Autonomous Shipment roll-out

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Table of Contents

1. Executive Summary **3**

2. Introduction to Business Problem **4**

3. Prototype Robot Selection **4**

3.1 Criteria & Requirements 5

3.2 Comparative Analysis 6

3.3 Complete Analysis using MCDA method 6-7

3.4 Sensitivity Analysis 7

3.5 Summary 7

4. Robots Allocation Strategy Across Stores **8**

4.1 Trial Objectives and Constraints 8

4.2 Allocation Plan 8-10

4.3 Summary 10

5. Results and Findings **10**

PART I: Autonomous Shipment roll-out: autonomous delivery trial

1. Executive Summary:

1. Purpose and Importance of the Trial Rollout:
    - To check **feasibility** and **scalability** of the project.
    - To optimize the model for **profitability**.
    - To find the best prototype robot for the trial rollout.
    - To find the **number of robots** to allocate for each store for this trial.
2. Objectives of the report:
    - To recommend business solutions for the problem.
    - To explain the methods used for analysing.
    - To validate and justify the choices for methods used.
    - To align the recommendations with the optimum solutions for business problem with justification.
    - To provide insights to management for better decision making assisted and backed by data.
3. Major Highlights:
    - Selected prototype robot: "**Deviant**"
    - Allocation strategy:

ROBOT: DEVIANT	Allocated Robots	No. of orders /- day
Grocery Store	19	171
Clothing Store	5	30
Sport Store	5	20
Total	**29**	**221**

    - Expected outcomes:
        - Total of **29** deviant robots are to be allocated.
        - In this solution we save **5700 GBP**.

2. Introduction to Business Problem:

In this trial, Autonomous Shipment is willing to optimize its use of autonomous robot drones while considering customer experience, cost-efficiency, market expansion, and stakeholder commitments.

1. Aim is to assess the **practicality and reliability** of this technology in a live environment.
2. The use of autonomous drones could lead to quicker deliveries, thereby meeting consumer expectations for rapid shipping enhancing **Customer Experience.**
3. Automation could potentially **reduce operational costs** associated with final-mile delivery, making it more **efficient and cost-effective**.
4. By partnering with various stores and covering a diverse range of products the trial aims to penetrate different market segments, provide an opportunity to understand customer preferences across various domains.
5. The trial also aims to fulfil the commitments to investors and the UK government by showcasing progress in innovative logistics technologies and securing potential future funding or support for other innovative projects.

3. Prototype Robot Selection

3.1 Criteria & Requirements:

Types of robot prototype to:

Model	Name
Robot A032	Archer
Robot B23	Bowler
Robot CJKL	Corner
Robot DSXX	Deviant

Criteria according to the management:

Criteria	Units	Aim
Carry Capacity	Litres	Maximize
Battery Size	Hours	Maximize
Average Speed	Km/h	Maximize
Cost per Unit	GBP	Minimize
Reliablity	Hours	Maximize

Reliability > Cost per Unit > Battery Size > Avg. Speed > Carrying

Using Battery Size score 3/5 as base we calculated scores for other criteria.

1. The figure explains the reliability as most important criteria amongst all with a score of 5 and contributional weight ratio of **0.33**.
2. Following reliability management feels cost per unit is also important and scores 4 with a weight ratio of 0.27.
3. Battery size comes out a third with a weight ratio of 0.20 and a score of 3.
4. Speed is not important therefore comes at fourth place with a score of 2 and weight ratio of 0.13.
5. Least important factor is Carrying Capacity with a score of 1 and weight ratio of 0.07.

The following excel provide information on the importance of each criteria as set by the management team.		SCORE	Normalization Table
CRITERIA	CALCULATION OF WEIGHTS : NORMALIZATION	Out of 5	Weight Ratio
Carrying Capacity	The carrying capacity is the least important criteria according to the majority of the management team.	1	0.07
Battery Size	After careful deliberation, the size of the battery is 3 out 5 stars important according the majority of the board. They believe that it is an important criteria but not as important as some others and that this would likely improved with better battery tech in the future anyway.	3	0.20
Average Speed	The speed is not as important as battery size but more important than carrying capacity.	2	0.13
Cost per Unit	The cost is more important that any other criteria except for the reliability. One of the management team considered it to be at least 25% of total consideration amongst all criteria.	4	0.27
Reliability	This is the most important consideration according to the management team and this is clearly favoured over all other criterias.	5	0.33
	TOTAL	15	1.00

3.2 Comparative Analysis:

- Below is a comparison of the four prototype robots against the established criteria.

	Robot_Prototype	Archer	Bowler	Corner	Deviant
1	Carrying Capacity	45	50	60	40
2	Battery Size	18	18	12	24
3	Average Speed	6	4	4	10
4	Cost Per Unit	5210	6250	4500	7100
5	Reliability	22	24	24	32

- Corner has the best Carrying Capacity.
- Deviant has the best Battery Size.
- Deviant has the best Average Speed.
- Corner has the least Cost per Unit.
- Deviant has the best Reliability.

3.3 Complete Analysis using MCDA method:

NOTE: All analysis is being performed in R Studio.

Reasons for choosing TOPSIS:

- Does complete evaluation of options, considering both the positive and negative aspects.
- It allows for flexible weight assignment to criteria.
- We can optimize the result as it can handle both benefit and cost criteria in the same analysis.
- Compares choices based on their proximity to the ideal solution for benefit criteria and their distance from the negative-ideal solution for cost criteria., (Aritad Alan Choicharoo et al, 2023)

As our business problem and variables aligns with the requirements of TOPSIS so TOPSIS is chosen for the analysis.

Following are some insights done while coding in R.

1. Performance Table is an important requirement for using the TOPSIS function in R. There have been multiple manipulations done to make the data in the required format. Below is the Performance table in the required format.

	Carrying Capacity	Battery Size	Average Speed	Cost Per Unit	Reliability
Archer	45	18	6	5210	22
Bowler	50	18	4	6250	24
Corner	60	12	4	4500	24
Deviant	40	24	10	7100	32

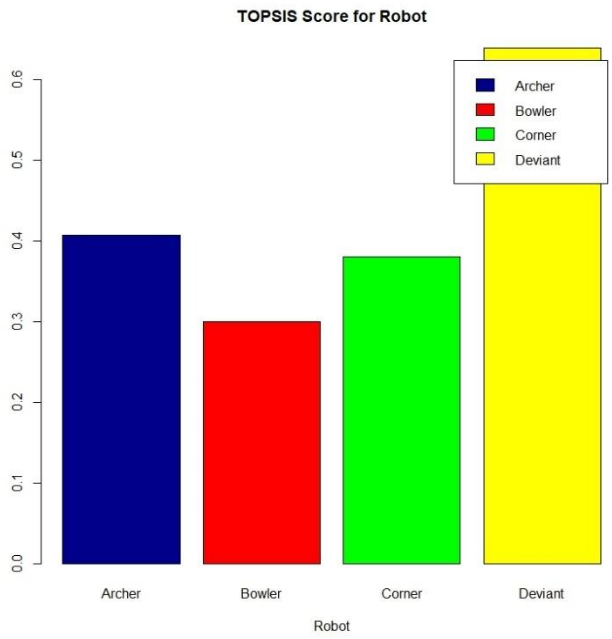
2. Next is to add weights and criteria vectors. This must be done in a certain format to ensure the functionality of TOPSIS.

```
> weights
Carrying Capacity      Battery Size     Average Speed     Cost Per Unit       Reliability
             0.07              0.20              0.13              0.27              0.33
> criteriaMinMax
Carrying Capacity      Battery Size     Average Speed     Cost Per Unit       Reliability
            "max"             "max"             "max"             "min"             "max"
```

3. Here down below is the result of the analysis. Robot prototype **"DEVIANT"** comes out on the top with the score of 0.639 which is superior to others.

```
> # TOPSIS Function
> overall1 <- TOPSIS(performanceTable, weights, criteriaMinMax)
> overall1
   Archer    Bowler    Corner   Deviant
0.4072789 0.3001903 0.3811823 0.6391262
```

4. Bar plot down below provides a visual clarification how **"DEVIANT"** seems to be the best possible solution.



3.4 Sensitivity Analysis:

With multiple iterations of sensitivity analysis (i.e. by some intentional alteration in weights).

Criteria	Carry Capacity	Battery Size	Average Speed	Cost per Unit	Reliablity
Weights	0.09	0.19	0.12	0.25	0.35

In this case, Deviant comes out at top with a score of 0.647.

3.4 Summary:

- After the TOPSIS analysis "Deviant" comes out at the top with a TOPSIS score of **0.693.**

Deviant	
Carry Capacity	40 Litres
Battery Size	24 Hours
Average Speed	10 Km/h
Cost per Unit	7100 GBP
Reliablity	32 Hours

4. Robots Allocation Strategy Across Stores:

4.1 Trial Objectives and Constraints:

- Objective
  - Is to find a right number of robots to allocate for the trial.
  - Maximize the number of orders in a day.
- Constraints
  - Each store must have at least **5** robots during the trial.
  - The total number of technician staff hours available to support this trial is **250** hours per week.
  - The cost of operation and acquisition must not be more than the budget **(2,50,000 GBP).**

4.2 Allocation Plan:

Goal Programming: Goal programming (GP) is a method for dealing with several objective decision-making problems. Linear goal programming has evolved based on the Dantzig, Charnes et al., Lee, Ignizio and many others have been instrumental in the development of various algorithms of linear goal programming. (Orumie et al, 2013)

Reason for choosing Goal Programming:

- For the task non-pre-emptive model seems appropriate.
- All the goals are of comparably equal importance.
- In a non-pre-emptive model the constraints have certain upper and lower limits if the solution is within those limits, it is considered optimal.
- Goal Programming can simultaneously consider several objectives and provide an optimal solution which can help achieve the desired goal.
- Goal programming can help us when we have multiple restrictions from which we want to deviate as little as possible.

Following are the steps for **Goal Programming**.

  - **"goalp"** is an R package for linear goal programming. It allows solving basic, weighted, and lexicographic linear goal programming problems, as well as a mixture of the weighted and lexicographic approaches. (Arun Gyawali et al, 2012)

- Next is to set the equations. This is the most important step while programming. Making equations using the conditions and constraints available from the management team.

- To understand how to make the equations let's look at the table below. Normalise the given data for a month.

Basic data given

	Grocery Store	Clothing Store	Sports Store
No. of Orders per day	9	6	4
Operating Cost per month	1600	1000	600
Staff Hours per week	10	7	5

Normalising for a month.

	Grocery Store	Clothing Store	Sports Store
No. of Orders per month	252	168	112
Operating Cost per month	1600	1000	600
Staff Hours per month	40	28	20

Adding Robot Cost: Deviant (7100 GBP)

	Grocery Store(x1)	Clothing Store(x2)	Sports Store(x3)
No. of Orders per month	252	168	112
Robot Cost+ Operating Cost per month	8700	8100	7700
Staff Hours per month	40	28	20

- Evidently equations come out to be:
  - **Man Hours:** 40*x1 + 28*x2 + 20*x3 = 1000
  - **Spend:** 8700*x1 + 8100*x2 + 7700*x3 <= 250000
  - **Orders:** 252*x1 + 168*x2 + 112*x3 >= 2660

- 5 robots must be allocated to each store. x1, x2 and x3 has minimum values of 5.

Variables	No. of Robots
x1	>=5
x2	>=5
x3	>=5

- Running Solver yields the optimal solution for all the given constraints shown in Figure below.

```
Problem formulation:
Man Hours : 40*x1 + 28*x2 + 20*x3 = 1000 | 1 1 | 1# 1#
spend : 8700*x1 + 8100*x2 + 7700*x3 ≤ 250000 | 0 1 | Inf# 1#
orders : 252*x1 + 168*x2 + 112*x3 ≥ 2660 | 1 0 | 1# Inf#
x1 lBound 5
x2 lBound 5
x3 lBound 5
```

```
Objective function value: 0

Solution:
   value    type
x1    19 integer
x2     5 integer
x3     5 integer
```

```
Deviations:
             d-    d+ w- w+  p-  p+
Man Hours     0     0  1  1   1   1
spend      5700     0  0  1 Inf   1
orders        0  3528  1  0   1 Inf
x1_lBound    NA    14 NA  0  NA Inf
x2_lBound    NA     0 NA  0  NA Inf
x3_lBound    NA     0 NA  0  NA Inf
```

- Here d- signifies negative deviation and d+ signifies positive deviation.
- As objective value function is 0 so all the constraints are satisfied with this solution. Because in goal programming it accounts for deviations from the desired targets for each of these goals.

4.3 Summary:

- A positive deviation of **14 robots** can be seen for x1(No. of robots for Clothing Store).
- There's a negative deviation of **5700 GBP** in spending.
- Orders shows a positive deviation of **3528** orders in a month.

5. Results and Findings:

5.1 Robot Selection Findings:

- After the TOPSIS analysis "Deviant" comes out at the top.
- With a TOPSIS score of **0.639** "Deviant" fits the ideal solution proximity better.
- "Deviant" reliability score of **32** and battery size of **24** Deviant outscores the other prototypes and fits criteria constraints the best.

5.2 Allocation Strategy Findings:

- With Goal Programming we found optimum number of robots to be used are **29**.
- Out of total of **29** deviant robots, **19** would be allotted to Grocery Store, **5** to Clothing Store, **5** to Sports Store.
- In this solution we save **5700 GBP**.
- Results shows **221** orders a day i.e. **171** orders a day for Grocery Store, **30** orders a day for clothing Store and **20** orders a day for Sports Store.