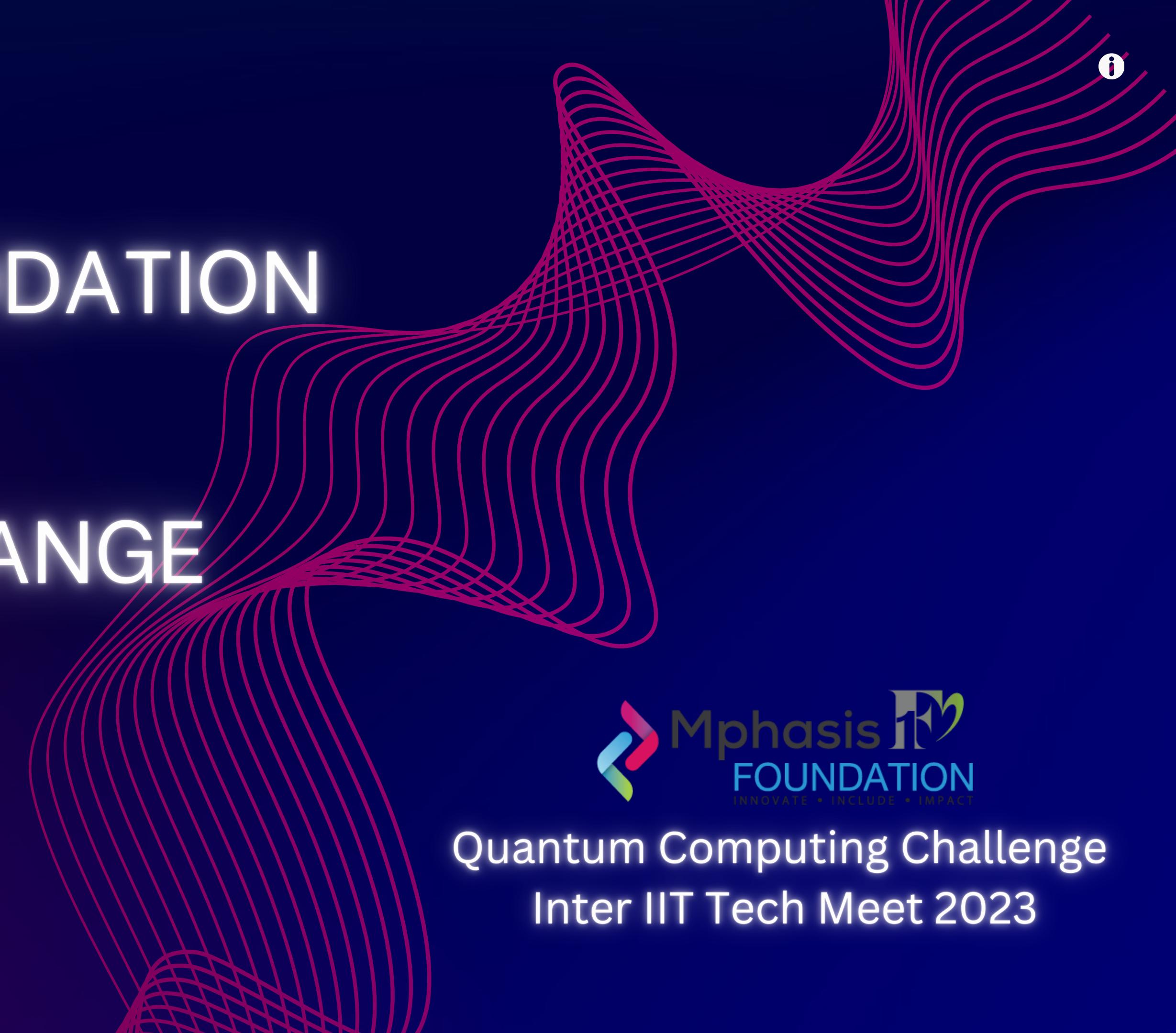


PASSENGER RE-ACCOMMODATION FOR A PLANNED SCHEDULE CHANGE

TEAM 79



Quantum Computing Challenge
Inter IIT Tech Meet 2023

BREAK DOWN OF PS

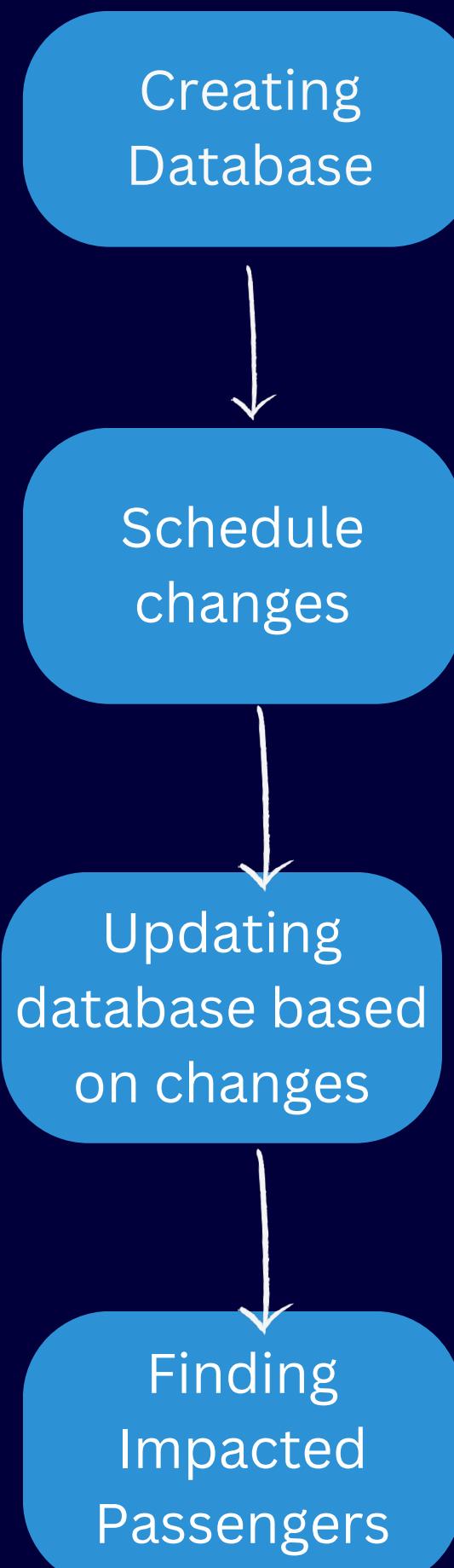
STEP 1 : Identify impacted flights and passengers with the proposed schedule changes

STEP 2 : Identify the suitable alternate flight for the impacted flights

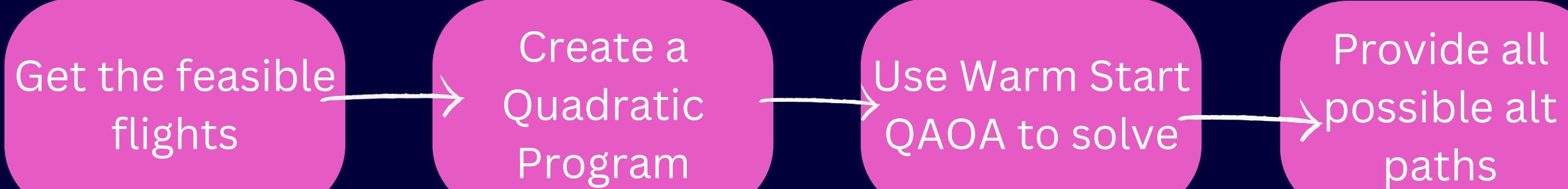
STEP 3 : Allocate the alternate solutions among passengers

SOLUTION OVERVIEW

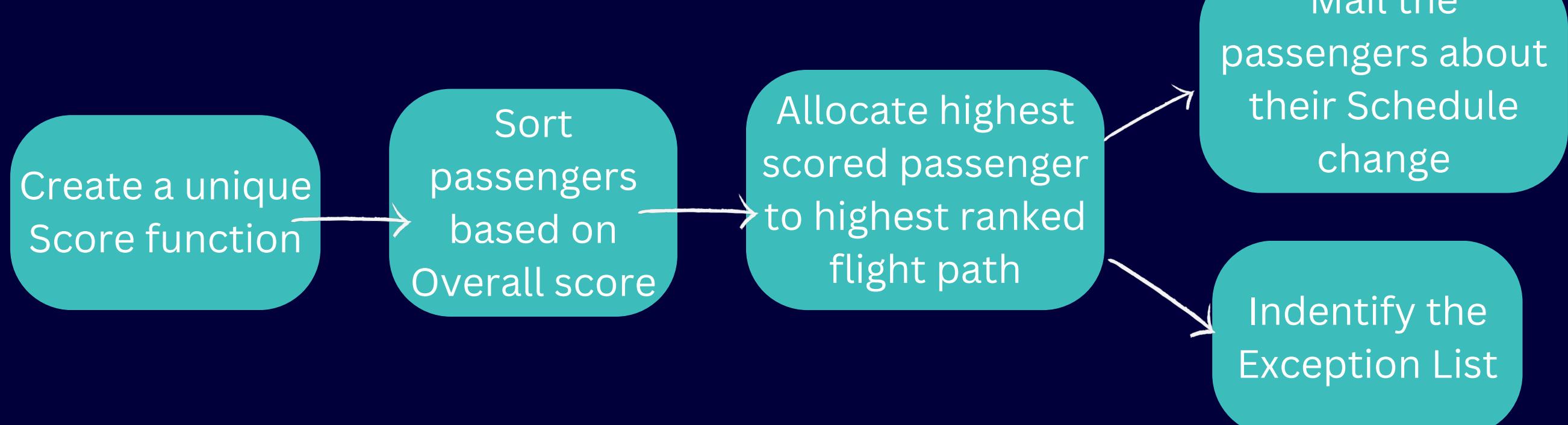
Identification



Flight Routing



Passenger Re-accommodation



PRE PROCESSING



ASSUMPTIONS

We assumed that the minimal information is provided about the schedule changes that are given to us :

If (flight is cancelled)

- 1. Flight Number
- 2. Date for which the flight is cancelled

If (flight is delayed)

- 1. Flight Number
- 2. Date for which the flight is delayed
- 3. New departure date & time
- 4. New arrival date & time

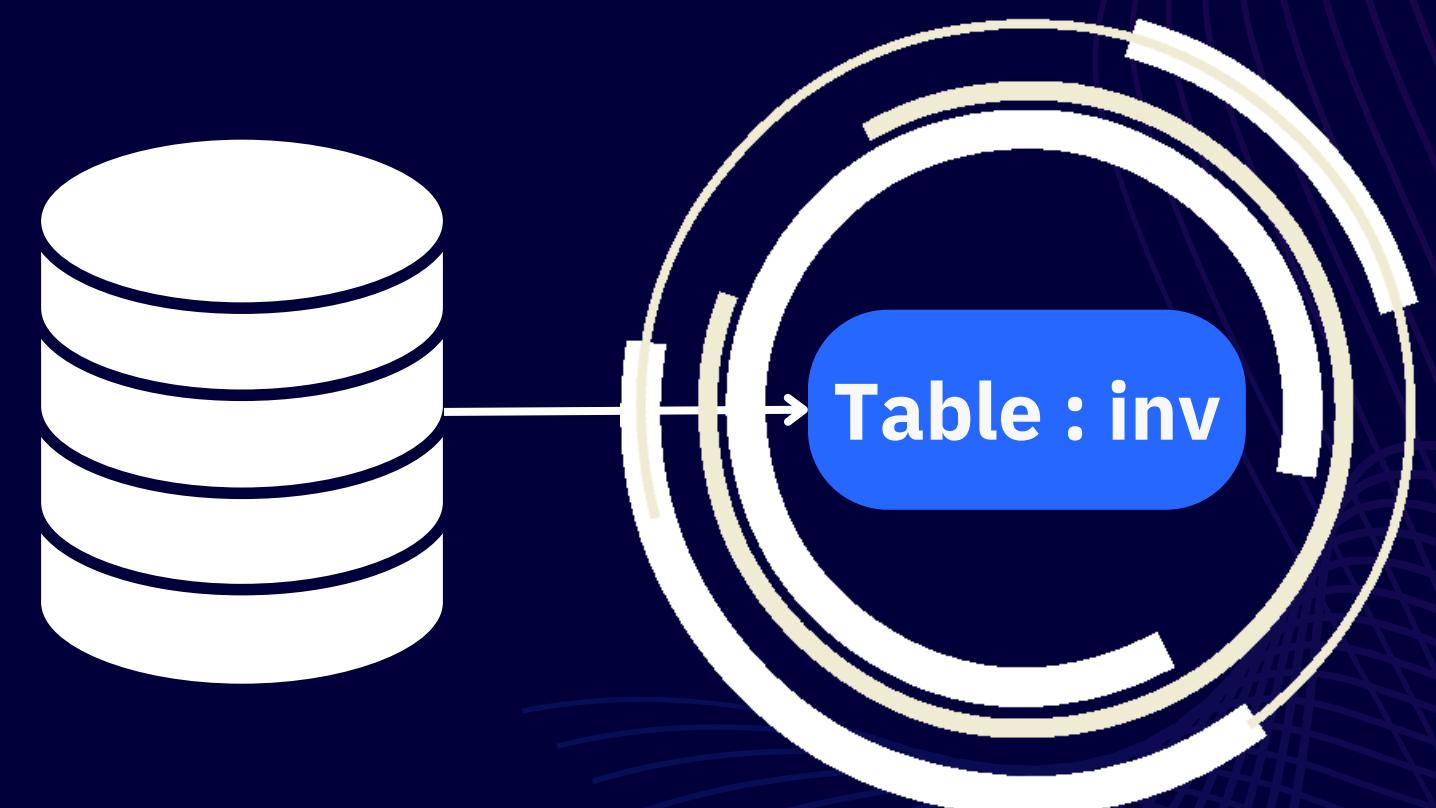
IMPACTED FLIGHTS

```
{ 'INV-ZZ-6984919': 'Cancelled',  
  'INV-ZZ-5183618': 'Delayed' }
```



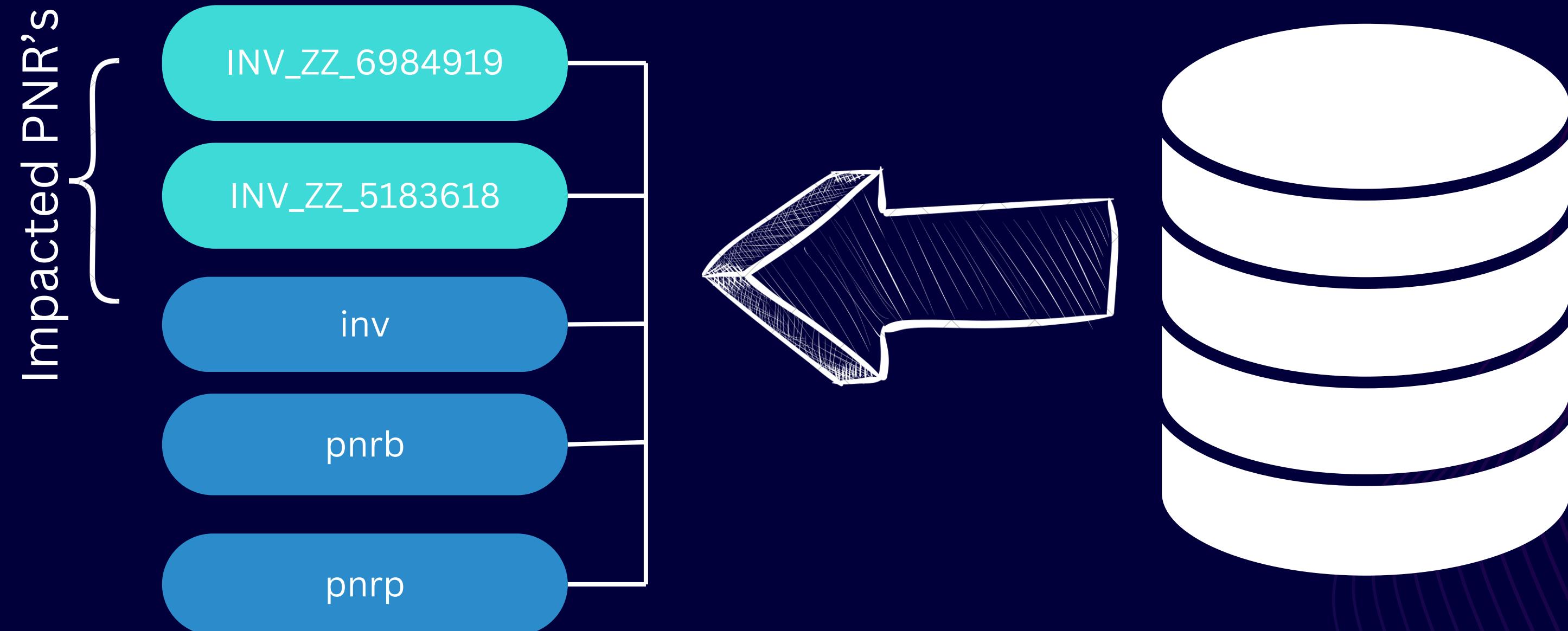
Given as one of the input
to flight routing

Also if the flight is delayed then the new departure and arrival date are updated in the database.

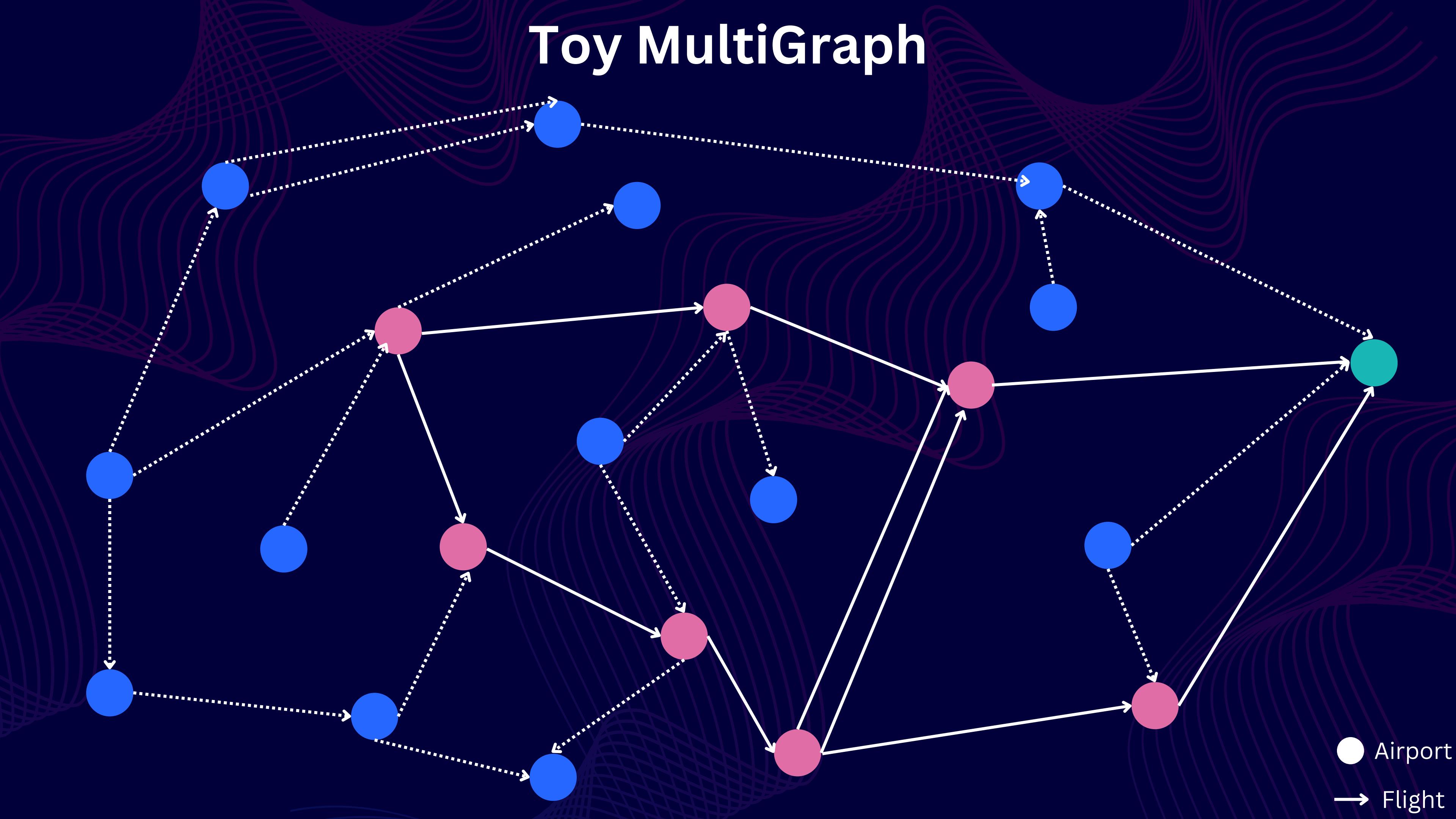


IMPACTED PNR'S

For each impacted flight the corresponding impacted passengers are stored in the database in a table with the table name being the inventory ID of the impacted flight and the entries in the table being the passenger booking rows



Toy MultiGraph



OPTIMISATION

Quadratic Program

Problems where we have to optimise a quadratic expression subject to some constraints

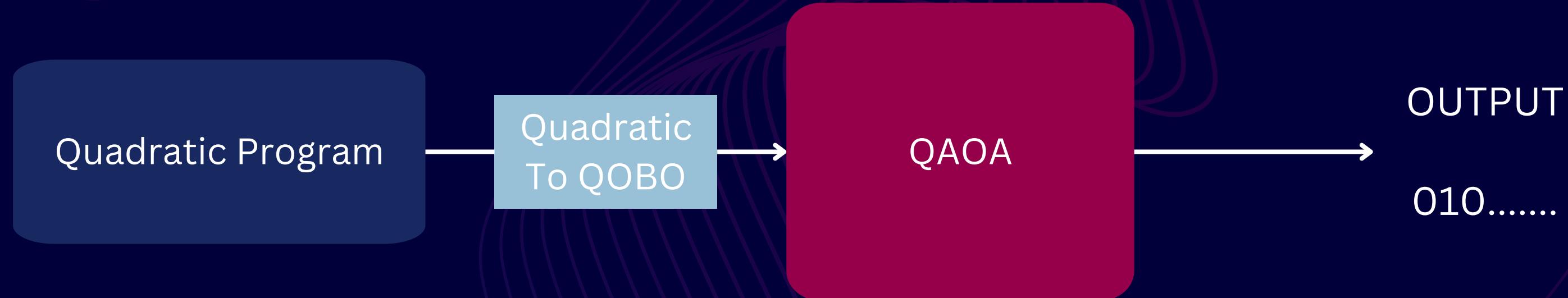
Our base approach for searching for alternate flights:

Each flight has two options -

- 1. It belongs in the current path**
- 2. It doesn't belong to the current path**

QUBO - Quadratic Unconstrained Binary Optimisation

Quadratic Program with only binary variables



The Objective Function

$$\min_{x_i; i \in \{0..n\}} x Q x^T + x G x^T + D x^T$$

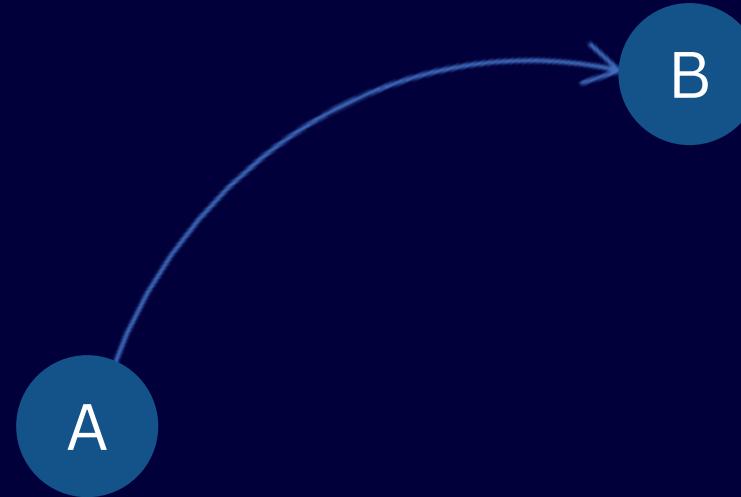
Constraints:

$$1 \leq \|x\|$$

$$Ax = 1$$

$$Bx = 1$$

$$\forall i \in \{0..n\} N_i x \geq 1$$



Q: Matrix Flight time

The Objective Function

$$\min_{x_i; i \in \{0..n\}} x Q x^T + x G x^T + D x^T$$

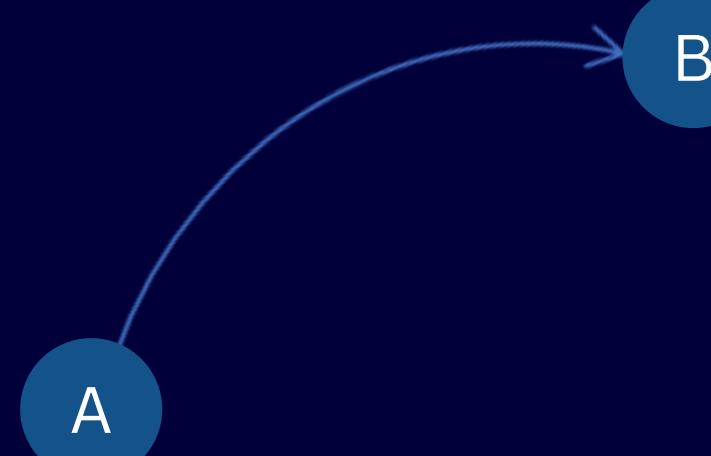
Constraints:

$$1 \leq \|x\|$$

$$Ax = 1$$

$$Bx = 1$$

$$\forall i \in \{0..n\} N_i x \geq 1$$



Q: Matrix Flight time



G: Matrix Ground Time

The Objective Function

$$\min_{x_i; i \in \{0..n\}} x Q x^T + x G x^T + D x^T$$

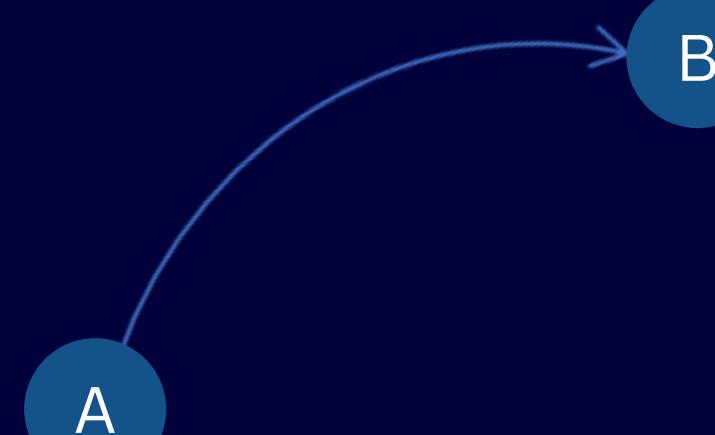
Constraints:

$$1 \leq \|x\|$$

$$Ax = 1$$

$$Bx = 1$$

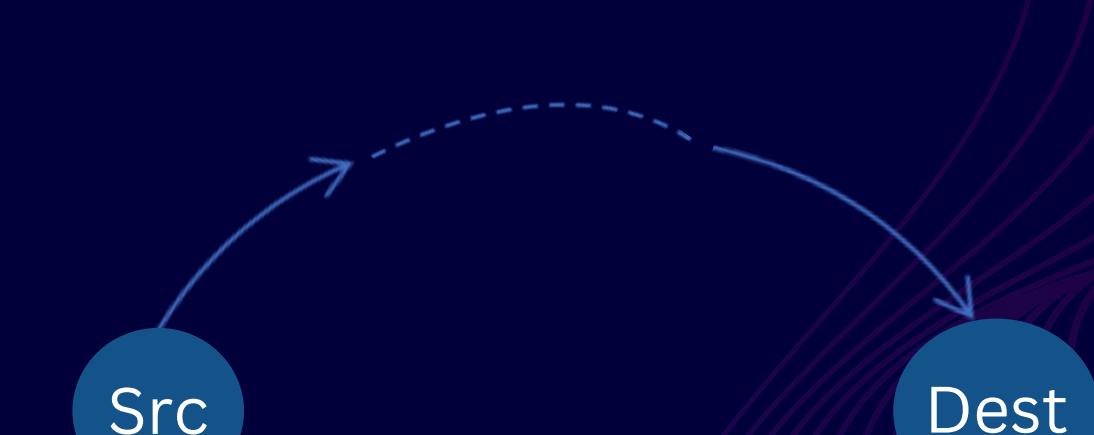
$$\forall i \in \{0..n\} N_i x \geq 1$$



Q: Matrix Flight time



G: Matrix Ground Time



D: Matrix Total Delay

The Objective Function

$$\min_{x_i; i \in \{0..n\}} x Q x^T + x G x^T + D x^T$$

Constraints:

$$I \leq Ix$$

$$Ax = 1$$

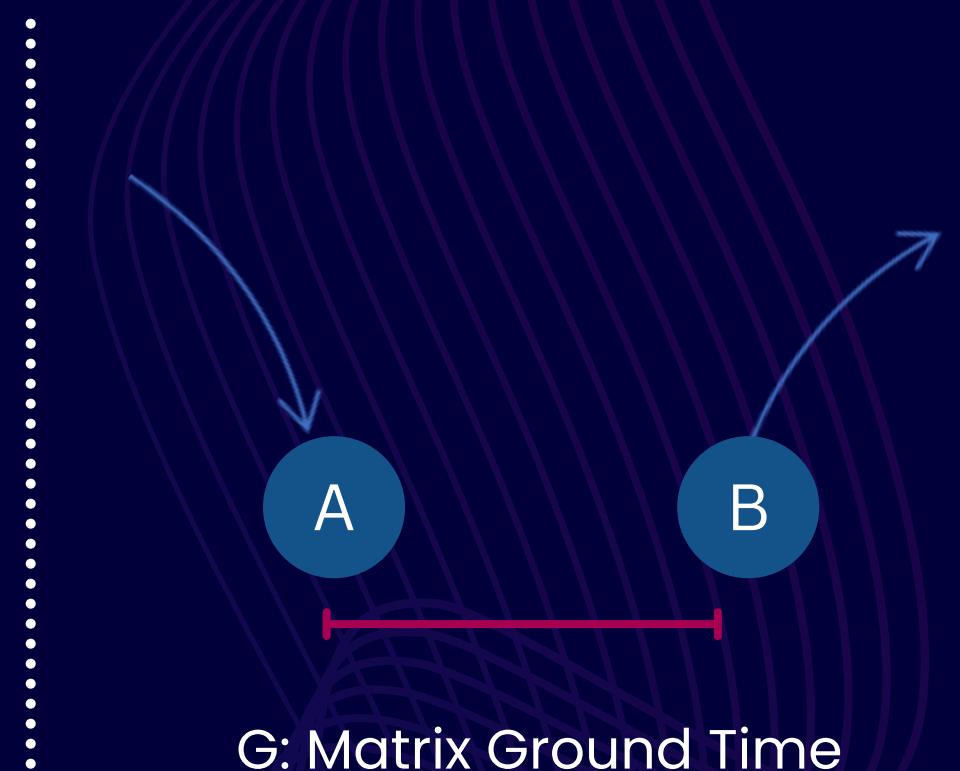
$$Bx = 1$$

$$\forall i \in \{0..n\} N_i x \geq 1$$

I : Identity matrix, Atleast one flight is ON for the path.



Q: Matrix Flight time



G: Matrix Ground Time



D: Matrix Total Delay

The Objective Function

$$\min_{x_i; i \in \{0..n\}} x Q x^T + x G x^T + D x^T$$

Constraints:

$$1 \leq \|x\|$$

$$Ax = 1$$

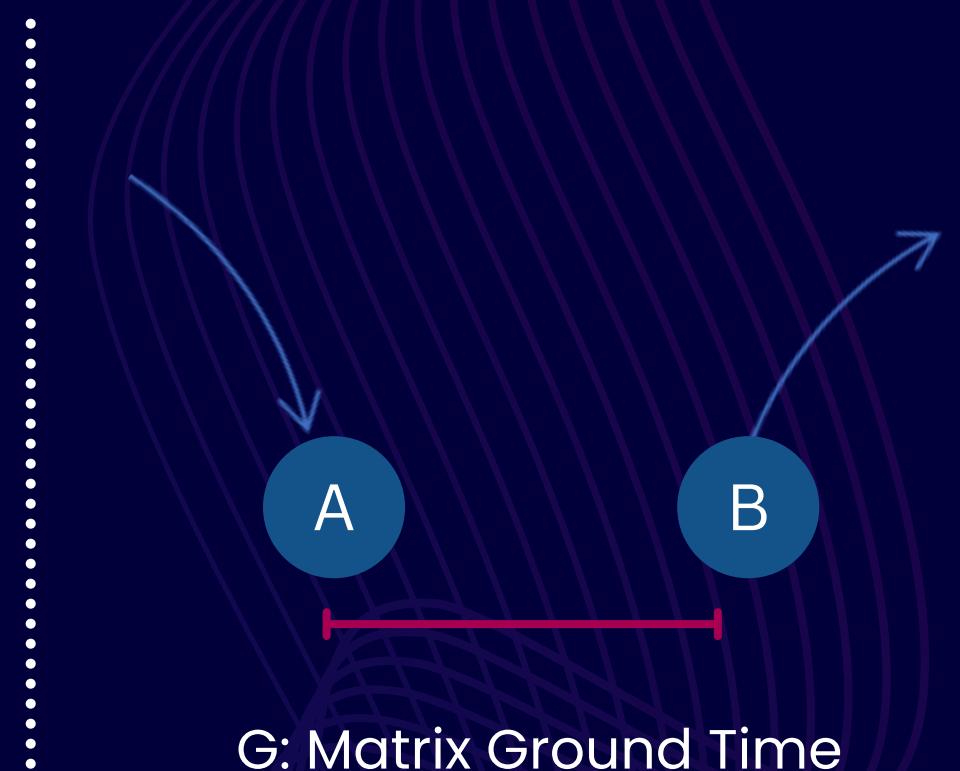
$$Bx = 1$$

$$\forall i \in \{0..n\} N_i x \geq 1$$

A : Matrix Depart, Only and only one flight **must** depart from departure Airport of Affected flight.



Q: Matrix Flight time



G: Matrix Ground Time



D: Matrix Total Delay

The Objective Function

$$\min_{x_i; i \in \{0..n\}} x Q x^T + x G x^T + D x^T$$

Constraints:

$$1 \leq \|x\|$$

$$Ax = 1$$

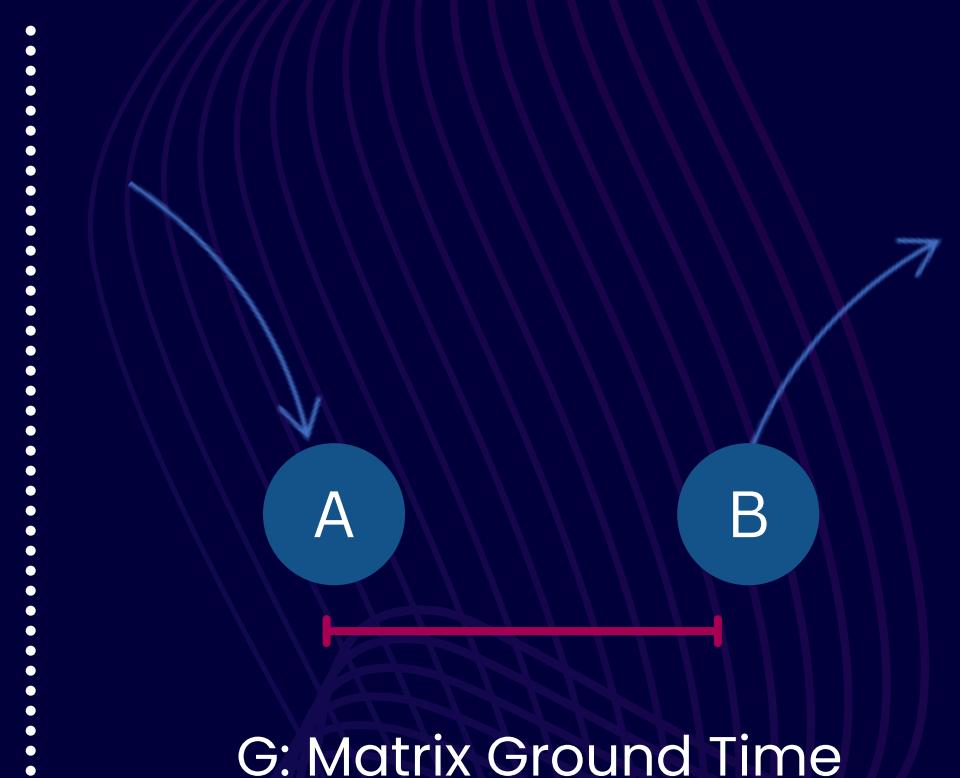
$$\underline{Bx = 1}$$

$$\forall i \in \{0..n\} N_i x \geq 1$$

B : Matrix Arrival, Only and only one flight **must** arrive at arrival Airport of Affected flight.



Q: Matrix Flight time



G: Matrix Ground Time



D: Matrix Total Delay

The Objective Function

$$\min_{x_i; i \in \{0..n\}} x Q x^T + x G x^T + D x^T$$

Constraints:

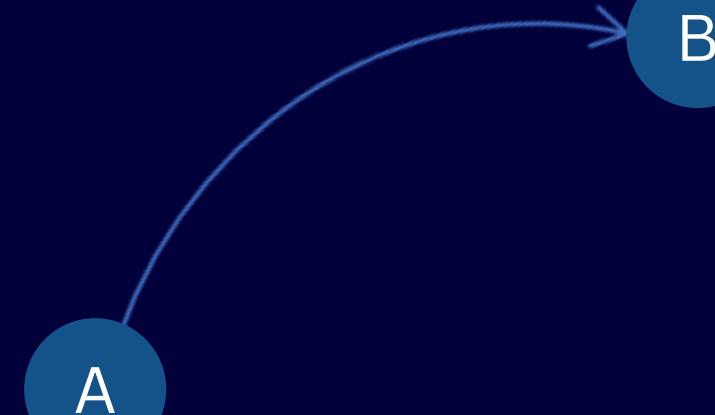
$$1 \leq \|x\|$$

$$Ax = 1$$

$$Bx = 1$$

$$\forall i \in \{0..n\} N_i x \geq 1$$

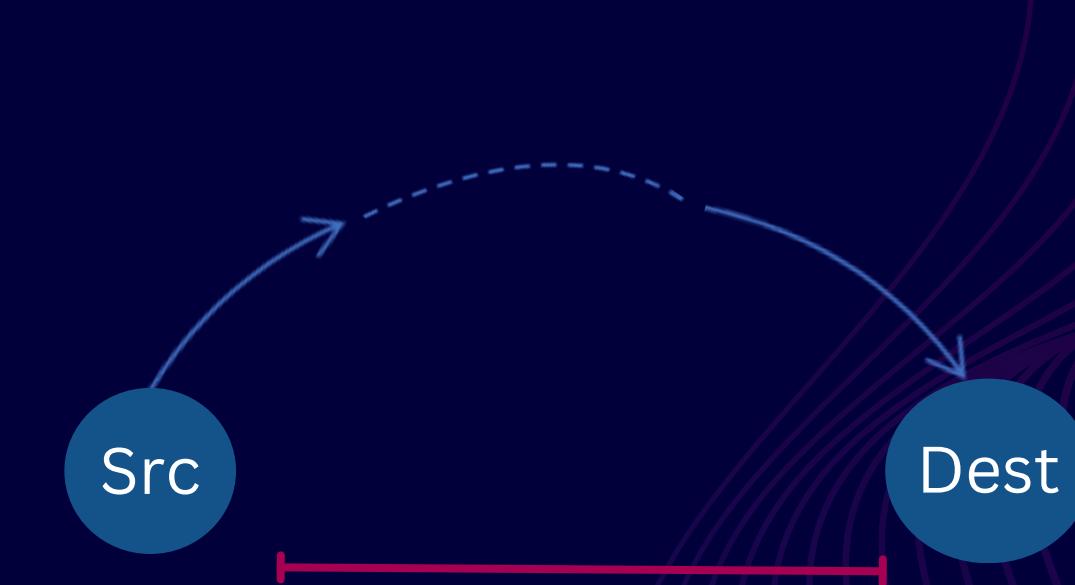
N_i : Neighbour Matrix for i^{th} flight, There must be atleast one neighbour for every flight.



Q: Matrix Flight time



G: Matrix Ground Time



D: Matrix Total Delay

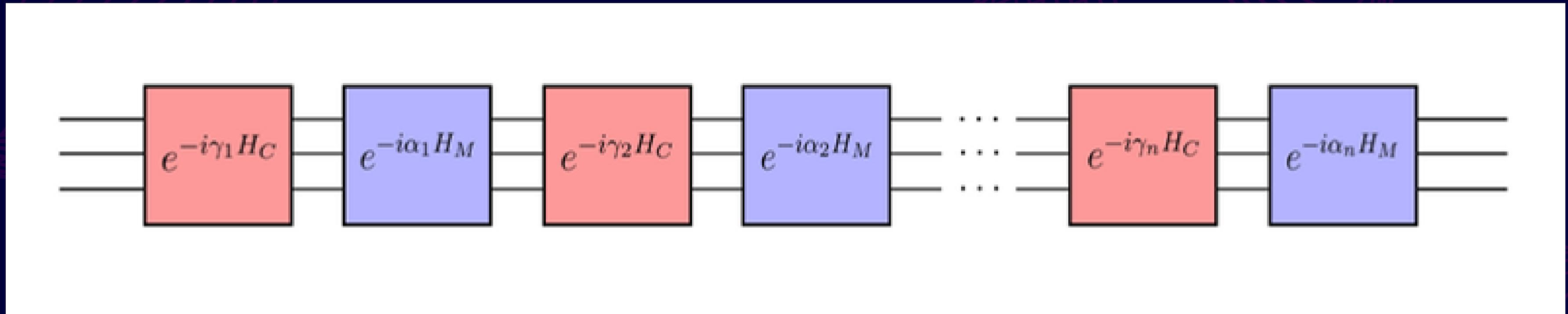
Quantum Solver

QAOA - Quantum Approximate Optimisation Algorithm



Each Qubit represents a Flight

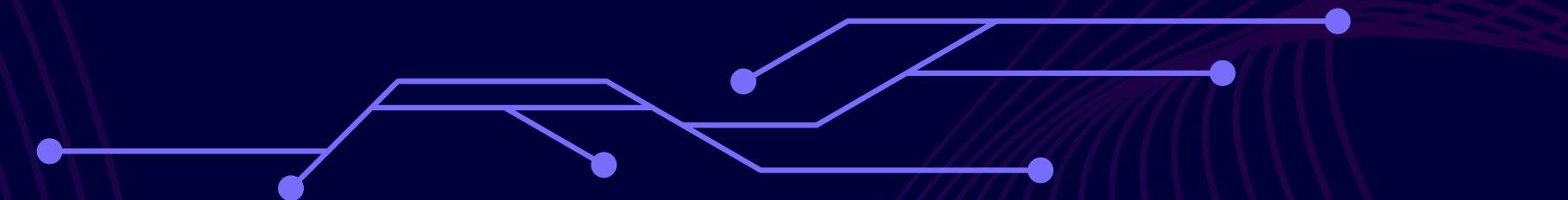
QAOA Circuit



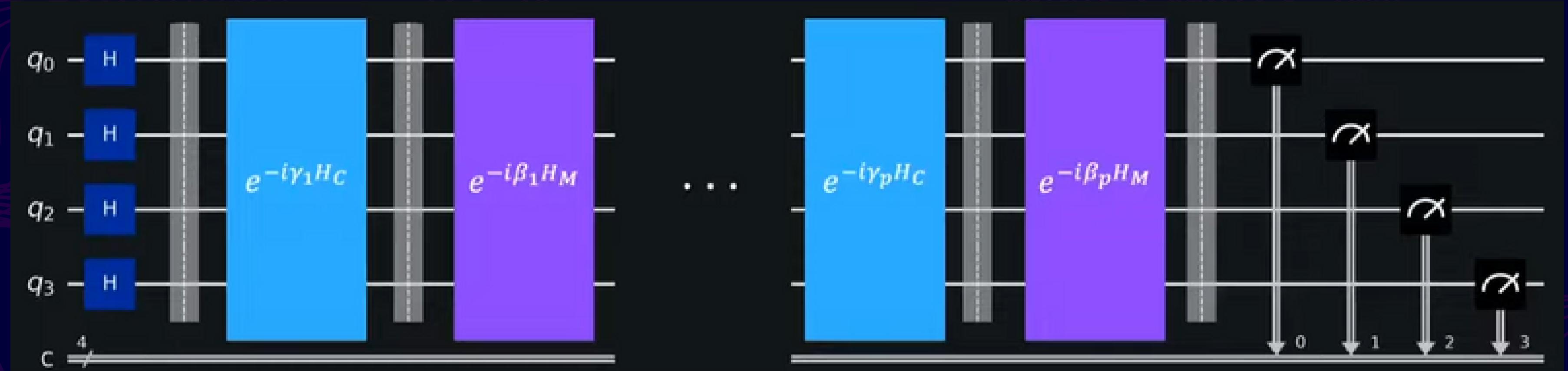
Pic cred : PennyLane

HC - Cost Operator

HM - Mixer Operator



Warm Start QAOA



Pic cred : IBMQ

Start with a suitable initial state to increase the probability of getting a better solution
Our initial state -
all qubits put into a superposition of basis states

Software Used

IBM Qiskit Library

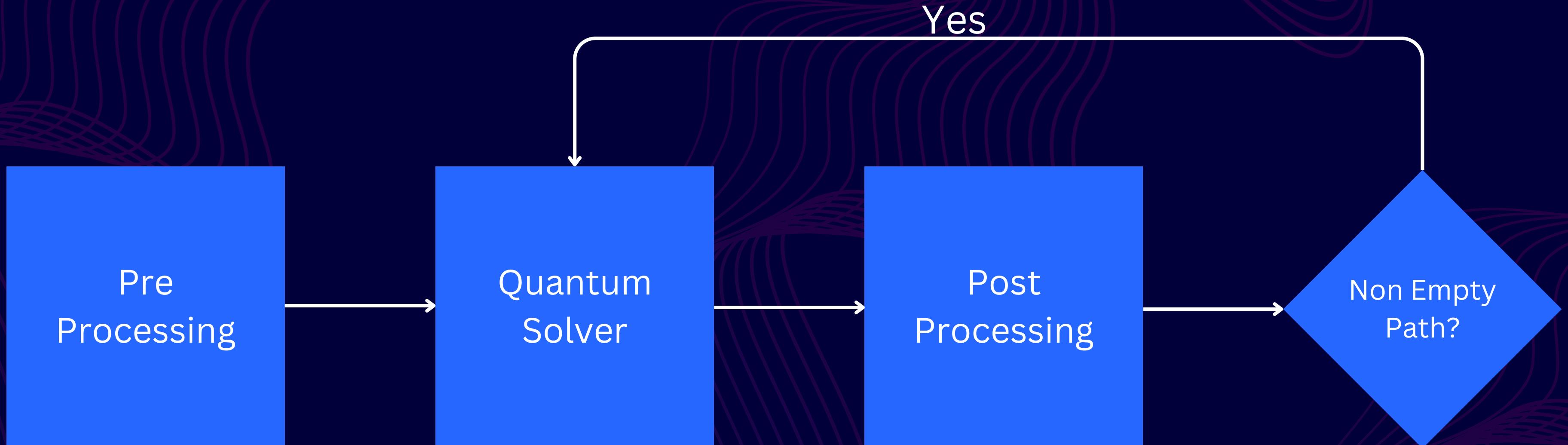
Library Functions of -

1. QAOA
2. WarmStartQAOA Optimiser

Classical Optimiser used as subroutine -

Cplex Optimiser

Approach



For each affected flight

Optimisation Output

Dictionary with
1. Keys as Inventory IDs
2. Values as all possible
alternate paths

```
[ [InventoryId  
ScheduleId  
CarrierCode  
Dep_Key  
FlightNumber  
AircraftType  
DepartureDate  
DepartureDateTime  
ArrivalDateTime  
DepartureAirport  
ArrivalAirport
```

Affected Flight

```
InventoryId  
ScheduleId  
CarrierCode  
Dep_Key  
FlightNumber  
AircraftType  
DepartureDate  
DepartureDateTime  
ArrivalDateTime  
DepartureAirport
```

```
INV-ZZ-6984919  
SCH-ZZ-9117133  
ZZ  
ZZ20240403BLRCCU2504.0  
2504.0  
Boeing 777  
04/03/2024  
2024-04-03 15:35:00  
2024-04-03 18:17:00  
BLR
```

QAOA

1

0:00:00.194056

CPLEX

2

0:00:00.245137

Classical Optimizers

- ADAM = 13 seconds
- SPSA = 19 seconds
- AQGD = 58 seconds
- COBLYA = 0:00:00.259484
- Gradient Descent = 49 seconds
- NELDER = 0:00:00.415791
- NFT = 6 seconds
- POWELL = 0:00:00.485886
- SLSQP = 0:00:00.213210
- TNC = 0:00:00.372630
- UMDA = 1 minute 20 seconds

Comparison of Various Algorithms



LOCATION

Scoring PNRs:



WCHR



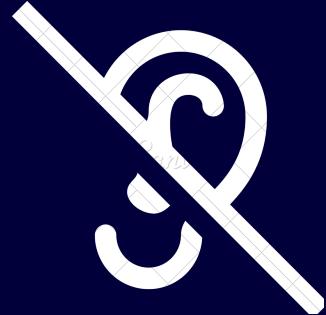
UNMR



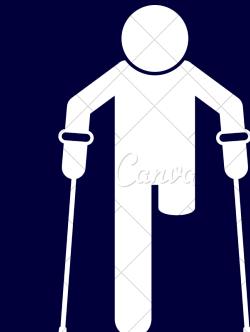
CHLD



BLND



DEAF



WCHS

SSR

FirstClass BusinessClass EconomyClass

Cabin & Class



CLASS GRADING

Economy
Class

Premium
Class

Business
Class

First
Class

UPGRADE
&
DOWNGRADE

MAILING SYSTEM

Dear Michele McDonald,

We regret to inform that your planned flight 2504 on 2024-04-03 15:35:00 has been Cancelled.
We have provided some alternate flight options as given below:

1. 2504 departing on 2024-04-04 15:35:00, assigned Economy Class.

Best wishes,
Airlines

Each affected passenger get a mail from airlines if :

- If a Flight is delayed
- If a Flight is delayed or canceled and has alternate flight(s)
- If a Flight is canceled and no alternate solutions are available

FUTURE WORK

API Based rule engine updation

Finalisation of flight path and passenger seat based on user input

