PART 1

AutonomousShipment with Last Leg Logistics for Delivery Trial

Making all the products available at doorsteps is very demanding in today's world, and this demand will be satisfied by "AutonomousShipment" with their autonomous robots in partnership with Last Leg Logistics. This report will provide a way so that AutonomousShipment can make important decisions for the trial to be rolled out.

Executive Summary

- AutonomousShipment, with a budget of GBP 250,000, will initiate month-long delivery trials from stores such as groceries, clothing, sports, and tech stores in the Leeds area utilizing prototype robots for doorstep deliveries.
- It is anticipated that the system will benefit customers with expedited delivery and the company by optimising cost efficiencies.
- By delving into the analysis of key components, such as robots and stores, it has been determined that 30 DSXX-deviant robots will be deployed, making them a great fit for the company's overarching goals and objectives.

Robot information

<u>The four prototype robots are:</u>

1. Robot A032 – Archer

2. Robot B23 – Bowler

3. Robot CJKL – Corner

4. Robot DSXX – Deviant

<u>Criteria for selection</u>

1. Carrying Capacity – litres

2. Battery Size – hours

3. Average Speed – km/hr

4. Cost per unit – GBP

5. Reliability – Estimate average time between instances of breakdown in hours.

<u>Importance of criteria</u>

Reliability > Cost Per Unit > Battery Size > Average Speed > Carrying Capacity

Store information

The below details include the number of orders to deliver per day per robot, followed by the operating cost and the technical staff per week.

1) Grocery Store

    9 orders

    1600 GBP per month

    10 technical staff

2) Clothing Store

    6 orders

    1000 GBP per month

    7 technical staff

3) Sport Equipment Store

    4 orders

    600 GBP per month

    5 technical staff

Constraints and Goals

- At least 5 robots per store
- Maximum orders per day
- Limited man hours of 250 per week in total
- Total robots within the trial budget

Solution

1. Robot choice

The goal is to select a robot from the four potential prototypes based on the importance of criteria set out by the management team. Table 1.1 outlines the data of criteria for each robot.

	Carrying capacity	Battery	Average Speed	Cost	Reliability
Weight	0.067	0.2	0.133	0.267	0.333
Archer	45	18	6	5210	22
Bowler	50	18	4	6250	24
Corner	60	12	4	4500	24
Deviant	40	24	10	7100	32

Table 1.1: Data for each robot's criteria

The criteria depicted in the table do not exhibit a linear relationship with one another, and hence, the choice is determined by the Multi Criteria Decision Analysis method of TOPSIS (Technique for Order of Preference by Similarity to Ideal Solution). The alternative with the least distance to the positive ideal solution (PIS) and the furthest distance to the negative ideal solution (NIS) is considered optimal. The PIS is the best possible solution, while the NIS is the worst possible solution. The weights in Table 1.1 (highlighted) are assumed based on the significance determined by the management team, denoting the percentage of importance for each criterion, from qualitative to quantitative. Upon assessing the weights and importance designated by the management team, the most important criterion for choosing the robot is its reliability.

TOPSIS facilitates a comprehensive evaluation of the quantitative approach to decision-making for each alternative robot. NIS and PIS are calculated based on the weights and criteria for each alternative robot using normalisation techniques and, accordingly, computing the final value, representing the score for each robot. The numerical score streamlines the decision-making process, with the robot attaining the highest score being the chosen one.

The table below illustrates the distances computed using the Euclidean formula between each alternative to the NIS and PIS.

Prototype robot	NIS	PIS
Archer	0.057843923	0.085278862
Bowler	0.040519948	0.095668415
Corner	0.062228886	0.103291008
Deviant	0.110316752	0.060874328

Table 1.2: NIS and PIS of each

The red and green highlighted alternatives signify the best and worst options. The chart below displays the score for each robot alternative, calculated as NIS/(NIS+PIS).

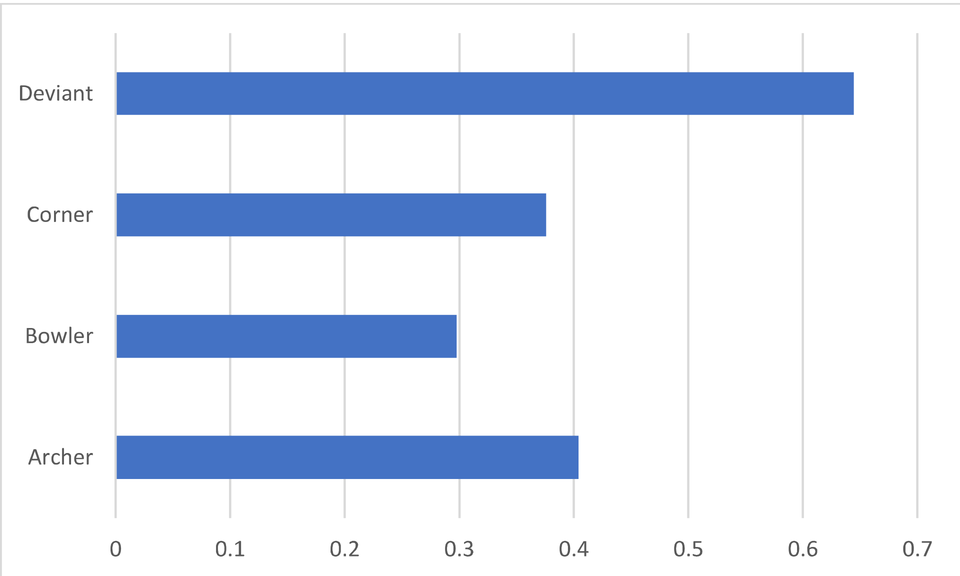

Figure 1.1: Bar chart representing the scores of all the robots.

As depicted in Figure 1.1 Robot DSXX – Deviant has scored the highest, solidifying its position as the most optimal choice aligning with the management team's priorities. Moreover, a comprehensive examination of Table 1.1 reveals that Robot DSXX – Deviant exhibits superior performance across multiple criteria.

2. Allocation of robots at different locations

The allocation of robots at various locations is essential, given the budget constraint of GBP 250,000. The primary objective is to allocate a fixed number of DSXX – Deviant robots across different stores.

In addressing the multiple objectives, goal programming is employed. This technique utilizes mathematical optimization, well-suited for solving complex decision-making problems with conflicting goals. It allows considering trade-offs between different objectives and finding a balanced solution.

Let x_1, x_2, x_3 represent the number of Deviant robots allocated for grocery, clothing, and sports equipment stores, respectively.

$9x_1 + 6x_2 + 4x_3 = 95$ …………………………………………………………………………….. (1)

$(7100 + 1600)\, x_1 + (7100 + 1000)\, x_2 + (7100 + 600)\, x_3 = 250000$ ……………………………….. (2)

$10x_1 + 7x_2 + 5x_3 = 250$ …………………………………………………………………………….. (3)

LHS and RHS:

Equation (1)

The goal is to maximize daily orders for all the stores by allocating a certain number of Deviant robots to each store. LHS has the minimum orders for each location multiplied by the number of robots. Whereas RHS is set to 95, calculated as the minimum of 5 robots for each location, resulting in 95 orders completed each day.

Equation (2)

The goal is to equate LHS to RHS, considering the trial budget of GBP 250,000 as the RHS. The LHS contains values representing the operational cost per robot, including the cost per unit of Deviant robot (GBP 7100) multiplied by the number of robots.

Equation (3)

The goal is to minimize or equalize LHS to RHS since there are only 250 technician man hours per week indicated as the RHS. LHS has the number of technician man hours available for each store multiplied by the number of robots.

These three equations are employed in goal programming to determine the optimal values of x_1, x_2, x_3. The below table gives an overview of how the variables (number of robots) were derived.

Goals	x_1	x_2	x_3	d_{1+}	d_{1-}	d_{2+}	d_{2-}	d_{3+}	d_{3-}	LHS	RHS
Orders	9	6	4	-1	1					215	95
Budget	8700	8100	7700			-1	1			250000	250000
Technician	10	7	5					-1	1	245	250
Lower limit	5	5	5	0	0	0	0	0	0		
Decision variable	17	5	8	0	0	0	0	0	0		
									objective function:		0

Table 2.1: Calculations for Goal programming

Goal programming incorporates deviation variables (d_{1+}, d_{1-}, d_{2+}, d_{2-}, d_{3+}, d_{3-}) for objectives 1, 2, and 3 as addressing conflicting goals. These variables, such as d_{1+}, d_{1-}, signify positive and negative deviations, indicating whether the actual achievement surpasses or falls short of the target level. Here, the deviational variables have yielded 0 deviations as the constraints are fulfilled for all three objectives (equations). The target level is the

RHS, while the actual achievement is denoted by the LHS. The goal is to minimize the objective function, which is the sum of all the deviational variables. The lower limit is 5 robots per store, while the decision variables are the actual achievement variables obtained after solving the goal programming problem.

The optimal allocation suggests 17 Deviant robots for grocery stores, 5 for clothing stores, and 8 for sports equipment stores. This represents the optimal solution, as it fully utilizes the GBP 250,000 budget. Consequently, the robots will deliver 215 orders per day with only 245 hours of technician labour per week.

The below pie chart illustrates the cost distribution across stores.

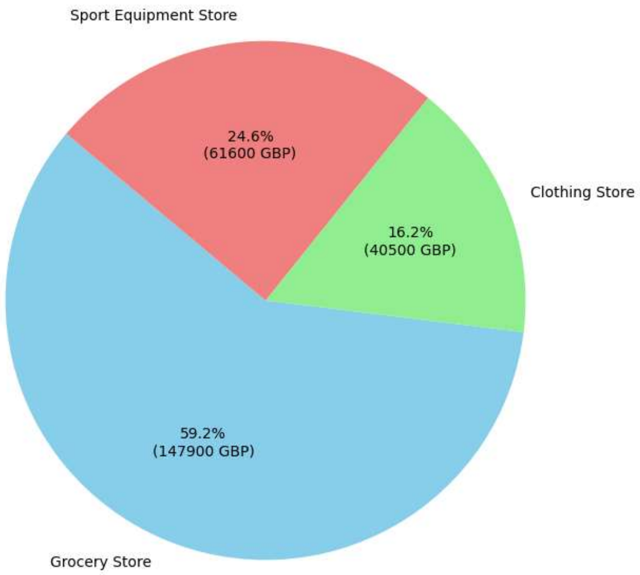

Figure 2.1: Pie chart representing the cost distribution for each store.

The number of robots obtained is optimal, particularly for the grocery store, which has the highest daily order volume. This aligns with the trial's goal of maximizing as many orders as possible per day. Moreover, the solution adheres to the trial's budgetary constraints. Additionally, the allocation considers the availability of technician hours without exceeding the constraints. This solution not only aligns with the overarching trial goals but also underscores considerations of operational efficiency and cost-effectiveness and fulfils the specified constraints.

Conclusion

To operate the trial of doorstep delivery services in the Leeds area, the company needs to invest in 30 DSXX – Deviant robots, which provide high reliability, better battery, and speed. Despite the relatively higher cost per unit, these are the best choice for fast and higher deliveries per day, benefiting the company and the customers too, gradually mitigating concerns about the higher cost per unit. The anticipated success of the trial while staying within the budget and achieving satisfactory results for all goals. Substantial demand for groceries, ensuring maximum orders will be delivered per day, will stimulate an increase in orders creating a positive feedback loop, making a great profit for AutonomousShipment and Last Leg Logistics. With this solution, we can ensure a profitable and sustainable venture and capitalize on the growing market.