DEPARTMENT OF MECHANICAL ENGINEERING TECHNOLOGY

Faculty of Engineering and the Built Environment

UNIVERSITY OF JOHANNESBURG

Doornfontein Campus

Design of a Seed Sowing Robot

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Subject: 250PJMMI3B

Date: Date of submission

DECLARATION

I (We) swear that this is the original work of the author(s). All information obtained directly or indirectly from other sources has been fully acknowledged. Furthermore, it represents my (our) own opinions and not necessarily those of the University of Johannesburg.

Signed **Date**

ABSTRACT

These instructions give you guidelines for preparing your report. Use this document as a template if you are using Microsoft Word 6.0 or later. Otherwise, use this document as an instruction set. The report should be word processed using Times New Roman Font 12, 1.5 spacing, Justified on the page.

Write the synopsis only when you have finished the entire report. This is a most important section that is largely instrumental in determining the reader's first impression of the project. The purpose of the synopsis is to tell the reader what the report is all about - in other words to enable the reader to ascertain quickly the purpose, extent and conclusion of the project. (In practice synopsis is often the only part of a report that is read). The synopsis must be written concisely in good prose (not point form) and short, explicit sentences should be used. Two to three hundred words are usually sufficient. Do not be vague - include appropriate numerical information to give the reader an idea of the magnitudes of some of the main quantities involved. Be sure to state clearly the main functions of the machine or system that you have designed.

The abstract should briefly address the following:

- What was the problem?
- Why was it done?
- How was it done? (Methodology)
- What were the results?
- What are the conclusions and recommendations?

ACKNOWLEDGEMENTS

It is fitting to acknowledge people who made a direct contribution to the project.

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LIST OF SYMBOLS, ABBREVIATIONS

All symbols and unfamiliar abbreviations which are used in the text must be clearly defined and explained in this section. The order in which the symbols are listed is usually:

- English letters and symbols
- Greek symbols
- Superscripts
- Subscripts
- SI-units of all symbols must be supplied as part of the definition.

1. INTRODUCTION AND BACKGROUND

Agriculture plays an important role in South Africa's food security and economic development (Mare, 2016). As the demand for efficient and sustainable farming grows, it is needed that we find ways to improve agricultural processes. The traditional methods have limitations such as precision, efficiency adaptability to different soil textures and depth of seed when sowing. The need to automate the farming industry is needed to address the following challenges, labor intensive working, time consuming processes and uneven distribution of seed. There are already existing mechanical seeders, but they lack certain features such as adaptability to different types of seed and depth of seed sowing according to the seed type and they require extensive human intervention. They are high in price and require a lot of maintenance making them less accessible to small and medium-sized farms or even backyard farming.

There are already existing seed sowing methods which are manual as well as automated, they all have their advantages and disadvantages as well as limitations. Some of the already existing seed sowing robots have the following disadvantages, accuracy is reduced due to clod and mad that gets stuck in between the components and it is a challenge since electronic components cannot withstand the vibration and high temperature since the robot work in an open sunlight area (Abdulrahman, 2017). Regardless of the challenges there are also benefits that the device provides, it requires less human intervention, more accurate in seed placing and even less skilled people can get it to operate (Abdulrahman, 2017). There are already seed sowing robots in the market, to name one there is the FarmDroid FD20 by the company named FarmDroid, it is a fully automated solar powered robot that can seed and deweed. One of its best features is that it is a green energy operating device, making it a great investment for the future as it does not contribute to the release of toxic gas which leads to climate change and global warming. (FarmDriod, 2022).

To address the problems mentioned above, this project aims to design, improve and develop an autonomous seed sowing robot that will automate the sowing process while improving efficiency, precision and adaptability, also the seed sowing robot will be having a solar system to make it more efficient so that it will recharge the battery while it is the agricultural field working and also be able to working in different weather conditions. By integrating control mechanisms, sensors, solar system and automated movement, this autonomous robot aims to optimize seed placement, reduce seed wastage, be more efficient and reduce human labor which will contribute to sustainable and precision agriculture.

2. ADOPTION OF SCAMPER IN DESIGN DEVELOPMENT

The Agricultural sector already has access to seed sowing robots which are available in the market. We will first discuss some of the existing seed sowing robots, analyze and identify their key features.

1. **FarmDroid FD20** – Solar powered precision sowing and weeding robot (FarmDriod, 2022)

Figure 1: Farmdroid FD20 autonomous Field Robot (Agtecher, n.d.)

FarmDroid FD20 is a solar powered autonomous robot which is designed for both seed sowing and weeding. It uses high precision GPS to plant seeds at exact locations and return later to remove weeds mechanically.

Key Features

- Solar powered – operates on renewable energy source
- GPS guided precision – Ensure seeds are planted in a straight line.
- Weeding capability – Eliminates the need for herbicides making it friendly to the environment.
- Low maintenance – Simple mechanical design with no complex hydraulics.

Limitations

- Limited to row crops – may not work well for all types of farming.
- Expensive to purchase – Though it saves money in the long run, the initial investment is very high

2. **Agriointelli Robotti LR** – Autonomous multi-purpose farming robot (Robotics, 2024)

Figure 2: ROBOTTI LR autonomous farming robot (Agrointelli, n.d.)

Robotti LR is a fully autonomous tractor that can perform various agricultural tasks including seed sowing, tilling and spraying. It runs on a diesel engine allowing it to work for extended periods of time.

Key Features

- Multi- functional – can switch between seeding, fertilizing and tilling.
- Autonomous GPS navigation – No human invention required
- Efficient – Works continuously for long hours

Limitations

- Diesel powered – can tribute to climate changes since it emits toxic gases into the atmosphere.
- Expensive and bulky – Not suitable for small scale farms.

3. **FarmWise Titan FT-35 -** AI-powered vision technology for precision farming (Rodnitzky, 2021)

Figure 3: FarmWise Titan FT-35 (Nine, 2023)

Originally designed as a weeding robot, the Titan FT-35 can also be adapted for seeding planting using its AI-based vision system. It can identify crops and adjust operations in real time based on plant growth.

Key Features

- AI- powered plant recognition – Can identify weeds vs crops
- High precision in seed placement – uses advanced camera technology.
- Environmental friendly – uses less chemical

Limitations

- High reliance on AI and sensors – needs constant update and maintance
- Not optimized for large scale farming sowing – more suited for specialty crops

4. **ecoRobotix Autonomous Weeder** – Solar powered AI based weeding and sowing (Ecorobotix, n.d.)

Figure 4: Erorobotic's autonomous Robot weeder (Erorobotix, n.d.)

Primary designed as a solar-powered weeding robot, but it can be adapted for precision seed planting in organic farming. It uses AI and computer vision to detect weeds and apply treatments selectively.

Key Features

- Eco-friendly and chemical free – Uses solar energy and precise weed control.
- Autonomous operation – Minimal human input needed.
- Lightweight and compact – can be used in small farms or greenhouses.

Limitations

- Limited to certain field conditions – not designed for deep soil sowing.
- Slow operation – Works best for small scale precision farming.

We will develop our design based on the existing robots in the market since we understand their strengths and limitations. By applying the SCAMPER technique, we can enhance these designs and create an innovative, efficient, cost effective, less human input, accurate, easy to maintain and use seed sowing robot for small farms. The technique is relevant because it enables incremental improvements based on existing designs. It will help us align the design with small farmers' needs, ensuring that the robot remains affordable, low maintenance, accurate and easy to operate.

Table 1: SCAMPER application table

SCAMPER Strategy	Application to existing designs	Modification for our design
S – Substitute	Replace wheels with tank tracks for better traction on uneven terrain.	Use tank tracks instead of wheels to improve stability and ensure straight line movement on rough farmland.
	Replace battery only power with solar panels for sustainability.	Use solar energy to power robot, reducing dependency on external charging and low operational costs.
	Replace manual control system with mobile app-based operation.	Implement remote control via a smartphone app, allowing farmers to operate the robot from a distance.
C – Combine	Merge seed sowing and watering into one system.	Integrate a small water dispensing system to ensure soil moisture after planting.
A – Adapt	Modify the seed dispenser to handle multiple seed types and spacing.	Implement an adjustable seed dispensing system that allows to farmers to change settings for different seed types and planting depths.
	Use terrain sensors for automatic adjustment on uneven ground.	Add real time soil and terrain detection sensors to adjust seed distribution accordingly.
M – Modify (Magnify/Minify)	Reduce weight for portable and efficiency.	Use lightweight but durable materials like aluminium instead of heavy steel.
P – Put to Another Use	Use the robot for weeding in addition to sowing.	Add rotary blades or mechanical arm to remove weeds as it plants seeds.
E – Eliminate	Remove unnecessary hydraulic systems to reduce complexity.	Use electric actuators instead of hydraulics, making maintenance easier and reduce costs.
R – Rearrange	Move the seed hopper from the top to the rear for better balance.	Position the seed container at the back for better weight distribution and improve stability.

By applying SCAMPER we aim to create to create a low cost , high efficiency seed sowing robot that moves effectively on uneven terrain, ensures accurate and uniform seed placement, requires less human input, reduces operational cost with solar power and has multiple farming functions beyond seed such as weeding.

3. DEFINITION OF PROBLEM

3.1. Problem statement

Small scale farmers in South Africa rely heavily on manual seed sowing methods, which are labor intensive, time consuming and inconsistent in terms of seed placement, spacing and depth. This inefficiency leads to reduced crop yields, uneven plant growth and increased operational costs. Uneven terrain poses a challenge making it difficult to maintain straight planting rows and uniform soil coverage.

There is a need to automate the seed sowing process so that human effort may be reduced while ensuring precision, efficiency and cost effectiveness. The current market solutions are often too expensive or complex to maintain, making it inaccessible to small scale farmers. The design for an autonomous seed sowing robot is proposed. The robot should be able to sow and cover seeds accurately according to crop requirements. It must be able to adapt to different seed types, spacing and soil conditions. The robot should be able to travel in straight lines on uneven terrain and be cost effective, easy to operate and require minimal maintenance. Small scale farmers will benefit from improved productivity, reduced labor costs and enhanced food production efficiency contributing to overall growth of the agricultural sector.

3.2. Requirements

Table 2: Design requirements table

Design need	Specify requirements
Easy to operate and maintain	• Have simple operation interface • Require no specialized training
Precise seed placement	• Sow seeds at consistent depth and spacing based on crop requirement
Ability to work on uneven terrain	• Travel in straight lines on rough and sloped surfaces without deviation.
Multi seed compatibility	• Accommodate different seed sizes and types
Cost effective	• Minimize production and operational costs

Automated operation	• Remotely controlled
Low energy consumption	• Battery powered • Solar powered
Durability and reliability	• Operate in hot weather conditions • Water resistant material
Adjustable seed depth and spacing	• Allow user to set different depth and spacing
Uniform soil coverage	• Properly cover seeds after planting
Lightweight and portable	• Not excessively heavy

3.3. Constraints

Size and weight

- Must not exceed 1.2 meters in width
- Total weight must be less than 50kg

Terrian and mobility

- Operate on uneven terrain with a slope of up to 15 degrees
- Maintain straight line path even on rough ground

Power and energy

- Must be battery powered with solar panel integration
- Operate for a minimum of 4 hours on a full charge

Seed sowing

- Adjustable depth between 10 mm and 50 mm depending on crop type
- Maintain a uniform seed spacing of 50 mm to 300 mm based on user settings

Material and durability

- Dust resistant
- Water resistant
- High temperature resistant
- Made of aluminum and reinforced plastic

Automation and control

- Autonomous with Remote control
- Less expensive GPS system

Economic and cost

- Not exceeding R20 000
- Require low maintenance

Environmental

- Use eco-friendly materials
- Minimize soil disturbance
- Emit zero harmful gases

3.4. Criteria

Precision in seed sowing

- Seed spacing accuracy ≤ ±5 mm.
- Seed depth accuracy ≥ 90

Navigation and Terrain Adaptability

- Straight-line deviation ≤ 5 cm per meter.
- Operates on slopes up to 15 degrees.
- Ground clearance ≥ 100 mm to avoid obstacles.

Multi-Seed Compatibility

- Adjustable seed spacing from 50 mm to 300 mm.
- Adjustable seed depth from 10 mm to 50 mm.

Energy and Power Efficiency

- Battery-powered with ≥ 4 hours of operation per charge.
- Optional solar power integration.

Material and Durability

- Withstands temperatures from -10°C to 45°C.
- Weather-resistant materials with IP54 dust and water resistance rating.

Portability and Weight Limitations

- Weight ≤ 50 kg.
- Overall width ≤ 1.2 meters for row compatibility.

Ease of Use and Maintenance

- Setup and calibration ≤ 5 minutes.
- Modular design for easy component replacement.

Cost and Affordability

- Manufacturing cost ≤ R20 000
- Maintenance cost ≤ R 5 000 per year.

Soil and Environmental Impact

- Soil disruption ≤ 20% of the ploughing area.
- Zero emissions (battery-powered and non-polluting).

Functionality

- Must sow seeds and cover soil in one operation.
- Autonomous or remote-controlled operation.

4. FUNCTIONAL ANALYSIS

Functional analysis is the next step in the Systems Engineering process after setting goal and requirements. Functional analysis divides a system into smaller parts, called functional elements, which describe what we want each part to do. We do not include the how of the design or solution yet.

You can perform a preliminary analysis in this section. Your proposed system can be analysed as follows:

- Divide the system into subunits;
- Describe each subunit by a complete list of functional requirements;
- List all the ways the functional requirements of each subunit can be realized;
- Study all combinations of partial solutions.

Example of good narrative for this section (credit to Mr Zwart: Design of Scraper Winch with safety features BEngTech 2022)

A Functional analysis is used to decompose the complexity of the machine into smaller sections that are less complex.

Component	**Function**
Motor	Provides power to the winch in form of a rotational force
Drum	Is designed that the steel wire rope is winded on the drum.
Controls	Designed to acuate the movement of the winch
Clutch	To transfer the power of the motor to the gears
Guidance rollers	To assist the drum in guiding the steel wire rope from left to right onto the drum
Worm gear	The worm gear will transfer the power from the clutch to the drum

The motor will provide power to the winch drum in terms of a rotational force. The motor is then connected to clutch, which transfers the power of the motor to worm gear assembly. The worm gear assembly will transfer the power generated by the motor to the drum. The drum will have a gear mounted inside and the worm gear will basically turn the drum.

The steel wire rope that is mounted on the drum will be either winded on the drum or released depending on the direction of the drum. The controls that are connected to the clutch will be used to control the rotation of the drum and hence determine if the winch is pulling a load or being released. The controls will be mounted onto the clutch that controls the power delivery and rotation.

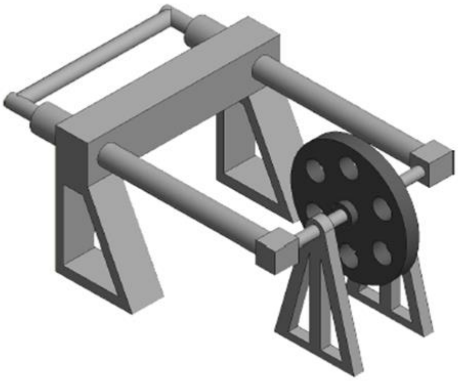
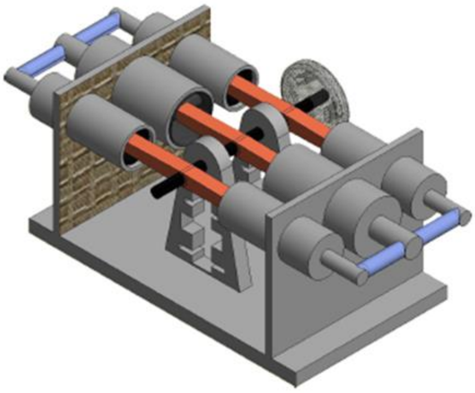
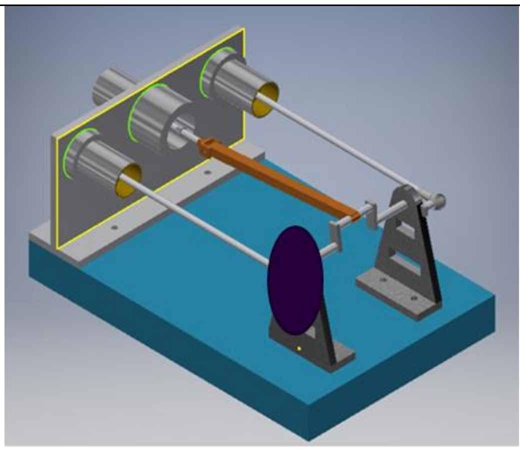
5. DESIGN DEVELOPMENT

In this section the various solutions that were considered are described in outline. Sketches or diagrams will almost certainly be necessary here. Do not give an exhaustive discussion of the rejected solutions in the body of the report; such detail should be relegated to an appendix. After describing the various possible schemes, the section must conclude with justification of the choice of the best one of these for detailed development.

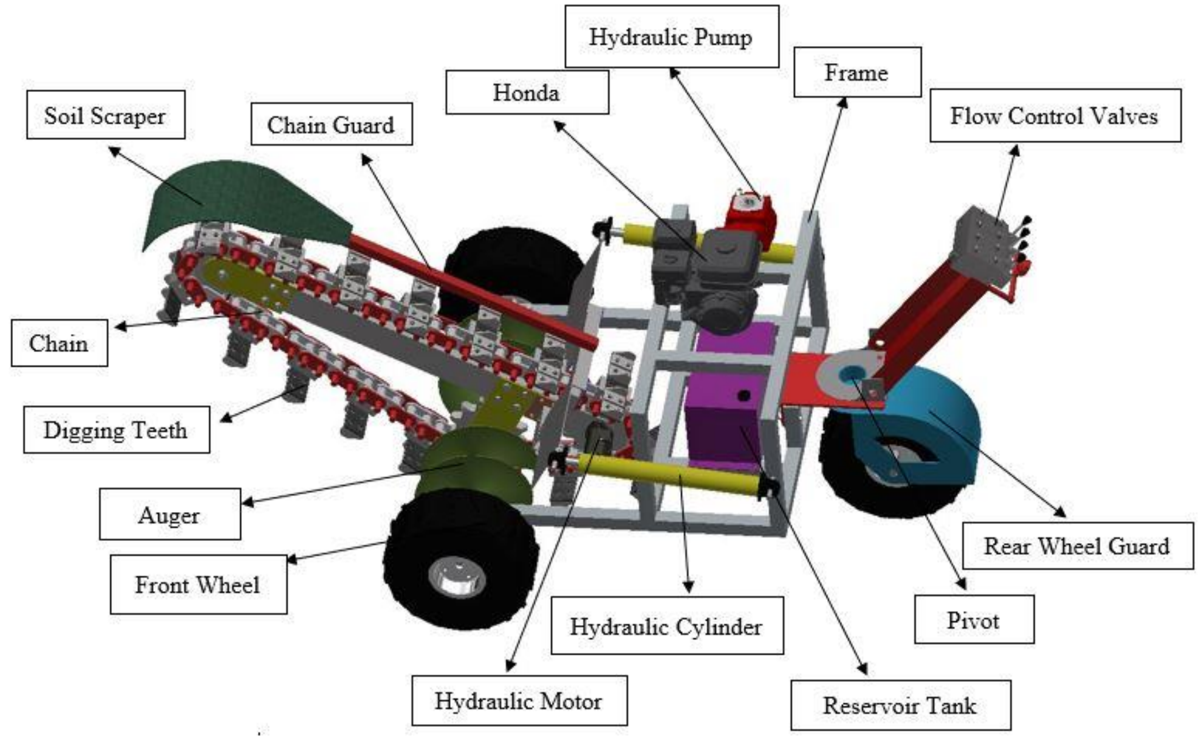
In this decision-making process the relative importance of the various criteria will have to be established and applied. The use of decision making techniques such as evaluation tables (Matousek, 1963) and criterion functions (Woodson, 1966) can be valuable if used wisely. If complex details are involved these should be included in an appendix and only the results used in this section. Suggested subheadings are as follows:

5.1. Concept generation

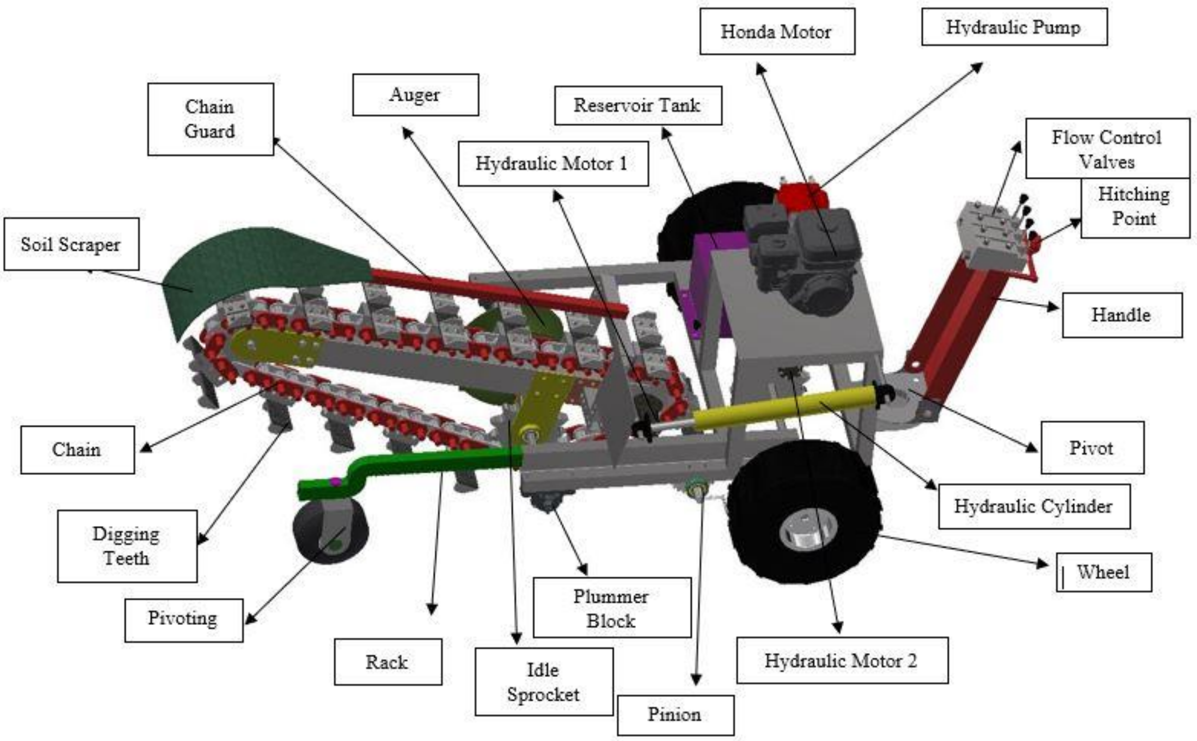
Each concept must be described separately. Some examples of expected illustrations are provided for your guidance.

 *Concept 1 (Beta type)*	 Concept 2 (Vertical double acting gamma)
 Concept 3 (Quad-piston gamma	 *Concept 4 (Horizontal double acting gamma)*

Illustrations showing typical design concepts (credit to K. Linde, T. S. Hlongwane, K. Netshikhudini, K. M. Mphahlele, M. K. Ramudzuli, V. P. Cibi, Design and construction of a low cost sterling engine, BEngTech 2020)

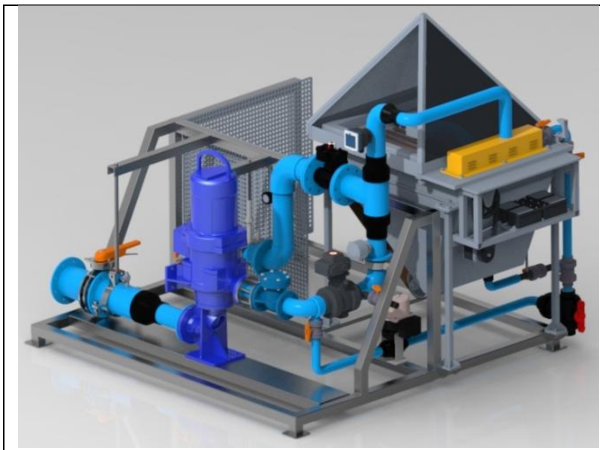


Concept 1



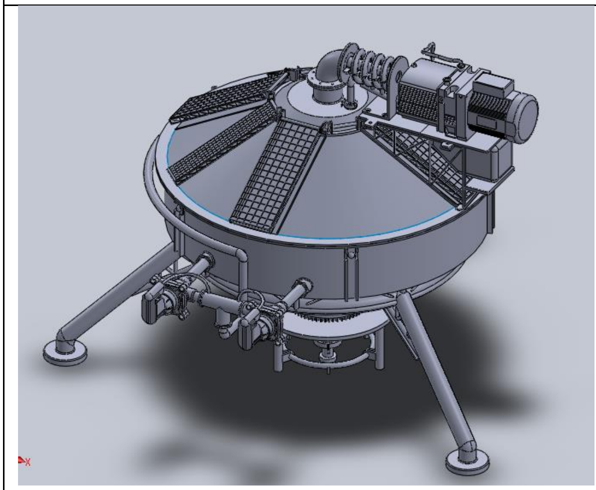
Concept 2

Illustrations showing typical design concepts (Credit to A. Magoma. Design of a powered portable trench digging machine, BTech 2018)

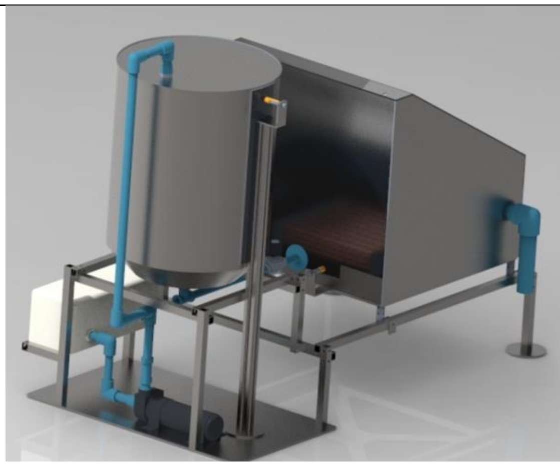


Concept 1

Concept 2



Concept 3



Concept 4

Illustrations showing typical design concepts (credit to K Digkale, Design of a solar water purification system, BTech design 2019)

5.2. Concept evaluation

Form decision matrix to unbiasedly evaluate different ideas based on a weighted set of objectives the design team decides are important for the solving the problem. Typical examples are provided in the following section.

To rate the concepts, a scale of 1 to 5 is recommended:

Relative Performance	Rating
– Much worse than reference	1
– Worse than reference	2
– Same as reference	3
– Better than reference	4
– Much better than reference	5
Reference points need not be the same for all criteria.	

		Reference		Concept 2		Concept 3		Concept 4	
Specifications (or list of criteria)	Weight (W)	Rating (R)	W×R	R	W×R	R	W×R	R	W×R
Technical Performance	19%	3	0.57	3	0.57	4	0.76	2	0.38
Reliability	15%	3	0.45	4	0.6	4	0.6	3	0.45
Maintainability	15%	3	0.45	1	0.15	2	0.3	4	0.6
Life Cycle Cost	13%	3	0.39	3	0.39	2	0.26	5	0.65
Development Risk	0%	3	0	1	0	1	0	4	0
Production Rate	8%	3	0.24	5	0.48	2	0.16	3	0.24
Schedule	10%	3	0.3	4	0.4	2	0.2	3	0.3
Safety	20%	3	0.6	4	0.8	1	0.2	5	1
TOTAL			3		3.31		2.48		3.62

5.3. Top two concepts

Provide clarity about the rationale behind the selection of the two best designs based on the design matrix.

In case some features of the proposed design could be integrated in a single concept to form the final design, such details can be inserted in this section.

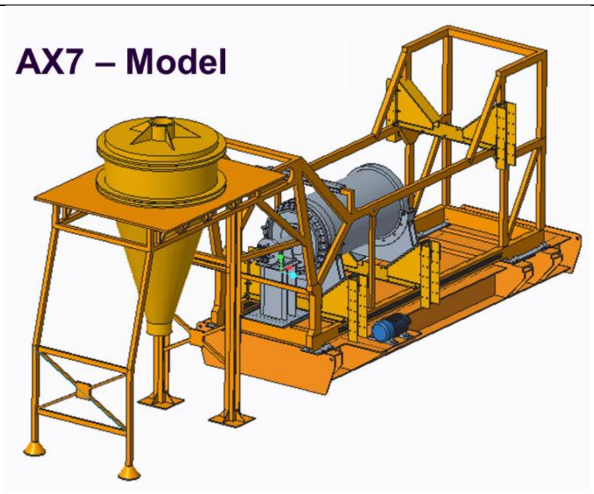
6. DESCRIPTION OF FINAL DESIGN

This section must include specifications of the final design solution. The reader must be given a clear picture of the product by including salient features such as performance characteristics, overall dimensions, total mass, efficiency, production cost, etc. The specifications should be given in tabular form.

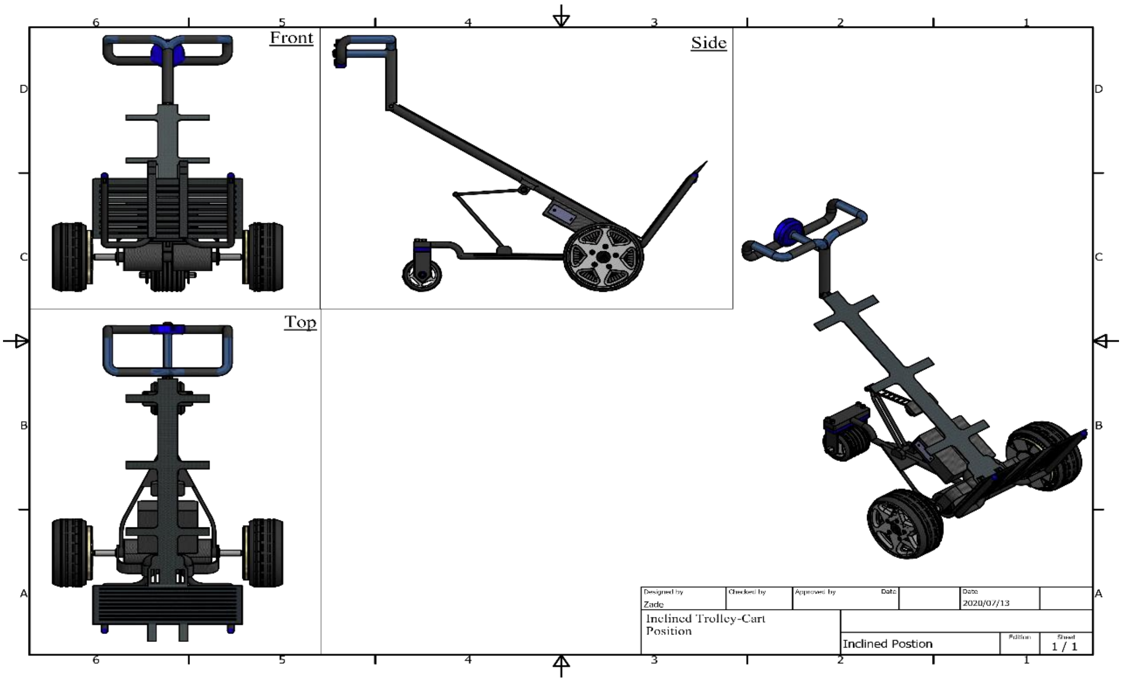
Only specifications of the overall machine should be included here; specifications of detail parts are not of interest.

Suggested subheadings are as follows:

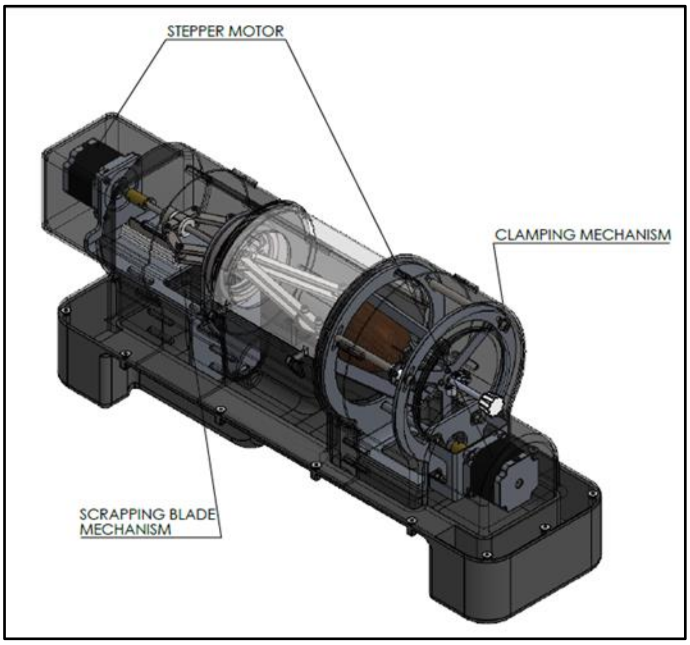
6.1. Overall design



Example of suitable illustration for this section (credit to T.C Phapano. Design of a grinder and mixer for Cement Manufacturing, BTech 2018)

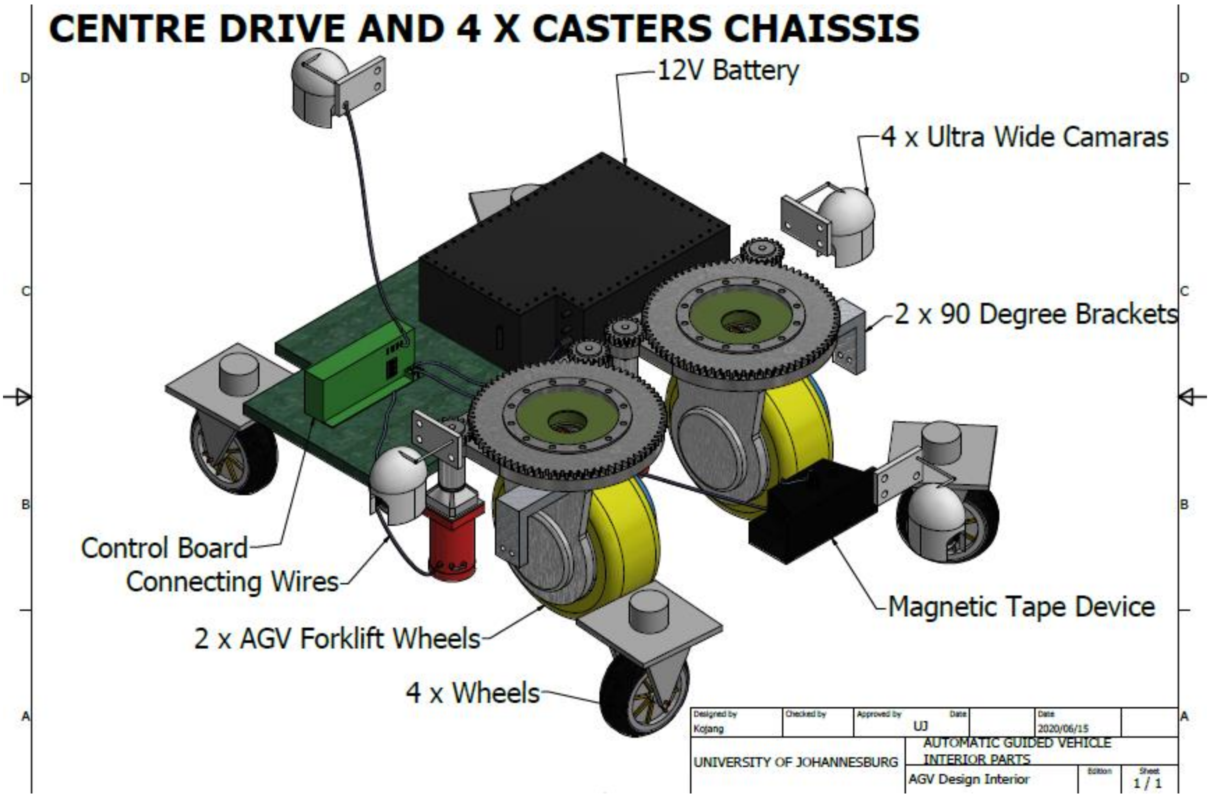


Example of suitable illustration for this section (credit to Siyaya SG, Nkomo S, Masindi OM, Hendricks ZC, Ngomane BR, Mafanya K, Makane M, Mogale N. Design of sensor controlled convertible cart-trolley. BEngTech 2020)

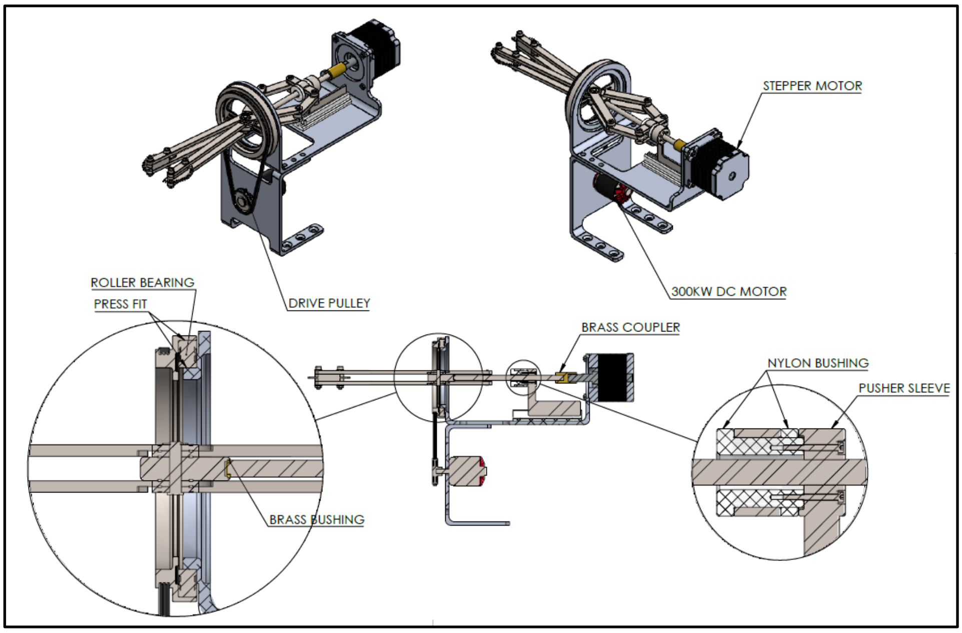


Example of suitable illustration for this section (credit to Mendes B, Design of Automated Coconut Scraping Machine. BTech design 2019)

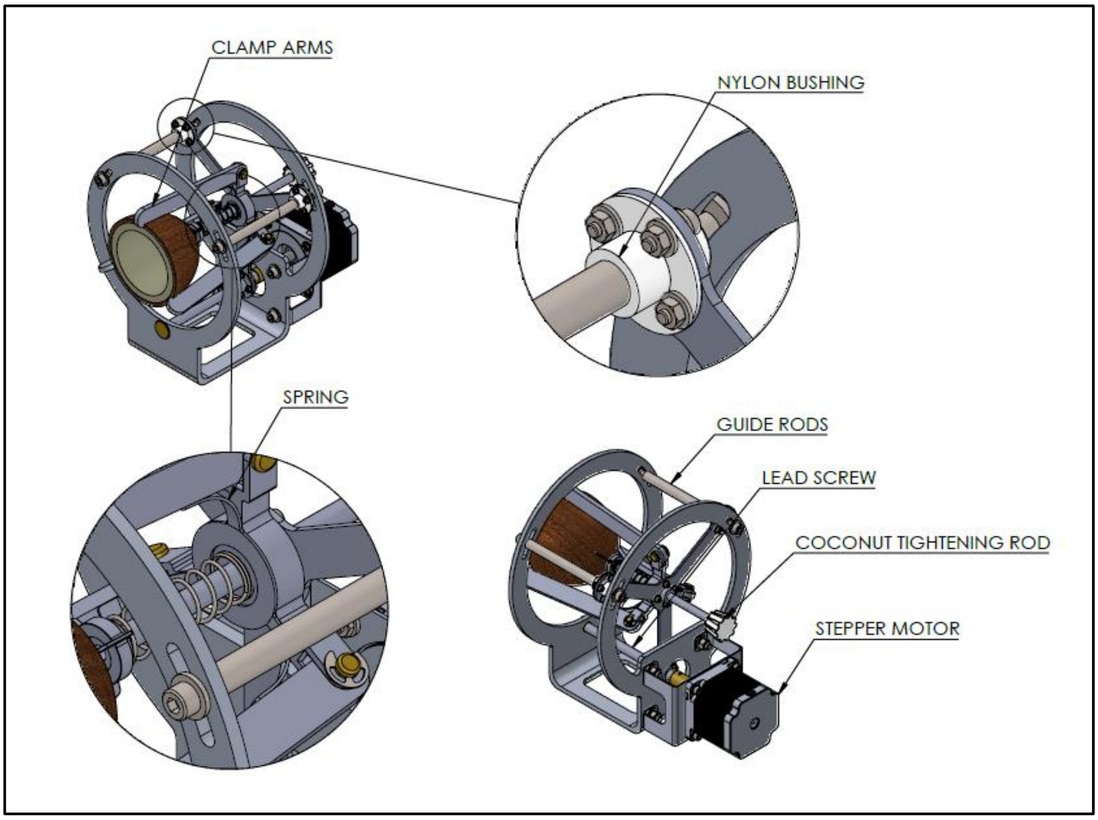
6.2. Detailed design description



Example of suitable illustration for this section (credit to Khumalo O, Parbhoo KP, Mukucha LT, Mpoko P, Mhlangu KC, Seleke KC, Mukombami AK, Mabuza S. Design of a light-weight material-handling Automated Guided Vehicle (AGV), BEngTech design 2020)



Example of suitable illustration for this section (credit to Mendes B, Design of Automated Coconut Scraping Machine. BTech design 2019)



Example of suitable illustration for this section (credit to Mendes B, Design of Automated Coconut Scraping Machine. BTech design 2019)

General guidance on Tables and Figures

All tables and Figures must be named. Caption of Table must always be located above the actual table. However, caption of Figures must be located below the actual figure.

Table 1. An example of inserted table.

An example of a column heading	Column A	Column B
And an entry	1	2
And another entry	3	4
And another entry	5	6

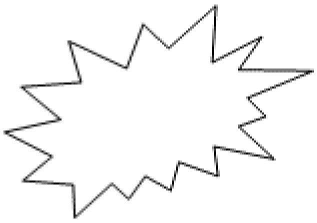


Fig 1: Example of an Inserted Figure

NB: Additional details that support the design can be inserted in the appendix section. Note that all appendices must be referred to within the report.

7. COMPLETE DESIGN MATERIAL SELECTION

In this section, you can insert details related to the following:

- Brief overview of the importance of material selection in mechanical engineering design.
- Explanation of how material properties impact design, performance, and manufacturing.
- Detailed description of the criteria used to select materials (strength, stiffness, durability, corrosion resistance, etc.).
- Prioritization of criteria based on their importance to the project.
- List of materials considered for the project.
- Justification for why each material was initially considered (e.g., known properties, availability, past experience).
- Methods used to evaluate materials (tests, simulations, literature review, etc.).

- Results of material tests and analysis (strength tests, thermal conductivity, fatigue tests, etc.).
- Detailed rationale behind the final material choice.
- Comparison with alternative materials considered.
- Explanation of how the selected material meets or exceeds design requirements and constraints.
- Discussion on how the selected material influences manufacturing processes (machining, casting, molding, etc.).
- Consideration of material availability and lead times.
- Comparison with costs of alternative materials.
- Assessment of environmental impact (carbon footprint, recyclability, reuse).
- Consideration of sustainability factors in material selection.

8. ASSEMBLY, OPERATING, AND MAINTENANCE SPECIFICATIONS

Here are the key elements to include:

1. Assembly Specifications:
    - Assembly Sequence: Detailed step-by-step instructions or diagrams showing how components should be assembled.
    - Assembly Tools and Fixtures: Specification of tools, jigs, fixtures, or assembly aids required for efficient assembly.
    - Tolerance Requirements: Tolerance stack-up analysis and specifications to ensure proper fit and alignment during assembly.
    - Fastening Methods: Description of fasteners (bolts, nuts, screws) used, including sizes, torque specifications, and tightening sequences.
    - Interchangeability: Consideration of interchangeable parts and modular assembly where applicable.
2. Operating Specifications:
    - Operating Conditions: Range of operating temperatures, pressures, speeds, and other environmental conditions under which the design is intended to perform.
    - Performance Requirements: Specification of expected performance metrics (e.g., efficiency, speed, load capacity).

- Control Systems: Description of control mechanisms or systems used to operate the equipment (manual, automated, feedback systems).
- Safety Considerations: Safety features incorporated into the design to protect operators and prevent accidents.

3. Maintenance Specifications:
   - Routine Maintenance Procedures: Detailed instructions for routine maintenance tasks (cleaning, lubrication, inspection).
   - Scheduled Maintenance: Frequency and procedures for scheduled maintenance activities (replacement of wear parts, calibration).
   - Troubleshooting and Diagnostics: Guidelines for diagnosing common issues and troubleshooting procedures.
   - Spare Parts Requirements: List of critical spare parts, part numbers, and suppliers.
   - Accessibility for Maintenance: Design features that facilitate easy access to components for maintenance and repair.
4. Documentation and Training:
   - Technical Manuals: Preparation of comprehensive technical manuals or documentation for assembly, operation, and maintenance.
   - Training Requirements: Identification of training needs for operators and maintenance personnel.
   - User Instructions: Clear and concise instructions for end-users on how to operate and maintain the machine safely and effectively.
5. Regulatory Compliance:
   - Compliance Requirements: Adherence to relevant industry standards, regulations, and safety codes.

9. COMPLETE CALCULATIONS, ANALYSIS, AND DATA INTERPRETATION

Here are the key elements to include:

1. Introduction
   - Objective: Briefly state the purpose of this section and what you aim to achieve through the calculations, analysis, and data interpretation.

- Scope: Outline the key topics covered in this section, such as the parameters being calculated, methods of analysis, and the types of data being interpreted.

2. Design Requirements and Constraints

- Functional Requirements: Describe the functional requirements of the machine. Example: "The machine must be able to handle a load of 1000 kg with a safety factor of 2."
- Design Constraints: List any constraints that must be considered, such as material properties, dimensions, and regulatory standards. Example: "The maximum allowable deflection for the main shaft is 0.5 mm."

3. Component Sizing Calculations

- List of Components: Identify the components that need to be sized (e.g., shafts, gears, bearings, etc.).
- Formulas and Theories: Describe the theoretical basis and formulas used for each component calculation. Example: "The diameter of the shaft is calculated using the torsion equation $T = \frac{\pi}{16}\tau d^3$, where T is the torque, τ is the shear stress, and d is the diameter of the shaft."
- Parameters and Assumptions: List all parameters involved in the calculations and any assumptions made. Example: "Assume a shear stress of 60 MPa for the shaft material."
- Step-by-Step Calculations: Provide detailed step-by-step calculations for each component. Example:
- Calculate the torque on the shaft.
- Determine the allowable shear stress.
- Compute the required diameter of the shaft.

4. Sub-Assembly Specifications

- Identification of Sub-Assemblies: Describe the sub-assemblies of the machine (e.g., transmission system, support structure, motor, pump etc.).
- Calculation of Specifications: Provide calculations for the specifications of each sub-assembly.

Example: "For the transmission system, calculate the gear ratios and select appropriate gears based on power transmission requirements."

- Drawings and Diagrams: Include detailed drawings and diagrams to illustrate the design and layout of each sub-assembly.
  Example: "Figure 2 shows the schematic layout of the transmission system with labeled components."

5. Analysis of Results

- Verification of Calculations: Verify the calculations through analysis methods such as finite element analysis (FEA) or simulation.
  Example: "The shaft design was verified using FEA to ensure that the maximum stress does not exceed the allowable limit."
- Comparison with Design Requirements: Compare the calculated results with the design requirements and constraints.
  Example: "The calculated shaft diameter meets the design requirement of a maximum deflection of 0.5 mm."

6. Data Interpretation

- Discussion of Results: Discuss the implications of the calculated results and their impact on the overall design.
  Example: "The larger diameter shaft increases the overall weight of the machine but ensures reliability under maximum load conditions."
- Identification of Potential Issues: Identify any potential issues or areas of concern based on the calculations and analysis.
  Example: "The selected bearings may require frequent lubrication under high load conditions."
- Recommendations: Provide recommendations for design improvements or further research.
  Example: "Consider using a hollow shaft to reduce weight while maintaining strength."

7. Bill of Materials (BOM)

The Bill of Materials (BOM) is crucial for detailing all the components and materials required to construct the designed product or system. It a comprehensive list of components and materials needed for assembly that can be presented in tabulated format. It consists of:

- Components and Materials List:
  - Component Identification: Detailed list of all components, parts, and materials required for the project.
  - Descriptions: Specifications and descriptions of each item (e.g., part number, description, quantity per assembly).
  - Material Specifications: Material specifications for each part or component (e.g., material type, grade, dimensions).
- Quantities and Units:
  - Quantity Breakdown: Quantities of each item needed for the entire project and for each assembly level.
  - Units of Measure: Units of measure used for quantities (e.g., pieces, meters, kilograms).

8. Comprehensive cost analysis

Here are the key details to include in the cost analysis section of the project:

- Material Costs:
  - Cost Estimation: Estimation of material costs per unit and total material cost for the entire project.
- Manufacturing Costs:
  - Labor Costs: Estimation of labor costs for manufacturing processes such as machining, welding, assembly, etc.
  - Overhead Costs: Allocation of overhead costs (e.g., facility costs, utilities) to the manufacturing process.
  - Tooling and Equipment Costs: Costs associated with specialized tools, equipment, and fixtures required for manufacturing.
- Assembly Costs:

  - Assembly Labor: Estimation of labor costs for assembling components into the final machine.
  - Fixtures and Jigs: Costs associated with jigs, fixtures, and assembly aids used during the assembly process.
  - Testing and Inspection: Costs associated with quality control, testing, and inspection processes to ensure product quality.
- Transportation and Logistics:
  - Shipping Costs: Estimation of transportation costs for delivering raw materials and shipping finished products.
  - Logistics Costs: Costs associated with inventory management, warehousing, and distribution.
- Prototype and Testing Costs:
  - Prototype Development: Costs associated with prototyping and testing iterations of the design.
  - Testing Equipment: Costs for acquiring or renting specialized testing equipment and facilities.
- Lifecycle Costs:
  - Operational Costs: Estimation of operational costs (e.g., energy consumption, maintenance) over the machine's lifecycle.
  - Maintenance and Repair Costs: Costs associated with routine maintenance, repair, and replacement of components.
- Cost Breakdown and Analysis:
  - Total Cost: Summation of all costs (material, manufacturing, assembly, etc.) to determine the total cost of the design.

- Cost Allocation: Allocation of costs to different components or subsystems of the machine.
- Cost Comparison: Comparison of the total project cost against budget constraints and cost targets.

- Cost-Reduction Strategies:
    - Value Engineering: Identification of opportunities to reduce costs without compromising performance or quality.
    - Alternative Designs: Evaluation of alternative design options to achieve cost savings.
- Risk Assessment:
    - Cost Risk Factors: Identification of potential risks that could impact cost estimates (e.g., material price fluctuations, supplier reliability).
    - Risk Mitigation: Strategies to mitigate cost risks and uncertainties.

10. SUSTAINABILITY, THE IMPACT OF ENGINEERING ACTIVITIES, AND PROFESSIONAL ETHICS

Incorporating sustainability, the impact of engineering activities, and professional ethics and responsibilities into a mechanical engineering design project adds depth and relevance to the project. Here are details to include under each of these aspects:

Sustainability

1. Environmental Impact Assessment:
    - Life Cycle Assessment (LCA): Evaluation of the environmental impacts associated with the design, manufacturing, use, and disposal phases of the product.
    - Carbon Footprint: Quantification of greenhouse gas emissions generated throughout the product lifecycle.

- Resource Use: Analysis of resource consumption (e.g., energy, water, raw materials) and identification of opportunities for resource efficiency.

2. Design for Sustainability:
    - Material Selection: Use of eco-friendly materials with minimal environmental impact (e.g., recyclable, biodegradable, renewable).
    - Energy Efficiency: Integration of energy-efficient technologies and practices to reduce energy consumption during operation.
    - Waste Minimization: Strategies to minimize waste generation during manufacturing and use phases (e.g., lean manufacturing principles, circular economy concepts).
3. Social and Economic Sustainability:
    - Social Impact: Consideration of social factors such as labor conditions, community impacts, and stakeholder engagement.
    - Economic Viability: Evaluation of the economic feasibility and long-term profitability of sustainable practices and technologies.
4. Regulatory Compliance and Standards:
    - Environmental Regulations: Adherence to local and international environmental regulations and standards.
    - Certifications: Pursuit of certifications (e.g., ISO 14001) and eco-labels demonstrating environmental performance.

Impact of Engineering Activity

1. Environmental and Social Impact Assessment:
    - Environmental Footprint: Assessment of the broader environmental impacts of engineering activities (e.g., construction, manufacturing).

- Social Impact: Evaluation of social implications such as community displacement, cultural heritage preservation, and equitable resource distribution.

2. Risk Assessment and Mitigation:
   - Risk Identification: Identification of potential environmental and social risks associated with the project.
   - Mitigation Strategies: Development of mitigation measures to minimize adverse impacts and enhance project sustainability.
3. Stakeholder Engagement:
   - Community Relations: Engagement with local communities and stakeholders to understand concerns and incorporate feedback into project planning.
   - Public Participation: Transparency in decision-making processes and opportunities for public involvement.

Professional Ethics, Responsibilities, and Norms of Engineering Practice

1. Ethical Considerations:
   - Code of Ethics: Adherence to professional codes of ethics (e.g., ASME, ECSA Code of Ethics) governing engineering practice.
   - Conflict of Interest: Management of conflicts of interest and ethical dilemmas that may arise during project execution.
2. Responsibility to Society:
   - Public Safety: Ensuring designs prioritize public safety and well-being.
   - Sustainability Commitment: Demonstrating a commitment to sustainable development and responsible resource use.
3. Professional Integrity:

- Honesty and Integrity: Upholding principles of honesty, integrity, and accountability in all engineering activities.
- Quality Assurance: Implementation of quality assurance processes to ensure designs meet established standards and specifications.

4. Legal and Regulatory Compliance:
    - Compliance: Adherence to legal requirements and regulations relevant to the engineering project (e.g., building codes, safety standards).
    - Professional Liability: Awareness of professional liability and risk management practices.
5. Continuing Education and Professional Development:
    - Continuous Learning: Commitment to ongoing professional development and staying current with advancements in engineering technology and practices.

11. CONCLUSION & RECOMMENDATIONS

A design project will not normally have a conclusion in the sense of that of a laboratory project, as design is essentially the first stage of a longer process. However, a ‘Conclusions’ chapter should collate the important points of previous chapters and look ahead to aspects such as equipment performance in service.

It may occur that certain aspects of the problem cannot finally be resolved. In such cases, further work should be recommended. Be very careful that this does not become an exercise in ‘passing the buck’ for work that you should have done but did not do. This is a valuable method of informing the reader of gaps in current knowledge.

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APPENDIX A: Project timeline

Include the task name, the duration, the starting and finishing date in your Gantt chart.

APPENDIX B: name of your choice

Fig. B-1: name of your choice

Fig B-2: name of your choice

Table B-1: name of your choice

Table B-2: name of your choice

APPENDIX C: Technical Drawings

Include concept sketch. Concept sketch means a 3D isometric assembly sketch complete with item number, 3 overall dimensions and a parts list. The part list has the following headings:

Item no, bought or made, material, description, Qty

Fig. C-1: Name of your choice

Fig C-2: name of your choice

Fig C-3: name of your choice

Fig C-4: name of your choice

APPENDIX D: Meeting log card

GRADUATE ATTRIBUTES 11: Engineering Management

Note that all the GA indicators will be assessed based on your final report and your presentation. Some details are already part of your report, though. However, I would like to point out the GA11. You must absolutely incorporate some details in this section explaining how this GA is fulfilled. Here are some tips to assist you:

When presenting a final year design project in mechanical engineering, it's crucial to clearly demonstrate how various elements such as risk analysis, time and change management, quality assurance, and economics principles have been integrated into your project. Here's a breakdown of typical details to include for each element:

1. Risk Analysis

- ***Identification of Risks***: Describe the potential risks associated with the project. This can include technical risks, safety risks, environmental risks, and financial risks.
- ***Risk Assessment***: Provide a summary of the likelihood and impact of each identified risk. Use tools like risk matrices or failure modes and effects analysis (FMEA) to quantify these risks.
- ***Mitigation Strategies***: Explain the strategies you've implemented or planned to mitigate these risks. This might include design changes, additional testing, or contingency planning.
- ***Monitoring and Review***: Describe how risks will be monitored throughout the project lifecycle and how the risk management plan will be updated as necessary.

2. Time and Change Management

- ***Project Timeline***: Present a detailed project timeline or Gantt chart showing key milestones, deadlines, and phases of the project. Highlight major tasks and their expected completion dates.
- ***Change Management Procedures***: Explain the process for handling changes to the project scope, design, or requirements. Include how changes are documented, evaluated, and approved.

- ***Resource Allocation***: Discuss how resources (time, budget, personnel) are allocated and managed to stay on schedule. Mention any tools or software used for project management.
- ***Adaptation Strategies***: Illustrate how you adapted the project plan in response to unexpected challenges or changes in project scope.

3. Quality Assurance

- ***Quality Standards***: Outline the quality standards and benchmarks used for the project. Include any industry standards, codes, or best practices relevant to your design.
- ***Testing and Validation***: Describe the testing procedures and validation methods employed to ensure the design meets the required specifications. This may include prototype testing, simulations, and verification against design criteria.
- ***Inspection and Documentation***: Explain the inspection process and documentation practices used to maintain quality throughout the project. Include any checklists, audit reports, or quality control measures.
- ***Feedback and Improvement***: Discuss how feedback was gathered and used to improve the design. Mention any iterative improvements made based on testing results or stakeholder input.

4. Economics Principles

- ***Cost Analysis***: Present a detailed cost analysis of the project. This should include estimates of material costs, labor costs, manufacturing costs, and any other relevant expenses.
- ***Budget Management***: Show how the project budget was managed, including any financial planning, tracking, and control measures implemented to stay within budget.
- ***Economic Feasibility***: Discuss the economic feasibility of the project. Include considerations such as return on investment (ROI), cost-benefit analysis, and economic impact.
- ***Value Engineering***: If applicable, explain any value engineering practices used to optimize the cost and performance of the design. Highlight any cost-saving measures or design improvements made.