OPERATIONS MANAGEMENT

BST803 – ASSIGNMENT NO. 2
OPERATIONS ANALYSIS REPORT
SOCKS

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Word count: 1640/1500 +-10%

"I declare that this work is entirely my own and no part of it has been produced by Generative AI tools. "

Contents

Introduction

Pantherella's production was featured by BBC Inside the Factory, revealing how the organisation produces socks in a factory in the heart of Leicester (BBC, 2021). Established in 1937, the organisation possesses a USP based around authentic premium British-made socks, prioritising craftsmanship and high-quality materials (Pantherella, 2025). This report provides an operational, analytical toolkit, where section one provides a detailed overview of the company's current production processes, evaluating its current setup and advocating for potential improvements. Furthermore, it highlights control variabilities affecting the quality of the final product. Section two provides calculations based on forecasting, forecasting error and decision-making, exploring the best suitable options while considering Pantherella's values and current process capabilities.

The Process

1.1 Process Map

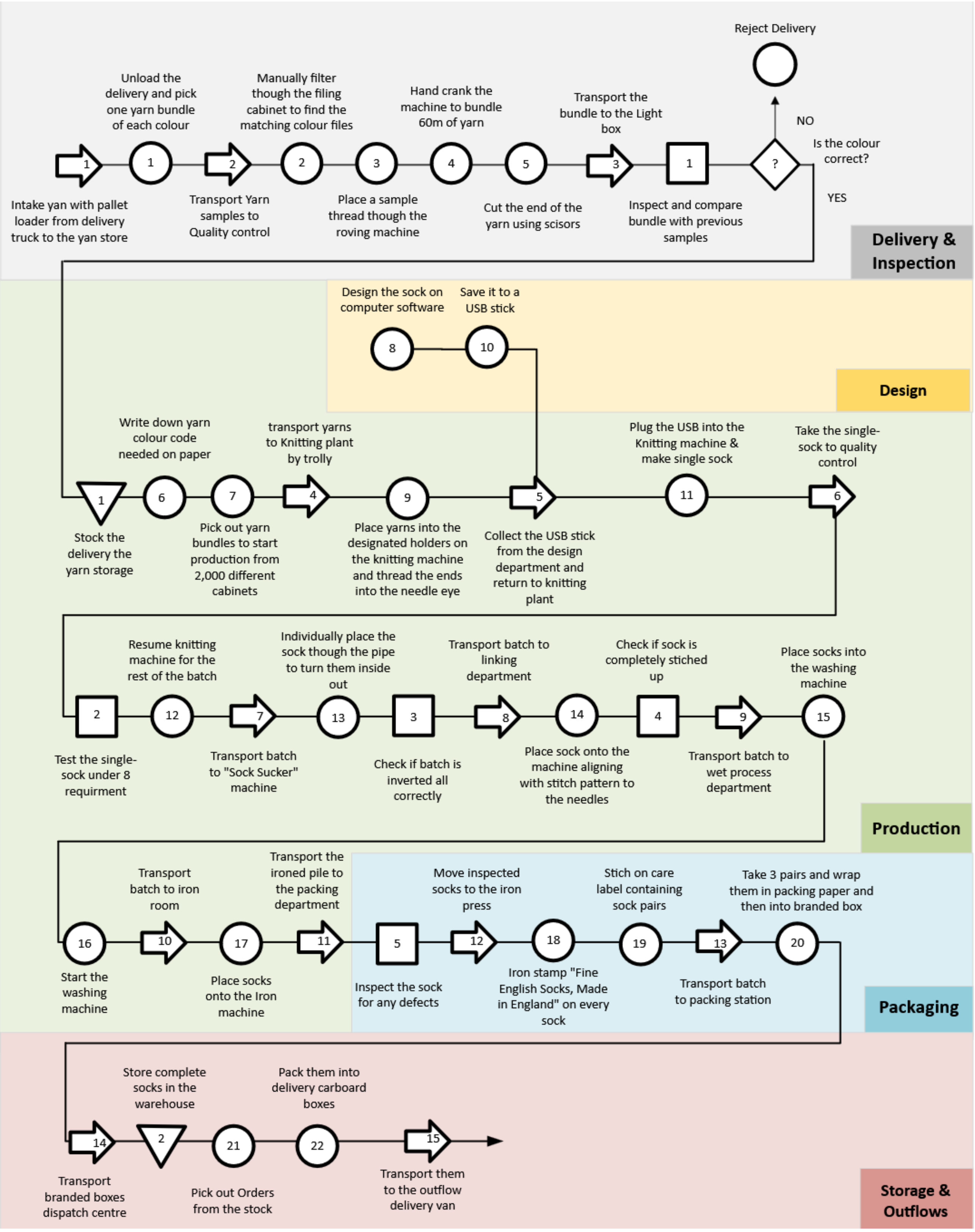

Figure 1: Initial Sock Process Map (Created using Viso)

1.2 Evaluating the Process

Changes	Processes Effected	Reason	Next Actions
Roving Process Eliminate	1 3 4 5	Set up for raw material verification is highly time-consuming, requiring individuals to set up and hand crank a roving machine for a yarn bundle sample for every colour delivered.	**Agreement with the supplier to supply yarn sample bundles within deliveries.**
Stocking and Picking Reduce	6 7	Around 2,000 different cabinets and 1km of coded shelves can be time-consuming to pick. Additionally, it reduces raw material handling variability where bundles are stored in incorrect locations.	**Investment In RFID hand-held devices and tags** Passive RFID tags = ($0.5 x 2000) = $1,000 Handheld reader = $250 Investment = $1,250
Unessary Machine Processing Eliminate	7 13 3 8 14 4	Increase investment and reliance on all-in-one machines. Eliminating the subsequent steps where skill variability plays a critical role would be beneficial.	**All-in-one machinery** 64 machines x $33,000 = $2,112,000 Long-term investment
Overproduction Reduce	2	Three million worth of stock can satisfy 4 months' worth of demand. Overproduction and overstocking lead to expensive holding costs.	**Shifting to a Make-to-Order framework for big bulk orders with high variety**

Figure 2: Process improvement summary table

A critical process in sock production is inspecting the raw material delivered by the supplier. This is done by collecting a sample of different-coloured yarns, transporting them to the quality control room, and manually preparing a 60-meter bundle of thread to compare under a light box against the colour-specific file that contains a historical record of previous deliveries (BBC, 2021). Verification of colour variability is critical as Pantherella charges a premium price (£15-£75) for a single pair of socks, and consumers expect the highest quality standards (Pantherella's, 2025). Retailers may use different lighting within stores that can give an altered appearance, not as intended, leading consumers to purchase them assuming they look a certain way, to be then disappointed when the socks are taken under different lighting, mismatching their visual expectations (Summers, 2021; Slack, 2018).

The paper-based historical record-keeping allows the possession of a valuable physical archive. However, the current process is highly time-consuming, requiring the manager to repeat the entire process for every colour ordered. This can be refined by eliminating the roving and hand-cranking of the bundles' steps, which are necessary non-value-adding processes not directly contributing to the value of the sock but are needed for the inspection (Hillier, 2021), by outsourcing the sample requirement externally to the supplier. The existing contract can be altered to provide samples within deliveries, streamlining and reducing the time needed to prepare the inspection while allowing independent colour verification.

Another refinable process is storing and selecting raw materials in the yarn storage, which holds around 30 tonnes in approximately 2,000 different cabinets stored on a kilometre of coded racking (BBC, 2021). A recommendation is to invest in handheld RFID readers that can accurately detect the correct location of the cabinet, providing the user with an optimised route (Hassan, 2012). The readers work by detecting a radio wave of corresponding RFID tags that should be located next to the cabinets, replacing the inefficient task of aimlessly walking, trying to find the correct number and providing a navigational tool that can also replace the paper process (Hassan, 2012), where the items can be ticked off on the device once the task is completed (Chatzistefanou, 2023). This is essential as it reduces the chances of errors and process variabilities within raw material handling, eliminating the possibility of accidentally writing the wrong four-digit code down or placing similarly coloured yarns in the wrong cabinets.

Such errors can affect quality as misidentified yarns may proceed to production, creating inconsistencies and defects within the final product (Slack, 2018).

Pantherella adopts a worker-paced line firstly using 64 knitting machines to create the sock base, which is later vacuumed inside out and finally to the shaping area to needle and close the toe section (BBC; 2021; Nichol, 2023; Shapiro, 2013). The initial process is conducted by machine, but subsequent stages rely heavily on skilled labour, increasing the chances of skilled variability but also enabling exceptional craftsmanship, a core value deeply rooted in Pantherella (Pantherella, 2025). Variations within quality can occur during this process as skill discrepancies and fatigue are likely to reduce the accuracy of placing the needles precisely in-between the correct thread, leading to deviations of missed threads that are difficult to identify and may lead to holes affecting the quality of the product (Slack, 2018).

In a recent blog involving the production manager Simon, the organisation announced a shift towards modern machinery designed to streamline the production stages, consolidating multiple tasks into a single effective process (Nichol, 2023). Shifting production reliance to an all-in-one machine eliminates the consequential transporting, operating, and inspection processes, reducing the sock's lead time (Hillier, 2021). Although the machines are extremely costly, around £30,000 per, they reduce the potential for human errors, providing a more consistent quality (Evans, 2014). Process variability shifts from human skill towards machine setup, and adequate training is needed for operators.

Although the packing stages are extensive, Pantherella should maintain and convey a heightened-quality appearance. A recent survey indicated that “72% of consumers consider packaging as one of the biggest influences when purchasing premium or giftable items” (Punchard, 2024). The packing processes provide direct consumer value to the final product and, therefore, will not be changed.

Pantherella holds £3 million in completed sock stock inventory, enough to meet four months of demand (BBC, 2021). Holding large inventory volumes can support the business during periods of unexpected demand. However, the current city factory location emphasises that holding costs is expensive. Stock is difficult to liquidate quickly, and enormous capital is locked up that can be used to increase investments in modern machinery (Silver, 2016). Considering the over 1,300 different seasonal options available and the relatively short 17-hour production time, it is sensible to push the decoupling point back to the beginning of the process, making large batch orders once they are confirmed, reducing the complexity of forecasting for a wide range of variations and the chances of overproduction (Bowersox, 2020; Olhager, 2003). Pantherella can maintain the production of popular sellers in a low-capacity steady-state production (Slack, 2021). However, larger orders with wide varieties should be produced once placed, minimising unnecessary storage.

1.3 Evaluations in Practice

Process	Operations	Inspection	Transport	Storage	Delays
Initial Process	22	5	15	2	0
Improved process	16	3	13	2	0
Processes Removed	**6**	**2**	**2**	**0**	**0**

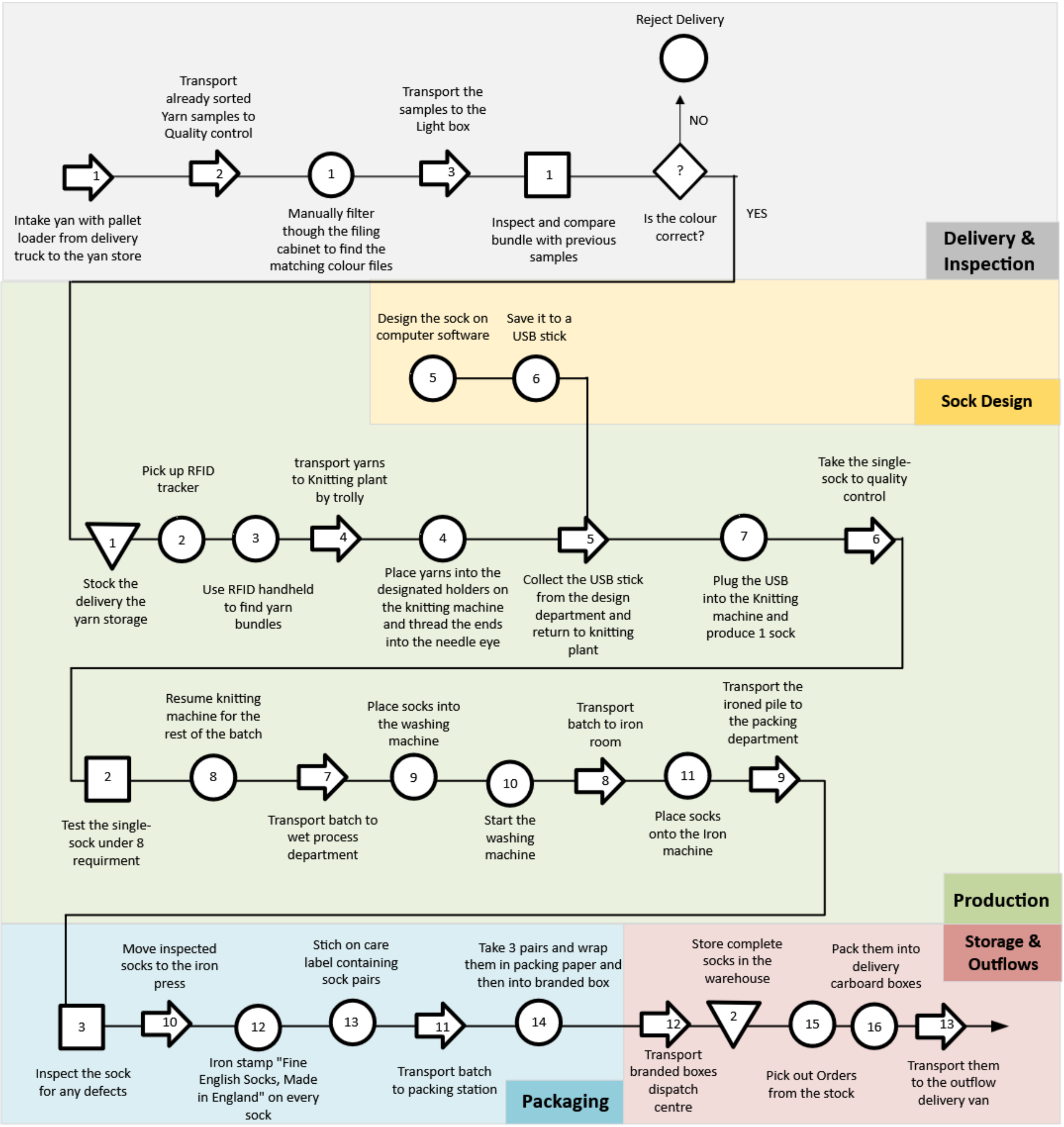

Figure 3: Improved Process Map (Created by C21084397, using Viso)

Forecasting and Decision-Making

2.1 Forecasting

Period	Number of Faulty products
Jan	30
Feb	35
March	55
April	68
May	64

Forecasting for June

Period	Naïve	Three Moving Average	SES
June	64	62.33	56.77

a. **Naïve method**

$$F_t = A_t - 1$$

$$F_t = 64$$

b. **3-period moving average**

$$F_t = \frac{A_{t-1} + A_{t-2} + A_{t-3}}{3}$$

$$F_t = \frac{64 + 68 + 55}{3}$$

$$F_t = 62.33$$

c. Exponential Smoothing with Constant of 0.4

Period	Number of Faulty products	SES
Jan	30	30
Feb	35	30
March	55	32
April	68	41.8
May	64	51.28
June	64	56.77

SES formula:

$$F_t = \alpha A_{t-1} + (1-\alpha)F_{t-1}$$

1) Jan:

$$F_1 = 30$$

2) Feb:

$$F_2 = 0.4 \times 30 + 0.6 \times 30 = 30$$

3) March:

$$F_3 = 0.4 \times 35 + 0.6 \times 30 = 32$$

4) April:

$$F_4 = 0.4 \times 55 + 0.6 \times 32 = 41.8$$

5) May:

$$F_5 = 0.4 \times 68 + 0.6 \times 41.8 = 51.28$$

6) June:

$$F_6 = 0.4 \times 64 + 0.6 \times 51.28 = 56.77$$

The most suitable method for forecasting faulty products would be the Naïve method as it places greater significance on the last periods of recorded data (Armstrong, 2001). With a gradual increase but no clear trend or seasonality traits within the data, the simple yet effective method can respond faster to erratic fluctuations caused by various factors affecting quality inconsistencies, such as their skilled workforce, quality of raw material or machine variabilities (Hyndman, 2018). By identifying the issue sooner, Pantherella can solve the problem promptly, preventing more unnecessary waste of premium sock raw materials such as cashmere and silks that can lead to significant financial losses for the company (Carvalho, 2023; Slack, 2022). If faulty products slip through the quality inspections, it could jeopardise their well-established 88-year reputation for quality socks (Pantherella, 2025).

The three-moving average and Simple exponential smoothing, which place a 60% weight on the previous month's forecast, significantly dampen the overall results (Ostertagová, 2011). Hindering the quality control teams' visibility in identifying causation factors swiftly, resulting in a delayed response.

2.2 Forecasting Accuracy

a. Old Machine

Old Machine

Month	Demand	Old Machine	Absolute Error	Squared Error	Absolute percentage error
1	592	590	|592-590| = **2**	2^2 = **4**	|592-590| / 592 = **0.34%**
2	550	562	|550-562| = **12**	12^2 = **144**	|550-562| / 550 = **2.18%**
3	565	572	|565-572| = **7**	7^2 = **49**	|565-572| / 565 = **1.24%**
4	573	570	|573-570| = **3**	3^2 = **9**	|573-570| / 573 = **0.52%**
5	590	597	|590-597| = **7**	7^2 = **49**	|590-597| /590 = **1.19%**
6	592	593	|592-593| = **1**	1^2 = **1**	|592-593| /592 = **0.17%**
Mean			**5.33**	**42.67**	**0.94%**

b. New Machine

New machine

Month	Demand	New Machine	Absolute Error	Squared Error	Absolute percentage error
1	592	595	|592-595| = **3**	3^2 = **9**	|592-595| /592 = **0.51%**
2	550	565	|550-565| = **15**	15^2 = **225**	|550-565| /550 = **2.73%**
3	565	576	|565-576| = **11**	11^2 = **121**	|565-576| /565 = **1.95%**
4	573	575	|573-575| = **2**	2^2 = **4**	|573-575| /573 = **0.35%**
5	590	594	|590-594| = **4**	4^2 = **16**	|590-594| /590 = **0.68%**
6	592	593	|592-593| = **1**	1^2 = **1**	|592-593| /592 = **0.17%**
Mean			**6**	**62.67**	**1.07%**

c. Summary Table

Error Summary Table

Machine	MAE	MSE	MAPE
Old	**5.33**	**42.67**	**0.94%**
New	**6**	**62.67**	**1.07%**

Based on the calculations, the old machine should be chosen as it exhibits smaller forecasting errors (Hillier, 2021). A smaller forecasting error in this situation suggests that the old machine is better at aligning performance to Pantherella's current demand, which is critical to minimise the chances of overproducing or underproducing. Producing excess inventory would elevate their already £3 million worth of stock and lead to unnecessary holding costs. Additionally, their more than 1,300 designs risk unsold variations, which may be difficult to liquidate. On the other hand, underproducing fails to meet demand, leading to stockouts that would consequentially impact customer service levels and undermine Pantherella's brand reputation for customer satisfaction (Pantherella, 2023).

While the new machine may perform at a better standard and offer additional modern features, its current performance is less in line with Pantherella's current needs. If demand exceeds the old machine's output capabilities, a re-evaluation is needed to justify the additional £30,000 purchasing cost for the new machine.

2.3 Decision-Making

Payoff Table

	Good	Medium	Poor
Design A	100	20	20
Design B	70	50	-40
Design C	90	40	-20

Regret Matrix

-	Good	Medium	Poor
Design A	100-(100) = 0	50- (20) = 30	20 - (20) = 0
Design B	100 - (70) = 30	50 - (50) = 0	20 - (-40) =60
Design C	100 - (80) = 10	50 - (40) = 10	20 - (-20) = 40

Design A	Max (0,30,0) = 30	Min (30,60,40) = 30
Design B	Max (30,0,60) = 60	
Design C	Max (10,10,40) = 40	

Based on the calculations, design A (30) should be selected, as it possesses the smallest possible regret in the worst-case scenario. Minimax is appropriate for Pantherella as changing the process requires substantial capital and resource investments. It ensures that even in the worst-case scenario, the company will face the smallest possible loss relative to the best outcome possible (Anderson, 2023).

A risk-averse mindset minimises the chances of potential consequences if Pantherella faces undesirable outcomes (Hillier, 2021). This is particularly important as Pantherella relies on skilled employees, and the factory city location indicates high operational costs. Minimax reduces the chances of facing higher-than-intended risk levels that could lead to financial difficulties and potential employee layoffs, an extremely difficult decision due to employees possessing specific skills while having a deep-rooted generational heritage (Pantherella, 2025). Additionally, process redesign for socks may require investing in specialised customised machinery that is extremely expensive, which, in undesirable outcomes, will be challenging to resell onto second-hand markets or forced to sell for scrap value, regretting and losing significant capital (Vranakis, 2012).

Conclusion

To conclude, this report provides an in-depth look into the production processes of Pantherella's socks alongside interpreted forecasting and decision-making calculations. By analysing their current operational processes, it was evident that the organisation possesses inefficiencies, notably the initial inspection process, inventory control management, reliance on skilled labour, and outdated machinery. Recommendations include outsourcing the raw material samples, implementing an RFID handheld device, increasing investments into all-in-one machinery and rethinking how the organisation could reduce the quantity of stocked finished goods. Within section two, the Naïve method is best for forecasting faulty products, as it places a greater significance on the last actual demand period. The old machine should also be chosen due to it being better in line with current demand patterns, and lastly, design A as it minimises potential regret.

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Appendix

All tables, graphs and cover page created by writer (C21084397)

Calculations were created from LatTeX and screenshotted

Process for sock production: Working out

Title:	Sock Production	Completed by:	Mustafa Abduljabbar
	"As is" ☒ "As should be" ☐ "As could be" ☐	Date:	9th January

#	**Task Description**	Time Units	Distance Units	Operation	Inspection	Transport	Storage	Delay	VA	NNVA	NVA	Key
				○	□	⇦	▽	D				Notes
1	Intake bay of 800 kilos of yarn, with pallet loader into the Yarn Store	60m				✓				✓		Shipment is dropped off at the side of a residential road and must be squeezed through a small door.
2	Hand-pick the selection of colours from the delivery			✓							✓	
3	Take samples to quality control					✓				✓		
4	Filter through the filing cabinet to find the correct colour file.			✓						✓		
5	Place the tread on the roving machine.			✓						✓		
6	Hand cranks the roving machine to rove 60m of thread.			✓						✓		Easier to visualise the colour if it's in a bundle
7	Cut the end of the thread with Scissors.			✓						✓		
8	Take the bundle and place it in the light cabinet.					✓				✓		
9	Inspect the yarn bundle under 3 different lighting settings and compare it with previous records.				✓					✓		
10	Store the rest of the intake from earlier into separate filing cabinets.						✓			✓		Capacity 30 tonnes
11	Write the colour codes of yarns needed on paper			✓						✓		

12	Find the correct colours to start production from 2000 different filing cabinets.	30m	1km of coded racking	✓						✓		Yarn colour code is on paper. 1:30hrs in
13	Transport the collection of yarns to the Knitting Plant.					✓				✓		
14	Place the yarns into the machine and thread the end into the allocated needle eye.	20m		✓					✓			70% cotton, 30% Nylon
15	In the design department, design the sock on a computer			✓					✓			Process in parallel
16	Save the design code on a USB			✓						✓		
17	Transport the USB stick from the design department back to the knitting plant.					✓				✓		
18	Place the USB stick into the knitting machine and press the start button. Only produce 1st sock.			✓					✓			Created in Batches 120 socks in 10hrs 1 sock = 5 mins
19	Transport the 1st sock to quality control.					✓				✓		
20	Inspect the sock for correct design strength and size requirements.				✓					✓		8 different tests
21	Resume production on the knitting machine of the rest of the 119 socks	10hrs		✓					✓			13:40hrs time stamp
22	Transport the batch of socks to "Sock Sucker"					✓				✓		Socks have to be
23	Place the top end of the sock along the machine individually. A vacuum will pull them inverted.			✓						✓		Socks have to be inside out for the next process. Capacity 20 socks a min
24	Check if all socks are inverted properly.				✓					✓		
25	Transport batch to toe linking department					✓				✓		
26	Place the sock onto the machine while aligning the needles with the stitch pattern	90min		✓					✓			The process is very technical. If a stitch is missed, a whole will be left.
27	Inspect if the sock is completely stitched up.				✓					✓		15: 46 in
28	Transport the batch to the Wet process department.					✓				✓		
29	Place the socks into the washing machine.			✓					✓			Soften the fabric for a nice finish.
30	Press the start button to start the washing machine.	3m		✓						✓		
31	Transport the batch to the ironing room.					✓				✓		
32	Place the socks levelled on the moving ironing machine.			✓					✓			The machine takes the socks, irons them and lays them into
33	Transport the piles of socks to the packing department.					✓				✓		Time 16:13hrs
34	Inspect the sock for quality/ deformities.				✓					✓		Checking every sock heals and toe for any holes – 120 per hr.
35	Take the batch to the iron press.					✓				✓		

36	Iron a stamp on each pair.			✓					✓			“Fine English Socks, Made in England”
37	Stich on the care label for each pair			✓					✓			
38	Transport the batch to the packing station.					✓				✓		
39	Take 3 pairs, wrap them together in paper and place them into a branded box	20 mins		✓					✓			
40	Transport the now boxed-up socks to the Dispatch location.					✓				✓		
41	Store the complete sock in the warehouse.						✓				✓	
42	Once an order is placed, pick the socks and place them into a basket			✓						✓		
43	Place them into the cardboard box for final packaging			✓					✓			
44	Transport boxes into the van					✓				✓		
	Totals:	17:18hrs		22	5	15	2	0	11	31	2	Tv Viewer perspective
		Percentages %:		50%	11%	34%	5%	0%	25%	70%	5%%	

Improved Process for Sock Production: Working out

Title:	Sock Production (IMPROVED)	Completed by:	Mustafa Abduljabbar
	“As is” ☒ “As should be” ☐ “As could be” ☐	Date:	9th January

#	**Task Description**	Time Units Min	Distance Units	Operation ○	Inspection □	Transport ⇦	Storage ▽	Delay D	VA	NNVA	NVA	Key Notes
1	Intake bay of 800 kilos of yarn, with pallet loader into the Yarn Store					✓				✓		Shipment is dropped off at the side of a residential road and must be squeezed through a small door.
2	Take already sorted samples to quality control					✓				✓		
3	Filter through the filing cabinet to find the correct colour file.			✓						✓		
4	Take the bundle and place it in the light cabinet.					✓				✓		
5	Inspect the yarn bundle under 3 different lighting settings and compare it with previous records.				✓					✓		
6	Store the rest of the intake from earlier into separate filing cabinets.						✓			✓		Capacity 30 tonnes
7	Pick up a Handheld RFID reader			✓						✓		
8	Find the correct colours with RFID navigational tool		1km of coded racking	✓						✓		
9	Transport the collection of yarns to the Knitting Plant.					✓				✓		

10	Place the yarns into the machine and thread the end into the allocated needle eye.			✓					✓			70% cotton, 30% Nylon
11	In the design department, design the sock on a computer			✓					✓			Process in parallel
12	Save the design code on a USB			✓						✓		
13	Transport the USB stick from the design department back to the knitting plant.					✓				✓		
14	Place the USB stick into the knitting machine and press the start button. Only produce 1st sock.			✓					✓			Created in Batches 120 socks in 10hrs 1 sock = 5 mins
15	Transport the 1st sock to quality control.					✓				✓		
16	Inspect the sock for correct design strength and size requirements.				✓					✓		8 different tests
17	Resume production on the knitting machine of the rest of the 119 socks			✓					✓			13:40hrs time stamp
18	Transport the batch to the Wet process department.					✓				✓		
19	Place the socks into the washing machine.			✓					✓			Soften the fabric for a nice finish.
20	Press the start button to start the washing machine.			✓						✓		
21	Transport the batch to the ironing room.					✓				✓		
22	Place the socks levelled on the moving ironing machine.			✓					✓			The machine takes the socks, irons them and lays them into
23	Transport the piles of socks to the packing department.					✓				✓		Time 16:13hrs
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25	Take the batch to the iron press.					✓				✓		
26	Iron a stamp on each pair.			✓					✓			“Fine English Socks, Made in England”
28	Stich on the care label for each pair			✓					✓			
29	Transport the batch to the packing station.					✓				✓		
30	Take 3 pairs, wrap them together in paper and place them into a branded box			✓					✓			
31	Transport the now boxed-up socks to the Dispatch location.					✓				✓		
32	Store the complete sock in the warehouse.						✓				✓	
33	Once an order is placed, pick the socks and place them into a basket			✓						✓		
34	Place them into the cardboard box for final packaging			✓					✓			
35	Transport boxes into the van					✓				✓		

Totals:	17:18hrs		16	3	13	2	0	10	23	1	Tv Viewer perspective
	Percentages %:		47%	9%	38%	6%	0%	29%	67%	3%	