Dynamic Routing and Scheduling of a Call-Taxi System

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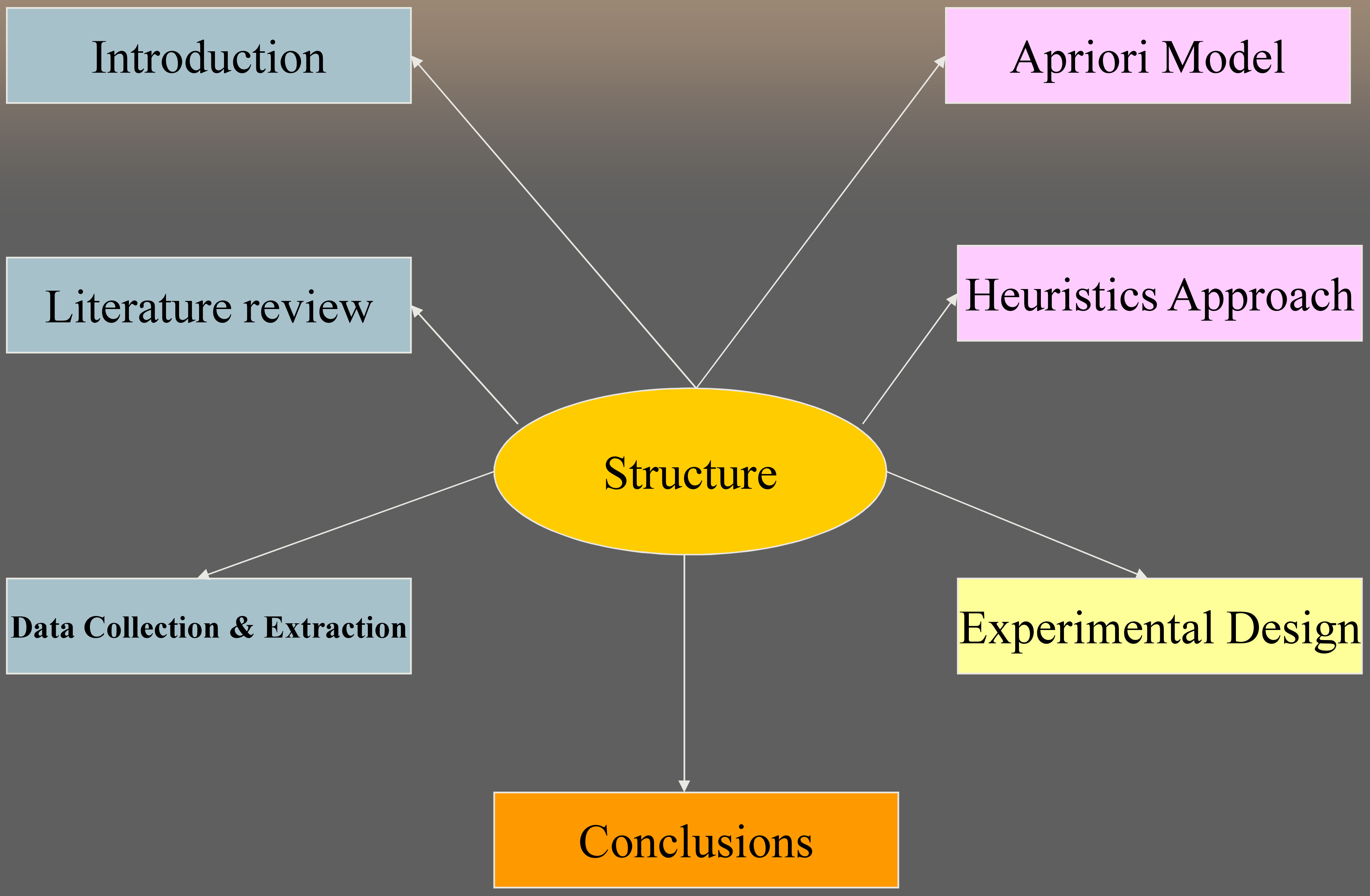

Introduction
Apriori Model
Literature review
Heuristics Approach
Structure
Data Collection & Extraction
Experimental Design
Conclusions

1. Introduction

- Routing – Freight, Emergency dispatch, Network evacuation, Call-bus systems, etc
- One such context – Call taxi optimization
- Motivation
  - Growing demand
  - Significant revenues
  - Need for optimization, decision support tools
  - Limitations of the current tools

Problem Definition and context

- Fleet size – ‘m’ and No. of request – ‘n’
- Requests – Origin, Destination, Pick up Time
- How do you allocate and dispatch taxis ??
- Which satisfy a certain set of objectives
- Context
  - Static
  - Dynamic
- Definitions
  - Decision variables – Fleet size, Call-offset time
  - Performance measures – Revenue, ADM, % calls rejected, % calls late serviced, car waiting time

Objectives

- Models - Maximize revenue generated
- Minimize
  - fleet size required
  - average dead mileage
  - car-waiting time
  - % rejection
  - % late serviced

- To test and validate the reliability of the models proposed with real time data.

- Develop a decision support application

Different Perspectives of the Problem

- System Operator's perspective
  - Max revenues, % accepted calls
  - Min taxi-idle times, dead-mileage

- User's perspective
  - LOS (pick-up times)
  - Tariffs (Cost of service)
  - Very less call-offset time

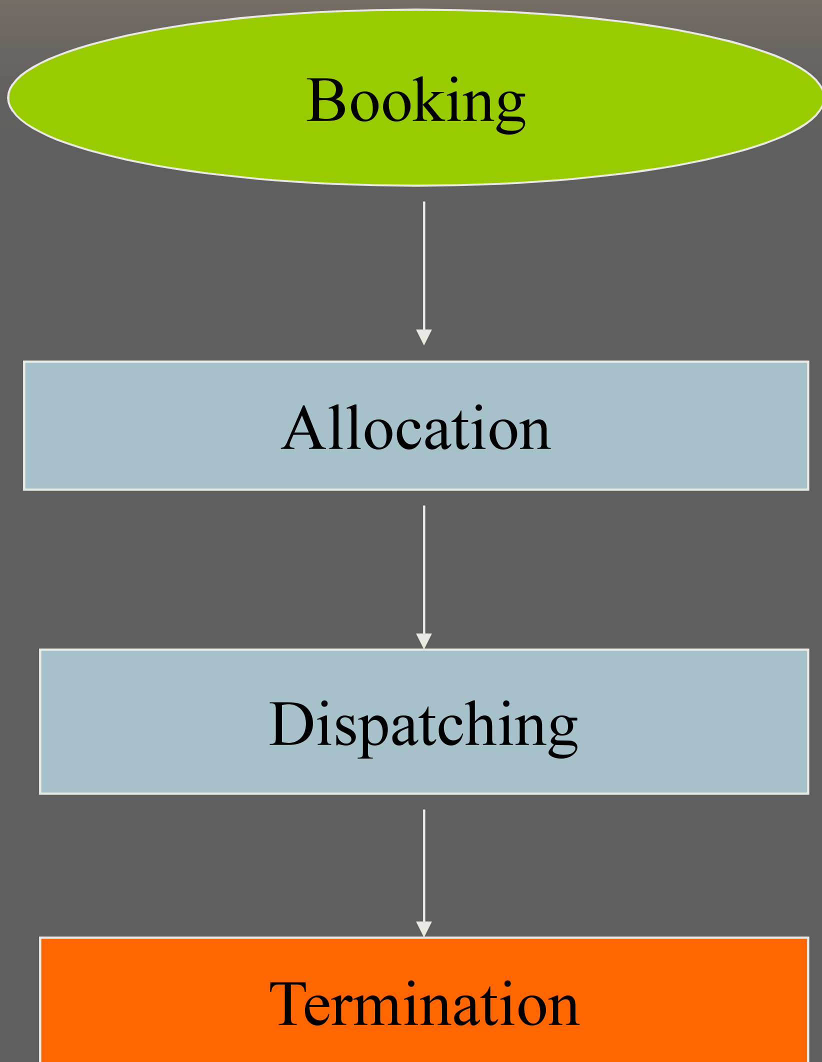
Scope

- A single source node (Hub)
- Link travel times are constant, no congestion
- Drivers do not use their judgment (Operator based)
- Taxis serve - one job at any given point of time
- Taxis move with constant speed
- Data obtained from a single cal taxi firm
- Time Windows
- No cancellation

2. Literature Review – Approaches

- Insertion and genetic algorithm approach
- Trip chaining strategy for advanced taxi booking
- Network equilibrium taxi model approach
- Mixed integer programming formulation approach
- Real time heuristics approach
  - Simple heuristics
  - Advanced heuristics
- Effects of taxi information systems on efficiency and quality of services

Current state of practice - Chennai



- 3-4 zones (40 vehicles)
- Software – 3 screens
- Bid for allocation
- Dispatcher discretion

- Human judgment

Gaps in Literature – This study will address

- Either static or the dynamic independently.
- Software that embed the mathematical models
- Sensitivity of the decision variables

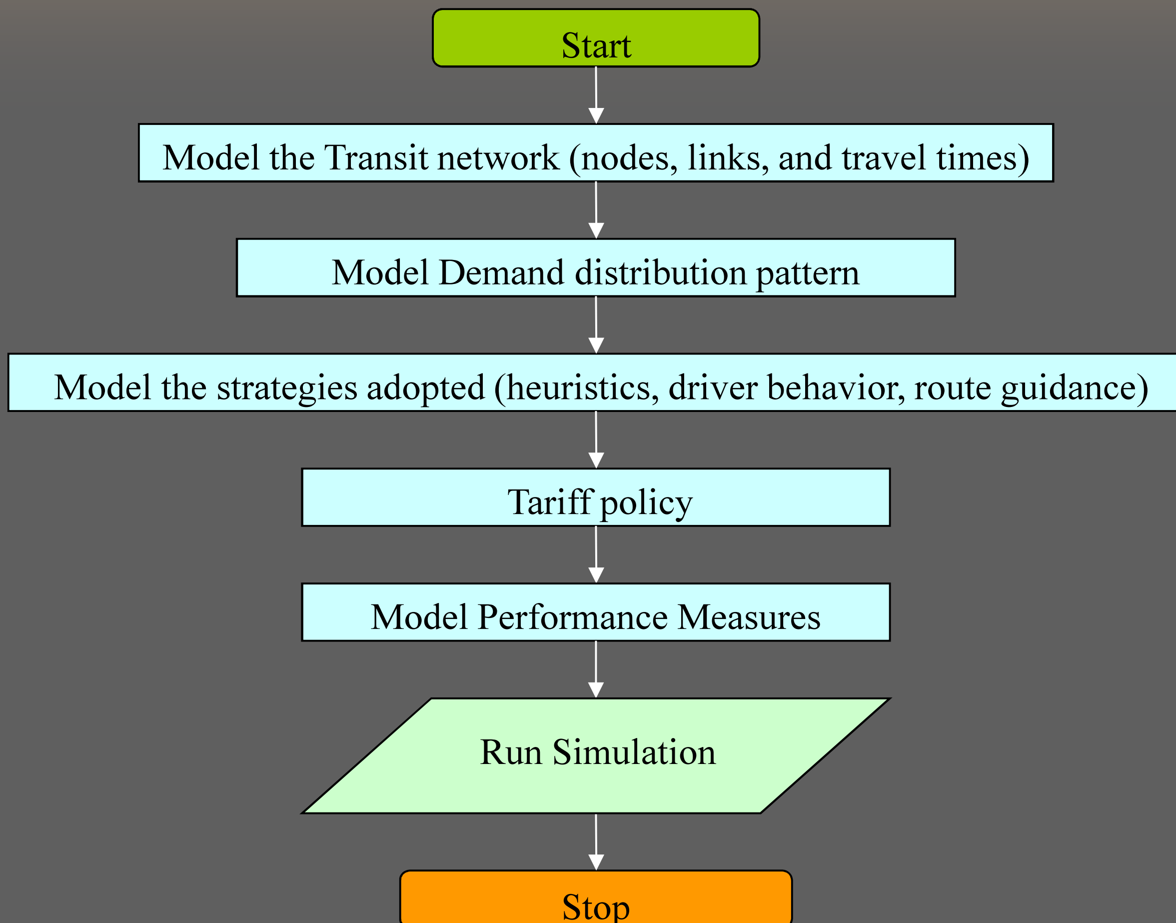
Applications of this study

- Planning level decision support
- Operation level decision support
- Analysis Insights

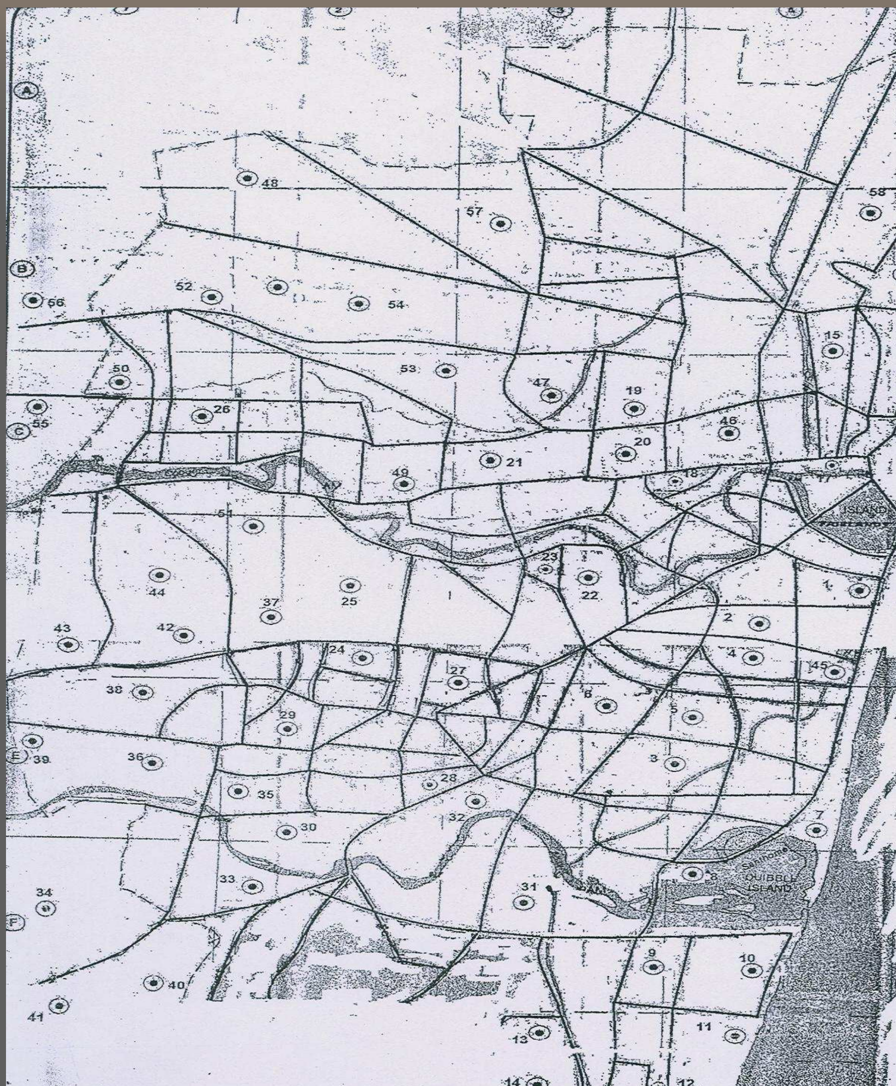
3. Data collection and Extraction process

- Data collection
  - 3 operators were contacted
  - The problem with benefits of such a study was explained clearly
  - Raw data – Obtained 30 day data for month of Jan, 2006 for testing and validation
  - This data – Extraction and refining process
- Lessons learnt
  - Modeling issues
  - Practical constraints

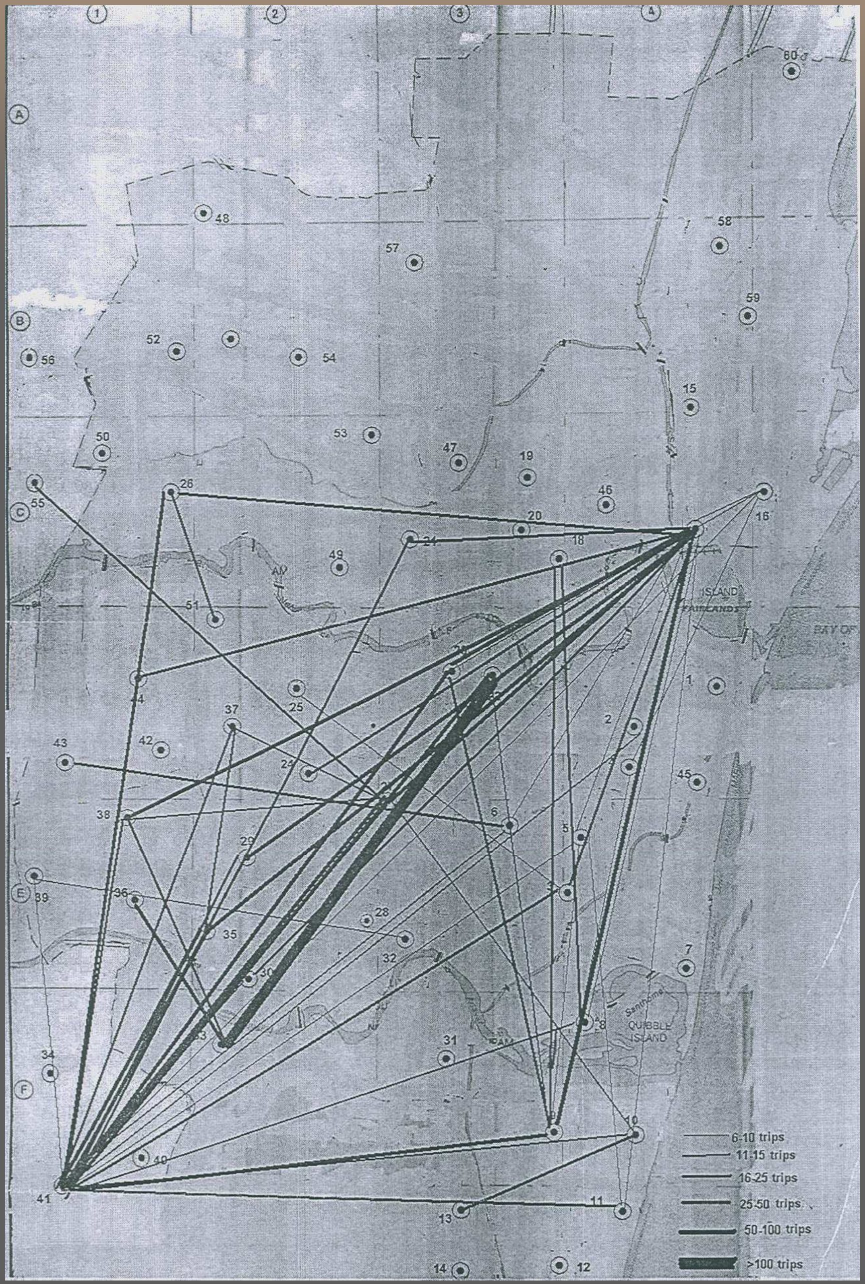
Modeling issues learnt



Chennai zonal map – Modeled transit network



ZONE ID	ZONAL AREAS	
1	CHEPAUK	
2	TRIPLICANE	
3	MYLAPORE	MANDAVELI
4	ROYAPETAH	SATYAM THEATRE
5	ALWARPET	TTK ROAD
6	RK SALAI	GOPALPURAM
7	PATTINAPAKKAM	
8	R.A.PURAM	SAVERA
9	ADYAR	I.I.T
10	BESANT NAGAR	



- Desire lines
- Concentration of trips around the airport and the railway stations

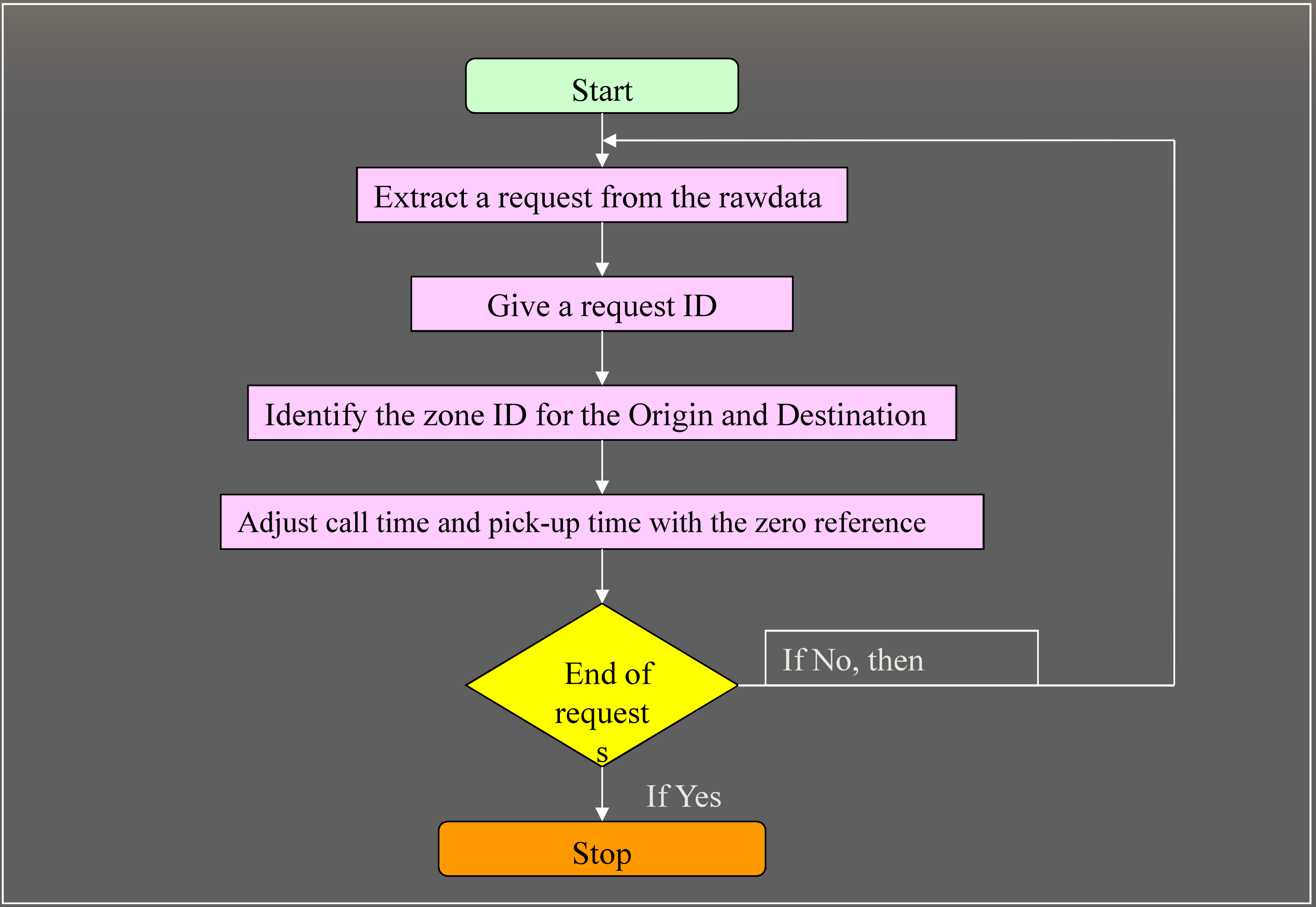
Raw data

Request ID	AU11012310002
Booking date	1/1/2006
Request date	1/1/2006
Call time	14:23
Pick-up time	15:00
Origin	TNagar
Destination	Anna Nagar
Allotment time	14:32
Dispatch time	14:51
Taxi idle time	13:14
Vehicle ID	104
Start meter	17017
End meter	17037
Revenue generated	220

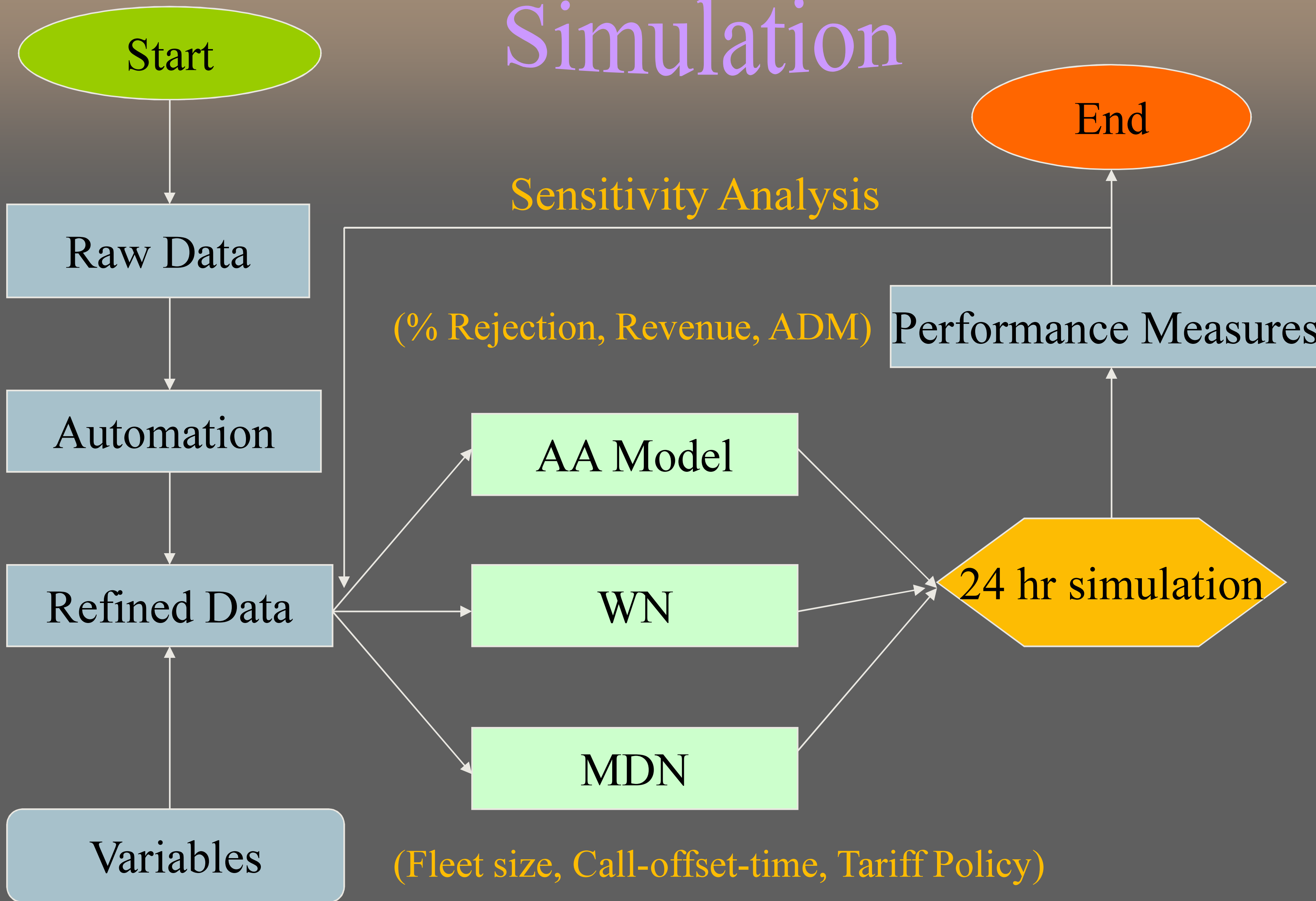
Format required

Request ID	1
Call time	863
Pick-up time	900
Origin ID	26
Destination ID	25

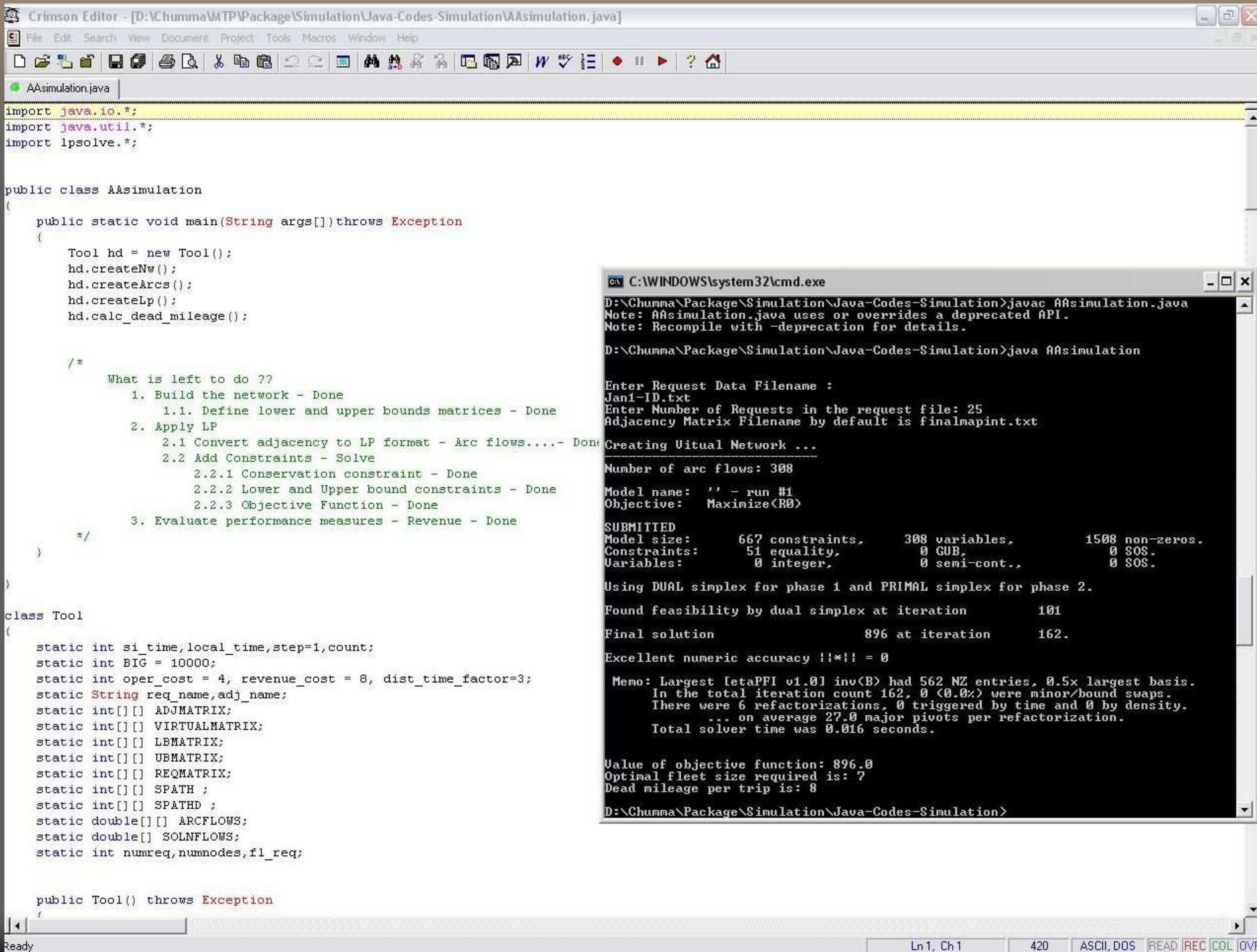
Automated refining process



Simulation


Start
Raw Data
Automation
Refined Data
Variables
Sensitivity Analysis
End
(% Rejection, Revenue, ADM)
Performance Measures
AA Model
WN
MDN
24 hr simulation
(Fleet size, Call-offset-time, Tariff Policy)

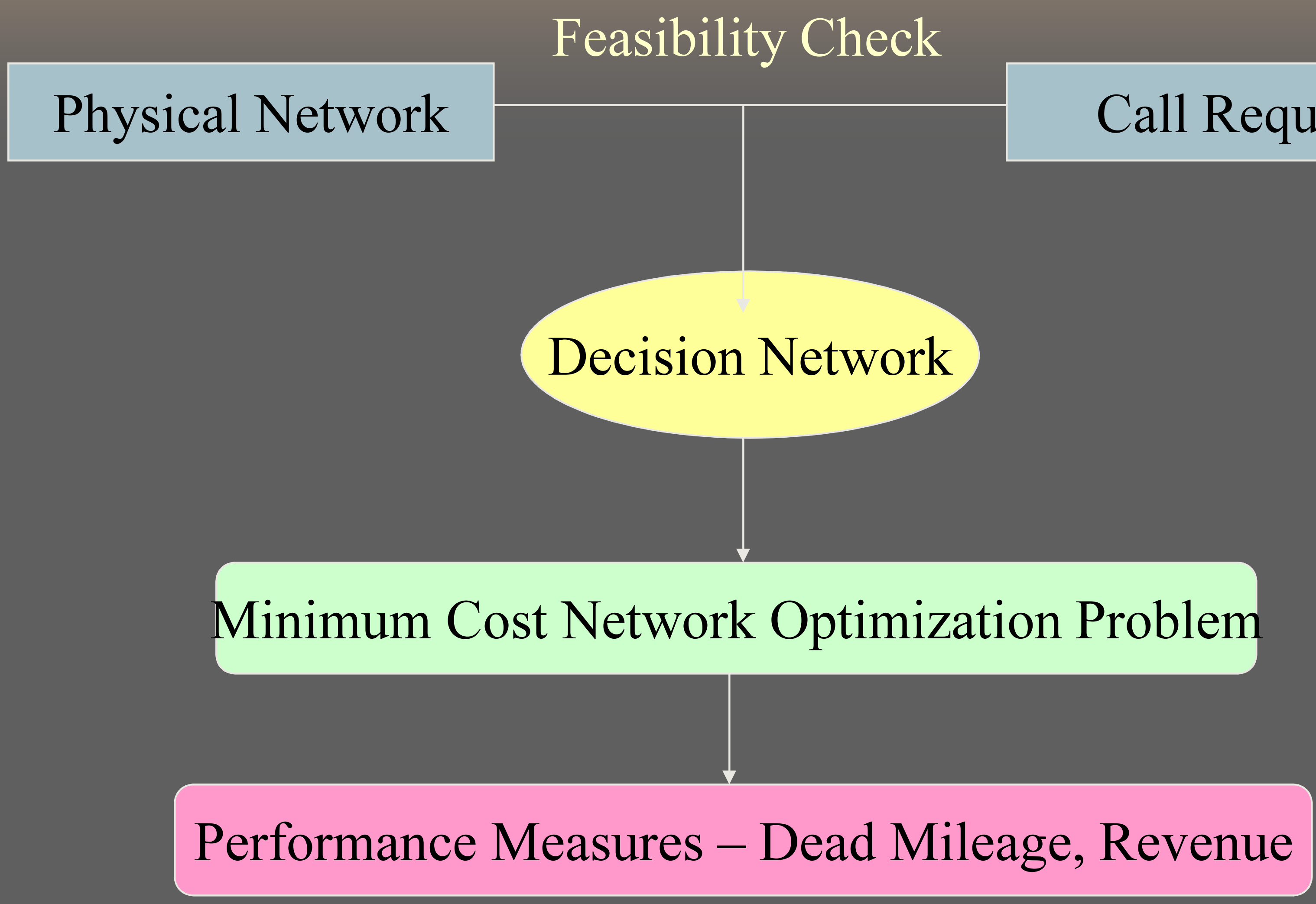
Simulation Screen-shot



4. Apriori model

- Inputs required
  - The apriori known request set for the day
  - Time period of operation
  - Physical network (Distance and travel time matrices)
- Input variables
  - **L**ij , Uij (Lower and upper bounds)
  - Cij, Tij (cost and travel times on the arcs Aij)

The Apriori Problem – Implementation



Objective function and constraints

- Objective function
  - Maximize the revenue generated
- Constraints
  - Time constraint
  - Capacity constraint
  - Conservation of flow constraint

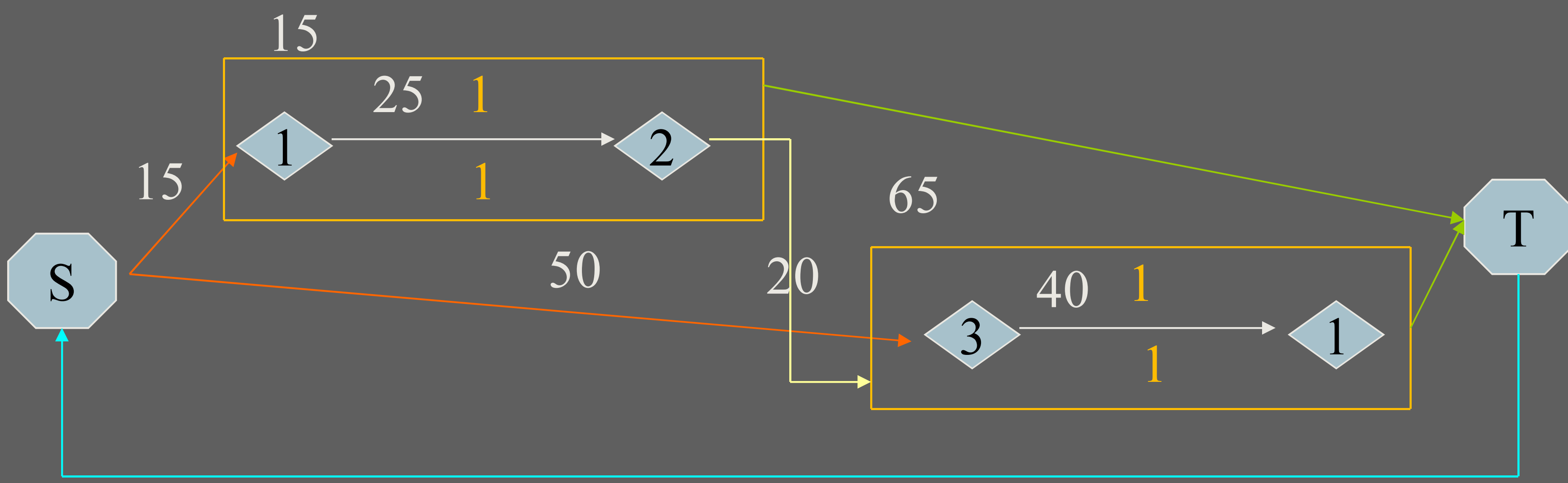
Final Problem Formulation as an LP

- Network **G = (N, A)** where **N** = {$\mathbf{n_0}$; n_1; : : : ; n_n} is the **node set** and **A** = {(A_{ij}); A_{ij} є A, $i \neq j$ }is the arc set.
- Vertex n_0 represents a depot (source) - Fleet of **m** vehicles,
- l_{ij}, u_{ij} and C_{ij} are the lower, upper bounds and the cost of traveling on the link $\mathbf{A_{ij}}$. $\mathbf{F}_{ij}$ be the flows on the Arc $\mathbf{A_{ij}}$.
- $l_{ij} \leq \mathbf{F}_{ij} \leq u_{ij}$ {Lower and upper bound}
- $\sum \mathbf{F}_{ij} = \sum \mathbf{F_{ji}}$ {Flow conservation constraint}

- *Objective function*: Minimize $\sum \mathbf{C}_{ij} * \mathbf{F}_{ij}$ for every $\mathbf{A}_{ij}$ є A

Example

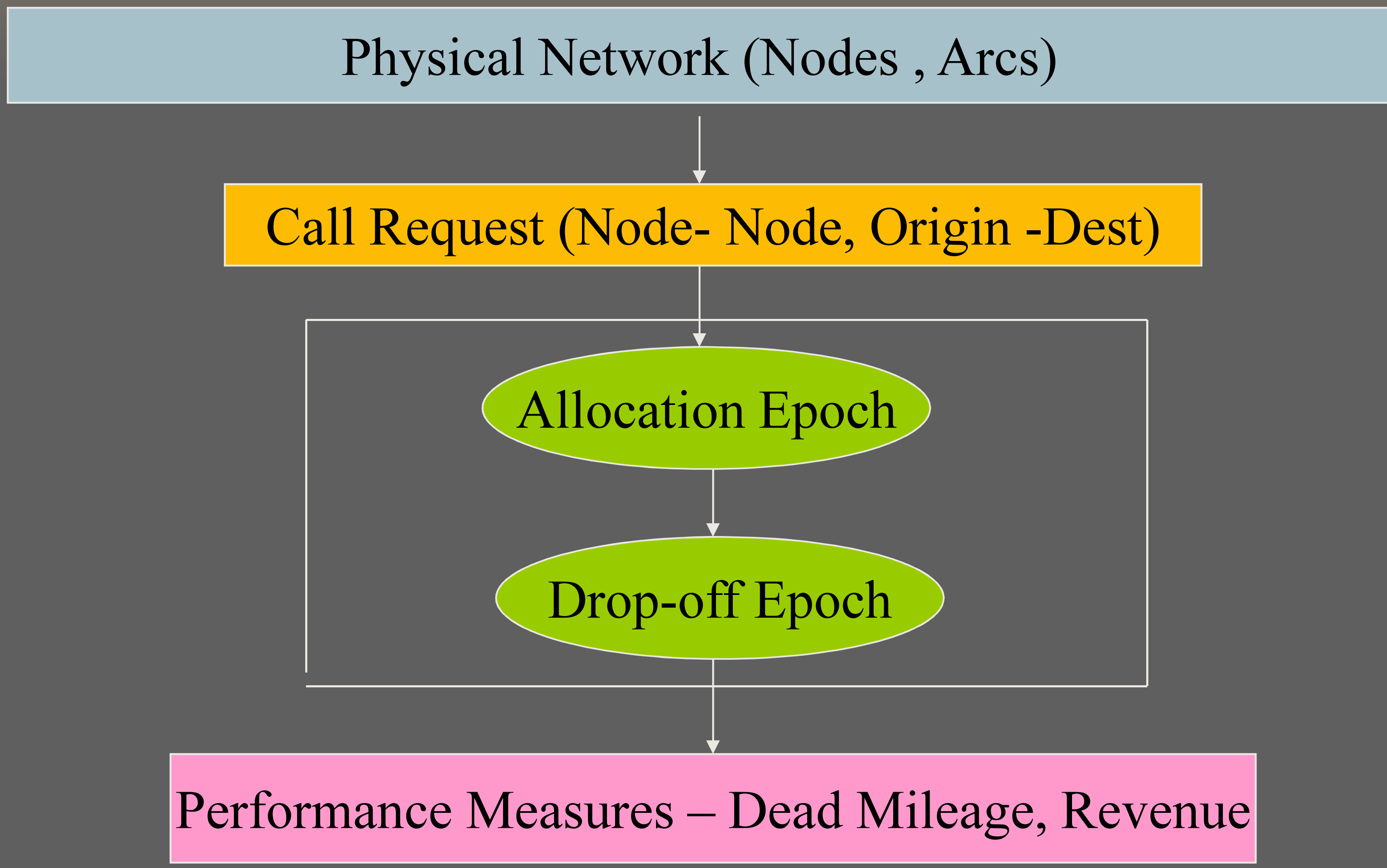
- Each request is represented as a link with LB and UB as 1.
- The connectivity between two requests link nodes is established based on feasibility .



5. Heuristics approach

- Need for the heuristics
  - Demand is an unknown function of:
    - Time
    - Space
- Heuristics refers to local rules for making:
  - Routing and Scheduling decisions
- Not global optimal

Heuristics approach model outline



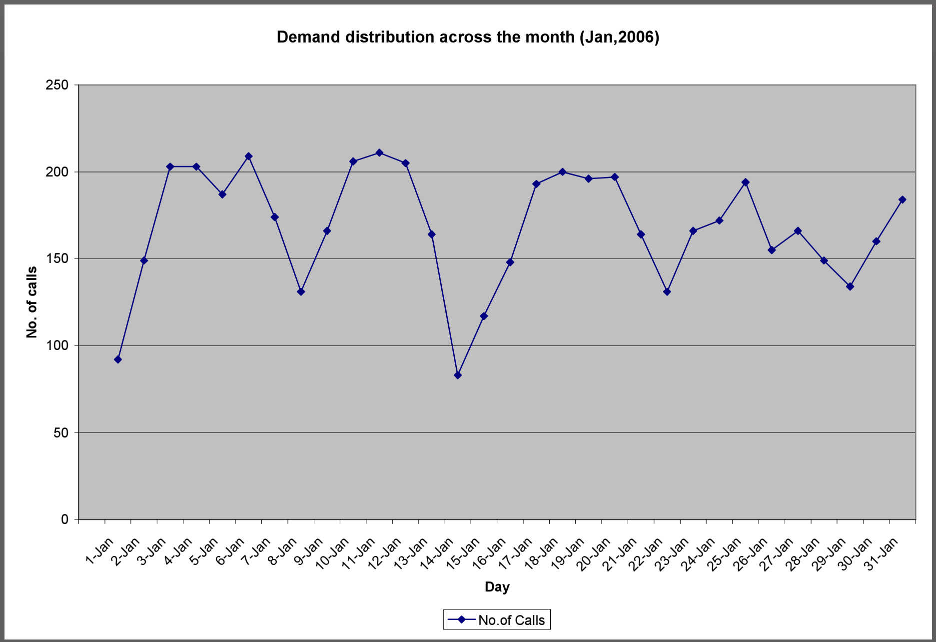
Heuristics approach

- Two heuristics strategies
  - Wait @ node – WN model
  - Move to desirable node – MDN model
- Logic – Demand is an unknown function of time and space
- Decision epochs
  - Which taxi should be allocated a request
  - What happens to the taxi after the drop-off

6. Experimental design & procedure - Results

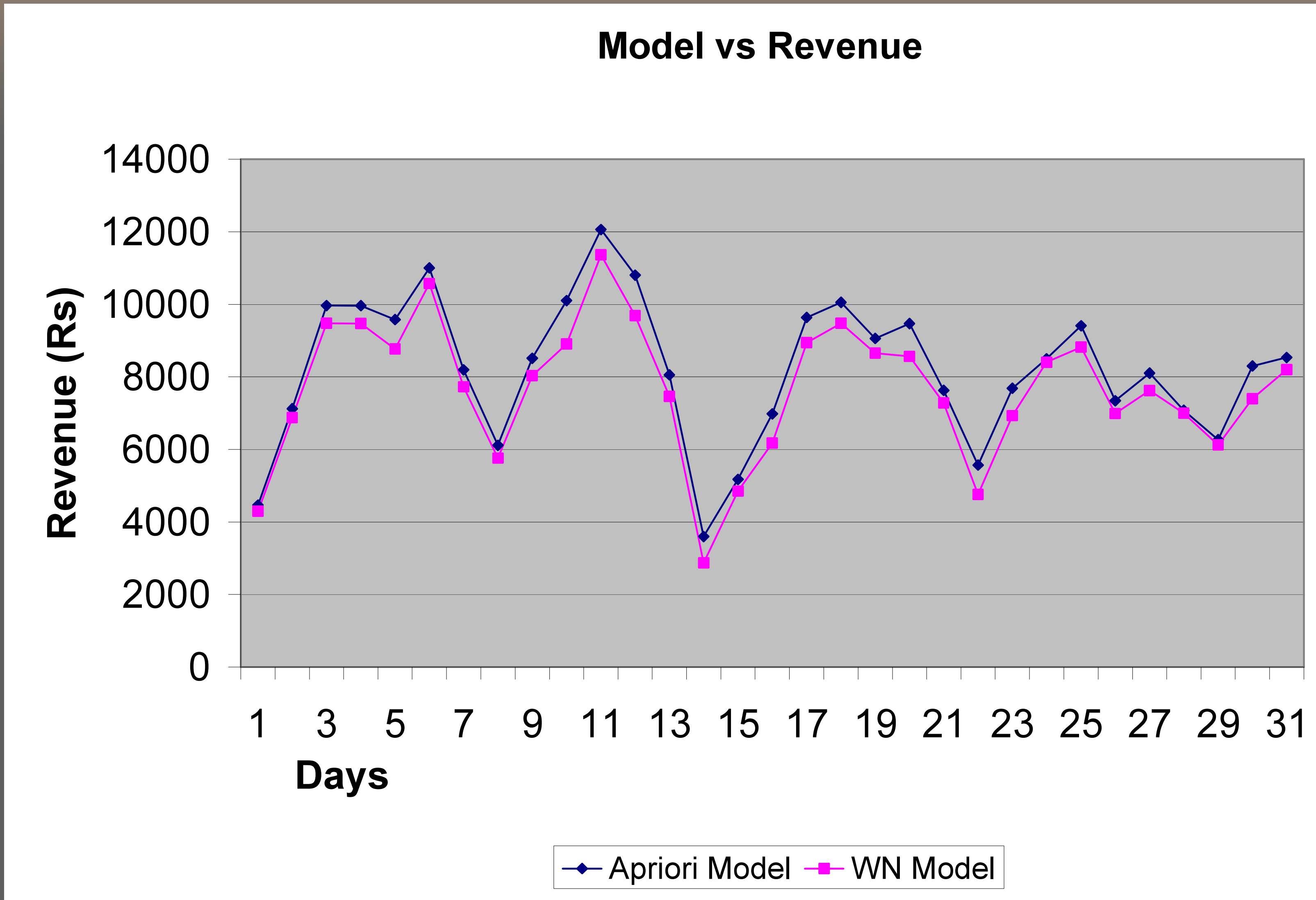
- Factors chosen and their effect on the performance of the system
  - Demand size
  - Fleet size
  - Call-offset time
- Performance measure – Its significance
  - Revenue generated
  - Average dead mileage
  - % of calls rejected due to fleet constraint
  - % Calls late serviced
  - Taxi waiting time

Demand distribution

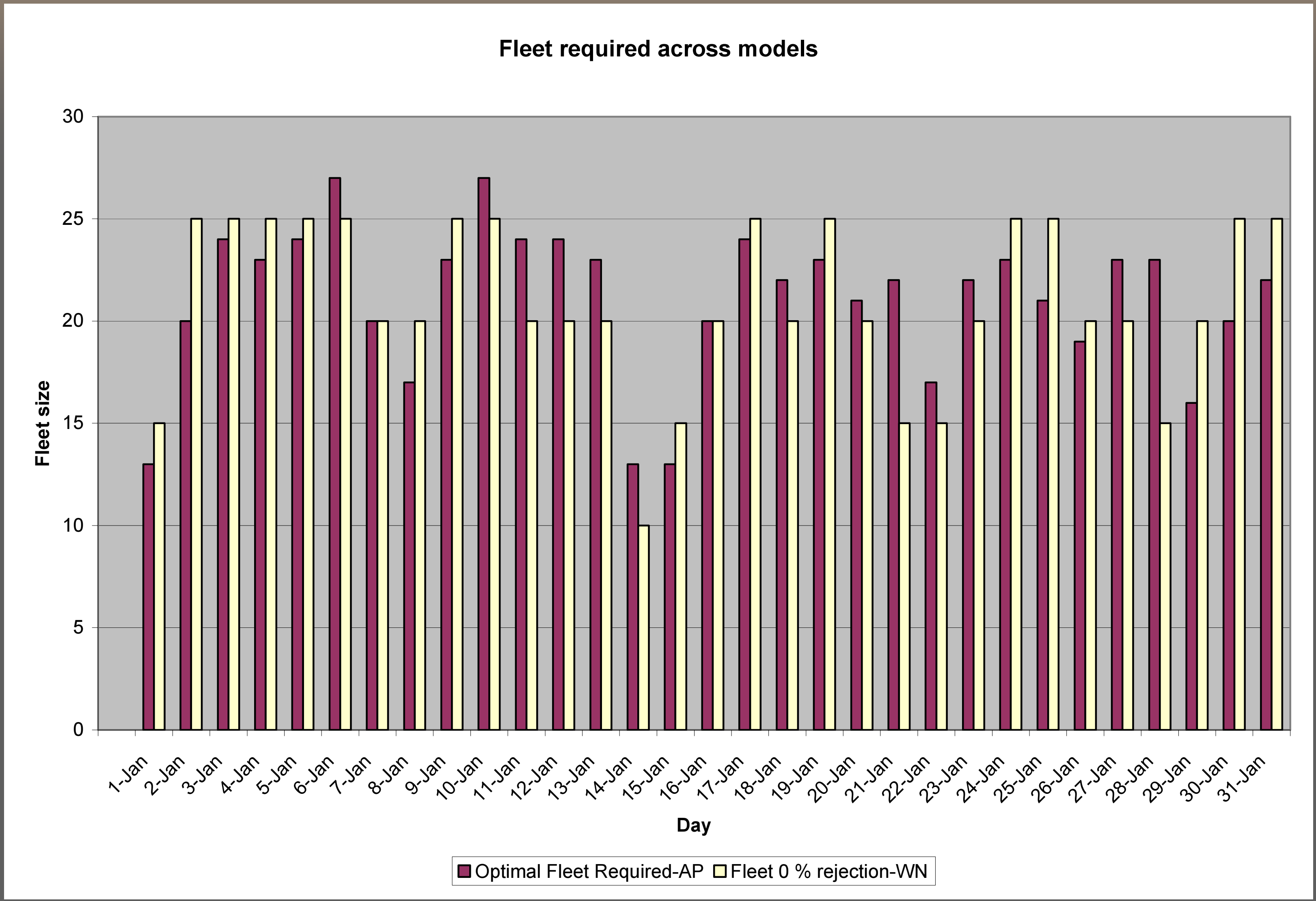


Average	168
Minimum	83
Maximum	211

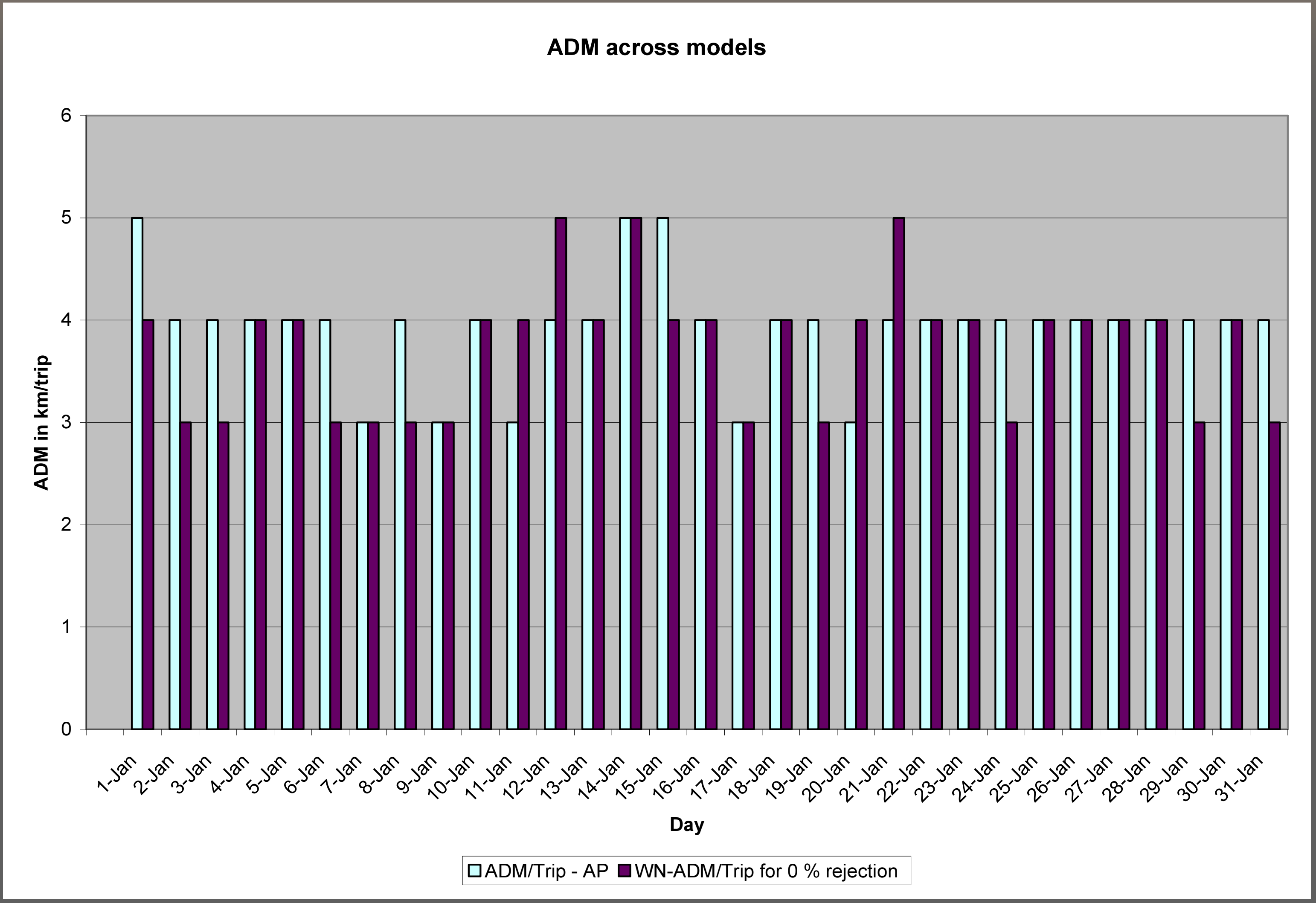
Model Vs Revenue



Fleet size Vs Model

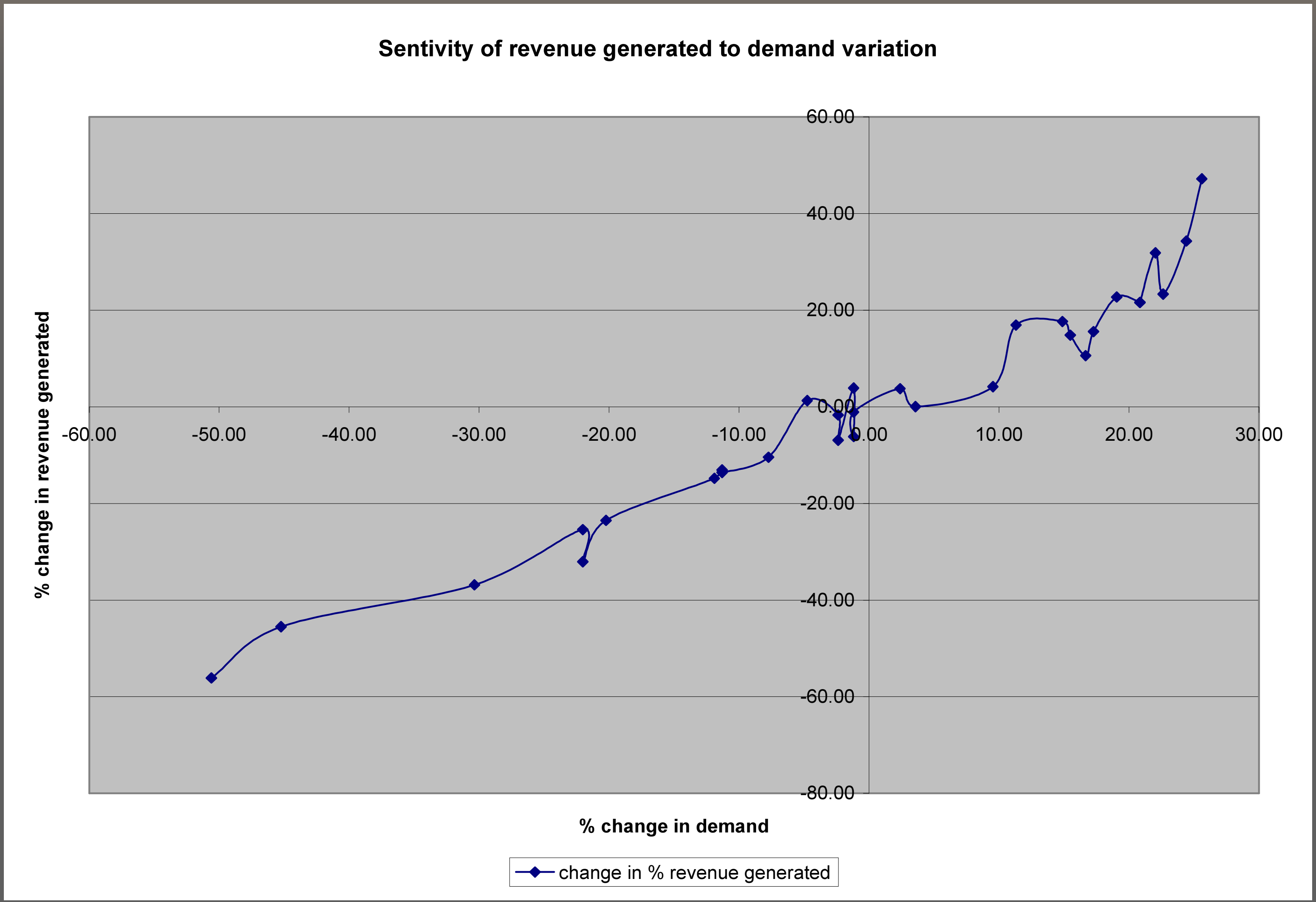


ADM Vs Model

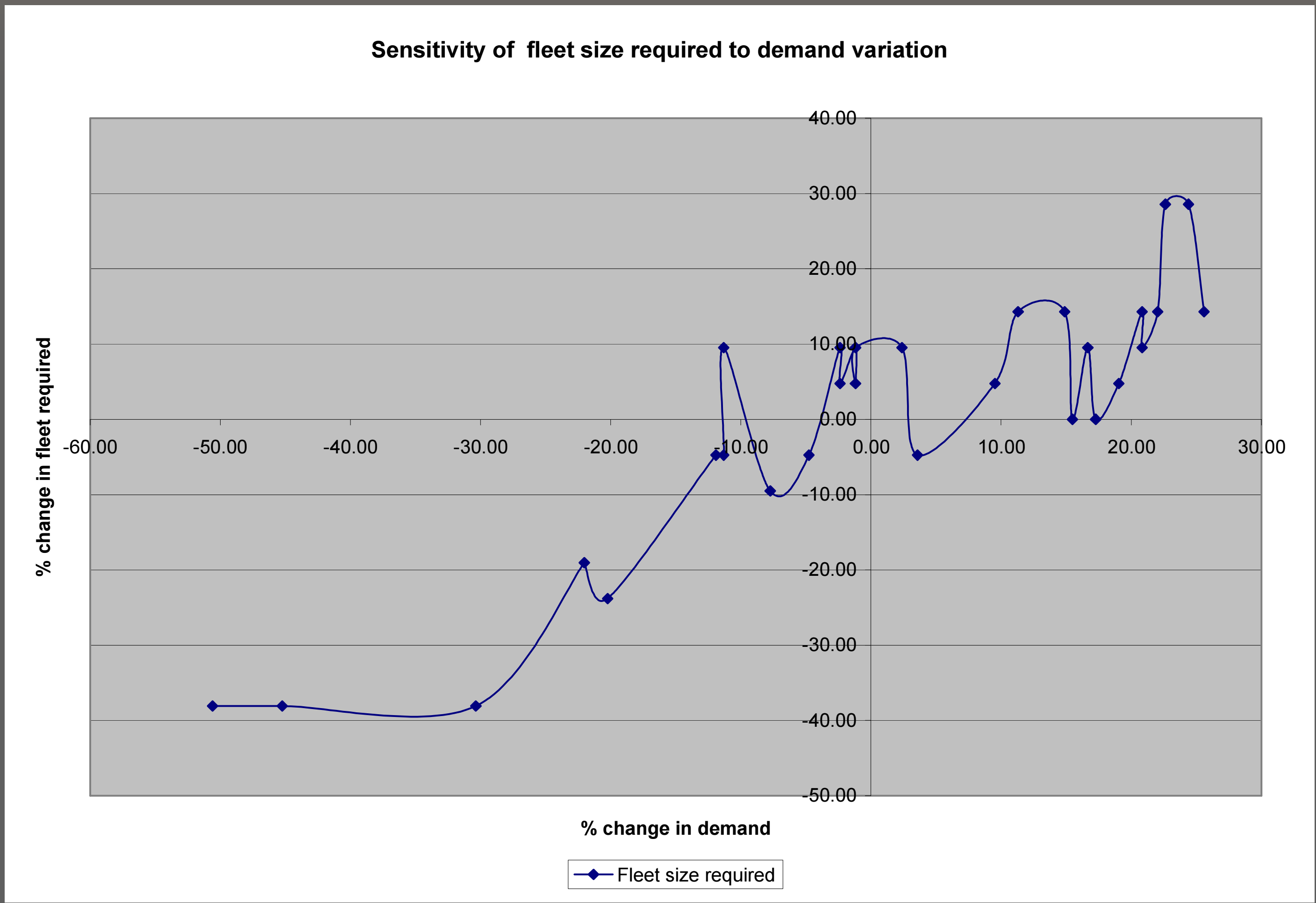

ADM across models
ADM in km/trip
0
1
2
3
4
5
6
1-Jan
2-Jan
3-Jan
4-Jan
5-Jan
6-Jan
7-Jan
8-Jan
9-Jan
10-Jan
11-Jan
12-Jan
13-Jan
14-Jan
15-Jan
16-Jan
17-Jan
18-Jan
19-Jan
20-Jan
21-Jan
22-Jan
23-Jan
24-Jan
25-Jan
26-Jan
27-Jan
28-Jan
29-Jan
30-Jan
31-Jan
Day
ADM/Trip - AP
WN-ADM/Trip for 0 % rejection

Sensitivity Analysis – WN Model

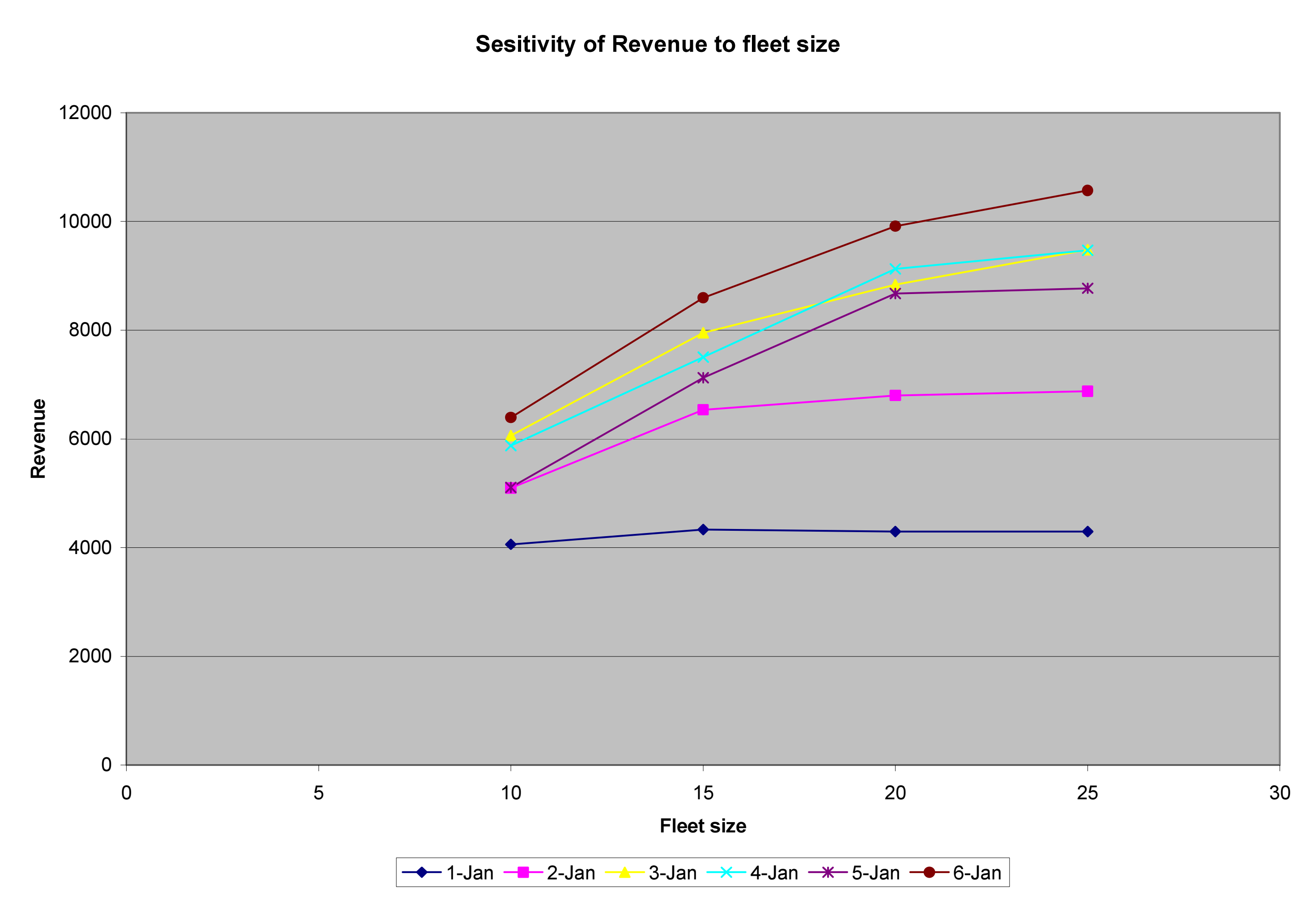
Sensitivity of revenue to demand size



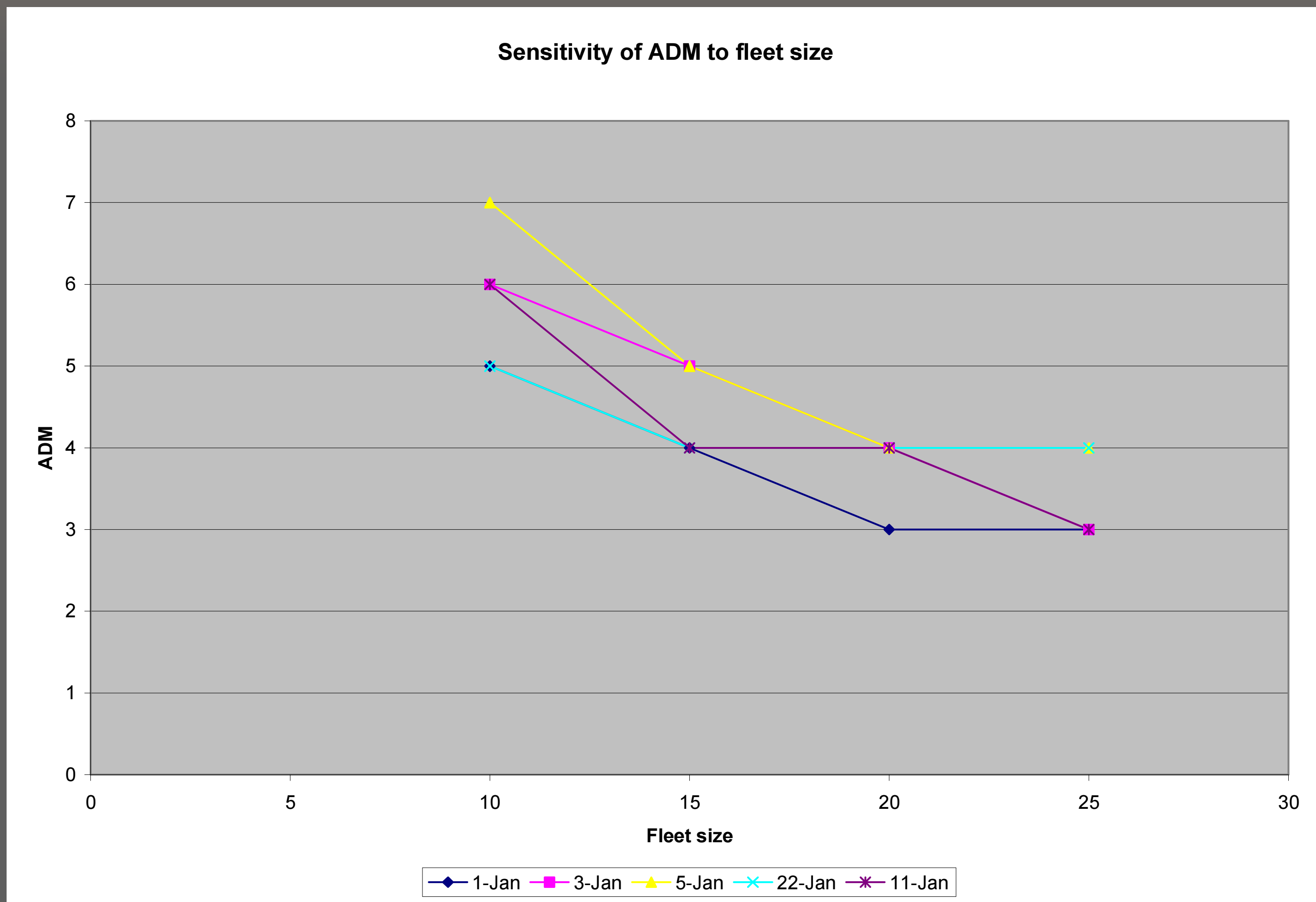
Sensitivity of fleet size to demand size



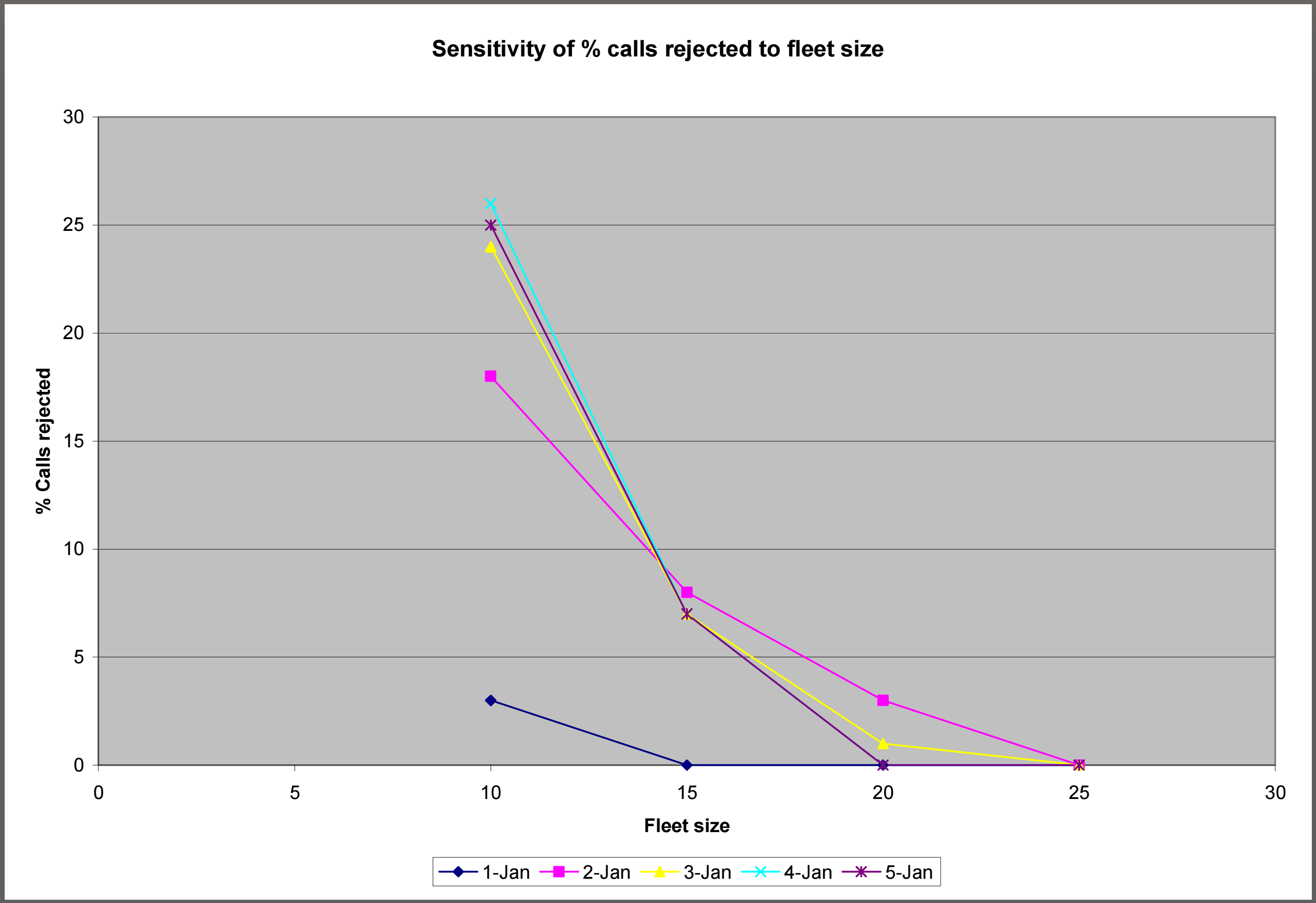
Sensitivity of Revenue to fleet size



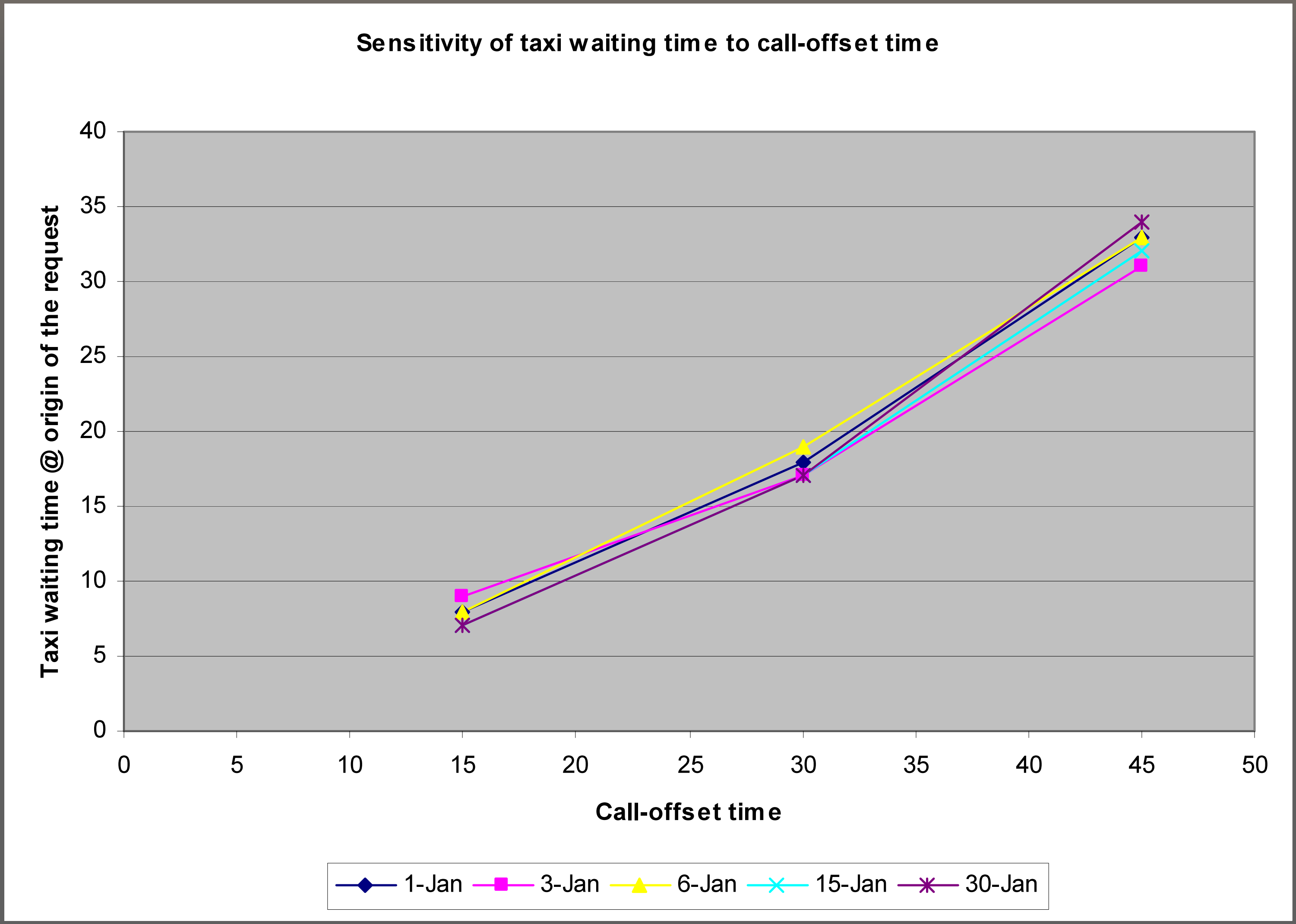
Sensitivity of ADM to fleet size



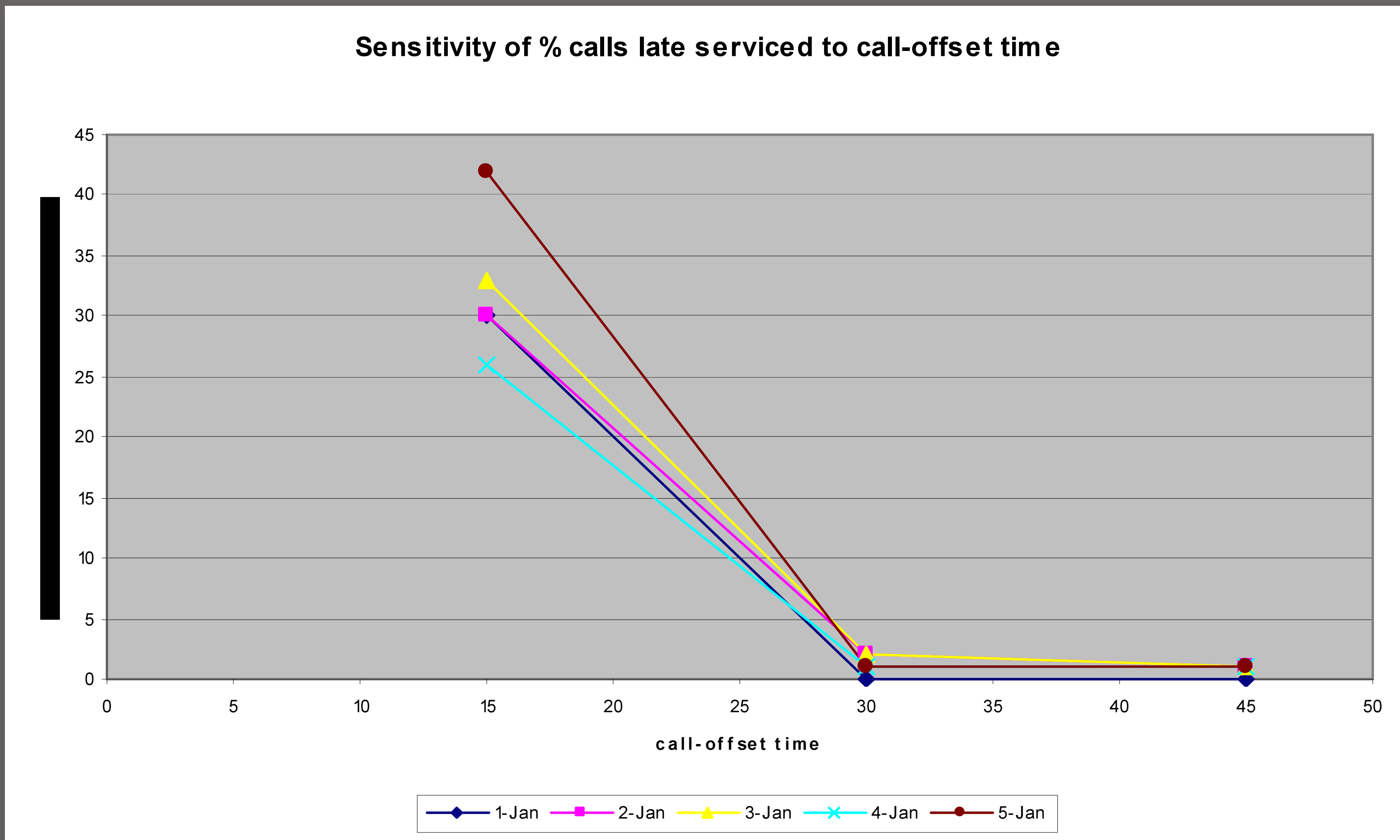
Sensitivity of % rejected to fleet size



Sensitivity of taxi waiting time to CO



Sensitivity of % late serviced to CO



Conclusions

Findings from the simulations

- Demand is high in the start and it falls sharply on weekends and national holidays
- A very large portion of the demand is directed around the airport and the central railway stations zones.
- Heuristic-optimal values of fleet size and call-offset time are 25 taxis and 30 minutes respectively for an average demand size of 160-180 calls per day

Continued …

- Steep ↓% of calls rejected : fleet size↑10 to 15
- Improvement reaches saturation at the heuristic optimal value of the fleet size i.e. 25
- ↑No. of taxis maintained :↓ADM, maintenance cost↑
- Taxi waiting↑as :↑call-offset time , (no delay)
- **Just 8 % gap** - WN model and the Apriori

Major contributions of the study

- Proposed heuristic models to increase the efficiency of the call - taxi operations
- Proposed optimization models to cross-check the goodness of the heuristics
- Testing – Real time data
- Developed a good decision support tool for the call – taxi operations

Scope for future work

- Applied other cities - effect of variations in demand patterns, difference in network components
- More advanced and far-sighted strategies, which take into account the stochastic characteristics
- Complicated instance which model
  - Real-time information available
  - Congestion on the network links
  - Sudden break-down of vehicles
  - Driver behavior, passenger behavior (cancellations)
- Integrate - technological advances - ITS and GPS
- Car – pool and call-bus systems

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Sources codes

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Thank you
Very much
Questions ???


Taxi Booking..
GPS
TAXI