OPTIMISING STARTUP MANUFACTURER'S SUPPLY CHAIN: ANALYSIS AND INVENTORY SYSTEM DESIGN

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ABSTRACT

The study addresses the challenges a startup manufacturing company encounters amid expansion, primarily due to inconsistent production levels and inadequate inventory management practices. It investigates carefully identified scenarios to enhance supply chain efficiency and evaluates the feasibility through financial analysis. Additionally, a basic raw material inventory management system is designed to ensure an adequate supply of raw materials for continuous production. A ten-step scenario analysis methodology is used to complete the scenario analysis, complemented by the DMADV methodology to design the inventory management system. The scenario analysis yielded that investing in new machinery is the optimal expansion strategy. The inventory management system effectively tracks raw material and finished goods inventory levels with additional useful features. This study provides insights into overcoming challenges in the startup manufacturers' supply chain and lays a foundation for further refinement of the supply chain.

Keywords: startup manufacturing, supply chain optimisation, scenario analysis, inventory system design

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1. INTRODUCTION

1.1 Background

Startup businesses are focused on a single product or service that founders want to bring to the market [1]. These businesses often lack a completely formed business concept and the capital to advance to the next stage of development [1]. Startups usually have limited resources, a small team, and high uncertainty and risk. Common challenges startup manufacturing businesses face include a lack of skilled workers, inventory, project management, consumer trends, scaling, and globalisation. Additionally, inventory management and production scheduling-related problems are some of the leading causes of startup failures [2]. Over- and under-stocking inventory leads to cash flow problems, a primary concern for startups. Inventory investment is a significant portion of a small business's total budget; however, inventory control is one of their most ignored management areas [3]. Many small companies have an excessive amount of cash tied up in inventory due to poor inventory management or an inability to handle inventory efficiently [3].

Company XYZ is a small start-up manufacturer specialising in genuine leather and sheepskin slippers. It was established in June 2021 and officially began manufacturing in November 2021. The highest recorded production rate is 75 pairs per week, averaging 30 pairs per week. The slippers are available in three styles: mule, classic, and cosy, each in 5 to 6 colour options. Several factors influence company XYZ's demand variability, including seasonal demand fluctuations, supply chain disruptions, and market competition. Seasonal factors impact slipper sales, with higher demand during colder months. Supply chain issues, such as delays from long lead times, port congestions and supplier shutdowns, have disrupted production. Additionally, the company's strategy to scale production from 75 pairs per week in 2022 to 1100 pairs per week by the end of 2025 introduces variability, requiring accurate inventory management.

1.2 Problem Investigation

The company is experiencing inconsistent production levels and shutdowns due to a periodic shortage of raw materials. The shortage resulted in the production facility being unable to manufacture products for five out of the past fifteen months. They can enter the retail market but require higher and more consistent production levels. The root cause of the material shortage is determined using the 5 WHYS analysis tool introduced by Toyota in the 1930s [4].

Table 1: 5 WHYS analysis tool to determine the root cause

Question	Answer	Countermeasure Used
Why did production stop?	Shortage of raw materials.	Ordered more materials.
Why was there a shortage of raw materials?	Ordered materials from China with unpredictable and long lead times.	Ordered material in larger quantities.
Why are the lead times long and unpredictable?	The products must be shipped, and South African harbours face significant issues.	Unsuccessfully sourced for raw materials in South Africa.
Why are raw materials not sourced locally?	Processed sheep skins are rare and of lower quality than imported sheepskins.	Ordered from China again.

The shortage of sheepskin availability in South Africa is the primary root cause of production issues, as illustrated in Table 1. Bezuidenhoudt [5] notes that very few merino skins are processed in South Africa; most are salted, exported, and processed overseas. Ludolph [6] further supports this, stating that over 98% of unprocessed skins are exported, with China being the largest market.

Figure 1 visually represents that sheepskin shortage is the leading cause of production shutdowns, emphasising the critical nature of this issue.

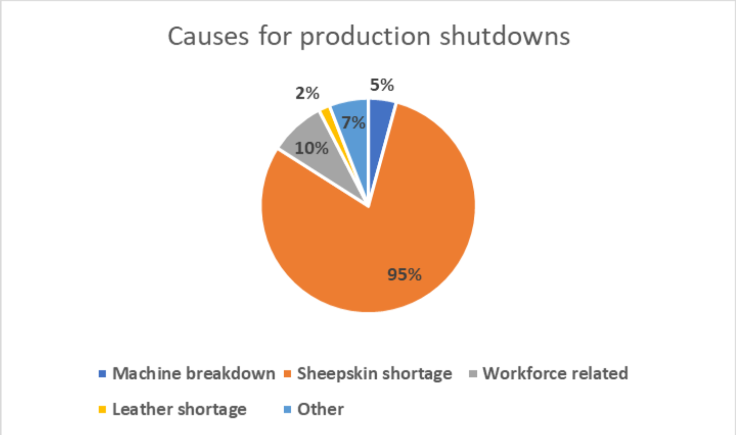


Figure 1: Causes for production shutdowns

Importing materials from China to South Africa has long and highly variable lead times (around four months). This unpredictability makes it challenging for the company to place large orders in advance. Company XYZ faces additional constraints as a startup regarding limited capital and insufficient storage space. These factors prevent the company from making large enough orders to serve as safety stock. Consequently, production is frequently halted due to raw sheepskin shortages, highlighting the need for improved inventory control measures. This lack of inventory control procedures is the second root cause of interrupted production.

1.3 Problem Statement

The company's inability to enter the retail sector is attributed to inconsistent production rates stemming from poor inventory management practices.

1.4 Aim and Objectives

The project aims to address the factors causing inconsistent production levels by investigating different scenarios to improve the efficiency of the supply chain. A financial analysis will be conducted to assess the feasibility of each scenario. Furthermore, a basic inventory management system was designed to ensure an adequate supply of raw materials. Both solutions aim to work in conjunction to ensure improved continuous production.

The objectives are to:

1. Investigate the inconsistent production levels and identify the root cause.
2. Conduct a scenario analysis to determine future business expansion options for the organisation.
3. Design a fit-for-purpose basic inventory management system for the organisation.

2. LITERATURE STUDY

2.1 Inventory Management

Inventory is usually the most significant asset on a company's balance sheet [7]. The primary goal of inventory management is to determine when items should be ordered and how much should be ordered [7]. Inventories allow different entities of a supply chain to operate independently. The famous trade-off exists between quicker customer demand response and more expensive inventory investment expenses.

2.1.1 Types of Inventories

Inventory exists in the upper and lower echelons of the supply chain. The upper echelons are the inventories closer to the customer, such as the retail store and warehouse inventory. The inventories in the lower echelon are for the raw materials and the manufacturing plant. The lower echelon inventories are used to ensure efficient production processes. [7]

The identified root cause falls within the lower echelon inventory and will be the focus point.

2.1.2 Inventory Management Software

Inventory management software is a digital tool designed to automate and improve tracking and managing inventory efficiency. It allows businesses to monitor stock levels, manage customer orders, and oversee incoming shipments to reduce costs and increase operational efficiency. In manufacturing, it helps to manage the flow of raw materials and parts through the supply chain and keep track of essential production documents, such as bills of materials and work orders. [8]

Inventory software features encompass various functionalities vital for efficient inventory management. These include real-time inventory tracking, purchase order and supplier management, multiple warehouse support, accounting and commerce integrations, production management and optimisation, and reporting and analytics.

2.2 Scenario Analysis

Scenario analysis is a valuable method to assess different possible outcomes and potential risks associated with various business expansion strategies. In this study, scenario analysis is exclusively used to identify the optimal business expansion strategy required by the company. Scenario analysis assesses expansion strategies, guiding the company's growth decisions. The following scenario analysis model was adapted from Kosow and Gabner [9]:

1. **Define scenarios:** Identify different expansion scenarios, such as facility expansion, supplier changes, outsourcing, and equipment acquisition.
2. **Identify key variables:** Determine the critical factors that will significantly influence each scenario, such as market demand, costs, supplier performance, and equipment efficiency.
3. **Determine possible values:** Assign a range of values to each key variable to represent various potential scenarios.
4. **Create data tables:** Set up data tables or spreadsheets to calculate outcomes based on the input values for each scenario.
5. **Calculate scenario outcomes:** Use the data tables to calculate each expansion strategy's financial performance, risks, and opportunities.
6. **Visualise results:** Present the scenario outcomes visually using charts or graphs to compare the scenarios.
7. **Sensitivity analysis:** Conduct sensitivity analysis to understand how changes in specific variables impact overall results.
8. **Interpret results:** Analyse the scenario model outcomes to gain insights into potential benefits and risks.
9. **Make informed decisions:** Use the insights from scenario models to make well-informed decisions about the best expansion strategy.
10. **Monitor and update:** Continuously monitor business performance and adjust scenario models as new data becomes available to stay responsive to changing market conditions.

2.3 DMADV Methodology

The Define-Measure-Analyse-Design-Validate (DMADV) methodology is widely used in various industries. It is beneficial in sectors where process quality, efficiency, and customer happiness are essential success factors. Manufacturing, healthcare, financial services, and telecommunications are among the industries that have successfully applied the DMADV technique. [10]

DMADV is focused on the process of designing a new product, service or process, incorporating the following phases [10]:

1. **Define:** Define the process and design goals.
2. **Measure:** Measure and identify critical-to-quality characteristics of the product, service or process. This includes risk and production capabilities.
3. **Analyse:** Analyse the data to find the best design.
4. **Design:** Design and test the product, service or process.
5. **Verify:** Ensure that the design output meets the design input requirements (verification) and that the designed product performs satisfactorily under actual or simulated conditions of intended use (validation).

Nieves-Castro [11] used the DMADV methodology to implement and improve inventory management. DMADV was used to define the project scope, measure cycle times and holding costs, analyse their impact on inventory management and identify opportunities for reduction. The inventory management system was then redesigned to address these findings. Finally, the redesign was validated with a prototype, and it was found that along with a 20% decrease in holding costs, the cycle times were also significantly reduced. [11]

Furthermore, a financial services company revamped its performance management system using the DMADV methodology. Initially, they defined goals for a comprehensive system and measured the current system's limitations through stakeholder interviews. The analysis identified key problems and requirements, leading to a design phase that chose average performance as a dynamic target baseline. Lastly, automated data validation and verification were employed to test functional and IT perspectives. The five-step DMADV methodology was successfully used to design a new management system within 12 months. [12]

2.4 Verification and Validation Methodology

Verification and validation are crucial for designing an effective and accurate product or service. Verification ensures the model is built correctly, whereas validation ensures the suitable model is built according to the customer's requirements [13].

2.4.1 Sensitivity Analysis

Sensitivity analysis was performed to verify the unit cost and break-even point calculations for the different scenarios. This approach is commonly employed in business and economics. The most significant advantage of a sensitivity analysis is that it can uncover errors in the original benchmarks and reduce uncertainty and unpredictability [14].

Utilising surveys with Likert scale questions served as a robust validation tool. Using this scale to design questions that capture the opinions and insights of relevant stakeholders, the Likert scale responses offer a quantifiable way to gauge the alignment of real-world perceptions with the scenario analysis outcomes. [15]

2.4.2 Inventory Management System

The inventory management system was custom-designed to fit the company's needs and expectations. White box and black box testing verify and validate new software developments. Table 2 explains the test differences [16].

Table 2: Software verification techniques

	Black Box Testing	White Box Testing
Definition	A software testing method that evaluates a software system's functionality without prior knowledge of how it operates internally.	A software testing method that tests a software system's internal operations.
Performed	The test is performed from the user's perspective.	The test is performed from the developer's perspective.
Goal	Evaluating if the system fulfils the user's needs and performs as predicted.	Testing the system's internal logic, performance, and efficiency.
Types of Testing	System testing and acceptance testing.	Unit testing and integration testing.

Table 3 defines the different types of tests used for black-and-white box testing [16]. This table is a valuable reference point, delineating the distinct methodologies and their respective roles in the testing process.

Table 3: Test definitions

Type of Test	Explanation
System Testing	Verifies the entire inventory management system, ensuring all components and functions work together to meet the system's requirements and objectives.
Acceptance Testing	Evaluates whether the inventory management system satisfies user requirements. It often involves user acceptance testing to validate that the system meets user expectations and business needs.
Unit Testing	Focuses on testing individual system components to ensure they perform as expected. It helps to identify and rectify errors at the smallest functional level.
Integration Testing	Checks the interaction and integration between different system components to validate that they work together correctly.

A combined approach of white box and black box testing methods represents a robust strategy for verifying and validating the inventory management system.

3. CONCEPTUAL DESIGN

3.1 Scenario Analysis

Scenario analysis was performed to determine the best business decision regarding the manufacturing cost of slippers. The unit cost of the slippers was calculated for different scenarios based on varying quantities sold. Considering different quantities sold, the break-even point for each scenario was calculated and compared.

3.1.1 Methodology

The ten-step scenario analysis methodology discussed in the literature review was followed to complete the scenario analysis, and Microsoft Excel was used for all the calculations. Figure 2 displays the methodology that was followed throughout the section.

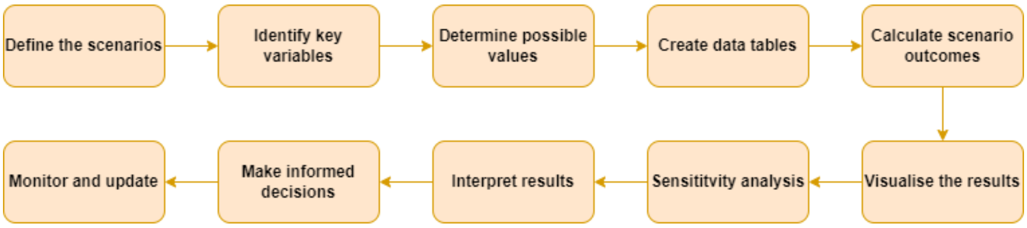


Figure 2: Scenario analysis methodology

3.2 Inventory Management System

The inventory management system focuses on the lower-echelon inventory. The root cause of the company lies within the lower echelon inventory and requires inventory management techniques to manage the acquisition phase of the supply chain.

3.2.1 Conceptual Inventory Management System Requirements

The requirements for the company's inventory management system are to:

- Efficiently manage inventory, including overseeing stock levels, lead times, reorder points, and safety stock.
- Calculate material requirements.
- Align inventory levels with the available capacities.
- Generate reports and analytics about the inventory and production performance.
- Employ an intuitive, user-friendly interface.

3.2.2 Software Selection

Table 4 summarises the software suitable for developing a basic inventory management system.

Table 4: Software comparison

Software	Description	Advantages	Disadvantages
Microsoft Excel	Microsoft Excel is a widely used spreadsheet software developed by Microsoft. Users can create custom inventory sheets, record product information, track quantities, and calculate basic inventory metrics.	• Can be used for MRP, P-model and Q-model systems • Flexible • Cost-effective • Familiarity	• Limited scalability • Manual data entry • Time-consuming to create or modify • Requires technical skills for advanced features • Dashboards are not standard
Katana	Katana is an inventory management software specifically designed for small and medium-sized manufacturers. It provides tools for managing inventory, production, and sales in a centralised platform.	• Can be used for MRP and P-model systems • User-friendly • Centralised control • Real-time data • Dashboards for reporting purposes	• Requires manual monitoring for Q-model systems. • The free version has limitations • Limited customisation • Learning curve
Odoo	Odoo is an open-source ERP platform with MRP functionality.	• Can be used for MRP, P-model and Q-model systems • Comprehensive • Cost-effective • Open-source • Scalability	• High-level complexity • Steep learning curve • Only two modules are free

A weighted criteria table was used to select the most suitable software for an inventory management system. The weights are assigned to the criteria based on their specific significance to the company.

The inventory management system will be designed using Microsoft Excel with Visual Basic Application (VBA) programming. VBA will be used to create a user-friendly interface, automate tasks, and design a dashboard to improve user-friendliness and functionality. The choice was made because the company is already familiar with using spreadsheets for basic inventory and production processes.

Table 5: Software evaluation

Criteria	Weight (%)	Score (Out of 5)	Weighted Score	Score (Out of 5)	Weighted Score	Score (Out of 5)	Weighted Score
		Microsoft Excel		Katana		Odoo	
Ease of Development	15%	2	0.3	4	0.6	3	0.45
Ease of Use	20%	4	0.8	3	0.6	3	0.6
Cost	20%	5	0.8	1	0.2	3	0.6
Customisation	15%	5	0.75	2	0.3	4	0.6
Ease of Customisation	15%	3	0.45	3	0.45	4	0.6
MRP Functionality	5%	3	0.15	5	0.25	5	0.25

Technical Support	10%	3	0.3	3	0.3	5	0.5
Total	**100%**		**3.55**		**2.7**		**3.1**

4. FINAL DESIGN

This section details solutions developed to address identified root causes. It includes two solutions: a scenario analysis for optimal business expansion and an inventory management system for effective monitoring and material requirement planning. These solutions have been refined from their initial conceptual designs with minor improvements.

4.1 Scenario Analysis

The ten-step scenario analysis methodology discussed in the literature review will be followed to complete the scenario analysis.

4.1.1 Define Scenarios

1. **Current state (using new suppliers):** This scenario involves utilising new local raw material suppliers. The company will continue to operate with their existing machines and production process.
2. **Outsourcing production processes:** The company can subcontract specific production processes to nearby shoe-manufacturing companies. The processes that will be outsourced include cutting, lasting, glueing, skiving, sole pressing, quality checking and debossing.
3. **Acquiring new machines:** The company has identified crucial machines that could enhance its production rate. These machines include a debossing press, a sole press, and a three-phase clicker press.

4.1.2 Identify Key Variables

All variables across the various scenarios are held constant, except for the specific variables that require adjustment due to each scenario. The critical variables that will notably impact each scenario are raw material costs, equipment costs, direct labour costs, fixed costs and outsourcing expenses.

4.1.3 Determine Possible Values (Input Data)

All scenarios were calculated for 150, 300, 600, and 1200 pairs sold monthly. The company's objective for 2023 was to sell 300 pairs of slippers per month and double that quantity annually. These quantities provided sufficient data to draw meaningful conclusions.

4.1.4 Create Data Tables

The input data and calculations have not been included in this report due to the proprietary and sensitive nature of the information, which is the company's intellectual property.

4.1.5 Calculate Scenario Outcomes and Visualise the Results

Calculating the unit cost is crucial to a company's operational analysis, offering insights into product production efficiency [17]. The unit cost represents the cost of manufacturing and selling a single product unit. It is imperative to strive for the lowest possible unit cost as it directly impacts profit maximisation. The break-even point (BEP) serves as a vital indicator, revealing the minimum number of products that must be sold for the company to achieve profitability [18]. The BEP is calculated using the weighted sales distribution of the different shapes. Furthermore, it is calculated for the four different quantities to be produced since the variable and fixed costs change as the quantities change. The BEP is calculated as follows:

$$\frac{(Fixed\ Cost + Direct\ Labour + Machine\ Cost)\ x\ \%\ Shape\ Sales\ Distribution}{(Selling\ Price - Variable\ Cost)} \quad (1)$$

The unit cost results are summarised in Figure 3, and the BEP calculations in Figure 4. It is important to note that the company can only manufacture 300 units at the current facility. Therefore, calculations must be made for various output units to determine the best strategy for the future.

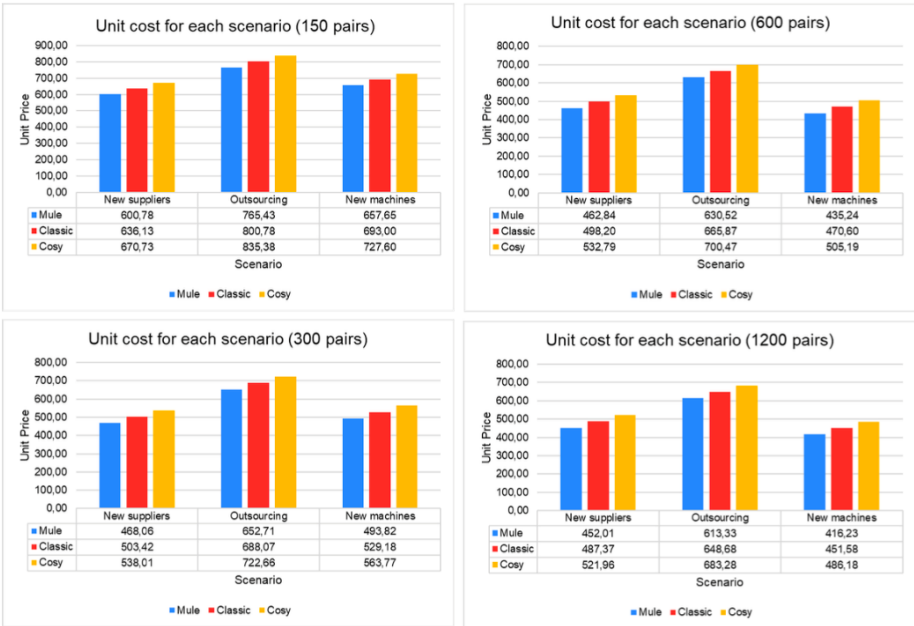


Figure 3: Unit cost comparison summary

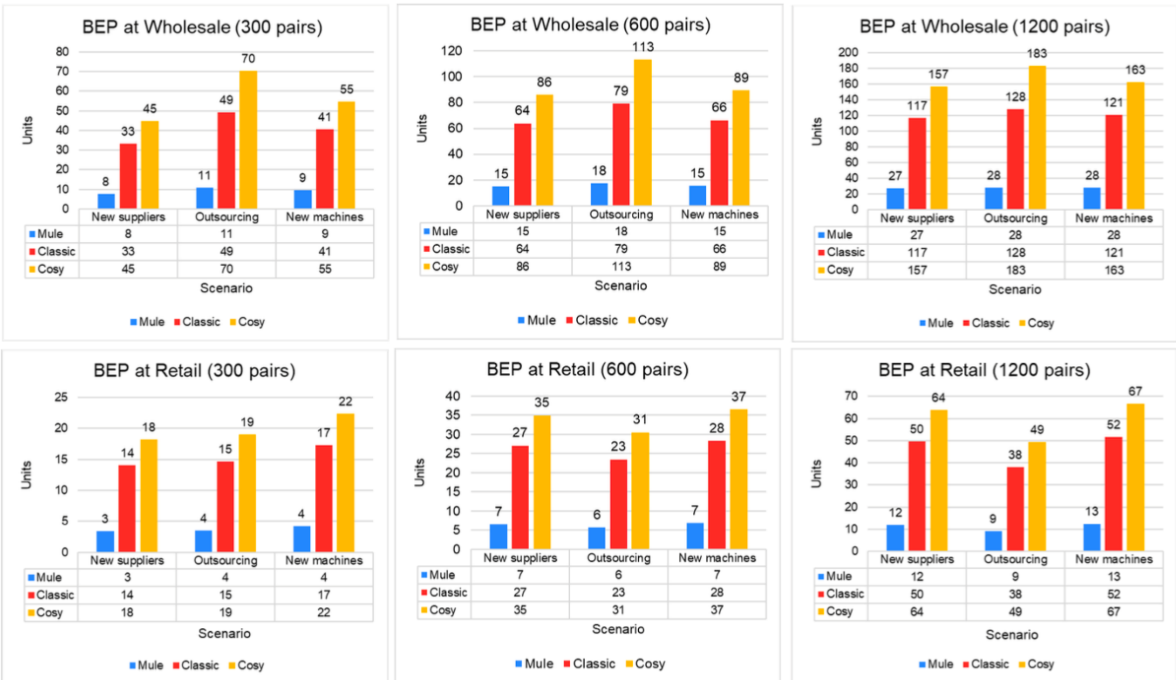


Figure 4: Break-even point comparison summary

4.1.6 Sensitivity Analysis

Sensitivity analysis is performed and discussed in detail in the succeeding verification section of this report.

4.1.7 Interpret Results

Upon analysing the unit cost calculations, it is evident that producing 300 pairs is most efficient using existing manufacturing procedures and new suppliers. Introducing machinery becomes more cost-effective for 600 pairs or more production goals. Outsourcing specific production procedures is prohibitively expensive, resulting in high unit costs and minimal profit margins, even when producing 1,200 pairs for wholesale. The scenario with the new supplier has the lowest break-even point (BEP) for various quantities at wholesale prices, closely followed by the new machinery scenario. However, if products are sold at retail prices, the outsourcing scenario becomes most favourable due to its lower BEP, as the new supplier and machinery scenarios require higher sales volumes to offset labour and machinery costs before becoming profitable.

4.1.8 Make Informed Decisions

The company's plan to enter the retail market by the end of 2024 and produce 1,200 pairs of slippers monthly by 2026 will significantly impact the break-even point (BEP) calculations, primarily due to the shift towards wholesale pricing. Investing in new machinery is deemed worthwhile based on the unit cost and BEP calculations. Flexibility to extend the payback period beyond the initial 12 months is available, mainly if unit cost concerns arise during the project's early phase. This extension will significantly reduce unit costs once the machines are fully paid off, substantially enhancing profit margins on all future products. Furthermore, embracing a machinery-based production approach offers the company greater control over the manufacturing process and mitigates significant risks.

4.1.9 Monitor and Update

Continuous monitoring of the spreadsheets is imperative, and the scenario models must be fine-tuned as new data becomes available to ensure accuracy in a dynamic environment with ever-changing future conditions and volatile variables.

4.2 Inventory Management System

The focus in developing the inventory management system has been on addressing the need for inventory management. The system is tailored to the company's requirements to ensure that it is an efficient inventory and production management tool. The inventory management system has been developed using Microsoft Excel and VBA as outlined in the conceptual design. The data used to build the model is based on two weeks of information provided by the company to ensure the model is relevant and accurate.

4.2.1 Features of the System

An overview of the different system features is provided below, with selected screenshots to explain the functionality without the reader interacting with the system.

a) Navigation Panel

The navigation panel serves as the "home" screen, allowing access to various inventory management system features through relevant icons.

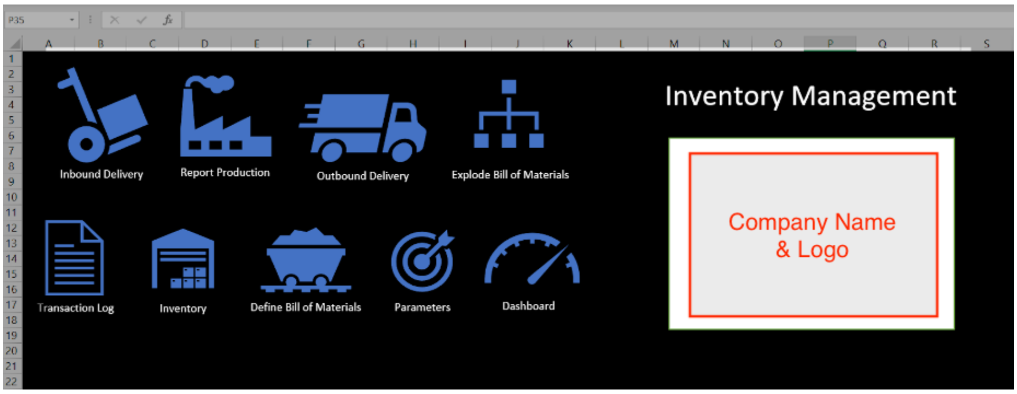


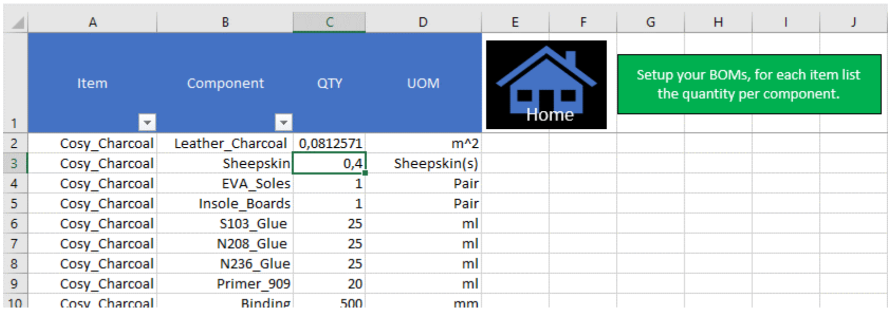
Figure 5: Navigation panel

b) Parameters

A sheet with operating parameters in dropdown lists is used for the parameters function, reducing errors and improving the interface. Users can add parameters like customers and retailers. Defined parameters include raw materials, units of measurement, customers, products, warehouses, shapes, colours, and sizes.

c) Bill of Materials

The Bill of Materials (BOM) lists materials and quantities needed for each product, including a 10% safety factor for material availability and error accommodation. This BOM is crucial for the material availability check feature.



Item	Component	QTY	UOM
Cosy_Charcoal	Leather_Charcoal	0,0812571	m^2
Cosy_Charcoal	Sheepskin	0,4	Sheepskin(s)
Cosy_Charcoal	EVA_Soles	1	Pair
Cosy_Charcoal	Insole_Boards	1	Pair
Cosy_Charcoal	S103_Glue	25	ml
Cosy_Charcoal	N208_Glue	25	ml
Cosy_Charcoal	N236_Glue	25	ml
Cosy_Charcoal	Primer_909	20	ml
Cosy_Charcoal	Binding	500	mm

Figure 6: BOM example

d) Production Order Management

Production orders are added via a user-friendly form in VBA. Upon submission, the system checks material availability, deducts raw materials from available inventory, and updates the finished goods inventory. If materials are insufficient, a warning message appears, and no materials are deducted.

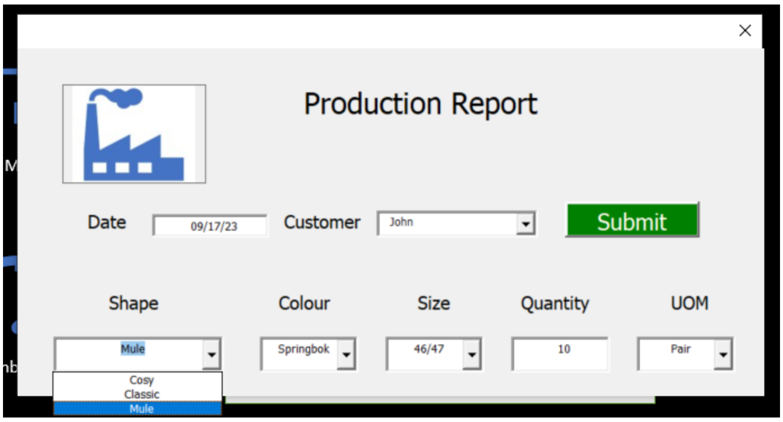
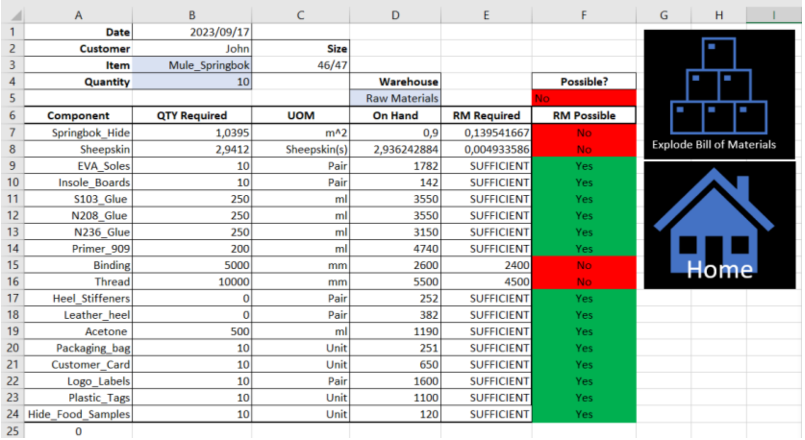


Figure 7: Production report form

e) Material Availability Check

This feature verifies raw material availability for production, using the BOM to determine requirements and compare with inventory levels. It also functions as a simulation tool for future production and material planning without impacting inventory levels.



	A	B	C	D	E	F
1	Date	2023/09/17				
2	Customer	John	Size			
3	Item	Mule_Springbok	46/47			
4	Quantity	10		Warehouse		Possible?
5				Raw Materials		No
6	Component	QTY Required	UOM	On Hand	RM Required	RM Possible
7	Springbok_Hide	1,0395	m^2	0,9	0,139541667	No
8	Sheepskin	2,9412	Sheepskin(s)	2,936242884	0,004933586	No
9	EVA_Soles	10	Pair	1782	SUFFICIENT	Yes
10	Insole_Boards	10	Pair	142	SUFFICIENT	Yes
11	S103_Glue	250	ml	3550	SUFFICIENT	Yes
12	N208_Glue	250	ml	3550	SUFFICIENT	Yes
13	N236_Glue	250	ml	3150	SUFFICIENT	Yes
14	Primer_909	200	ml	4740	SUFFICIENT	Yes
15	Binding	5000	mm	2600	2400	No
16	Thread	10000	mm	5500	4500	No
17	Heel_Stiffeners	0	Pair	252	SUFFICIENT	Yes
18	Leather_heel	0	Pair	382	SUFFICIENT	Yes
19	Acetone	500	ml	1190	SUFFICIENT	Yes
20	Packaging_bag	10	Unit	251	SUFFICIENT	Yes
21	Customer_Card	10	Unit	650	SUFFICIENT	Yes
22	Logo_Labels	10	Pair	1600	SUFFICIENT	Yes
23	Plastic_Tags	10	Unit	1100	SUFFICIENT	Yes
24	Hide_Food_Samples	10	Unit	120	SUFFICIENT	Yes
25	0					

Figure 8: Material availability check and simulation tool

f) Inbound and Outbound Delivery Management

Like the production order form, the inbound delivery form allows materials to be added to the raw material inventory using dropdown lists for materials and quantities. The outbound delivery form records customer orders and tracks the inventory of finished goods. It alerts users if stock is insufficient to fulfil an order, prompting a check of inventory levels.

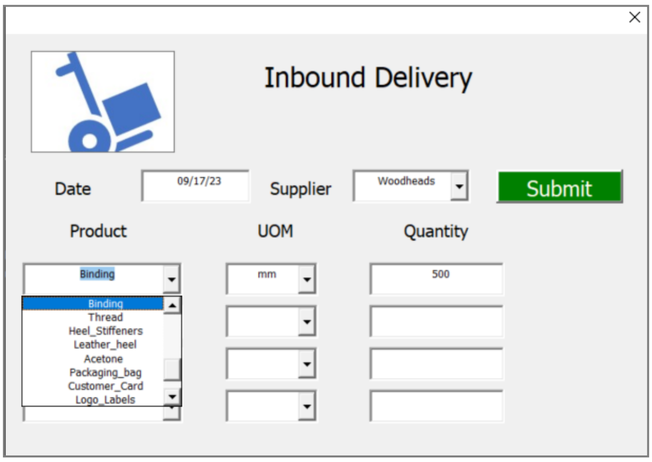


Figure 9: Inbound delivery form

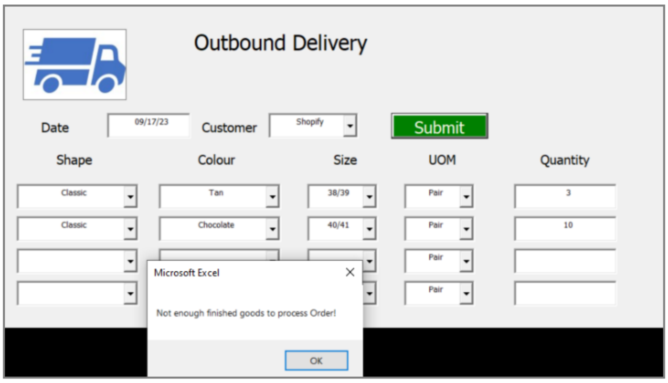


Figure 10: Outbound delivery form

g) Transaction Log

The transaction log records all inbound, production, and outbound transactions, providing data for the inventory sheet via pivot tables. It is not intended for frequent user interaction but can manage errors or manual corrections.

h) Inventory

The inventory feature uses pivot tables based on the transaction log to show stock levels of raw materials and finished goods, aiding supply chain management. Pivot tables can be filtered and adjusted for more detail on the stock on hand.

i) Dashboard

The dashboard summarises valuable information using graphs and pivot tables, providing insights into sales distribution, production quantities, and inventory levels. It includes slicers for period-specific data.

5. VERIFICATION AND VALIDATION

5.1 Verification

5.1.1 Scenario Analysis

The sensitivity analysis verified the scenario analysis by evaluating how variations in crucial input variables affected the break-even point (BEP) for wholesale and retail price scenarios. The variables adjusted included wholesale and retail prices, variable costs, fixed costs, and machine payback periods. The analysis used Excel's 'what-if' function, highlighting base case output cells and comparing changes to these outputs. The realistic and consistent results verified the BEP calculations for all scenarios, confirming that the system could handle changes in wholesale and retail prices, variable costs, fixed costs, and machine payback periods.

Wholesale and retail prices: Adjusting the wholesale and retail prices showed that BEP increased when prices were lowered and decreased when prices were increased. Wholesale prices significantly impacted the BEP, especially in the outsourcing scenario, suggesting that negotiation with retailers to raise wholesale prices could drastically lower BEP.

Variable costs: Changing the variable costs, which include direct material and indirect costs, demonstrated that increased variable costs led to higher BEP and vice versa. The impact was significant when products were sold wholesale in the new suppliers' scenario.

Fixed costs: Altering the fixed costs revealed that lowering fixed costs decreased BEP, and increasing them raised BEP. Fixed costs had a notable impact on BEP when products were sold wholesale.

Machine payback period: Extending the payback period for new machines reduced the monthly BEP, as costs were spread over a more extended period. This reduction could improve cash flow and flexibility in financial management.

Company verification: The scenario analysis was verified through a review and approval process by the company's general manager and stakeholders, who provided input variables and costs, ensuring the results were accurate and reliable.

5.1.2 Inventory Management System

White box testing: White box testing aims to evaluate the system's internal logic and performance. There are two types of white box tests: unit and integration testing. Unit testing focuses on testing individual units or components of the system in isolation to ensure they perform as expected. Integration testing checks the interaction and integration between different units or elements of the system to validate that they work together correctly.

1. **Unit testing:** Unit tests for various system features, such as adding production orders, checking raw material availability, integrating new BOMs, and monitoring real-time inventory levels, were conducted. All tests passed, verifying that individual features worked accurately.
2. **Integration testing:** Integration tests verified that different components of the inventory management system worked together seamlessly. Tests included integrating production order management with material availability checks, inventory deductions with production order management, and the inventory and production monitoring dashboard. All tests passed, ensuring accurate and cohesive system performance.

5.2 Validation

5.2.1 Scenario Analysis

Validation survey: A validation survey was conducted using Google Forms to gauge the industry partner's alignment with the final design. The survey results strongly agreed that the unit cost calculations, BEP calculations, and scenario analysis were reliable and provided valuable insights for decision-making and business expansion.

5.2.2 Inventory Management System

Black box testing: Black box testing evaluates the system's functionality and performance from a user perspective through system testing and user acceptance testing.

1. **System testing:** System testing used real-life data to replicate transactions, ensuring all features required by the company were included and thoroughly tested for functionality. The process confirmed the system's performance in real-world scenarios.
2. **User acceptance testing (UAT):** UAT ensured the system met the company's requirements and worked seamlessly. Tests included placing and managing orders, user-friendliness, dashboard insights, inventory level tracking, flexibility, and budget software. All tests passed, validating the system's readiness for future implementation.

6. CONCLUSION

The startup company on which the research project is based has an opportunity to enter the retail market. A business expansion strategy and adequate inventory management are crucial to optimising the supply chain and ensuring the company can enter the retail market soon. Three potential business expansion scenarios were considered, and a scenario analysis was conducted to aid decision-making. This analysis compared the unit cost and break-even points of these three scenarios. Furthermore, an inventory management system was designed to handle raw materials and finished goods inventories better.

In conclusion, the scenario analysis recommends investing in new machinery as the optimal expansion strategy. Implementing an inventory management system holds great potential, considering the company's current need for such a system. Correctly utilising these tools will lead to notable improvements in the startup manufacturer's supply chain.

7. LIMITATIONS AND RECOMMENDATIONS

The scenario analysis relies on data susceptible to change due to evolving economic conditions, rendering the analysis accurate only if no significant changes occur. Verification of the variables employed in the study is advisable.

The inventory management system is designed to track inventory levels and manage orders cost-effectively. Although it has a feature to verify material availability, it does not create material procurement plans. Investing in MRP software is highly recommended as production rates escalate and become more challenging to manage. It offers enhanced features such as demand forecasting, production planning, material procurement planning, and scheduling.

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