DRONE PATH OPTIMIZATION

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IMPORTANT INSTRUCTIONS

Participants are expected to build a versatile model that can work with reasonable variety of inputs
A sample format of both inputs and outputs is provided which can be used to build the model. Upto three larger input datasets will be provided two days before the final presentation
Do not miss the several important notes that are provided below each table in the following sheets.
Assumptions, if any, need to reasonable and well documented
Participants are free to chose any programming language or tools to develop their own model. However, commercial software may not be used.

EVALUATION CRITERION

The teams will be evaluated on the following criterion. Lower rank criterion is more important. E.g., a team achieving higher 'Demand Met' will score higher than another team that is delivering lower 'Total Cost'.

1. Demand Met
2. Total Cost (ref Objective function for cost components)
3. Number of drones deployed
4. Model Performance

The above criterion will be evaluated for both the original plan and the replan (in case of delivery failures).

OBJECTIVE FUNCTION

1. Meet maximum possible demand
2. Zero orphaned drones
3. Minimize Total Cost

Cost components:
Energy Cost
Maintenance Fixed Cost
Maintenance Variable Cost

IMP CONSIDERATIONS

- There are six drone types with certain count of each available to deploy.
- There are upto three warehouses which are used to service the demand.
- The demand data will be provided for 3 days including the warehouse pegging. There can be upto potentially 50 data points per Warehouse per day.
- A demand must be fulfilled within its permissible delivery window.
- Drones may not "rest" except for warehouses, demand point and recharge points. However, they can idle while hovering in mid-air.
- Drones may travel at less than their max speed.
- The drones are "warehouse agnostic" i.e. they can return or deliver from any warehouse.

E.g. a drone may deliver WH1's demand, then go to WH2 to recharge and then deliver WH2's demand.

- All drones must return to *a* Warehouse at the end of the day.
- All drones may not be used on all days.
- An 'orphaned' drone is one which has drained its charge while not at charging station or warehouse.
- Charging time is a linear function of remaining battery.
- Drones can be assumed as point objects. More than one drone can occupy the same coordinates at the same time.
- Fixed pick-up and drop time of 3 mins for *each* item.
- During pick-up and drop, drone is turned off and not using any energy.
- A customer can refuse a delivery at the point of delivery with a probability of 2%. These are referred as Delivery Failures.
- The Delivery Failure only becomes known at the end of drop-time.

E.g. if the drone reaches at 10:00:00 at customer location. Failure will be known at 10:03:00 at which point replanning would be required.

-Delivery windows fall between 8 AM - 12 PM(afternoon). However, drones may return to a warehouse after 12 PM as well.
-All drones will have a specific identifier. The convention to denote a specific drone is "D" <drone type number><identifier between A-Z> E.g. D6Z corresponds to 26th drone of Type 6.

- All drones can be assumed to start with full charge on 8AM on Day 1
- Drones can fly at [X,Y,0] i.e. at the ground level. Z=0 can be assumed to be a caliberated axis value.

INPUT DATASET

Two input files will be provided named "Demand.csv" and "Parameters.csv" respectively

Demand.csv contains Demand data
Parameters.csv contains all the other relevant variables --
Max Speed (M)
Unit cost of Energy (c)
NoFlyZone coordinates
WH Coordinates
Recharge Stations Coordinates
Speed Profile Coefficients (P,Q)
Energy Profile Coefficients (A,B,C)
Available Drones' Count

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INPUTS

Table	Link
Item Master	Link
Demand	Link
Drone Master	Link
Speed Profiles	Link
Energy Consumption	Link
WH & Recharge Stations	Link
No fly Zones	Link
Costs	Link

OUTPUT TABLES

Table	Link
Cost Report	Link
Drone Paths	Link

The data in the above tables is for conceptual understanding only. Actual table formats are provided in accompanying CSVs

ReadMe

ITEM MASTER

		Dimension (cm)		
Item Id	**Weight (KG)**	**Length**	**Breadth**	**Height**
Item-1	1	5	8	5
Item-2	6	5	10	8
Item-3	4	5	10	15
Item-4	2	15	10	8
Item-5	5	20	15	10

Notes:

The item table will remain static, i.e. the list of five items and corresponding dimensions will not change across the input scenarios

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DEMAND

	Demand ID	Serving WH	Item	Day	X	Y	Z	Delivery Window Start	Delivery Window End	Delivery Failure
	D[X]	WHi	Item-[1-5]	Day [1,2,3]	X1	Y1	Z1	HH:MM:SS	HH:MM:SS	0
Example	D1	WH1	Item-1	Day 1	-1836	994	50	10:00:00	10:20:00	0
	D2	WH2	Item-3	Day 1	-975	-1545	70	10:10:00	10:30:00	1
	D3	WH3	Item-4	Day 2	-1698	131	50	11:00:00	11:25:00	0
	D4	WH3	Item-5	Day 3	1075	1027	20	08:00:00	08:25:00	0

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Notes:

There can be upto 50 demand records per day for three days

Delivery windows will be between is 8 AM - 12 PM. All deliveries must be completed within their particular delivery windows. However, drones may return to the warehouse after 12 PM as well.

All the coordinates are in mts and are with respect to WH1 at (0,0)

A demand must be served from its predetermined serving Warehouse.

IMP: Participants not attempting Complexity #2: Multiple Warehouses, may ignore the demand pertaining to all the Warehouses except WH1.

IMP: Participants not attempting Complexity#3: Dynamic Replanning, may ignore 'Delivery Failure' Col.

Delivery Failure:

"1" denotes a delivery failure at the point of delivery.

*A delivery failure can **not** be assumed at the beginning of the day. Hence, the plan can't account for specific delivery failures.*

Once the delivery failure occurs, a new plan must be generated and executed.

Teams will hence provide two sets of outputs -- one for the day's beginning and one post the failure.

DRONE MASTER

Drone Type	Drones Available	Battery Capacity (mAh)	Base Weight (kg)	Payload Capacity (KG)	Payload Capacity (cu.cm)	Max Slots	Max Speed (m/s)
DroneType1	DT1Count	2000	2	5	200	1	M
DroneType2	DT2Count	2500	2.5	6	500	1	M
DroneType3	DT3Count	3000	3	7	1000	2	M
DroneType4	DT4Count	4000	3.5	8	2000	2	M
DroneType5	DT5Count	5000	4	9	3000	2	M
DroneType6	DT6Count	10000	5	10	5000	4	M

Notes:

Payload capacity is over and above base weight of the drone

Max Slots denotes the number of items drone can carry at one time (regardless of the size e.g. a drone with 2 slots can carry 1 unit of Item1 and 1 unit of Item5 or 2 units of Item4 etc.)

M is the maximum possible speed for drone (in m/s). M is same for all the drone types

All available drones may or may not be deployed

DTiCount varies between [0,26]

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COST COMPONENTS

Drone Type	Maintenance Fixed Cost (per day)	Maintenance Variable Cost (per hour of flight time)
DroneType1	$10	$5
DroneType2	$15	$8
DroneType3	$20	$13
DroneType4	$20	$15
DroneType5	$30	$20
DroneType6	$50	$25

Notes:

The energy costs are provided in Recharge Stations page

On a particular day, if a particular drone is not deployed, then Maintenance Variable Cost is zero for that drone. However, we still continue to incur Maintenance Fixed Cost

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Speed Profiles

Max XY Speed = M - P*f*

Max Z upward Speed = M - Q*f*

Max Z downward Speed = M + Q*f*

where,
M is the maximum possible speed for drone (in m/s)
f is the fraction of maximum payload
P, Q are coefficients that vary by drone type

$P_i \in [1, 10]$
$Q_i \in [1, 10]$

where i denotes drone type.

Notes:
Example:
For M=20, and P2 = 10 for DroneType2
Drone max speed will be 20 m/s when empty and 15 m/s when carrying a payload of 3 KG (3/6 or f = 0.5)

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Energy Consumption Profile

Energy Consumed per second (in mAh) = $W(A + BS + CH)$

where,
W is lift weight incl drone weight (in Kgs)
S is speed (in m/s)
H is vertical altitude gain (in mts)

and,
A,B,C are coefficients that vary by drone type
$A_i \in [0.01, 1]$
$B_i \in [0.01, 2]$
$C_i \in [0.01, 4]$
where i denotes drone type.

Notes:
Weight includes drone weight and payload.
A,B,C can vary by drone type
H component is only considered for height gain. The component doesn't apply for altitude loss

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WH & RECHARGE STATIONS

			Location (in mts)	
Station ID	**Charging Slots**	**Charging Current**	**X**	**Y**
WH1	∞	5 A	0	0
WH2	∞	5 A	XW1	YW1
WH3	∞	5 A	XW2	YW2
A	1	3 A	XA	YA
B	1	3 A	XB	YB
C	1	3 A	XC	YC
D	4	3 A	XD	YD
E	5	3 A	XE	YE

Notes:

Cost of energy is $ c per Ampere (provided as an input variable)

X and Y are the coordinates of charging stations and Warehouses

A drone while waiting for a charging slot at a charging station can "rest" without spending any energy

No energy loss is assumed. A 2A current can fully charge 2000 mAh battery in 1 hour

All the coordinates are with respect to WH1 at (0,0)

There can be upto three warehouses (including the Base Warehouse at 0,0)

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NO FLY ZONES

	Vertex 1			Vertex 2			Vertex 3			Vertex 4			Vertex 5			Vertex 6			Vertex 7			Vertex 8		
	X	**Y**	**Z**	**X**	**Y**	**Z**	**X**	**Y**	**Z**	**X**	**Y**	**Z**	**X**	**Y**	**Z**	**X**	**Y**	**Z**	**X**	**Y**	**Z**	**X**	**Y**	**Z**
Zone 1	X11	Y11	Z11	X12	Y12	Z12	X13	Y13	Z13	X14	Y14	Z14	X15	Y15	Z15	X16	Y16	Z16	X17	Y17	Z17	X18	Y18	Z18
Zone 2																								
Zone 3																								
Zone 4																								
Zone 5																								
Zone 6																								
Zone 7																								
Zone 8																								
Zone 9																								
Zone 10																								
Example	100	0	0	120	0	0	120	50	0	100	50	0	100	0	15	120	0	15	120	50	15	100	50	15

Notes:

All no-Fly Zones are assumed to be cuboids

Drones can touch the 'surfaces' of no fly zones but can not penetrate

All the coordinates are with respect to WH at (0,0)

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Cost Report

Example

	FLIGHT TIME (in sec)			RESTING/ WAITING TIME (in sec)			CHARGING TIME (in sec)			MAINTENANCE VARIABLE COST ($)			ENERGY COST ($)		
Drone ID	Day 1	Day 2	Day 3	Day 1	Day 2	Day 3	Day 1	Day 2	Day 3	Day 1	Day 2	Day 3	Day 1	Day 2	Day 3
D1A															
D1B															
D1C															
D1D															
D1E															
D2A															
D2B															
D2C															
D2D															
D2E															
D3A															
D3B															
D3C															
D3D															
D3E															
D4A															
D4B															
D4C															
D4D															
D4E															
D5A															
D5B															
D5C															
D5D															
D5E															
D6A															
D6B															
D6C															
D6D															
D6E															

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Notes:
The above table is for illustration only, actual output format will be shared as a sample data
The given example assumes 5 drones of each type (A-E). Available drones may changes as given in Drone Master.

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DRONE PATH

Example

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DroneID	Day	Time (in Seconds)	X	Y	Z	Activity	Payload Weight	Speed (m/s)	mAH Consumed	Energy Cost (c x mAh)
D1A	Day 1	1	0	0	0	PU-WH1	2	0	-	-
D1A	Day 1	2	0	0	0	PU-WH1	2	0	-	-
D1A	Day 1	3	0	0	0	PU-WH1	2	0	-	-
D1A	Day 1	4	0	0	0	PU-WH1	2	0	-	-
D1A	Day 1	5	0	0	0	PU-WH1	2	0	-	-
D1A	Day 1	6	0	0	0	PU-WH1	2	0	-	-
D1A	Day 1	7	0	0	0	PU-WH1	2	0	-	-
D1A	Day 1	8	0	0	0	PU-WH1	2	0	-	-
D1A	Day 1	9	0	0	0	PU-WH1	2	0	-	-
D1A	Day 1	10	0	0	0	PU-WH1	2	0	-	-
D1A	Day 1	11	0	5	0	T-L	4	5	10.4	0.10
D1A	Day 1	12	0	10	0	T-L	4	5	10.4	0.10
D1A	Day 1	13	0	15	0	T-L	4	5	10.4	0.10
D1A	Day 1	14	0	20	0	T-L	4	5	10.4	0.10
D1A	Day 1	15	0	25	0	T-L	4	5	10.4	0.10
D1A	Day 1	16	0	30	0	T-L	4	5	10.4	0.10
D1A	Day 1	17	5	30	0	T-L	4	5	10.4	0.10
D1A	Day 1	18	10	30	0	T-L	4	5	10.4	0.10
D1A	Day 1	19	15	30	0	T-L	4	5	10.4	0.10
D1A	Day 1	20	20	30	0	T-L	4	5	10.4	0.10
D1A	Day 1	21	20	30	2	T-L	4	2	2.8	0.03
D1A	Day 1	22	20	30	4	T-L	4	2	2.8	0.03
D1A	Day 1	23	20	30	6	T-L	4	2	2.8	0.03
D1A	Day 1	24	20	30	6	D2	4	0	-	-
D1A	Day 1	25	20	30	6	D2	4	0	-	-
D1A	Day 1	26	20	30	6	D2	4	0	-	-
D1A	Day 1	27	20	30	6	D2	4	0	-	-
D1A	Day 1	28	20	30	6	D2	4	0	-	-
D1A	Day 1	29	20	30	6	D2	4	0	-	-
D1A	Day 1	30	20	30	6	D2	4	0	-	-
D1A	Day 1	31	20	30	6	D2	4	0	-	-
D1A	Day 1	32	20	30	6	D2	4	0	-	-
D1A	Day 1	33	20	30	6	D2	4	0	-	-
D1A	Day 1	34	20	30	6	D2	4	0	-	-
D1A	Day 1	35	20	30	6	D2	4	0	-	-
D1A	Day 1	36	20	30	2	T-E	2	4	3.4	0.03
D1A	Day 1	37	23	30	0	T-E	2	6	7.4	0.07
D1A	Day 1	38	22	33	0	T-E	2	10	20.2	0.20
D1A	Day 1	39	21	36	0	T-E	2	10	20.2	0.20
D1A	Day 1	40	20	39	0	T-E	2	10	20.2	0.20
D1A	Day 1	41	19	42	0	T-E	2	10	20.2	0.20
D1A	Day 1	42	18	45	0	T-E	2	10	20.2	0.20
D1A	Day 1	43	17	48	0	T-E	2	10	20.2	0.20
D1A	Day 1	44	16	51	0	T-E	2	10	20.2	0.20
D1A	Day 1	45	15	54	0	R-RS1	2	0	-	-
D1A	Day 1	46	15	54	0	R-RS1	2	0	-	-
D1A	Day 1	47	15	54	0	R-RS1	2	0	-	-
D1A	Day 1	48	15	54	0	R-RS1	2	0	-	-
D1A	Day 1	49	15	54	0	R-RS1	2	0	-	-
D1A	Day 1	50	15	54	0	R-RS1	2	0	-	-
D1A	Day 1	51	15	54	0	C-RS1	2	0	-	-
D1A	Day 1	52	15	54	0	C-RS1	2	0	-	-
D1A	Day 1	53	15	54	0	C-RS1	2	0	-	-
D1A	Day 1	54	15	54	0	C-RS1	2	0	-	-
D1A	Day 1	55	15	54	0	C-RS1	2	0	-	-
D1A	Day 1	56	15	54	0	C-RS1	2	0	-	-
D1A	Day 1	57	15	54	0	C-RS1	2	0	-	-
D1A	Day 1	58	15	54	0	C-RS1	2	0	-	-
D1A	Day 1	59	15	54	0	C-RS1	2	0	-	-
D1A	Day 1	60	15	54	0	C-RS1	2	0	-	-
D1A	Day 1	61	15	54	0	C-RS1	2	0	-	-
D1A	Day 1	62	15	54	0	C-RS1	2	0	-	-
D1A	Day 1	63	-5	54	0	T-E	2	10	20.2	0.20
D1A	Day 1	64	-15	54	0	T-E	2	10	20.2	0.20
D1A	Day 1	65	-25	54	0	T-E	2	10	20.2	0.20
D1A	Day 1	66	-35	54	0	T-E	2	10	20.2	0.20
D1A	Day 1	67	-45	54	0	T-E	2	10	20.2	0.20
D1A	Day 1	68	-55	54	0	T-E	2	10	20.2	0.20
D1A	Day 1	69	-65	54	0	R-WH2	2	0	-	-
D1A	Day 1	70	-65	54	0	END	2	0	-	-
D2A	Day 1	1	0	0	0	PU-WH2	4	0	-	-
...										

ACTIVITY LEGEND	
C-WH[X]	Charging at WH. X denotes 1,2,3.
C-RS[X]	Charging at Recharge Station
R-WH[X]	Resting at WH
R-RS[X]	Resting at Recharge Station
D[X]	Waiting at demand point to deliver demand D[X]
PU-WH[X]	Waiting at WH to pick-up item
END	END of the day
T-L	Traveling with payload
T-E	Traveling empty

Notes:

The convention to denote a specific drone is "D" <drone type number><identifier between A-Z> E.g. D6Z corresponds to 26th drone of Type 6.
Total deployment count is sum of deployed drones for each day. (Count =3 in the example)
Waiting and resting doesn't consume any energy
The example uses hypothetical values (e.g. pickup in 10 sec)
Assuming c=$0.01

Example Notes:

[1-10 S]: Drone is picking up a 2KG item for demand D2 from warehouse WH1
[11-23 s]: Loaded drone is traveling to (20,30,6) to deliver for D2 demand
[24-35 s]: Drone is waiting for the item to be picked by the customer
[36-44 s]: Drone is traveling empty to Recharge Station 1
[45-50 s]: Drone is resting at the recharge station
[54-62 s]: Drone is charging at the recharge station 1
[63-68 s]: Drone is traveling empty towars WH2
[69 s]: Drone reaches WH2
[70 s]: End of day for the drone.

Energy Consumption illustration
Energy Consumed = W(AT + BS2 + CH)
Assuming A,B,C=0.1
Energy Consumed in 22nd Second = 2 [1+(2x2) + 2]