y26) Cadmium; cadmium compounds
(Y27) Antimony; antimony compounds
(Y28) Tellurium; tellurium compounds
(Y29) Mercury; mercury compounds
(Y30) Thallium; thallium compounds
(Y31) Lead; lead compounds
(Y32) Inorganic fluorine compounds excluding calcium fluoride
(Y33) Inorganic cyanides
(Y34) Acidic solutions or acids in solid form
(Y35) Basic solutions or bases in solid form
(Y36) Asbestos (dust and fibres)
(Y37) Organic phosphorus compounds [12]

3.2.3 Design and Development Matrix

Needs analysis		Target specifications		
Ref Need	Description	Ref Spec	Description	Objectives measurable + tolerance
Product				
N1	Resistant to environmental factors	SP1.1	Air/Water tight seals on body	Check for water or debris inside body of machine
		SP1.2	Maintain temperature regulation	Measure temperature of battery to be below 60 degrees
		SP1.3	Protect product against chemical, abrasion, heat and water resistance	Cover product in white protective paint
N2	Minimal damage to environment	SP2.1	Use of solar panels to charge the batteries	Incorporate 5 m by 5 m solars panels to produce 10 kW required
		SP2.2	Drill the necessary size hole to test the ground	Drill a hole 30cm deep with a diameter of 10cm
N3	Use computer units	SP3.1	AI computer	10 ± 5W / 2 ± 0.5 GHz clock speed / 16GM RAM / 500 ± 50 GB storage
		SP3.2	Microcontrollers	16 ± 4 MHz Processor Speed, 50 ± 20 KB of program memory
N4	Manufactured out of reusable materials	SP4	Use existing parts from the lab	60% of net weight to be made from re-used parts for prototype
N5	External parts to be bought within budget	SP5.1	External parts must bought within £500 total	Develop a purchasing record and bill of materials to keep track of spending
		SP5.2	Life cycle of the product should be minimum 3 years	Carry out routine maintence inspections, choose reliable components during the design phase
		SP5.3	Price to be competitive with similar products	Should be invoiced by client need (per square meet)
		SP5.4	Calibration test upon start up to ensure sensors are working	Calibration documentation created and test procedure to be carried out before use.
		SP5.5	The equipment is not inflamable	Use nonflammable materials
Platform				
N6	Travel on a range of surfaces	SP6.1	Drive on dirt/muddy ground	Maximum allowable X force/area to ground
		SP6.2	Drive on gravel ground	Should have a ground clearance of 50 cm
N7	User interface - Settings and mode changes	SP7	A wireless interface controlled via micro/radio waves or plugged in	Conduct user trials with the software, Allowable 1 Km from user on field for transmission of dat
N8	Incorporate suitable power system	SP8	A 20-60kWh lithium battery	A range of X km with an autonomy of 10-12 hours
N9	Uses electric motors	SP9	Uses Brushless DC motors for travel	Average lifespan of 10,000 ± 1,000 hours, Power of X W per motor
Mapping				
N10	Detect objects and obstacles	SP10.1	Identify rocks and rubble	Detect obstacles that are higher than the ground clearance (80mm)
		SP10.2	Avoid water	Avoid water within Xm of sensors (*temp sensors?*)
N11	Identify its own location	SP11	Sensor data processing algorithm	Resulting Pose data updates at 5 Hz, with sub-1meter accuracy
N12	Ability to plan routes (Path planning encompasses N1,2,3)	SP12	Plan routes between waypoints, changing if needed due to obstacles	Change route if an object is detected within 10m of sensors
N13	Stop in the case of emergencies	SP13	A suitable EBS system installed	Stop in a distance less than its own body length
N14	Contain suitable sensors for mapping	SP14.1	Location Sensor	Standalone componet can track location to within 1m, Sensor should have a refresh rate of X Hz
		SP14.2	Ranging sensors	Sensor should have a refresh rate of X Hz, Sensor should have a resolution of Y
Payload				
N15	Take samples	SP15	Collect soil required for test analysis	Drill and test a sample in under 300 seconds
N16	Supply sufficient torque to drill into ground	SP16	Use of suitable electric motors and gear boxes	Final supplied torque of X Nm

Figure 32: Design and Development Matrix for the product including Platform, Mapping and Payload subsystems.

3.2.4 CO_2 Human Workforce Model

Model Inputs	
Contingency for CO2 produced due to weight = 15%	1.15
CO2 emitted from different tranportation methods (kg of CO2/km)	
Pickup truck (based on Ford Ranger)	0.2116
Truck (based on Mitsubishi Canter Truck)	0.22816
Air cargo (per ton)	0.5
Ship (per ton) - Roll on roll off ferries	0.05166
Distances (km)	
Area covered by car on mine area	2010
Avg distance from SA mine to port (Durban)	570
Durban to Port of London ship distance	14893.874
Port of London to Royal Holloway Lab	45
Avg distance from SA mine to airport (Johannesburg)	100
Johannesburg to London flight distance	9068.67
Heathrow Airport to Royal Holloway Lab	10

Model Output	
CO2 Produced (kg)	
Sampling using pick up truck (Ford Ranger)	425.316
One trip from SA mine to port in truck	130.0512
Ship from SA to London	769.41753
One trip from London port to lab	10.2672
Total CO2 produced (kg)	**1335.0519**

Figure 33: Input and outputs of CO2 model for current method of geochemical sampling

3.7 Battery Capacity and Motor Rating Calculations

- Given target specifications: 10kph max. speed, dual motor, 12h operating time, max. incline 10°, 30cm wheel diameter.
- Power Draw (P_d) of entire robot needs to be found. The motor ratings must be determined first.

Table 12: Mass breakdown

Component	Mass (kg)
2x Motor	20
Battery	60
Wheels	20
Chassis	20
Rest (Electronics, Casing, etc.)	15
Total (m) incl. safety factor	**200**

- Using kinematics equations and target specifications of 10kph max. speed and 10° incline:
- Gravel/dirt surface assumed with offroad tyres providing coefficient of friction $\mu = 0.5$

It is found each motor's peak force should be: $F_m > 653\ N$

Using this, peak torque is calculated from the following equation: $\tau_m = F_m * r_w$, where r_w represents the wheel radius (15cm).

- It is found each motor's peak torque should be around 7Nm after a gear ratio reduction.

Motors of this rating and performance come with a usual peak power draw of 500W.

- Therefore, the following Power Draw list is generated:

Table 13: Power draw breakdown

Component	Peak Power Draw (W)
Drill system motor	100
2x Drive Motors	1000
Electronics (incl. regulators, protection circuits, etc.)	50
XRF	100
Total (incl. safety factor)	**1300**

- Next, the total energy consumption in Wh is found by:
  $$Consumption(Wh) = PowerDraw(W) \times OperatingTime(h)$$

- $1300(W) \times 12(h) = \mathbf{15600}(Wh)$ Total Consumption of ROMIE

- Following, the battery capacity (Ah) is found by dividing the consumption by the battery voltage which is chosen as 48V for compatibility with the drive motors.

$$Battery\ Capacity\ (Ah) = \frac{TotalEnergyConsumption(Wh)}{BatteryVoltage(V)} = \frac{15600}{48} = \boldsymbol{325\ Ah}$$

It is concluded that for **12h** of operation, a battery of capacity **325Ah** is needed.

Note: This justification was made for commercial purposes and omits many technical steps.

5.1 Manufacturing considerations

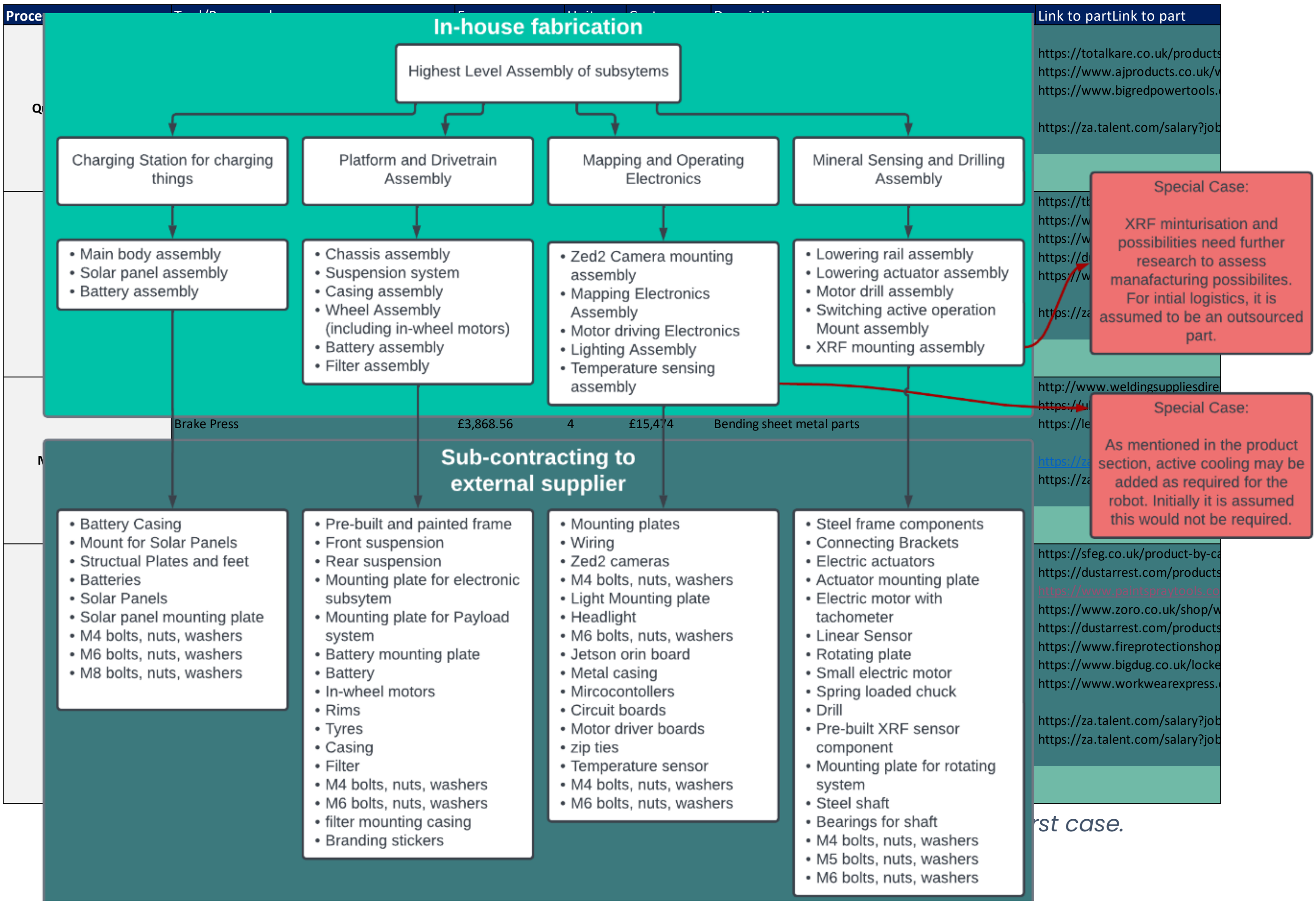

Figure 34: Parts decided for in-house and external sub-contracting. [55] [97]

5.2 Operational timings

Main Process	Breakdown of manufacture	Parts involved	Quantity	Tools required	Max Manafacture Time (minutes)	Min Manafacture Time (minutes)
2a Payload Assembly	Assembly of frame using bolts	steel frame components	8	Ratchets	60	20
		Connecting Brackets	8	torque wrench		
		M5 bolts, nuts, washers	24			
	Attach electric actuators to frame	Electric actuators	2	Ratchets	25	5
		M bolts, nuts, washers		torque wrench		
		mounting plate	1			
	attatch the motor (Inbuilt tacho) and tachometer to frame	Electric motor with tachometer	1	Ratchets	30	10
		M bolts, nuts, washers		torque wrench		
	Attactch linear sensor to frame	M bolts, nuts, washers		Ratchets	20	8
		Linear Sensor	1	torque wrench		
		Zipties				
	Rotating mount and attatchments	rotating plate	1	small crane	300	90
		DC motor	1	Ratchets		
		spring loaded chuck	1	torque wrench		
		drill	1			
		Pre-built XRF sensor component				
		mounting plate	1			
		M bolts, nuts, washers				
		M6 bolts, nuts, washers				
		Steel shaft	1			
		Bearings for shaft	2			
4a Electronics and Sensors	Assemble zed2 assembly and Light assembly	Mounting plates	1	Ratchets	40	10
		wiring		torque wrench		
		zed cameras	2			
		M bolts, nuts, washers				
		Light Mounting plate	1			
		Headlight	1			
		6 M bolts, nuts, washers				
	Assemble all controllers into a main computing unit	jetson orin board	1	Ratchets	90	30
		Metal casing	1	torque wrench		
		3 Mircocontollers	3	Plyers		
		Circuit boards	2			
		motor driver boards	1			
		zip ties				
		M bolts, nuts, washers				
		Temperature sensor	1			
1 Chassis	Chassis assembly	Pre-built and painted frame	1	small crane	240	40
		front suspension	1	Ratchets		
		rear suspension	1	torque wrench		
		Mounting plate for electronic subsytem	1	Battery storage unit		
		Mounting plate for Payload system	1			
		Battery mounting plate	1			
		Battery	1			
2b Payload to Chassis	payload shaft and bearings to chassis, motor to chassis	Payload assembly		Small crane	330	70
		Chassis assembly		Ratchets		
		M bolts, nuts, washers		torque wrench		
3a Wheels and motor construction	Attaching tyres to in motor wheels	in-wheel motors	2	Small crane	420	100
		rims	2	air compressor (for tyres)		
		tyres	4	tyre fitting machine		
3b Wheels to chassis	Wheels onto chassis	in-wheel motor driven wheels		Torque wrench	210	45
		wheels		Ratchets		
		M6 bolts		small crane		
4b Sensors electronics to chassis	Electronics to chassis, fit all connections together	6 M6 bolts, nuts, washers		Torque wrench	45	10
		Electronic subsytem		Ratchets		
		Zed Camera assembly		plyers		
		Zip ties				
5 casing to chassis	Attatching casing ontop of the chassis	Casing	1	small crane	55	15
		Filter	1	Torque wrench		
		M6 bolts, nuts, washers		Ratchets		
		filter mounting casing	1			
		Branding stickers				
7 quality checks	Quality checks	machine		computer	960	480
				multimeter		
				pressure gauge		
				camera		
				measuring tools		

Figure 36: Operations for assembly, parts, and tooling [58] [101]

5.3 Location comparisons

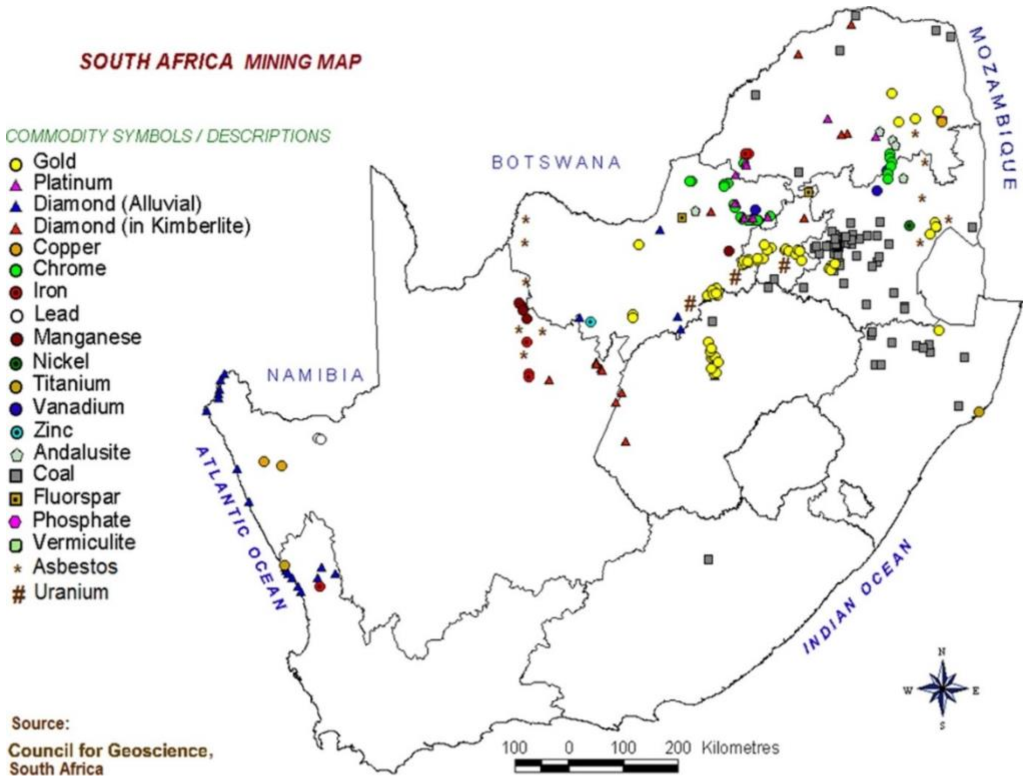

Figure 38: Map of existing mining sites in South Africa. [102]

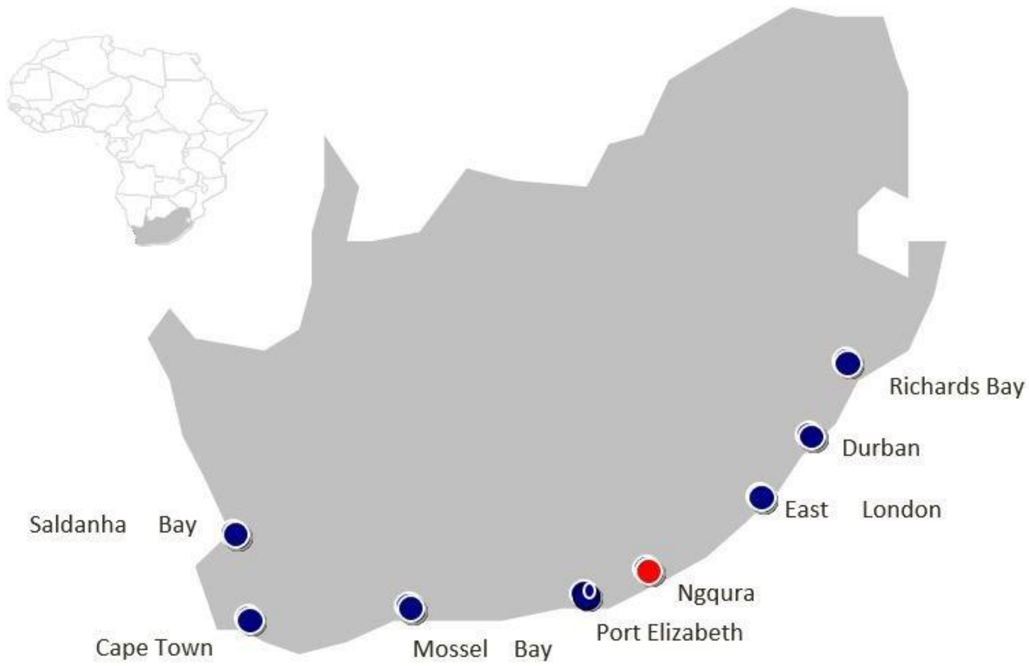

Figure 37: Map of ports within South Africa [96]

Region:	Cape Town			East London			Durban (eThekwini)			Johannesburg (Gauteng)		
	Cost (Rand	Area m²	£/m²	Cost (Ranc	Area m²	£/m²	Cost (Ranc	Area m²	£/m²	Cost (Ranc	Area m²	£/m²
Location 1	5900000	646	411	6500000	1310	223	17500000	1772	444	11200000	1180	427
Location 2	17500000	2320	339	6300000	610	465	17450000	1954	402	33000000	5888	252
Location 3	10000000	700	643	6950000	1736	180	26000000	1958	598	30000000	6053	223
Location 4	10200000	1287	357	10000000	2378	189	12500000	2600	216	4130000	413	450
Location 5	5900000	700	379	7300000	1325	248	19000000	2656	322	2700000	270	450
Location 6	8928000	558	720	5750000	651	397	35000000	2700	583	19000000	3428	249
Location 7	12500000	1004	560	6300000	500	567	33000000	3000	495	4950000	611	365
Location 8	3400000	358	427	4500000	734	276	18000000	3500	231	2400000	534	202
	Average £/m²:		480	Average £/m²:		318	Average £/m²:		411	Average £/m²:		327

Figure 39: Cost of buying industrial suitable facilities for regions in South Africa

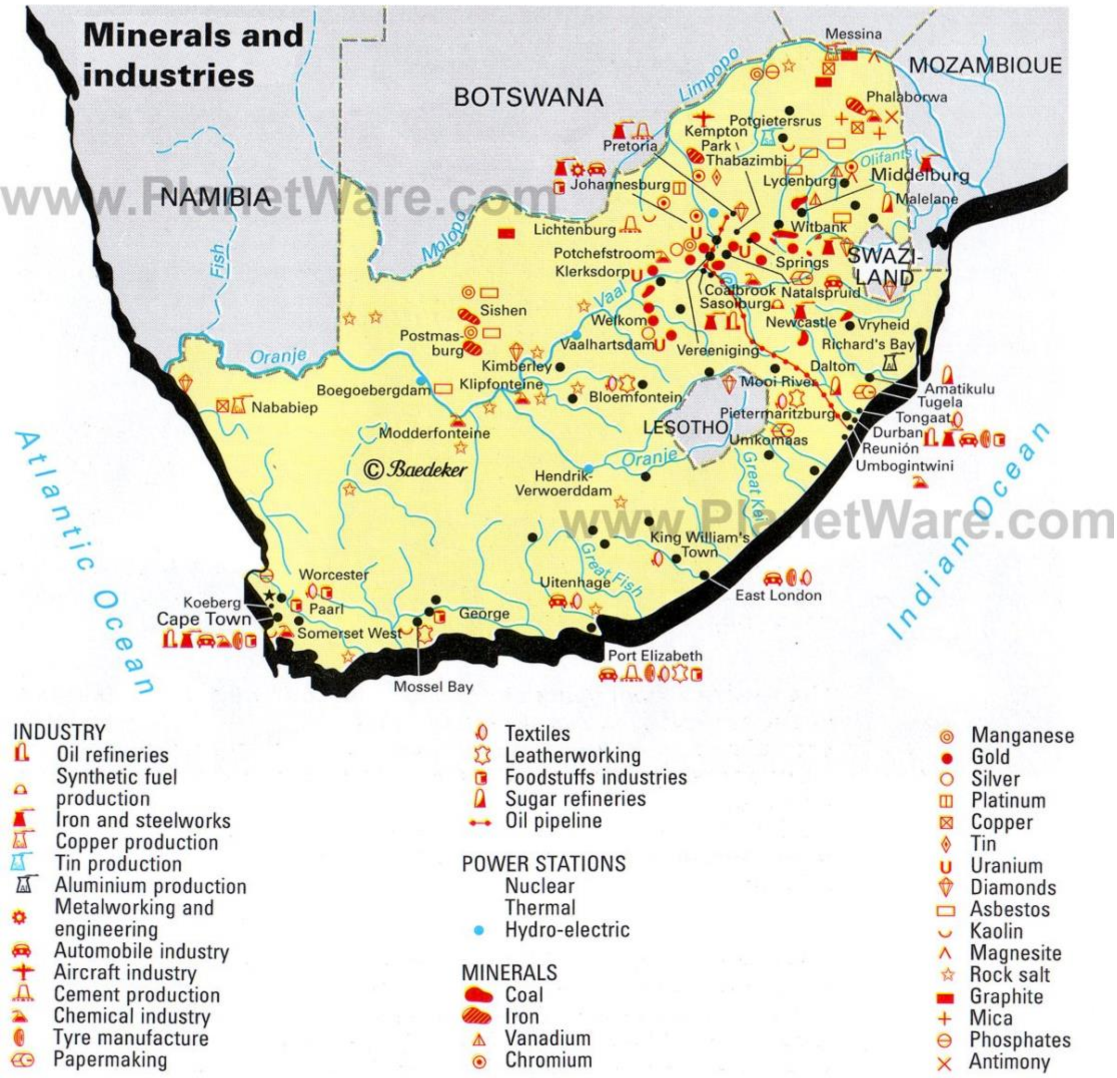

Figure 40: Map of existing industry in South Africa [104]

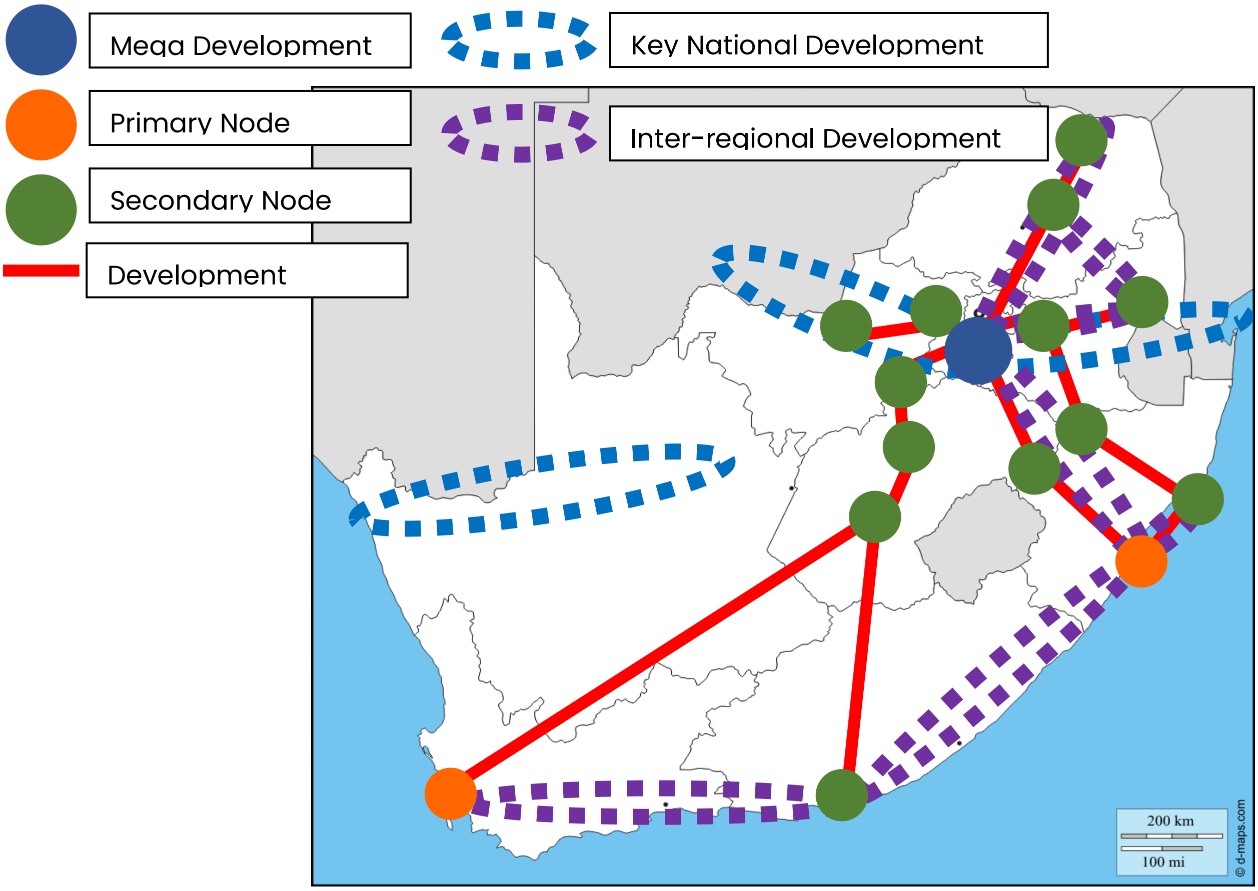

Figure 41: Map of development nodes and channels across South Africa [103]

6 FINANCIALS

6.1 Summary of the forecasts and key assumptions

6.1.1 Forecasts Summary

Forecasts Summary - Standard Case

Feature's type	Total over 9 years	Year - 2023	Year - 2026	Year - 2030
Sales revenue	27,360,000	0	1,520,000	4,560,000
Total OPEX	-6,136,041	-139,204	-737,915	-737,915
Total CAPEX	-3,464,199	-224,929	-451,089	-573,621
Net Income	15,301,052	-159,676	509,863	2,843,837
Capital Raise	1,900,500	1,900,500	0	0
Total Assets	218,516,369	5,387,529	5,441,327	33,437,914
Total Liabilities	218,516,369	5,387,529	5,441,327	33,437,914
FREE CASH FLOW	15,558,786	1,536,367	203,531	2,537,505

Figure 42: Forecasts Summary - B Case

Forecasts Summary - Standard Case

Feature's type	Total over 9 years	Year - 2023	Year - 2026	Year - 2030
Sales revenue	95,760,000	0	6,080,000	15,200,000
Total OPEX	-8,764,117	-139,204	-1,076,266	-1,076,266
Total CAPEX	-10,287,189	-224,929	-1,584,474	-1,339,408
Net Income	65,466,834	-159,676	3,715,671	10,717,592
Capital Raise	1,900,500	1,900,500	0	0
Total Assets	750,148,872	5,387,529	12,325,617	126,624,735
Total Liabilities	750,148,872	5,387,529	12,325,617	126,624,735
FREE CASH FLOW	61,895,635	1,536,367	2,490,343	10,104,928

Figure 43: Forecasts Summary - BS Case

Forecasts Summary - Definition

Feature's type

Sales revenue	How much money we are making from our contracts through our leasing model
Total OPEX	(Operating Expenses) are the day-to-day operations costs (rents, wages, overheads,etc...)
Total CAPEX	(Capital Expenditure) are the cost of fixed assets
Net Income	The results of the Profit and Loss (P&L) with tax applied
Capital Raise	Movement of cash going in and out
Total Assets	Resource with economic value
Total Liabilities	What the company owes
FREE CASH FLOW	Cash generated from normal business operations before interest payments

Figure 44: Forecasts Summary - Definition

6.1.2 Human Prospection Model

Model Inputs	
Business	
Samples done per/day	40
Logistic	40
Working hours/ day	10
Working Routine (weeks)	6
Human Workforce	5
Technical	
Regional Coverage (length - m)	10,000.00
Regional Coverage (width - m)	10,000.00
Sampling Coverage (length - m)	200
Sampling Coverage (width - mm)	50
Human pace (km/h)	4
Drilling Time (min)	15
Finances	
Samples	£15.00
Logistic/Samples	£5.00
Salaries/person/months	£500.00
Overheads (energy, maintenance, etc)/months	£5,000.00
Lab Analyse/samples	£22.00

Model Outputs	
Technical	
Total number of samples L	50
Total number of samples W	200
Total number of samples	10000
Prospection period (days)	250
Finances	
Total Prospection cost	£150,000
Total Logistic cost	£50,000
Total Lab analyse cost	£220,000
Total Crew salaries	£20,833
Total Net Cost	**£440,833**
Contigency	1.2
Total Contigency Cost	**£529,000**

Figure 45: Human Prospection Model

The input values were given by the geologist. The output table has been generated by PR.

Table 14: Output table for human prospection

OUTPUT	CALCULATION BREAKDOWN
THE TOTAL NUMBER OF SAMPLES	how much samples do we have in length * the number of samples we have in width
PROSPECTION PERIOD	total number of samples / by the number of samples that the workforce can prospect in a day
TOTAL PROSPECTION COS	price of sample * the total number of samples

TOTAL LOGISTIC COST	total number of samples * the logistic price
TOTAL LAB COST	Same logic as above

6.1.3 ROMIE Prospection Model

Model Inputs

Technical - Robot	
Number of samples to collect	10000
Robot's range (km)	100
Range (hours)	12
Battery charge (hours)	12
Max Speed (m/h)	10000
Total Length Covered (km)	2,000
Sampling and Analyse Processing (min)	5
Travelling time in between sampling (min)	1.2

Business	
Robot's Leasing price	95,000.00

Model Outputs

Technical - Robot	
Total Time to complete task (min)	6.2
Number of sample collected in one charging time in 12h	116
Number of days to cover area if running 12/7	86
Number of days to cover area if running 24/7	43
Total Number of Robot	2

Technical - Performance	
Time Gain compare to human action (ratio)	5.8

Finance - Robot	
Cost of Human Operation	**£529,000**
Cost of Leasing for operation	**£190,000**
Price ratio between the two model	**64%**

Figure 46: ROMIE prospection model

We have been basing our model on the lifetime of hour robot ROMIE with the following specifications: 12h of lifetime/runtime and 12h to charge it. We know the speed of 10km/h, the length to cover (2000km), the processing time (5 min) as well as the traveling time between sampling points (1.2min).

Table 15: Output table for ROMIE prospection

OUTPUT	CALCULATION BREAKDOWN
TOTAL TIME TO COMPLETE THE TASK	Processing time + travelling time in between the sampling points
NUMBER OF SAMPLES COLLECTED IN ONE CHARGING TIME	Range * 60 / Total time to complete the task
NUMBER OF DAYS TO COVER AREA IF RUNNING 12/7	Number of sample to collect/ Number of samples collected in one charging time

NUMBER OF DAYS TO COVER AREA IF RUNNING 24/7	Number of days to cover area if running 12/7/2
TOTAL NUMBER OF ROBOTS	NA - hardcoded
TIME GAIN COMPARED TO HUMAN ACTION (RATIO)	='Prospection Human Model'(time to prospect)/ Number of days to cover area if running 24/7
PRICE RATIO BETWEEN THE TWO MODEL	(Cost human operation-cost of leasing for operations)/cost human operation

6.1.4 Employees Costs

Roles	Expense	Unit	No. Months	Cost	Description
Engineering Departement					
Platform Engineer	£ 2,208.00	2	12	£ 52,992.00	
Mapping Engineer	£ 2,208.00	2	12	£ 52,992.00	
Payload Engineer	£ 2,208.00	3	12	£ 79,488.00	
Total Engineering Salaries (yearly)				£185,472.00	
Total Engineering Salaries (Quartely)				£ 46,368.00	
Business Departement					
Business Manager	£ 2,500.00	1	12	£ 30,000.00	
Project Manager	£ 2,500.00	1	12	£ 30,000.00	
Product Manager	£ 2,500.00	1	12	£ 30,000.00	
Operations Manager	£ 2,500.00	1	12	£ 30,000.00	
Quality Manager	£ 2,500.00	1	12	£ 30,000.00	
Risk Manager	£ 3,500.00	1	12	£ 42,000.00	
Finance Manager	£ 2,700.00	1	12	£ 32,400.00	
Human Resources Manager	£ 2,700.00	1	12	£ 32,400.00	
Total Business Salaries				£256,800.00	
Manufacturers					
Production Worker	£ 483.00	11	12	£ 63,756.00	
Technician Worker	£ 483.00	0	12	£ -	
Third-Party Labour	£ 100.00	1	1	£ 100.00	University Manufacturing
Total Business Salaries				£ 63,856.00	
Maintenance					
Janitor	£ 230.00	0	12	£ -	
Total Business Salaries				£ -	
Employe Benefits					
Benefits	£ 224.20	26	12	£ 69,950.40	including Life, Health insurance and pension plan
Total Business Salaries				£ 69,950.40	
Contigency	**1.3**				for any other employee cost that we did not plan
Total Employees costs (yearly)				£748,901.92	
Total Employees costs (quarterly)				£187,225.48	

Figure 47: Employee Costs table [80] [81]

6.1.5 Business Organisation Costs

	Expense		Unit	No. Months	Cost		Description
Bills							
Phone	£	13.50	26	12	£	4,212.00	
Landline	£	23.00	1		£	23.00	
Broadband	£	41.00	1	12	£	492.00	
Website Domain	£	1.50	1	12	£	18.00	
Microsoft packages	£	16.60	26	12	£	5,179.20	
Marketing and Advertising	£	1,500.00	1	12	£	18,000.00	mining and robot conferences
Total Bills costs					£	27,924.20	
Shipping							
Truck	£	100.00	1		£	100.00	Price changes depending the trip or shipping process
Boat	£	615.00	1		£	615.00	Price changes depending the trip or shipping process
Total Shipping costs					£	715.00	
Travel							
Train	£	40.00	7		£	280.00	two trips of 7 people
Flights	£	800.00	7		£	5,600.00	3 trips of 7 people will be needed
Total Travel costs					£	5,880.00	
Contigency		**1.3**					for any other facility cost that we did not plan
Total Business Organisation costs (yearly)					£	36,301.46	
Total Business Organisation costs (quarterly)					£	9,075.37	

Figure 48: Business organisation costs [82] [83] [84] [85] [86] [87] [88] [89]

6.1.6 Facility Costs

	Expense	Unit	No. Months	Cost	Reference	Description
R&D						
PCs	£ 1,000	26		£ 26,000	1	capacity of 7 people + workshop between 100-300m^2 (room for future staff), bills included
R-Tech TIG Welder	£ 3,100	2		£ 6,200	2	For designing and modifying metal parts
Sheet metal bender	£ 179	2		£ 358	3	For designing and modifying metal parts
Heavy Duty Workbench	£ 158	8		£ 1,264	4	For designing and modifying metal parts
Standing Pillar Drill	£ 1,100	1		£ 1,100	5	
Crane	£ 958	2		£ 1,916	6	Saftey for heavy objects
Complete tool set	£ 300	3		£ 900	7	
Torque Set power wrencgh	£ 259	6		£ 1,554	8	
Forklift	£ 11,700	1		£ 11,700	9	
Monitors	£ 124	52		£ 6,448	10	2/person
Laptop	£ 1,200	26		£ 31,200	11	testing
3D Printer	£ 3,200	2		£ 6,400	12	printing parts
Printer	£ 1,700	2		£ 3,400	13	printing anykind of size
Desk and supply	£ 300	26		£ 7,800	14	office desk
Fridge	£ 150	1		£ 150		
Kitchen stuff	£ 500	1		£ 500		
Total costs				£106,890.00		
Workshop						
Soldering	£ 40	4		£ 160	15	
Carton Live storage Flex	£ 769	15		£ 11,535	16	
Storage shelves (set of 5)	£ 900	5		£ 4,500	17	
air compressor (for tyres)	£ 160	2		£ 320	18	
Battery storage unit	£ 6,048	2		£ 12,096	19	
Laptop	£ 1,200	3		£ 3,600		
measuring tools (callipers for exan	£ 114	2		£ 228	20	
multimeter	£ 31	2		£ 62	21	
Plyers and similar	£ 227	8		£ 1,816	22	
pressure gauge (for tyres)	£ 100	2		£ 200	23	
INDUSTRIAL RATCHET 'P' TYPE	£ 163	40		£ 6,520	24	
small crane	£ 958	6		£ 5,748	25	
tyre fitting machine	£ 1,150	2		£ 2,300	26	
Torque Set power wrencgh	£ 259	6		£ 1,554	27	
Tools	£ 1,300	2		£ 2,600	28	
Storage shelves	£ 120	12		£ 1,440	29	
Electronic tools	£ 530	4		£ 2,120	30	
Assembly station	£ 120	4		£ 480	31	
Forklift	£ 220	2		£ 440	32	
Palettes	£ 100	2		£ 200		
Portable Crane	£ 250	1		£ 250	33	
Power Tools	£ 1,100	3		£ 3,300	34	
Total costs				£ 61,469.00		
Vehicle						
Truck	£ 17,000	2		£ 34,000	35	
Total costs				£ 34,000.00		
Contigency	1.3					for any other facility cost that we did not plan
Total Hardware Facility Cost				£263,066.70		
Building						
Office	£ 4,000.00	1	12	£ 48,000		capacity of 7 people + workshop between 100-300m^2 (room for future staff), bills included
Insurance	£ 120	1	12	£ 1,440		insuring the building as we have HV battery
Contigency	1.3					for any other facility cost that we did not plan
Total Facility costs (yearly)				£ 64,272.00		
Total Facility costs (quarterly)				£ 16,068.00		

Figure 49: Facility Costs [90]

6.1.7 Robot Hardware Costs

Main Process	Parts involved	Expense	Unit	No. Months	Cost	References tag
Payload Assembly	Steel frame components (8 bars)	£ 20	8		£ 163	1
	Connecting Brackets (8 L brackets)	£ 3	8		£ 24	2
	M5 bolts, nuts, washers	£ 1	24		£ 17	3
	Electric actuators	£ 118	2		£ 235	4
	M8 bolts, nuts, washers	£ 1			£ -	5
	Mounting plate	£ 9	1		£ 9	6
	Electric motor with inbuilt tachometer	£ 61	1		£ 61	7
	M8 bolts, nuts, washers	£ 1	4		£ 4	8
	M4 bolts, nuts, washers	£ 1	4		£ 4	9
	Linear Sensor	£ 25	1		£ 25	10
	Zipties				£ -	
	Rotating plate	£ 11	1		£ 11	11
	DC motor	£ 29	1		£ 29	12
	Spring loaded chuck	£ 90	1		£ 90	13
	Mounting plate	£ 9	1		£ 9	14
	M8 bolts, nuts, washers	£ 1	6		£ 6	15
	M6 bolts, nuts, washers	£ 1	4		£ 4	16
	Steel shaft	£ 7	1		£ 7	17
	Pre-built and painted frame	£ 676	1		£ 676	18
	2 front suspension	£ 40	1		£ 40	19
	2 rear suspension	£ 40	1		£ 40	20
	Mounting plate for electronic subsyterr	£ 25	1		£ 25	21
	Mounting plate for Payload system	£ 7	1		£ 7	22
	Battery mounting plate	£ 27	1		£ 27	23
	Bearings for shaft	£ 4	2		£ 9	24
	Earth Auger	£ 200	1		£ 200	25
	Drill Motor	£ 200	1		£ 200	
	XRF	£ 50,000	1		£ 50,000	26
	Station battery	£ 4,790	2		£ 9,580	
	Robot Battery	£ 2,395	1		£ 2,395	27
Total costs					£ 63,897.73	
Platform	Charging Stations	£ 10,000	1		£ 10,000	
	Communication	£ 50	1		£ 50	
	Body-lights	£ 50	1		£ 50	
	Controller	£ 200	1		£ 200	
	Rims	£ 50	4		£ 200	
	Brushless DC motors 500W	£ 200	1		£ 200	
	DC-DC power converters	£ 35	1		£ 35	
	Axles	£ 50	2		£ 100	
	Power socket connectors (for charging	£ 20	1		£ 20	
	Metal casing	£ 150	1		£ 150	28
	3 Mircocontollers	£ 40	3		£ 121	29
	Circuit boards	£ 19	2		£ 37	30
	motor driver boards	£ 12	1		£ 12	31
	Casing	£ 750	1		£ 750	32
	Chassis and chain drive	£ 300	1		£ 300	33
	Motors for drive train	£ 392	1		£ 392	34
	4 wheels	£ 45	4		£ 180	35
Total costs					£ 12,797.81	
Mapping	ZED stereo camera	£ 374	2		£ 749	36
	Nvidia Jetson Orin NX	£ 750	1		£ 750	37
	GPS	£ 63	1		£ 63	38
	Inertial Measurement Unit (IMU)	£ 17			£ -	39
	Encoders	£ 120	1		£ 120	40
	E-stop	£ 9	1		£ 9	41
	GPS	£ 31	1		£ 31	42
	Microcontrollers	£ 43	3		£ 129	43
Total costs					£ 1,851.15	
Contigency			**1.3**			For any parts that fails to work, we can plan a spare
Total Hardware Cost					£102,110.70	

Figure 50: Robot Hardware costs [91]

6.1.8 Robot Software Costs

	Expense	Unit	No. Months	Cost	Description
Payload					
Inventor	£ 213.33	2	12	£ 5,119.92	for cading design
Fusion360	£ 42.50	2	12	£ 1,020.00	for cading design
Vault	£ -	2	12	£ -	PDM software
Total costs				£ 6,139.92	
Platform					
Altium	£ 355.00	2	12	£ 8,520.00	
Matlab/ Simulink	£ 292.00	2	12	£ 7,008.00	
Gazebo	£ -	2	0	£ -	
Total costs				£15,528.00	
Mapping					
ROS	£ -	2		£ -	
Visual Studio	£ 45.00	2	12	£ 1,080.00	
Ubuntu	£ -	2			
Github	£ 17.50	2	12	£ 420.00	
Total costs				£ 1,500.00	
Contigency	**1.25**				For any software that we would need midway the processus
Total Payload costs (yearly)				£28,959.90	
Total Payload costs (quartely)				£ 7,239.98	

Figure 51: Robot Software Costs [92]

6.1.9 Summary Costs

Feature's type	Units	Value	Total over 9 years	Q1 - 2023	Q2 - 2023	Q3 - 2023	Q4 - 2023	Q1 - 2024	Q2 - 2024	Q3 - 2024	Q4 - 2024	Q1 - 2025	Q2 - 2025	Q3 - 2025	Q4 - 2025	Q1 - 2026	Q2 - 2026	Q3 - 2026	Q4 - 2026	Q1 - 2027
Action				Prototype (4months)	Investment: Opening our Seed A funding								Manufacturing Process							
Revenue																				
Contracts Live	#		192	0	0	0	0	0	0	0	0	0	0	0	0	3	3	3	3	4
Usage Rate of the Robot	m/quarter		56	0	0	0	0	0	0	0	0	0	0	0	0	2	2	2	2	2
Number of operational ROMIE (2/contracts)	#			0	0	0	0	0	0	0	0	0	0	0	0	6	6	6	6	8
Numbre of rescue ROMIE	#			0	0	0	0	0	0	0	0	0	0	0	0	3	3	3	3	4
Total number of ROMIE	#		36	0	0	0	0	0	0	0	0	0	0	0	0	9	9	9	9	12
Leasing Price per robot	$/month	95,000	72,960,000	0	0	0	0	0	0	0	0	0	0	0	0	1,140,000	1,140,000	1,140,000	1,140,000	1,520,000
Sales revenue	$		72,960,000	0	0	0	0	0	0	0	0	0	0	0	0	1,140,000	1,140,000	1,140,000	1,140,000	1,520,000
OPEX																				
Employees Salaries	$		-6,175,034	-100	-46,368	-46,368	-46,368	-46,368	-46,368	-46,368	-46,368	-46,368	-187,225	-187,225	-187,225	-187,225	-187,225	-187,225	-187,225	-187,225
Legal and Professional services	$		-200,000	0	0	0	0	-25,000	0	0	0	0	0	0	0	0	0	-25,000	0	0
Business Organisation	$		-323,927	0	0	0	0	0	0	0	0	-17,147	-34,519	-9,075	-9,075	-9,075	-9,075	-9,075	-9,075	-9,075
Facilty rent	$		-498,108	0	0	0	0	0	0	0	0	0	-16,068	-16,068	-16,068	-16,068	-16,068	-16,068	-16,068	-16,068
Software	$		-224,439	0	0	0	0	0	0	0	0	0	-7,240	-7,240	-7,240	-7,240	-7,240	-7,240	-7,240	-7,240
Total OPEX	$		-7,421,508	-100	-46,368	-46,368	-46,368	-71,368	-46,368	-46,368	-46,368	-63,515	-245,053	-219,609	-219,609	-219,609	-219,609	-244,609	-219,609	-219,609
CAPEX																				
Facility Hardware CAPEX	$		-263,067	0	0	0	0	0	0	0	0	0	-263,067	0	0	0	0	0	0	0
Robot Hardware CAPEX	$		-3,880,455	-249	-102,111	0	-102,111	0	0	0	0	0	0	0	0	-918,996	0	0	0	-306,332
CAPEX amortisation	$		-3,737,059	-12	-5,118	-5,118	-10,223	-10,223	-10,223	-10,223	-10,223	-10,223	-23,377	-23,377	-23,377	-69,327	-69,327	-69,327	-69,327	-84,643
Total CAPEX	$		-7,880,568	-249	-107,229	-5,118	-112,334	-10,223	-10,223	-10,223	-10,223	-10,223	-286,444	-23,377	-23,377	-988,323	-69,327	-69,327	-69,327	-390,975
Profit & Loss																				
Sales revenue	$		72,960,000	0	0	0	0	0	0	0	0	0	0	0	0	1,140,000	1,140,000	1,140,000	1,140,000	1,520,000
Operational cost	$		-7,421,508	-100	-46,368	-46,368	-46,368	-71,368	-46,368	-46,368	-46,368	-63,515	-245,053	-219,609	-219,609	-219,609	-219,609	-244,609	-219,609	-219,609
Amortisation (20%/year)	$		-3,737,059	-12	-5,118	-5,118	-10,223	-10,223	-10,223	-10,223	-10,223	-10,223	-23,377	-23,377	-23,377	-69,327	-69,327	-69,327	-69,327	-84,643
Operating income before tax	$		61,801,433	-112	-51,486	-51,486	-56,591	-81,591	-56,591	-56,591	-56,591	-73,738	-268,429	-242,986	-242,986	851,065	851,065	826,065	851,065	1,215,748
Tax (20%)	$		-12,608,123	0	0	0	0	0	0	0	0	0	0	0	0	-170,213	-170,213	-165,213	-170,213	-243,150
Net Income	$		49,193,310	-112	-51,486	-51,486	-56,591	-81,591	-56,591	-56,591	-56,591	-73,738	-268,429	-242,986	-242,986	680,852	680,852	660,852	680,852	972,598
Cash Flow Summary																				
EBITDA	$		65,538,492	-100	-46,368	-46,368	-46,368	-71,368	-46,368	-46,368	-46,368	-63,515	-245,053	-219,609	-219,609	920,391	920,391	895,391	920,391	1,300,391
Tax (20%)	$		-12,608,123	0	0	0	0	0	0	0	0	0	0	0	0	-170,213	-170,213	-165,213	-170,213	-243,150
CAPEX	$		-7,880,568	-249	-107,229	-5,118	-112,334	-10,223	-10,223	-10,223	-10,223	-10,223	-286,444	-23,377	-23,377	-988,323	-69,327	-69,327	-69,327	-390,975
Capital Raise	$		1,900,500	500	1,900,000															
FREE CASH FLOW	$		**46,950,301**	**151**	**1,746,403**	**-51,486**	**-158,702**	**-81,591**	**-56,591**	**-56,591**	**-56,591**	**-73,738**	**-531,496**	**-242,986**	**-242,986**	**-238,145**	**680,852**	**660,852**	**680,852**	**666,266**
Cash Beginning of Period	$		**455,475,715**	**0**	**151**	**1,746,555**	**1,695,069**	**1,536,367**	**1,454,775**	**1,398,184**	**1,341,592**	**1,285,001**	**1,454,775**	**923,279**	**680,293**	**437,308**	**199,163**	**880,015**	**1,540,866**	**2,221,718**
Cash End of Period (Cummulated FCF)	$		**502,426,015**	**151**	**1,746,555**	**1,695,069**	**1,536,367**	**1,454,775**	**1,398,184**	**1,341,592**	**1,285,001**	**1,211,262**	**923,279**	**680,293**	**437,308**	**199,163**	**880,015**	**1,540,866**	**2,221,718**	**2,887,984**
Cummulated FCF				151	1,746,555	1,695,069	1,536,367	1,454,775	1,398,184	1,341,592	1,285,001	1,211,262	923,279	680,293	437,308	199,163	880,015	1,540,866	2,221,718	2,887,984

6.1.10 PRltd's Valuation

Dates		**31/03/2023**	**30/06/2023**
FCF before capital raise		-349	-153,597
Weighted Average Cost of Capital (WACC)	25%		
Perpetual growth rate	3%		
Current value of FCF	**2,815,762**		
Year of nominal cash flow	2032		
Nominal FCF in 2032	4,131,148		
Terminal value	18,777,948		
Current value of terminal value	2,520,333		
Company enterprise value pre-money	**5,336,096**		

Figure 52: PRltd's Valuation - B case

Dates		**31/03/2023**	**30/06/2023**
FCF before capital raise		-349	-153,597
Weighted Average Cost of Capital (WACC)	25%		
Perpetual growth rate	3%		
Current value of FCF	**10,893,802**		
Year of nominal cash flow	2032		
Nominal FCF in 2032	12,971,433		
Terminal value	58,961,058		
Current value of terminal value	7,913,619		
Company enterprise value pre-money	**18,807,422**		

Figure 53: PRltd's Valuation - S case

Dates		**31/03/2023**	**30/06/2023**
FCF before capital raise		-349	-153,597
Weighted Average Cost of Capital (WACC)	25%		
Perpetual growth rate	3%		
Current value of FCF	**14,693,920**		
Year of nominal cash flow	2032		
Nominal FCF in 2032	17,304,533		
Terminal value	78,656,966		
Current value of terminal value	10,557,159		
Company enterprise value pre-money	**25,251,079**		

Figure 54: PRltd's Valuation - BS case

6.1.11 OPEX

OPEX		
Employees Salaries	$	-5,234,529
Legal and Professional services	$	-200,000
Business Organisation	$	-281,215
Facilty rent	$	-195,858
Software	$	-224,439
Total OPEX	$	-6,136,041

Figure 55: OPEX - B case

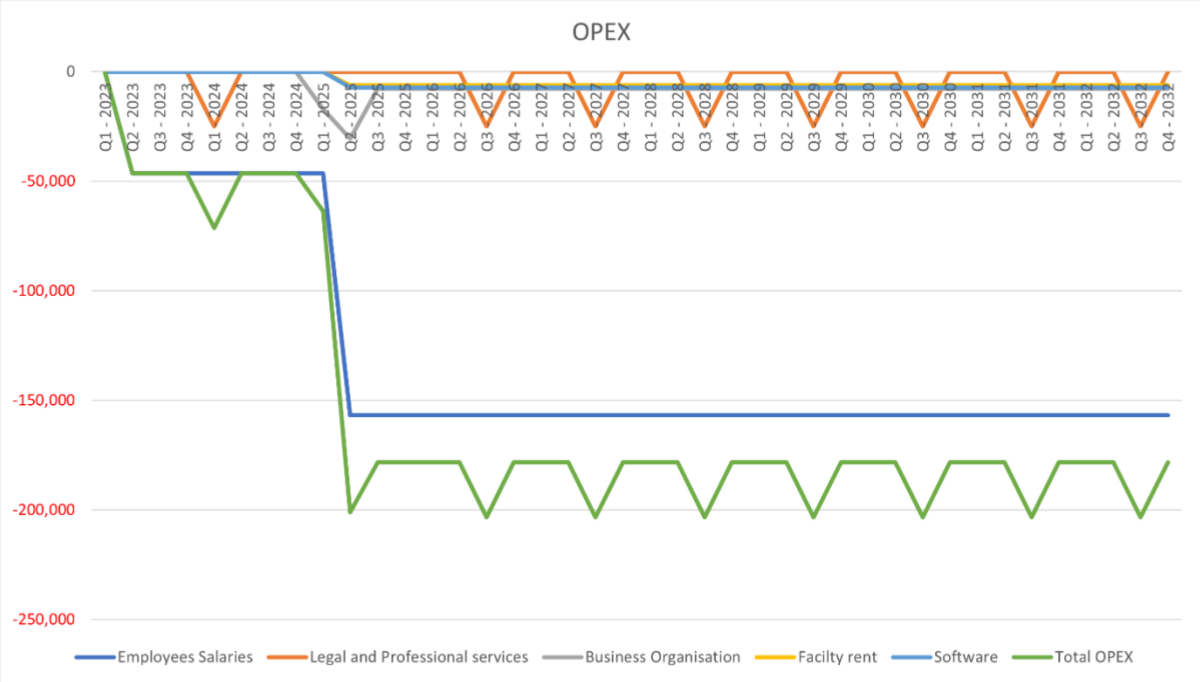

Figure 56: OPEX Graph - B case

OPEX		
Employees Salaries	$	-6,175,034
Legal and Professional services	$	-200,000
Business Organisation	$	-323,927
Facilty rent	$	-498,108
Software	$	-224,439
Total OPEX	$	-7,421,508

Figure 57: OPEX - S case

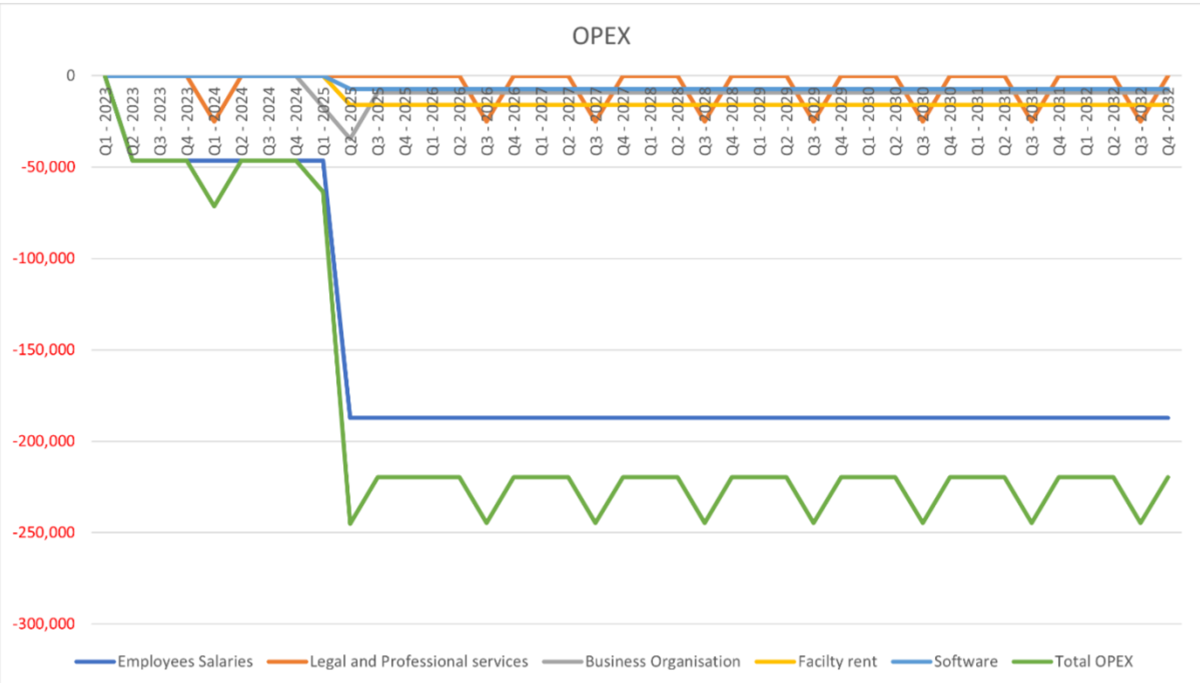

Figure 58: OPEX Graph - S case

OPEX		
Employees Salaries	$	-7,225,365
Legal and Professional services	$	-200,000
Business Organisation	$	-374,405
Facilty rent	$	-739,908
Software	$	-224,439
Total OPEX	$	-8,764,117

Figure 59: OPEX - BS case

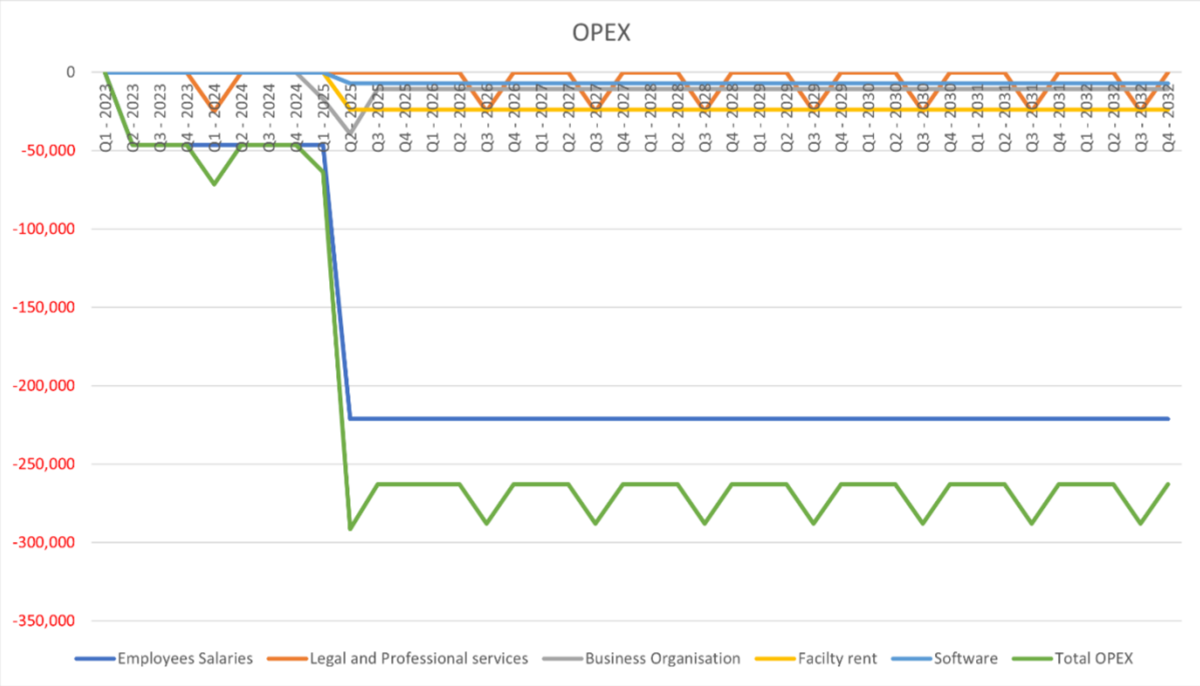

Figure 60: OPEX Graph - BS case

6.1.11 CAPEX

CAPEX		
Facility Hardware CAPEX	$	-212,980
Robot Hardware CAPEX	$	-1,429,798
CAPEX amortisation	$	-1,821,433
Total CAPEX	$	-3,464,199

Figure 61: CAPEX - B case

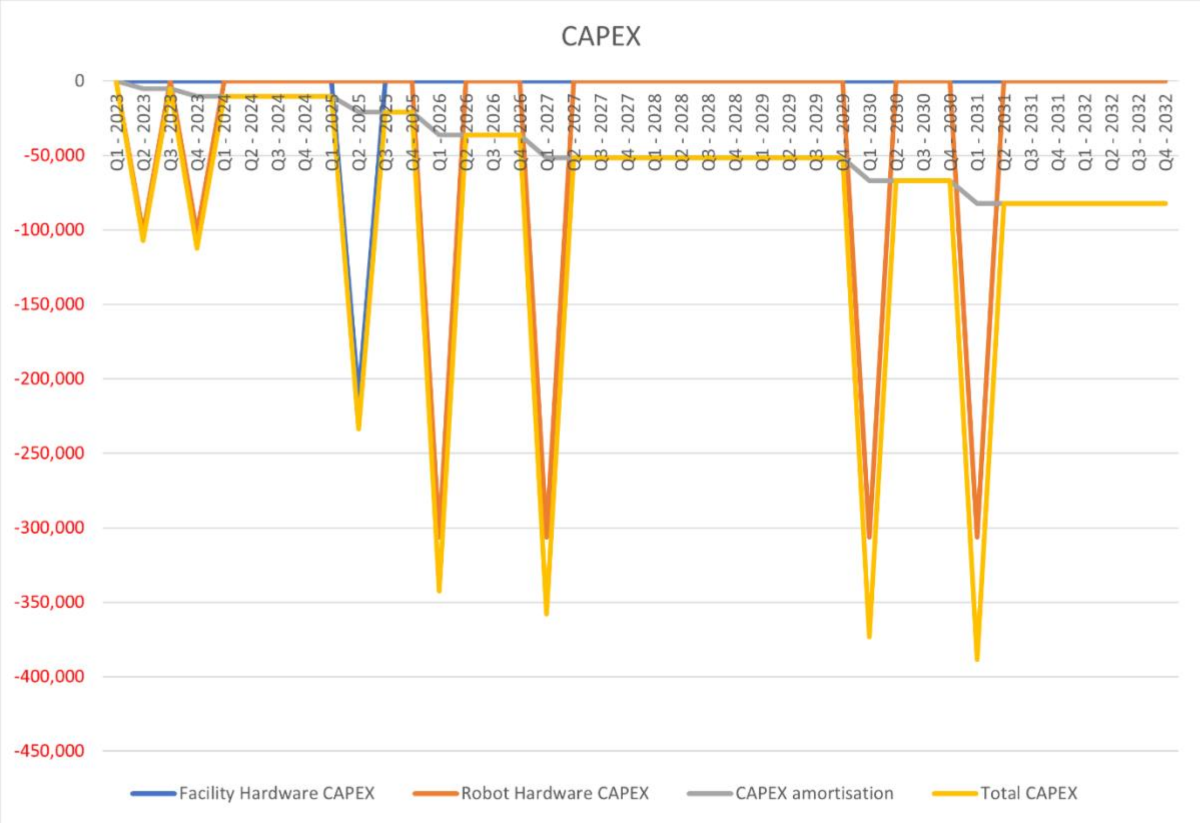

Figure 62: CAPEX Graph - B case

CAPEX		
Facility Hardware CAPEX	$	-263,067
Robot Hardware CAPEX	$	-3,880,455
CAPEX amortisation	$	-3,737,059
Total CAPEX	$	-7,880,568

Figure 63: CAPEX - S case

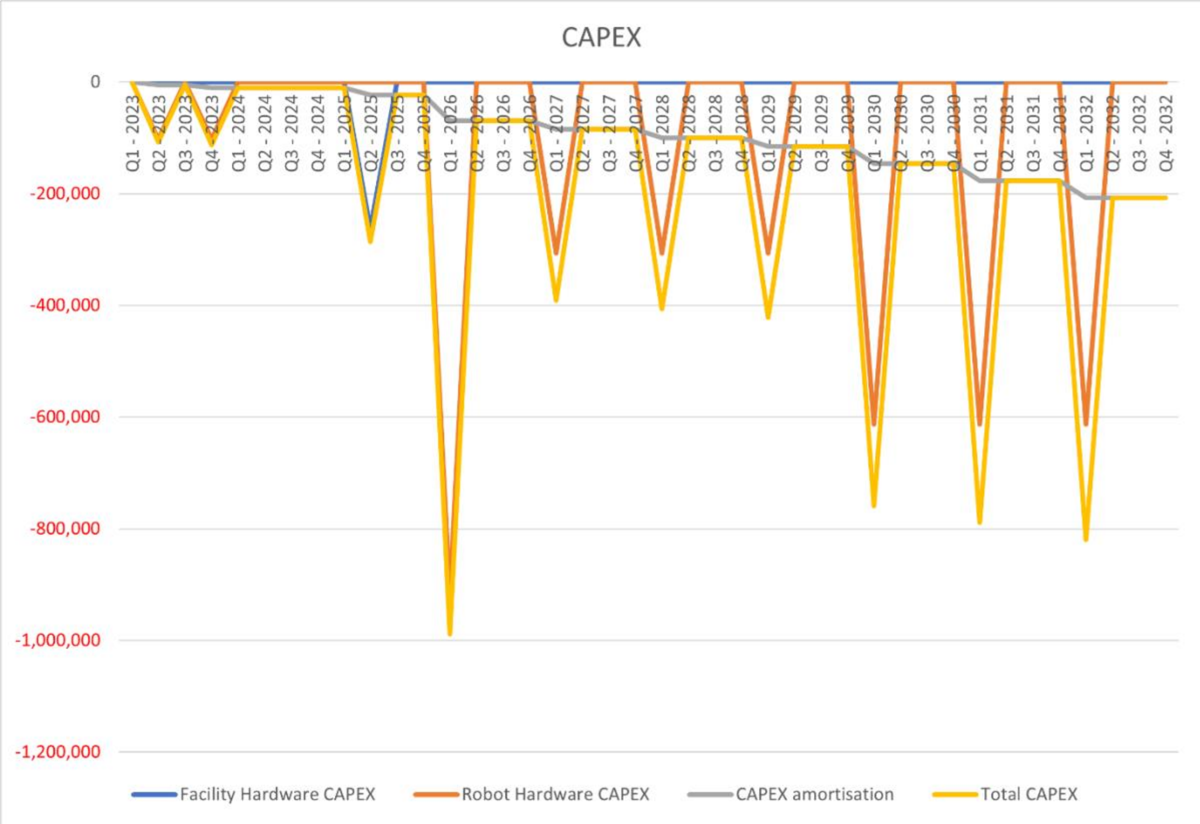

Figure 64: CAPEX Graph - S case

CAPEX		
Facility Hardware CAPEX	$	-365,928
Robot Hardware CAPEX	$	-5,105,783
CAPEX amortisation	$	-4,815,490
Total CAPEX	$	-10,287,189

Figure 65: CAPEX - BS case

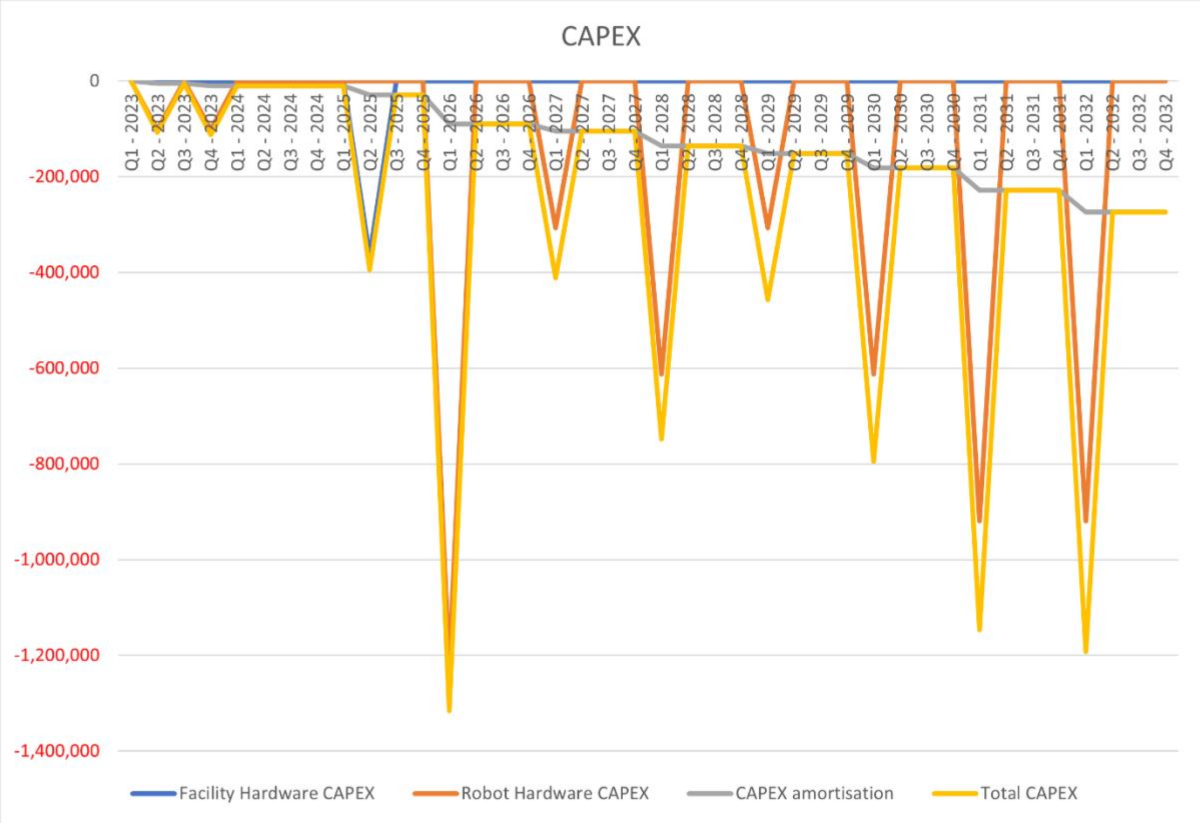

Figure 66: CAPEX Graph - BS case

6.1.11 Revenue

Revenue			
acts Live	#		72
ɜ Rate of the Robot	m/quarter		56
er of operational ROMIE (2/contracts)	#		
re of rescue ROMIE	#		
ıumber of ROMIE	#		12
ıg Price per robot	$/month	95,000	27,360,000
revenue	$		27,360,000

Figure 67: Total sales Revenue - B case

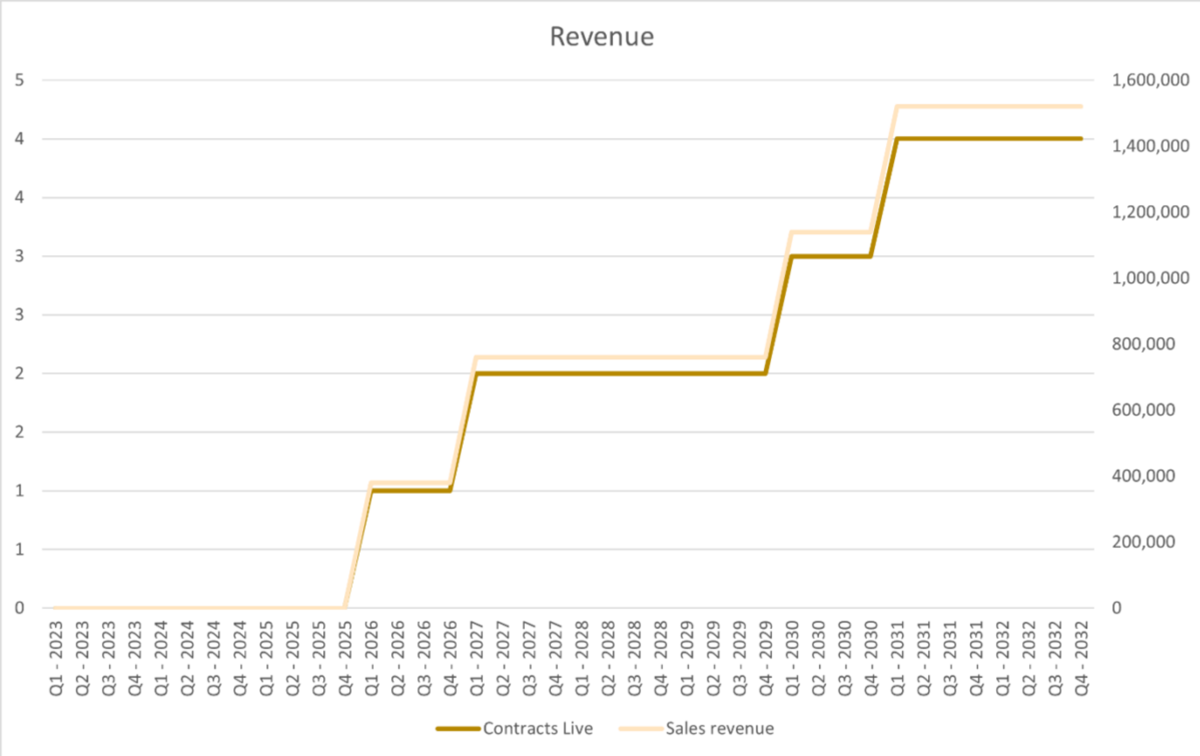

Figure 68: Total sales Revenue Graph - B case

Revenue			
acts Live	#		192
e Rate of the Robot	m/quarter		56
er of operational ROMIE (2/contracts)	#		
re of rescue ROMIE	#		
number of ROMIE	#		36
ng Price per robot	$/month	95,000	72,960,000
revenue	$		72,960,000

Figure 69: Total sales Revenue - S case

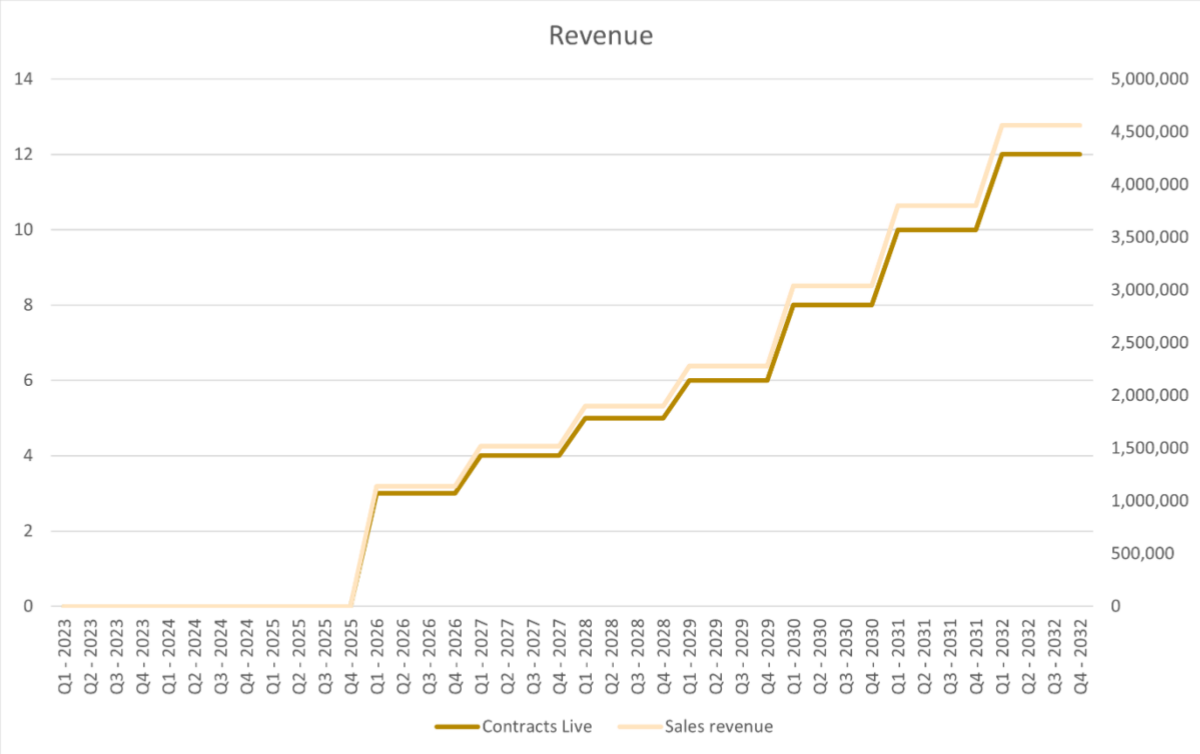

Figure 70:Total sales Revenue Graph - S case

Revenue			
acts Live	#		252
e Rate of the Robot	m/quarter		56
er of operational ROMIE (2/contracts)	#		
re of rescue ROMIE	#		
number of ROMIE	#		48
ng Price per robot	$/month	95,000	95,760,000
revenue	$		95,760,000

Figure 71: Total sales Revenue - BS case

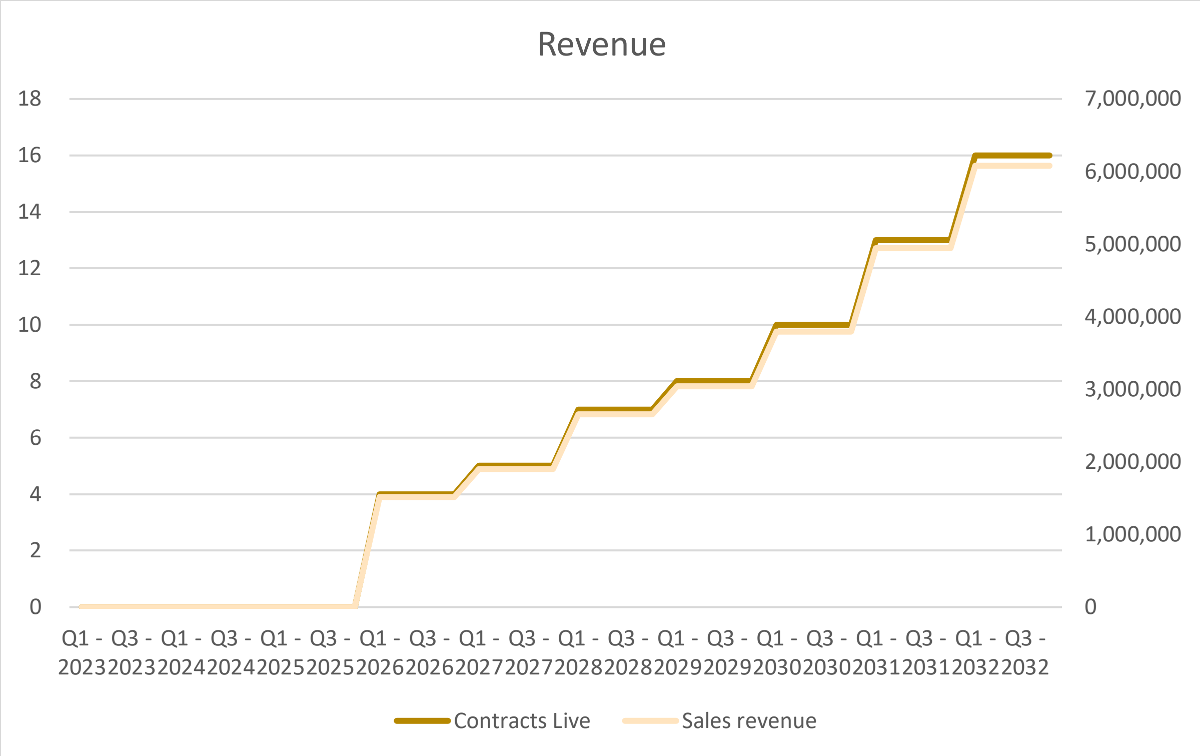

Figure 72: Total sales Revenue Graph - B case

6.2 - Cash Flow forecasts

6.2.2 B case

Cash Flow Summary	Total	Y - 2023	Y - 2024	Y - 2025	Y - 2026	Y - 2027	Y - 2028	Y - 2029	Y - 2030	Y - 2031	Y - 2032
EBITDA	21,223,959	-139,204	-210,472	-620,963	782,085	2,302,085	2,302,085	2,302,085	3,822,085	5,342,085	5,342,085
Tax (20%)	-4,101,474	0	0	0	-127,466	-419,213	-419,213	-419,213	-710,959	-1,002,706	-1,002,706
CAPEX	-3,464,199	-224,929	-40,894	-285,821	-451,089	-512,355	-206,023	-206,023	-573,621	-634,888	-328,556
Capital Raise	1,900,500	1,900,500	0	0	0	0	0	0	0	0	0
FREE CASH FLOW	**15,558,786**	**1,536,367**	**-251,366**	**-906,784**	**203,531**	**1,370,518**	**1,676,850**	**1,676,850**	**2,537,505**	**3,704,492**	**4,010,824**
Cash Beginning of Period	**166,529,427**	**3,441,775**	**5,730,918**	**4,580,538**	**2,342,716**	**4,907,321**	**11,308,389**	**18,015,789**	**25,554,673**	**37,455,172**	**53,192,135**
Cash End of Period (Cummulated FCF)	**182,088,213**	**4,978,142**	**5,479,552**	**3,673,754**	**2,546,247**	**6,277,839**	**12,985,239**	**19,692,639**	**28,092,178**	**41,159,664**	**57,202,959**

Figure 73: Cash Flow summary yearly - B case

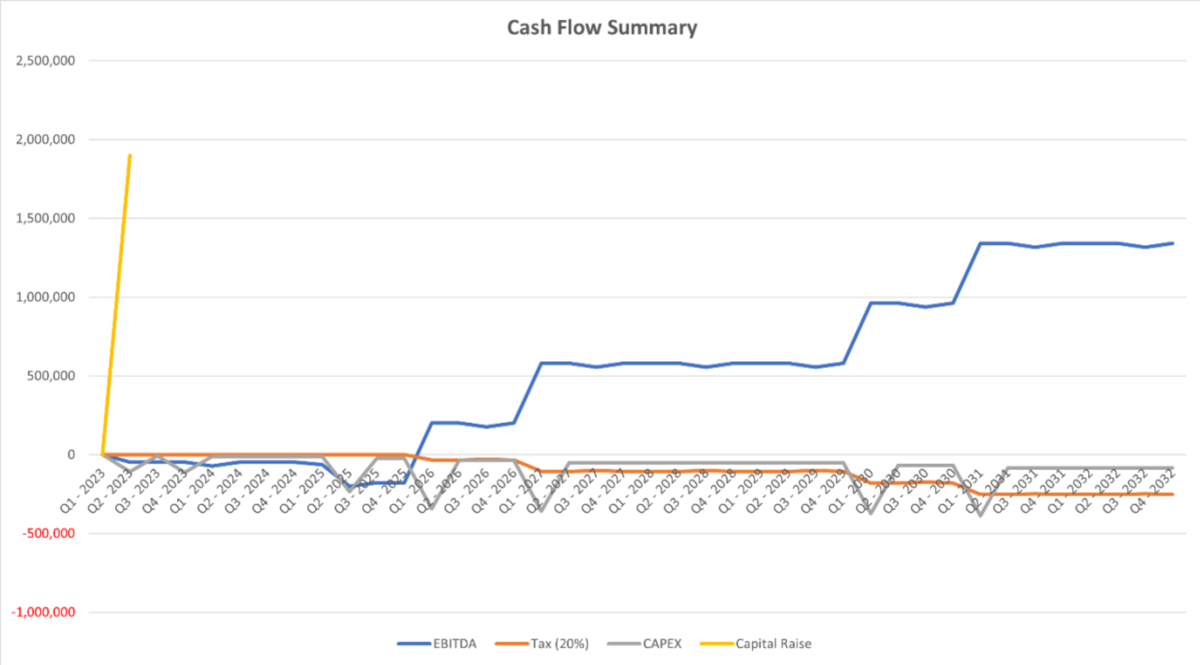

Figure 74: Cash Flow summary projection quarterly

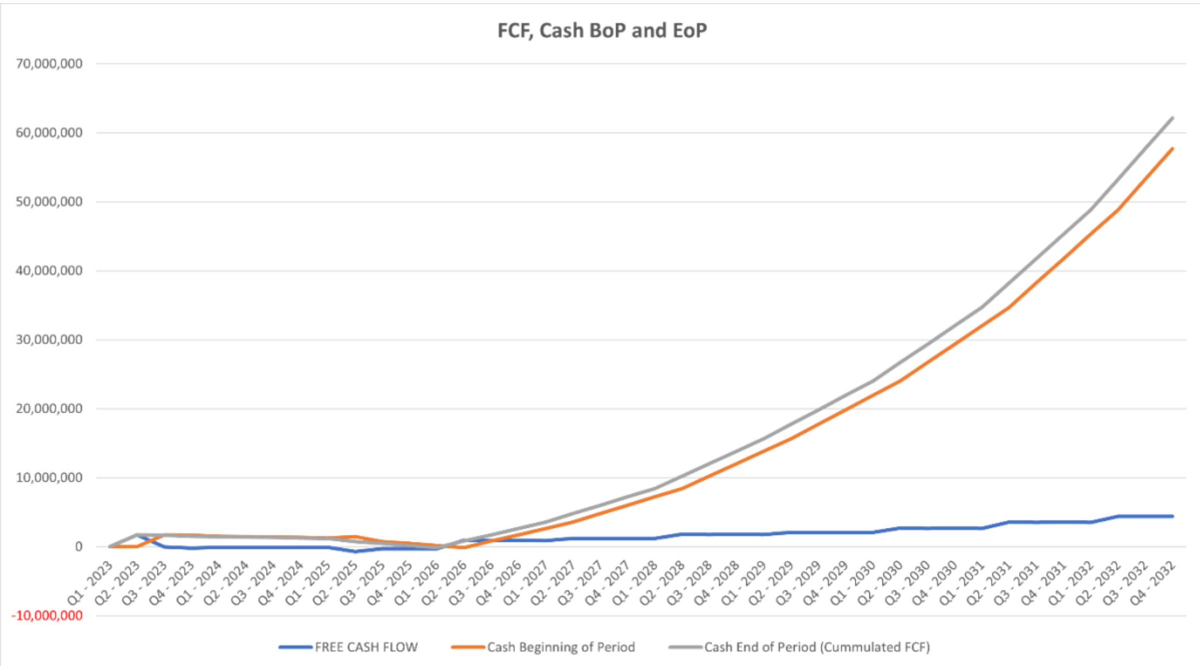

Figure 75: FCF, Cash EoP and Cash BoP graph - B case

6.2.3 BS case

Cash Flow Summary	Total	Y - 2023	Y - 2024	Y - 2025	Y - 2026	Y - 2027	Y - 2028	Y - 2029	Y - 2030	Y - 2031	Y - 2032
EBITDA	86,995,883	-139,204	-210,472	-880,578	5,003,734	6,523,734	9,563,734	11,083,734	14,123,734	18,683,734	23,243,734
Tax (20%)	-16,713,559	0	0	0	-928,918	-1,220,664	-1,804,158	-2,095,905	-2,679,398	-3,554,638	-4,429,878
CAPEX	-10,287,189	-224,929	-40,894	-461,711	-1,584,474	-726,744	-1,155,609	-910,543	-1,339,408	-1,829,539	-2,013,339
Capital Raise	1,900,500	1,900,500	0	0	0	0	0	0	0	0	0
FREE CASH FLOW	**61,895,635**	**1,536,367**	**-251,366**	**-1,342,289**	**2,490,343**	**4,576,326**	**6,603,967**	**8,077,286**	**10,104,928**	**13,299,556**	**16,800,517**
Cash Beginning of Period	**591,943,929**	**3,441,775**	**5,730,918**	**3,986,234**	**2,652,420**	**17,121,259**	**38,008,526**	**67,093,872**	**101,984,982**	**146,737,138**	**205,186,805**
Cash End of Period (Cummulated FCF)	**653,839,564**	**4,978,142**	**5,479,552**	**2,643,945**	**5,142,762**	**21,697,585**	**44,612,494**	**75,171,158**	**112,089,910**	**160,036,694**	**221,987,322**

Figure 76: Cash Flow summary yearly - BS case

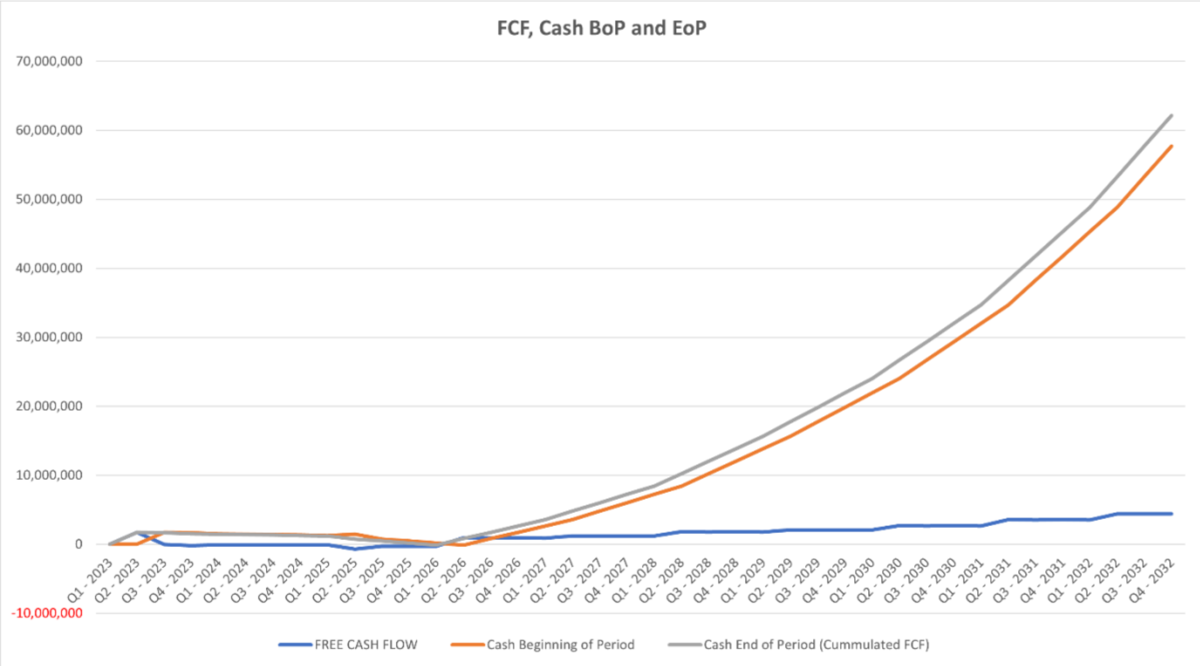

Figure 77: Cash Flow summary projection quarterly

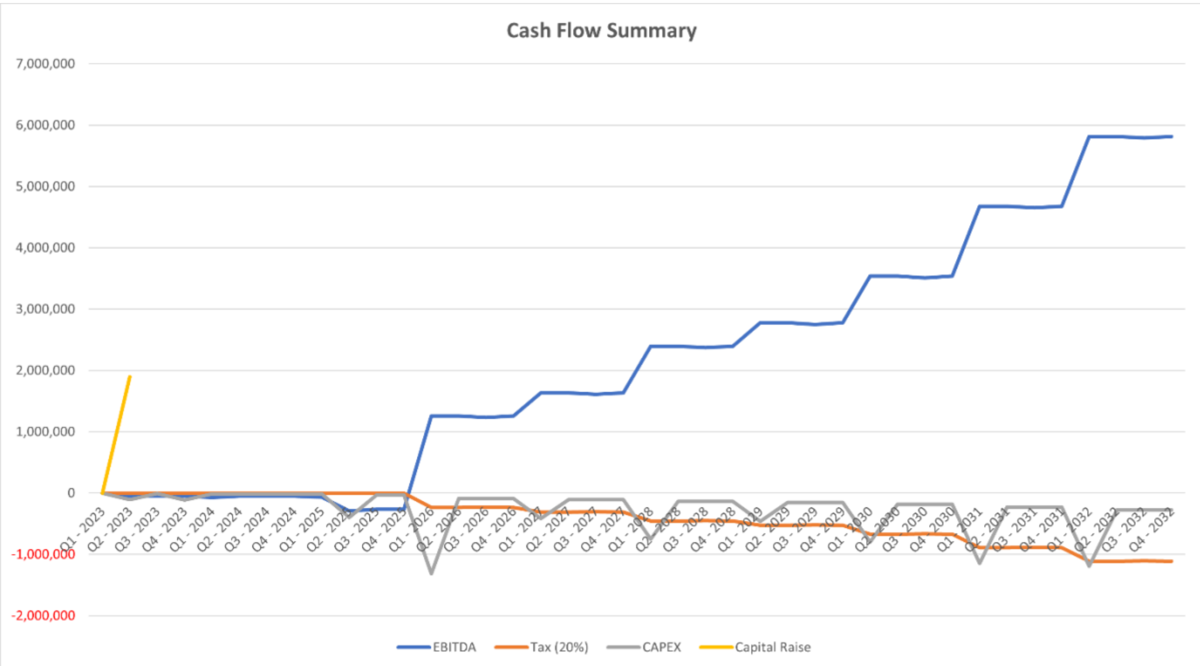

Figure 78: FCF, Cash EoP and Cash BoP graph - BS case

6.3 Projected Profit and Loss Accounts

6.3.1 B case

Profit & Loss	TOTAL	Y - 2023	Y - 2024	Y - 2025	Y - 2026	Y - 2027	Y - 2028	Y - 2029	Y - 2030	Y - 2031	Y - 2032
Sales revenue	27,360,000	0	0	0	1,520,000	3,040,000	3,040,000	3,040,000	4,560,000	6,080,000	6,080,000
Operational cost	-6,136,041	-139,204	-210,472	-620,963	-737,915	-737,915	-737,915	-737,915	-10,796,253	-737,915	-737,915
Amortisation (20%/year)	-1,821,433	-20,472	-40,894	-72,841	-144,756	-206,023	-206,023	-206,023	-2,985,754	-328,556	-328,556
Operating income before tax	19,402,526	-159,676	-251,366	-693,804	637,329	2,096,063	2,096,063	2,096,063	28,777,993	5,013,530	5,013,530
Tax (20%)	-4,101,474	0	0	0	-127,466	-419,213	-419,213	-419,213	-6,197,537	-1,002,706	-1,002,706
Net Income	15,301,052	-159,676	-251,366	-693,804	509,863	1,676,850	1,676,850	1,676,850	22,580,456	4,010,824	4,010,824

Figure 79: P&L Projection - B case

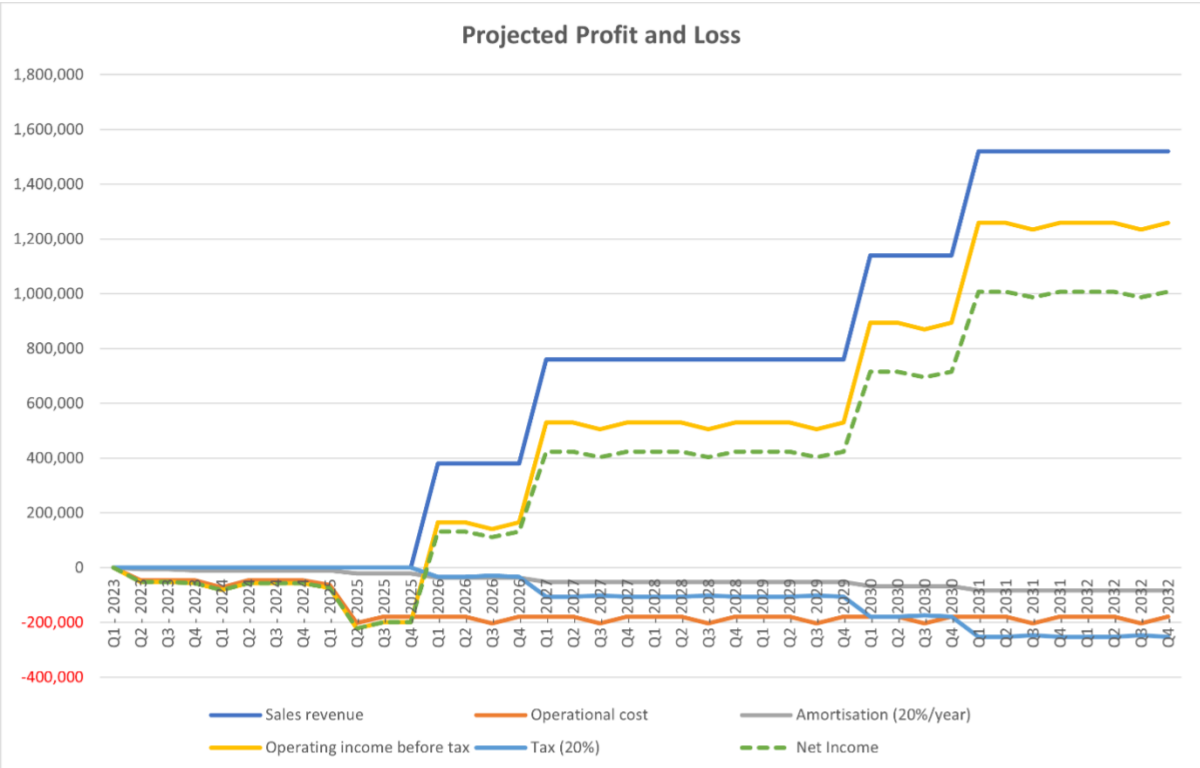

Figure 80: Overall projection per quarter graph - B case

6.3.3 BS case

Profit & Loss	TOTAL	Y - 2023	Y - 2024	Y - 2025	Y - 2026	Y - 2027	Y - 2028	Y - 2029	Y - 2030	Y - 2031	Y - 2032
Sales revenue	95,760,000	0	0	0	6,080,000	7,600,000	10,640,000	12,160,000	15,200,000	19,760,000	24,320,000
Operational cost	-8,764,117	-139,204	-210,472	-880,578	-1,076,266	-1,076,266	-1,076,266	-1,076,266	-15,375,701	-1,076,266	-1,076,266
Amortisation (20%/year)	-4,815,490	-20,472	-40,894	-95,783	-359,145	-420,412	-542,944	-604,211	-7,626,095	-910,543	-1,094,342
Operating income before tax	82,180,393	-159,676	-251,366	-976,361	4,644,589	6,103,322	9,020,789	10,479,523	124,438,203	17,773,191	22,149,392
Tax (20%)	-16,713,559	0	0	0	-928,918	-1,220,664	-1,804,158	-2,095,905	-25,442,602	-3,554,638	-4,429,878
Net Income	65,466,834	-159,676	-251,366	-976,361	3,715,671	4,882,658	7,216,632	8,383,618	98,995,601	14,218,553	17,719,513

Figure 81: P&L Projection - BS case

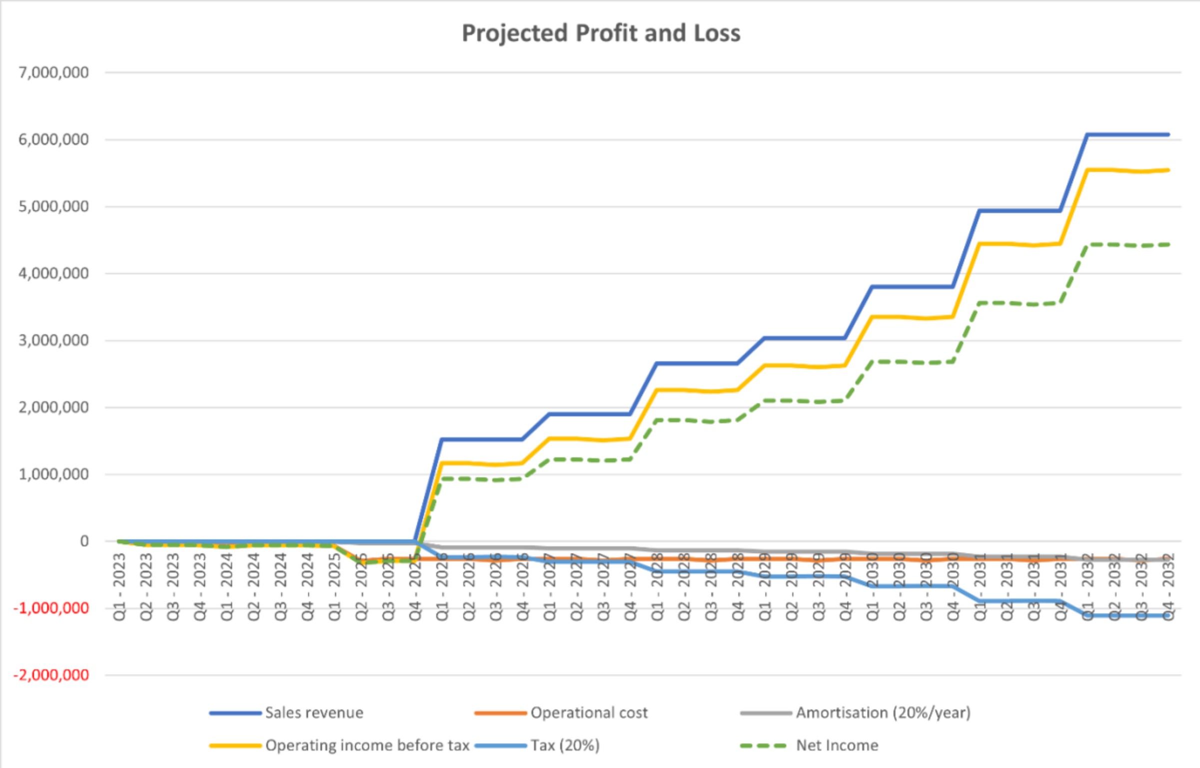

Figure 82: Overall projection per quarter graph - BS case

6.4 Projected Balance Sheet

6.4.1 B case

Balance Sheet (at end of period)	Total	Y - 2023	Y - 2024	Y - 2025	Y - 2026	Y - 2027	Y - 2028	Y - 2029	Y - 2030	Y - 2031	Y - 2032
Asset	36,428,157	409,387	817,830	1,456,771	2,895,080	4,120,408	4,120,408	4,120,408	5,345,736	6,571,065	6,571,065
Cash	182,088,213	4,978,142	5,479,552	3,673,754	2,546,247	6,277,839	12,985,239	19,692,639	28,092,178	41,159,664	57,202,959
Total Assets	218,516,369	5,387,529	6,297,382	5,130,525	5,441,327	10,398,247	17,105,647	23,813,047	33,437,914	47,730,729	63,774,024
		0	0	0	0	0	0	0	0	0	0
Capital	74,120,000	5,702,000	7,602,000	7,602,000	7,602,000	7,602,000	7,602,000	7,602,000	7,602,000	7,602,000	7,602,000
Net Income	144,396,369	-314,471	-1,304,618	-2,471,475	-2,160,673	2,796,247	9,503,647	16,211,047	25,835,914	40,128,729	56,172,024
Debt	0	0	0	0	0	0	0	0	0	0	0
Total Liabilities	218,516,369	5,387,529	6,297,382	5,130,525	5,441,327	10,398,247	17,105,647	23,813,047	33,437,914	47,730,729	63,774,024

Figure 83: Balance Sheet Projection - B case

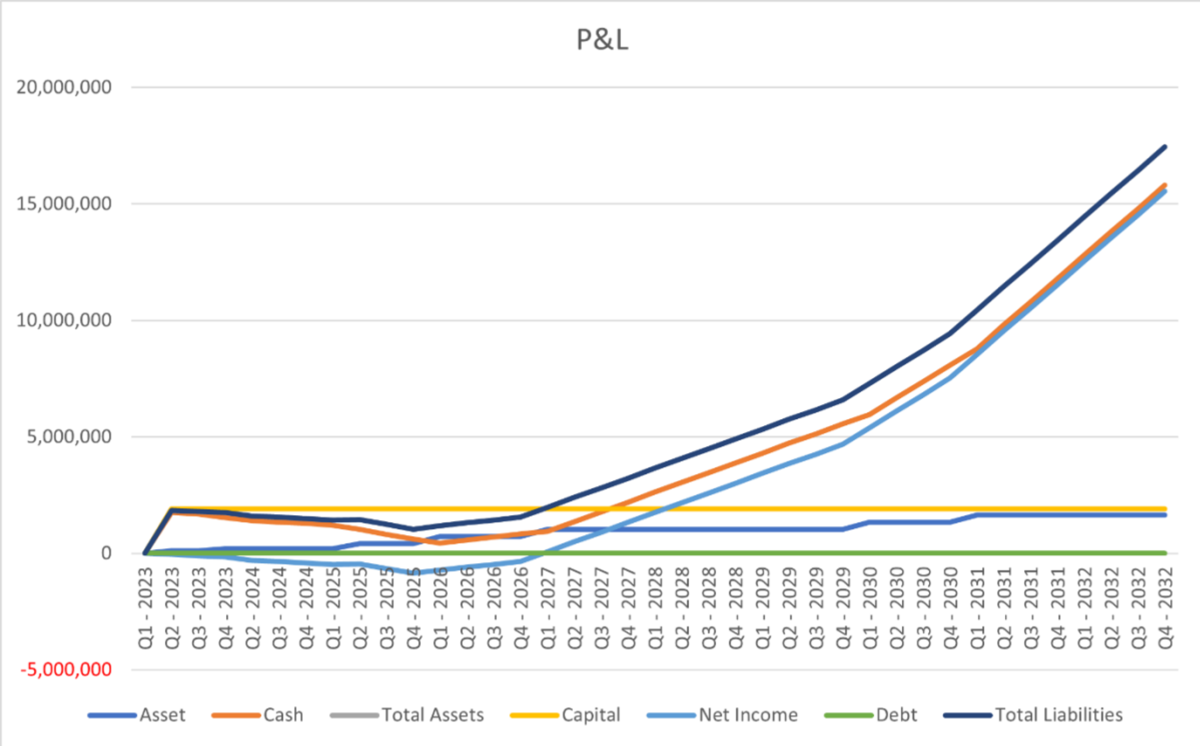

Figure 84: Overall projection per quarter graph - B case

6.4.2 – BS case

Balance Sheet (at end of period)	Total	Y - 2023	Y - 2024	Y - 2025	Y - 2026	Y - 2027	Y - 2028	Y - 2029	Y - 2030	Y - 2031	Y - 2032
Asset	96,309,309	409,387	817,830	1,915,614	7,182,855	8,408,183	10,858,840	12,084,168	14,534,825	18,210,810	21,886,795
Cash	653,839,564	4,978,142	5,479,552	2,643,945	5,142,762	21,697,585	44,612,494	75,171,158	112,089,910	160,036,694	221,987,322
Total Assets	750,148,872	5,387,529	6,297,382	4,559,559	12,325,617	30,105,768	55,471,334	87,255,327	126,624,735	178,247,505	243,874,117
		0	0	0	0	0	0	0	0	0	0
Capital	74,120,000	5,702,000	7,602,000	7,602,000	7,602,000	7,602,000	7,602,000	7,602,000	7,602,000	7,602,000	7,602,000
Net Income	676,028,872	-314,471	-1,304,618	-3,042,441	4,723,617	22,503,768	47,869,334	79,653,327	119,022,735	170,645,505	236,272,117
Debt	0	0	0	0	0	0	0	0	0	0	0
Total Liabilities	750,148,872	5,387,529	6,297,382	4,559,559	12,325,617	30,105,768	55,471,334	87,255,327	126,624,735	178,247,505	243,874,117

Figure 85: Balance Sheet Projection - BS case

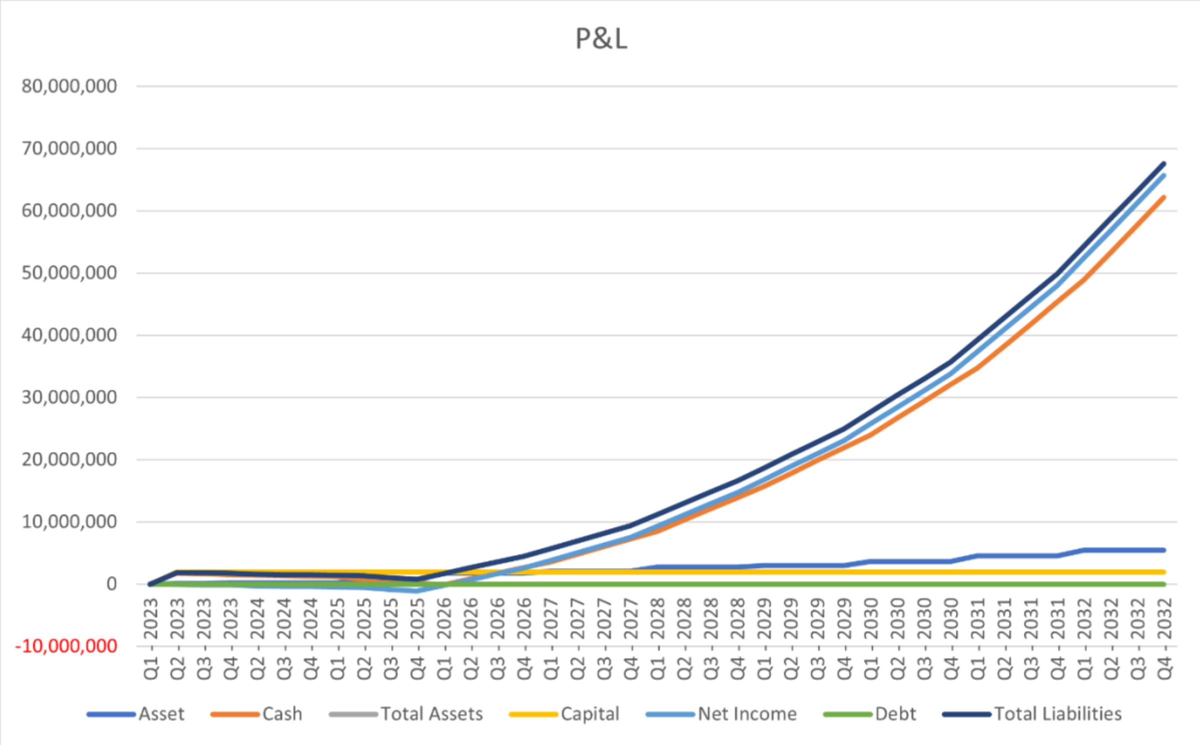

Figure 86: Overall projection per quarter graph - BS case

6.5 Principal Risks and sensitivity

6.6 Financing Requirements

6..6.1 PR's Valuation

The XNPV function takes as an input the rate (discount rate to apply to the cash flows), the values (series of cash flow corresponding to a schedule of payments in dates. One of the condition is that the series of values must contain at least one positive value and one negative value.) and dates (the range of dates corresponding to the cash flow): XNPV(rate, values, dates)

The XNPV is calculated as follow:

$$XNPV = \sum_{i=1}^{N} \frac{P_i}{(1 + rate)^{\frac{(d_i d_1)}{365}}}$$

The following represents our model (the dates and FCF before capital raise lines continue, it was cropped for a matter of space):

Dates	**31/03/2023**	**30/06/2023**	**...**
FCF before capital raise	-100	-51,431	...

Weighted Average Cost of Capital (WACC)	25%
Perpetual growth rate	3%
Current value of FCF	**13,146,279**
Year of nominal cash flow	2032
Nominal FCF in 2032	13,921,569
Terminal value	63,279,858
Current value of terminal value	8,493,279
Company enterprise value pre-money	**21,639,558**

Figure 87: Standard Case PR's Valuation

The above formula is applied to the current value of FCF. The first argument (rate) is the ***weighted average cost of capital (WACC)*** [93] which is the average rate that a company expects to enter the company according to the risks that it represents. The highest the rate is, the more the investor will receive in stakes. The second argument (**values)** corresponds to the ***FCF before capital raise,*** which is the FCF (see figure xx) minus the capital raised. It was taken on the total timeline of our financials. The third argument (**dates**) is simply the scheduled finances. This formula will generate the ***current value of FCF***. We need to calculate the ***Company enterprise value pre-money*** to know the company's valuation in 2032 (note that the schedule financed was generated until Q4-2031). The ***Perpetual growth rate*** is the simulated growth rate of the company after 2032. The ***Company enterprise value pre-money*** is the addition of the ***Current value of terminal value*** and the ***Current value of FCF***.

6.6.2 SEIS/EIS

SEIS vs EIS: what's the difference

	SEIS	EIS
Maximum full-time staff headcount	25	250 (or 500 for KICs)*
Maximum gross assets	£200,000	£15 million
Upper limit on trading period	2 years	7 years (or 10 years for KICs)*
Tax break for investors	50%	30%
Maximum individual investment per tax year	£100,000	£1 million (or £2 million for KICs)*
Maximum investment per calendar year	n/a	£5 million (£10 million for KICs)*
Maximum total investment	£150,000	£12 million (or £20 million for KICs)*
Limitations on spending funds	Must be spent within 3 years	Must be spent within 2 years

SEEDLEGALS

Figure 88: SEIS/EIS: what is the difference?

Bibliography

[1] Grandviewresearch, “Mining Automation Market Size, Share & Trends Analysis Report By Solution (Software Automation, Services), By Application (Metal Mining, Mineral Mining), By Region, And Segment Forecasts, 2023 - 2030,” Grandviewresearch, 2018-2021. [Online]. Available: https://www.grandviewresearch.com/industry-analysis/mining-automation-market . [Accessed 13 04 2023].

[2] G. D. Hert, Interviewee, *How Mining Companies Tackle the Sampling Process..* [Interview]. 27 February 2023.

[3] The Business Research Company, “Mining Global Market Report,” The Business Research Company, 01 2023. [Online]. Available: https://www.thebusinessresearchcompany.com/report/mining-global-market-report. [Accessed 08 04 2023].

[4] Grand View Research, “Mining Equipment Market Size,” Grand View Research, 01 2018. [Online]. Available: https://www.grandviewresearch.com/industry-analysis/mining-equipment-industry. [Accessed 08 04 2023].

[5] PR Newswire, “PR Newswire,” PR Newswire, 21 10 2022. [Online]. Available: https://www.prnewswire.com/news-releases/global-autonomous-mining-equipment-market-report-2022-2026--2031-rising-concerns-regarding-the-safety-of-mine-workers-are-expected-to-drive-the-market-301656127.html. [Accessed 08 04 2023].

[6] UK Government, “Set up a limited company: step by step,” 2023. [Online]. Available: https://www.gov.uk/set-up-limited-company. [Accessed 1 April 2023].

[7] SEEDLEGALS, “Free founders agreements for UK startups,” 2023. [Online]. Available: https://seedlegals.com/resources/free-founders-agreement-for-uk-startups/. [Accessed 1 April 2023].

[8] Globalization Partners, "South Africa Subsidiary," 2023. [Online]. Available: https://www.globalization-partners.com/globalpedia/south-africa-peo/subsidiary/#gref. [Accessed 1 April 2023].

[9] Acts Online, "Mine Health and Safety Act, Machinery and Equipment: Chapter 8," [Online]. Available: https://www.acts.co.za/mine_hea/r93_8__machinery_and_equipment. [Accessed 16 April 2023].

[10] iSERT, "NRCS Letter of Authority (LOA)," [Online]. Available: https://isert.co.za/safety-testing-nrcs-loa.html. [Accessed 16 April 2023].

[11] UL Solutions , "South Africa New Additional Scheme for SABS EMC CoCs," 14 December 2022. [Online]. Available: https://www.ul.com/news/south-africa-new-additional-scheme-sabs-emc-cocs. [Accessed 2 March 2023].

[12] Basel Convention, "BASEL CONVENTION: ON THE CONTROL OF TRANSBOUNDARY MOVEMENTS OF HAZARDOUS WASTES AND THEIR DISPOSAL," 27 May 2014. [Online]. Available: https://www.basel.int/Portals/4/Basel%20Convention/docs/text/BaselConventionText-e.pdf. [Accessed 2 March 2023].

[13] AST Recycling , "WHY SHOULD YOU RECYCLE E-WASTE," 2019. [Online]. Available: https://astrecycling.co.za/ewasterecycling#:~:text=As%20of%20the%2023rd%20August,waste%20equipment%20to%20be%20compliant.. [Accessed 3 March 2023].

[14] Global Reporting Initiative, "GRI Materials: 301," 2016. [Online]. Available: https://www.globalreporting.org/standards/media/1008/gri-301-materials-2016.pdf. [Accessed 14 April 2023].

[15] SA-Venues, "Northern Cape Weather And Climate," 2023. [Online]. Available: https://www.sa-venues.com/weather/northerncape.php. [Accessed 29 March 2023].

[16] SCHARF, “SCHARF LEV,” SCHARF, 2023. [Online]. Available: https://www.smtscharf.com/product/scharf_lev/?lang=en. [Accessed 6 April 2023].

[17] Climate Knowledge Portal, “South Africa - Climatology,” 2020. [Online]. Available: https://climateknowledgeportal.worldbank.org/country/south-africa/climate-data-historical. [Accessed 1 April 2023].

[18] Bruker, “How does XRF Work?,” 2023. [Online]. Available: https://www.bruker.com/en/products-and-solutions/elemental-analyzers/xrf-spectrometers/how-does-xrf-work.html#:~:text=XRF%20describes%20the%20process%20where,touching%20or%20damaging%20the%20sample.. [Accessed 10 April 2023].

[19] Azo Materials, “Automated OES and XRF Analyzer – ARL SMS-3500,” Azo Materials, [Online]. Available: https://www.azom.com/equipment-details.aspx?EquipID=1007. [Accessed 2 April 2023].

[20] A. Bochkovskiy, “yolov7/LICENSE.md,” 7 July 2022. [Online]. Available: https://github.com/WongKinYiu/yolov7/blob/main/LICENSE.md. [Accessed 2 April 2023].

[21] W. Lucetti, “zed-ros2-wrapper/LICENSE,” Stereolabs, 18 November 2022. [Online]. Available: https://github.com/stereolabs/zed-ros2-wrapper/blob/master/LICENSE. [Accessed 2 April 2023].

[22] Canonical, “Terms and Conditions,” Canonical, 17 April 2014. [Online]. Available: https://ubuntu.com/legal/terms. [Accessed 2 April 2023].

[23] V. Balaram, “Sample preparation for geochemical analysis: Strategies and significance,” ScienceDirect, February 2022. [Online]. Available: https://www.sciencedirect.com/science/article/pii/S2772582022000079. [Accessed 3 April 2023].

[24] UNEXMIN GeoRobotics, "UNEXMIN GeoRobotics," UNEXMIN GeoRobotics, [Online]. Available: https://www.unexmin.eu/unexmingeorobotics/. [Accessed 3 April 2023].

[25] UNEXMIN GeoRobotics, "The UX-1 robot," UNEXMIN GEORobotcs, [Online]. Available: https://www.unexmin.eu/the-project/the-ux-1-robot/. [Accessed 3 April 2023].

[26] Caterpillar, "Fleet | Cat | Caterpillar," Caterpillar, [Online]. Available: https://www.cat.com/en_US/by-industry/mining/surface-mining/surface-technology/fleet.html. [Accessed 4 April 2023].

[27] "MInes in South Africa," Africa Mining IQ, January 2023. [Online]. Available: https://projectsiq.co.za/mines-in-south-africa.htm. [Accessed 5 April 2023].

[28] "SA Mine 2022- Level up or reset," PricewaterhouseCoopers, Cape Town, 2022.

[29] "Agenda - 2023," Investing in African Mining Indaba, 2023. [Online]. Available: https://miningindaba.com/agendas/agenda-2023. [Accessed 15 April 2023].

[30] "Home," World Robot Conference, 2023. [Online]. Available: http://www.worldrobotconference.com/en. [Accessed 15 April 2023].

[31] A. Myburgh, "South Africa: Tax Incentives Are Essential For Getting South African Mining Exploration Investment Back On Track," ENSafrica, 17 May 2022. [Online]. Available: https://www.mondaq.com/southafrica/withholding-tax/1191782/tax-incentives-are-essential-for-getting-south-african-mining-exploration-investment-back-on-track. [Accessed 6 April 2023].

[32] P. Mitchell, "Top 10 business risks and opportunities for mining and metals in 2023," Ernst & Young, 26 September 2022. [Online].

Available: https://www.ey.com/en_gl/mining-metals/risks-opportunities. [Accessed 6 April 2023].

[33] A. Madubela, "Mine fatalities at a record low," Mail & Guardian, 31 January 2023. [Online]. Available: https://mg.co.za/news/2023-01-31-mine-fatalities-at-a-record-low-in-2022/. [Accessed 6 April 2023].

[34] "Security Challenges in Mining," Mineral Council South Africa, Johannesburg, 2022.

[35] M. Saleh, "Leading mining companies in Africa based on market capitalization as of December 2022," Statistica, 15 February 2023. [Online]. Available: https://www.statista.com/statistics/1064135/africa-mining-companies-market-capitalization/. [Accessed 6 April 2023].

[36] S. Galal, "Revenue of the mining industry in South Africa from 2013 to 2022," Statistica, 9 January 2023. [Online]. Available: https://www.statista.com/statistics/1342869/south-africa-mining-revenue/. [Accessed 6 April 2023].

[37] "Mining Companies in South Africa," Africa Mining IQ, January 2023. [Online]. Available: https://projectsiq.co.za/mining-companies-in-south-africa.htm. [Accessed 6 April 2023].

[38] "South Africa Mining Equipment Market 2022-2030," Mobility Foresights, 2022. [Online]. Available: https://mobilityforesights.com/product/south-africa-mining-equipment-market/. [Accessed 6 April 2023].

[39] "Mining Equipment Market Size, Share & Trends Analysis Report By Equipment Type (Underground Mining Equipment, Surface Mining Equipment), By Application (Metal Mining), By Region, And Segment Forecasts, 2023 - 2030," Grand View Research, 2021.

[40] "Mining Global Market Report 2023 – By Type (Mining Support Activities, General Minerals, Stones, Copper, Nickel, Lead, And Zinc, Metal Ore, Coal, Lignite, And Anthracite), By Process

(Underground Mining, Surface Mining), By Service Provider (Independent C," The Business Research Company, 2023.

[41] "Global Autonomous Mining Equipment Market Report 2022-2026 & 2031: Rising Concerns Regarding the Safety of Mine Workers are Expected to Drive the Market," ResearchAndMarkets, 2022.

[42] "Working Hours and Overtime," Labour Guide, [Online]. Available: https://labourguide.co.za/employment-condition/working-hours-and-overtime/. [Accessed 6 April 2023].

[43] "Mineral and Petroleum Resources Development Act 28 of 2002," South African Government, Pretoria, 2002.

[44] "Yellow Table," *International Construction May 2021,* p. 29, 2021.

[45] Cat® Fleet, "Position & Material," Cat® Fleet, 2013. [Online]. Available: https://s7d2.scene7.com/is/content/Caterpillar/C10338777. [Accessed 19 April 2023].

[46] Mining Weekly, "Sandvik develops vision for mining automation with AutoMine® Concept Underground Drill," Mining Weekly, 23 September 2022. [Online]. Available: https://www.miningweekly.com/article/sandvik-develops-vision-for-mining-automation-with-automine-concept-underground-drill-2022-09-23. [Accessed 19 April 2023].

[47] ClearPath Robotics, "Husky UGV," ClearPath Robotics, 2022. [Online]. Available: https://clearpathrobotics.com/husky-unmanned-ground-vehicle-robot/. [Accessed 18 April 2023].

[48] Innok Robotics, "Modular robot system for custom robots," Innok Robotics, 2022. [Online]. Available: https://www.innok-robotics.de/en/products/heros/. [Accessed 18 April 2023].

[49] N. Zajzon, "USE OF ROBOTICS AND AUTOMATION FOR MINERAL PROSPECTING AND EXTRACTION," UNEXMIN, ¡VAMOS! and RTM Projects, Bled, 2018.

[50] unexmin, “Work begins in the lab on UX-1: Part 2 – University of Miskolc,” unexmin, 13 June 2017. [Online]. Available: https://www.unexmin.eu/work-begins-in-the-lab-on-ux-1-part-2/. [Accessed 19 April 2023].

[51] “The World Bank in South Africa,” The World Bank, 30 March 2023. [Online]. Available: https://www.worldbank.org/en/country/southafrica/overview. [Accessed 6 April 2023].

[52] B. Roberts, “Promise or precarity? South African attitudes towards the automation revolution,” Taylor & Francis Group, London, 2021.

[53] Anglo American, “SDG Alignment,” Anglo American, 2019. [Online]. Available: https://southafrica.angloamerican.com/our-difference/sdg-alignment. [Accessed 6 April 2023].

[54] N. C. Mathebula, “Political Risk to Mining Sector in South Africa,” Journal of Political RIsk, 12 August 2022. [Online]. Available: https://www.jpolrisk.com/political-risk-to-the-mining-sector-in-south-africa/. [Accessed 6 April 2023].

[55] Hexagon AB, “Autonomous fleet deployment,” Hexagon, [Online]. Available: https://hexagon.com/solutions/autonomous-fleet-deployment. [Accessed 7 April 2023].

[56] S. N. Jha, “Autonmous Farm Equipment Market,” 2023. [Online]. Available: https://www.factmr.com/report/autonomous-farm-equipment-market. [Accessed 15 April 2023].

[57] Research And Markets, “Military Robots Global Market Report 2023: Increasing Adoption of Land-based Military Robots Drives Growth,” Yahoo!News, 30 March 2023. [Online]. Available: https://uk.news.yahoo.com/military-robots-global-market-report-141300132.html. [Accessed 15 April 2023].

[58] S. &. R. B. &. H. D. &. J. Kinkel, “The effects of in-house manufacturing and outsourcing on companies’ profits and productivity,” in *23rd International Annual EurOMA Conference*, Trondheim, 2016.

[59] W. B. a. C. H. (. Toni Hickey, "The Pros And Cons Of Licensing Technology," Law360, New York, 2018.

[60] C. N. I. A. M. Victor Chukwunweike Nwokocha, "The role of subcontracting on innovation: an assessment ofsmall and medium enterprises in Nigeria," *PRODUCTION & MANUFACTURING RESEARCH,* vol. 7, no. 1, pp. 88-108, 2019.

[61] A. P. a. M. S. Halimatussa'diah*, "Productivity improvement in the production line with lean manufacturing approach: case study PT. XYZ," in *MATEC Web of Conferences*, Yogyakarta, 2018.

[62] J. Davies, "The Benefits of Supplier Relationship Managment," Winman, 21 January 2023. [Online]. Available: https://www.winman.com/blog/bid/366854/the-benefits-of-supplier-relationship-management. [Accessed 8 April 2023].

[63] Deutsche Investitions, "Unlocking the benefits of local sourcing for companies," Steward Redqueen, 2018.

[64] E. Brown, "Nvidia unveils octa-core Jetson Orin NX and ships AGX Orin dev kit," LinuxGizmos, 23 March 2022. [Online]. Available: https://linuxgizmos.com/nvidia-unveils-octa-core-jetson-orin-nx-and-ships-agx-orin-dev-kit/#:~:text=The%20lead%20time%20is%208x,2022%2C%20are%20listed%20farther%20above. [Accessed 08 April 2023].

[65] O. Y. S. O. V. S. W. Y. Mustafa Cagri Gurbuz, "Global supply chains risks and COVID-19: Supply chain structure as a," *Journal of Business Research,* vol. 155, 2023.

[66] pallet2ship, "Sea Freight vs Air Freight - What you need to know," 2023. [Online]. Available: https://www.pallet2ship.co.uk/sea-freight-vs-air-freight/. [Accessed 15 04 2023].

[67] Labelmaster, "How to ship lithium batteries by air—in 2022 and beyond," 20 January 2022. [Online]. Available: https://blog.labelmaster.com/how-to-ship-lithium-batteries-by-air-as-of-april-1-2016/#:~:text=Yes%2C%20you%20can%20still%20ship%20lithium%20batteries%20by%20air.&text=However%2C%20lithium%20batter

ies%20packed%20with,commercial%20aircraft%2C%20subject%20to. [Accessed 15 04 2023].

[68] Serpac, "LITHIUM METAL BATTERIES UN3090," 2017. [Online]. Available: https://www.lithiumbatteries.it/en/un3090/. [Accessed 15 04 2023].

[69] Gwtimpex, "Differences Between Freight Forwarders & Customs Brokers," 2023. [Online]. Available: https://gwtimpex.co.uk/differences-freight-forwarders-customs-br. [Accessed 15 04 2023].

[70] DSV, "https://www.dsv.com/en-gb/support/faq/what-is-freight-forwarding," 2023. [Online]. Available: https://www.dsv.com/en-gb/support/faq/what-is-freight-forwarding. [Accessed 15 April 2023].

[71] Agility Logistics, "Agility," 2023. [Online]. Available: https://www.agility.com/wp-content/uploads/2020/09/Agility-South-Africa-Profile-2020-EN.pdf. [Accessed 15 April 2023].

[72] Indaba, Investing in African Mining, "THE WORLD'S LARGEST AFRICAN MINING INVESTMENT EVENT," Hyve, 2023. [Online]. Available: https://miningindaba.com/home. [Accessed 29 03 2023].

[73] World Robot Conference, "World Robot Conference," World Robot Conference, 2022. [Online]. Available: http://www.worldrobotconference.com/en/. [Accessed 29 03 2023].

[74] Linkedin, "Gerard De Hert," Linkedin, 06 04 2023. [Online]. Available: https://www.linkedin.com/in/g%C3%A9rard-de-hert-65a85913/. [Accessed 06 04 2023].

[75] Forrest Brown, "Grants and R&D tax credits – how to use both," Forrest Brown, 19 03 2018. [Online]. Available: https://forrestbrown.co.uk/news/grants-r-and-d-tax-credits/#:~:text=The%20grant%20money%20itself%20would,expenditure%20post%201%20April%202023.. [Accessed 05 04 2023].

[76] K. Davies, “GBP/USD forecast: What lies ahead for the pair?,” Capital, 2 November 2022. [Online]. Available: https://capital.com/gbp-to-usd-forecast-what-is-next-for-the-forex-pair. [Accessed 17 April 2023].

[77] World Gold Council, “About us,” World Gold Council, 2023. [Online]. Available: https://www.gold.org/. [Accessed 13 04 2023].

[78] Seed Legals, “What are SEIS & EIS? The essential guide for UK startups,” Seed Legals, 30 09 2022. [Online]. Available: https://seedlegals.com/resources/what-is-seis-eis-an-essential-read-for-uk-startups/. [Accessed 05 04 2023].

[79] HMRC Gov UK, “Claiming Research and Development (R&D) tax reliefs,” HMRC Gov UK, 01 04 2023. [Online]. Available: https://www.gov.uk/guidance/corporation-tax-research-and-development-rd-relief. [Accessed 05 04 2023].

[80] GOV UK, “Made Smarter Innovation: Industry ready Robotics and Automation,” GOV UK, 19 01 2023. [Online]. Available: https://apply-for-innovation-funding.service.gov.uk/competition/1437/overview/26e0e1ee-77e7-483c-bdb7-2e4ad79965a5. [Accessed 05 04 2023].

[81] British Business Bank, “R&D grants for smaller businesses,” British Business Bank, 01 04 2023. [Online]. Available: https://www.british-business-bank.co.uk/finance-hub/rd-grants-for-smaller-businesses/#:~:text=Through%20grants%20provided%20by%20the,25%2C%20the%20largest%20ever%20allocated.. [Accessed 05 04 2023].

[82] Department of Home Affairs, “Visas,” 2023. [Online]. Available: http://www.dha.gov.za/index.php/types-of-visas. [Accessed 7 April 2023].

[83] Talent.com, “Graduate Engineer Salary in United Kingdom - Average Salary,” Talent.com, [Online]. Available: https://uk.talent.com/salary?job=graduate+engineer#:~:text=Find%20out%20what%20the%20average%20Graduate%20Engineer%

20salary%20is&text=The%20average%20graduate%20engineer%20salary%20in%20the%20United%20Kingdom%20is. [Accessed 14 04 2023].

[84] Talent.com, “Factory Workers Salary in South Africa - Average Salary,” Talent.com, [Online]. Available: https://za.talent.com/salary?job=factory+workers#:~:text=Find%20out%20what%20the%20average%20Factory%20Workers%20salary%20is&text=The%20average%20factory%20workers%20salary%20in%20South%20Africa%20is%20R. [Accessed 14 04 2023].

[85] British Telecom, “SIM Only Deals | Compare SIMO Plans & Contracts | BT Mobile,” British Telecom, [Online]. Available: https://www.bt.com/products/mobile/sim-only-deals/. [Accessed 14 4 2023].

[86] Uswitch, “Business Broadband - UK's Best Business Packages | Uswitch.com,” Uswitch, [Online]. Available: https://www.uswitch.com/broadband/business-broadband/. [Accessed 14 04 2023].

[87] Cloudflare, “Cloudflare,” Cloudflare, 2019. [Online]. Available: https://www.cloudflare.com/en-gb/. [Accessed 14 04 2023].

[88] Mining Indaba, “Mining Indaba - Home Page,” Mining Indaba, [Online]. Available: https://miningindaba.com/Home. [Accessed 14 04 2023].

[89] Rac, “Rac - Home,” Rac, 2020. [Online]. Available: https://www.rac.co.uk/route-planner/mileage-calculator/. [Accessed 14 4 2023].

[90] dfsworldwide, “UK South Africa Shipping Rates 2022 | Air/Sea Freight Container,” dfsworldwide, [Online]. Available: https://www.dfsworldwide.com/shipping-to-south-africa.html. [Accessed 14 04 2023].

[91] The Trainline, “Trainline,” The Trainline, 2018. [Online]. Available: https://www.thetrainline.com/. [Accessed 14 04 2023].

[92] Britishairways, “Book Flights, Holidays, City Breaks & Check In Online | British Airways,” Britishairways, 2019. [Online]. Available: https://www.britishairways.com/travel/home/public/en_gb. [Accessed 14 4 2023].

[93] MyLib, “Facility cost,” MyLib, [Online]. Available: https://www.mybib.com/b/Q2Qzg2. [Accessed 14 04 2023].

[94] MyLib, “Hardware Costs,” MyLib, 14 04 2023. [Online]. Available: https://www.mybib.com/b/R8AYp7. [Accessed 14 04 2023].

[95] MyLib, “Software Costs,” MyLib, 14 04 2023. [Online]. Available: https://www.mybib.com/b/3dDRRW. [Accessed 14 04 2023].

[96] Investopedia, “Weighted Average Cost of Capital (WACC) Explained with Formula and Example,” Investopedia, 08 08 2022. [Online]. Available: https://www.investopedia.com/terms/w/wacc.asp. [Accessed 05 04 2023].

[97] Corning Data, “What is Production Line Balancing?,” 2021. [Online]. Available: https://corningdata.com/what-is-production-line-balancing/. [Accessed 8 April 2023].

[98] worldpopulationreview, “Population of Cities in South Africa 2023,” 2023. [Online]. Available: https://worldpopulationreview.com/countries/cities/south-africa. [Accessed 2023 April 6].

[99] T. Ahmed, “Locations of the South African commercial ports,” ResearchGate, 2018. [Online]. Available: https://www.researchgate.net/figure/Locations-of-the-South-African-commercial-ports_fig8_326774572. [Accessed 5 April 2023].

[100] Future Learn, “Metal AM In-House vs. Outsourcing,” LUT University, 2023 2023. [Online]. Available: https://www.futurelearn.com/info/courses/costs-and-benefits-in-additive-manufacturing-economic-feasibility-and-implications/0/steps/177677. [Accessed 6 April 2023].

[101] Health and Safety Executive, "Welding fume: protect your workers," HSE, 2023. [Online]. Available: https://www.hse.gov.uk/welding/. [Accessed 9 April 2023].

[102] Health and Safety Executive , "Construction solvents: Spraying," HSE, 2023. [Online]. Available: https://www.hse.gov.uk/construction/healthrisks/hazardous-substances/spraying.htm. [Accessed 4 April 2023].

[103] A. Velling, "What Is Sheet Metal Fabrication?," Fractory, 28 1 2020. [Online]. Available: https://fractory.com/what-is-sheet-metal-fabrication/. [Accessed 5 April 2023].

[104] L. E. F. A. L. Zineb Aman, "Improving efficiency of a production line by Using Overall," in *Faculty of Sciences, Moulay Ismail University*, Rabat, 2017.

[105] E. F. P. M. a. M. G. W Utembe, "Hazards identified and the need for health risk assessment in the South African mining industry," *Human & Experimental Toxicology,* vol. 34, no. 12, pp. Pages 1212-1221, December 2015.

[106] E. D. André Brandl, "Structuring South Africa's national economic space: A regional corridor network model approach," *Town and Regional Planning,* vol. 77, no. 1, pp. 120-136, 2020.

[107] PlanetWare, "South Africa - Minerals and Industries Map," 2023. [Online]. Available: https://www.planetware.com/map/south-africa-south-africa-minerals-and-industries-map-saf-afs4.htm. [Accessed 12 April 2023].