Problem: AutonomousShipment roll-out: autonomous delivery trial.

Introduction to Problem Statement

AutonomousShipment aims to revolutionise the delivery mechanism of different products using robot drones to conduct last-leg logistics and deliver products to customers' doorsteps. The company aspires to execute fast deliveries, cut operational costs, and optimise the product delivery system.

For this purpose, four different drone models have been developed, each with different specifications and capabilities. These drones can then be stationed at different stores for making deliveries from respective stores to customers.

For validating the research and development for this approach, a month-long trial is being conducted which will be focussed on maximising coverage of customers across different store types. For the trial to be successful it needs to cover all the objectives and This report outlines key decisions that are essential for the trial's success.

Decision 1: Choosing the best prototype robot for maximum utility from the four options available based on their "carrying capacity, Battery Size, Average Speed, Cost per Unit, and Reliability".

Decision 2: How to allocate the selected robot prototype across different stores for examining and comprehending the functionality and practicalities of using robots for deliveries.

This trial serves as a crucial phase to test and refine the autonomous delivery system and these decisions will significantly impact the trial's success and provide valuable insight into the robot's compatibility and readiness for the real world.

Decision 1: Choosing the Robot Variant

Picking the most efficient robot for the trial is of severe importance and extremely vital for the success of the trial. The robot prototypes along with their specifications are displayed in Table-1:

Robot Prototype	Archer	Bowler	Corner	Deviant
Robot Code	Robot A032	Robot B23	Robot CJKL	Robot DSXX
Carrying Capacity **(Litres)**	45	50	60	40
Battery Size **(Operational Hours)**	18	18	12	24
Average Speed **(km/hr)**	6	4	4	10
Cost Per Unit **(GBP)**	5210	6250	4500	7100
Reliability **(Hours) (Estimated Average time between an Instance of Breakdown)**	22	24	24	32

Table 1

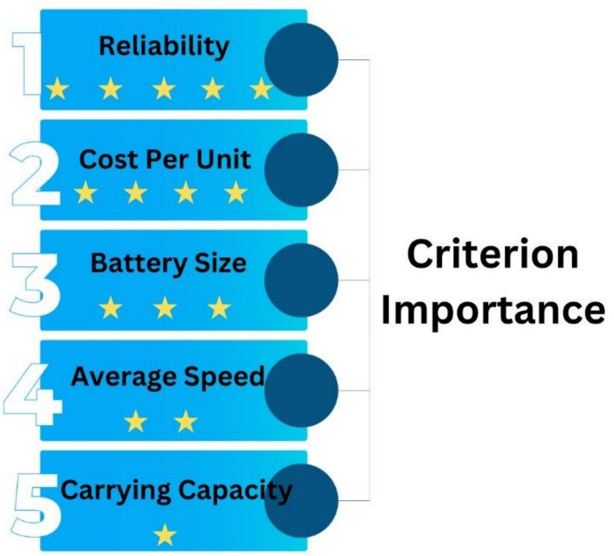


Figure 1.1: Criterion Importance Decided By Management

Based on the latest management meeting held in July 2023, the importance of each criterion is shown in Figure 1.1.

The maximum emphasis is on **reliability** and the least on the **carrying capacity.**

- All the criteria are quantitative.
- Except for cost, all other criteria are to be maximised.
- The unit of measurement is consistent across the dataset.
- Levels of importance are clear for each criterion.

For reaching an explicit, rational and efficient solution, while simultaneously considering different levels of importance, a technique *called **MCDA(Multi-Criterion Decision Making)*** is employed. Since a **numerical overall score** is desired for each alternative and every criterion into a function needs to be **maximised** (except for cost), a ***Multi-Attribute MCDA*** method is suitable for decision-making.

Choosing a Multi-Attribute Method:

The most popular multi-attribute methods are "**Weighted-Sum", "AHP", "TOPSIS"** and **"VIKOR"**

Since an alternative with the highest expected utility is to be found, ideal point methods like TOPSIS and VIKOR aren't good choices. They are used for finding the optimum between the positive ideal solutions and the negative ideal solutions which is not an objective for this analysis as the objective is clearly defined.

AHP(Analytical Hierarchy Process) requires a comparison of each pair of alternatives with each other whereas we have the overall ranking of criterion and not pairwise comparison. Therefore, AHP cannot be devised for our analysis.

Hence, *the **Weighted sum Method(WSM)*** aligns best with the current decision-making requirements. Also known as the Simple Additive Method(SAW) and Simple Multi attribute Rating Technique(Smart), WSM is a simple and straightforward method to find alternatives with the highest expected utility based on the criteria. WSM gives scores to each alternative and the alternative with the highest score is the best choice for the task.

Employing Weighted Sum Method:

To employ the WSM, each criterion must be weighted signifying their importance. The priority assigned by the management team to each criterion is as shown in Table-2:

Criterion	Criterion Importance by Management **[W]**	Normalised Weights [W/Total_W)]
Carrying Capacity	1/5	0.07
Battery Size	3/5	0.20
Average Speed	2/5	0.13
Cost Per Unit	4/5	0.27
Reliability	5/5	0.33
	Total_W=15/5=3	**Total**=1

Table 2: Criterion Weights

Summing up all the information in Table-3:

Robot Prototype	Weights	Archer	Bowler	Corner	Deviant
Carrying Capacity (Litres)	0.07	45	50	60	40
Battery Size (Operational Hours)	0.20	18	18	12	24
Average Speed (km/hr)	0.13	6	4	4	10
Cost Per Unit (GBP)	0.27	5210	6250	4500	7100
Reliability (Hours)	0.33	22	24	24	32

Table 3

Feature: Cost per unit is to be minimised, therefore for employing WSM, criterion is inversed to make the function maximised.

1/Cost Per Unit (1/GBP)	0.27	0.0001919386	0.0001600000	0.0002222222	0.0001408451

Now, All the criteria are to be **maximised.**

The table is **normalised**,

Normalised Value*= [Value of that Criteria / Sum of all value of that Criteria]*

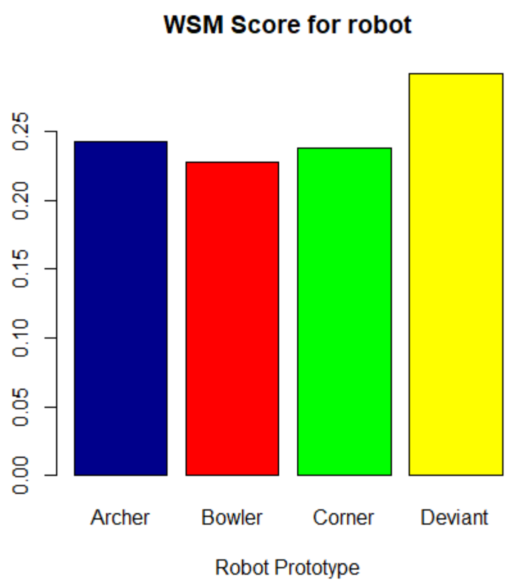
After normalising and inversing the cost per unit criteria, the Table looks like:

Robot Prototype	Weights	Archer	Bowler	Corner	Deviant
Carrying Capacity (Litres)	0.07	0.2307692	0.2564103	0.3076923	0.2051282
Battery Size (Operational Hours)	0.20	0.2500000	0.2500000	0.2500000	0.3333333
Average Speed (km/hr)	0.13	0.2500000	0.1666667	0.1666667	0.4166667
1/Cost Per Unit (1/GBP)	0.27	0.2684434	0.2237744	0.3107978	0.1969845
Reliability (Hours)	0.33	0.2156863	0.2352941	0.2352941	0.3137255

Table 4

Each Robot's final score is calculated by multiplying each criterion weight by the score for each alternative for each criterion, then summing the final score for each alternative.

The alternative with the highest score is the best!



The final score for each criterion is.

Archer: 0.2423100

Bowler: 0.2276815,

Corner: 0.2381009

Deviant: 0.2919075

In this case, "Deviant" emerges as the optimal robot prototype for the trial rollout.

Figure 1.2: WSM score for each Robot Prototype

Sensitivity Analysis: What-If Scenario with Equivalent Weightage

To confirm the solution, sensitivity analysis is done as a bit of a reality check to ensure that nothing is broken, and the thought process is not flawed.

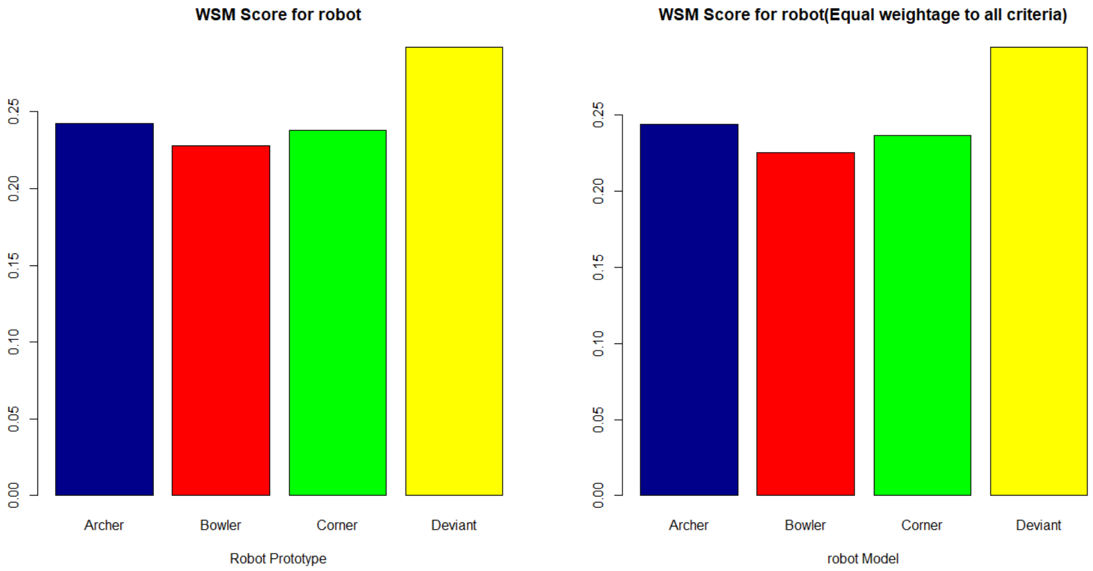


Figure 1.3: Bar Plot of WSM scored for different weights of criteria.

The comparison reveals that under the equivalent weightage scenario, the rankings of the robot prototypes remain consistent with the original scores with minor fluctuations in the final scores.

"Deviant" maintains its position as the top-performing alternative. This consistency across scenarios strengthens confidence in the decision-making process.

Decision 2: Allocation of Robots to Stores

With limited resources, the allocation of the robots must be optimum. The aim is to **maximize the order deliveries by robots per day** while taking into consideration:

1. Each store must have **at least 5** robots during the trial.
2. The total number of technician staff hours available to support this trial is **250 hours/week.**
3. The cost of operation and acquisition must not be more than the budget of **250000 GBP.**

As the main objective is to maximise order deliveries, **Linear optimisation** is the right approach for figuring out the number of robots to allocate to each store.

Delivery operation specifics are shown in Table-5.

Store Type	Estimated number of orders to be delivered per day per robot	Operating Cost per month per robot	Technician staff working hours per week per robot
Grocery Store	9	1600	10
Clothing Store	6	1000	7
Sports Equipment Store	4	600	5

Table 5

Let number of robots required by the Clothing Store is **Xc**, the Grocery store is **Xg** and the Sports equipment store is **Xs**. Therefore, the constraints for optimisation are:

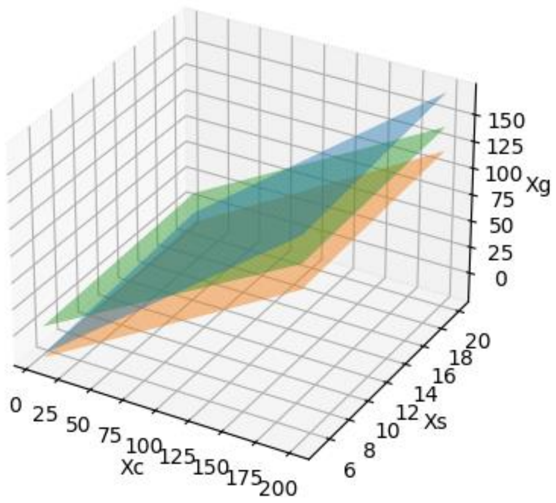


Fig 2.1: Optimisation of Constraint Equations

[Budget Constraint]

(Xg + Xc +Xs) * Price of one Robot + 1600*Xg +1000*Xc+ 600*Xs <=250000

The price of one prototype of Deviant is **7100** GBP.

[Technician working Hours Constraint]
10*Xg + 7*Xc + 5*Xs <= 250

[Min Robot per store constraints]
Xg, Xc, Xs>=5

[Maximising Order Deliveries]
9*Xg + 6*Xc + 4*Xs = **max**

Solving we get, **Xg=19, Xc=5, Xs=5**. Therefore,

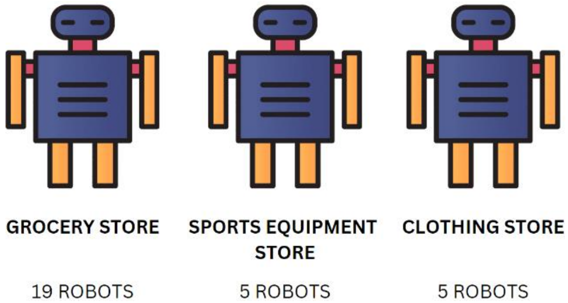


Figure 2.2: Distribution of Robots per store

Total no' of orders delivered per day = 221.

Total Technical Hours used per week= 250

Total Amount of money spent = 24430 GBP

All the constraints are satisfied!!

Therefore, Distribution of robots this way is optimal.

However, the distribution of Robots is not uniform. Another **Alternative approach is Xg=15, Xc=10, Xs=5**, with this number of orders delivered is 215 (6 less than the optimum solution) but the allocation of robots among stores is more distributed, still within the budget and 5 technician working hours per week is saved which might be more beneficial for the trial run.

Summary

After extensive research, **Deviant** is the best prototype robot for maximum utility from the four options available based on their "carrying capacity, Battery Size, Average Speed, Cost per Unit, and Reliability and is the best robot prototype for the Trial Run. This decision is also backed by the Weighted sum Multi-Criterion Decision Making Method.

To achieve maximum competence for the trial period **19** robots may be distributed to the Grocery Store, and **5** robots to both the Sports equipment store and clothing store respectively. This satisfies all the constraints of budget and technical hours and maximises the order deliveries i.e. **221 orders per day.**