Systems Engineering 520

A Discrete-Event Simulation Case Study

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Lecture 8

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Tompkins County Recycling and Solid Waste Center

Tompkins County Recycling and Solid Waste Center

- Collects garbage, yard waste, scrap metal, hazardous waste and recyclables from local residents, businesses and trash haulers

- Acts almost as a drive-through facility

- Customers get out of their cars for only for short durations

- Serves about 800 vehicles per day

- This number goes up to 1100 on Saturdays

- Want to decrease the overall time that the customers spend in the facility

- Want to identify the bottlenecks

Layout of RSWC

Figure 1 — Existing Site Plan. Traffic Study, Tompkins County Recycle & Solid Waste Center, City of Ithaca, New York.
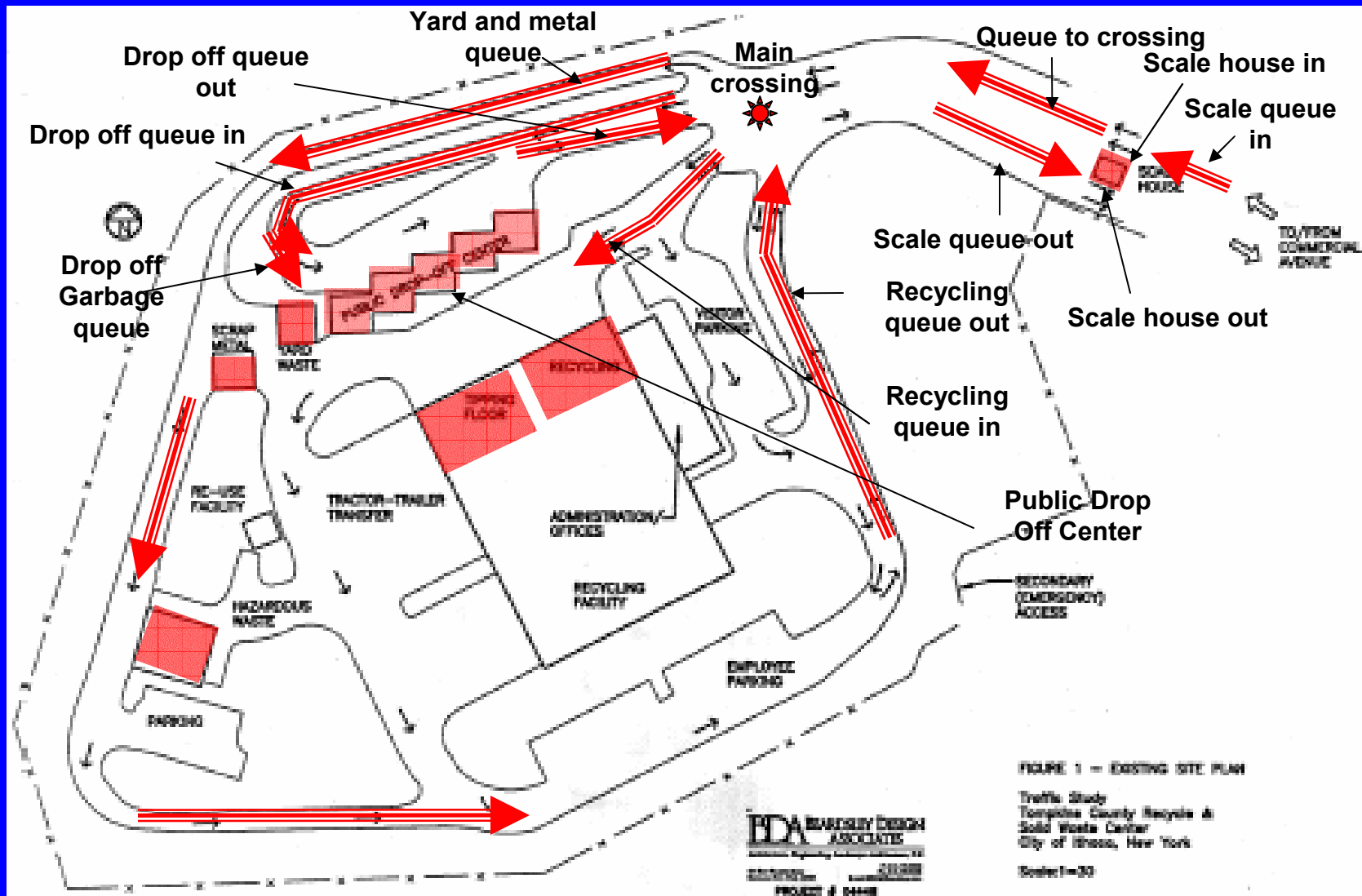
Data Collection

- Service times at the following servers

  Scale house in and out

  Five drop off area locations (two garbage locations, two paper locations and one container location)
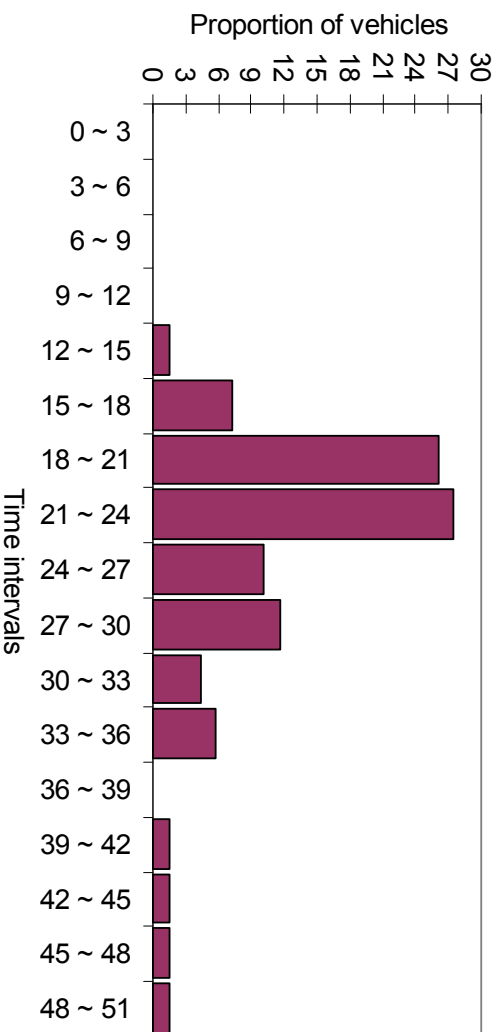
  Yard waste collection station

  Scrap metal location,

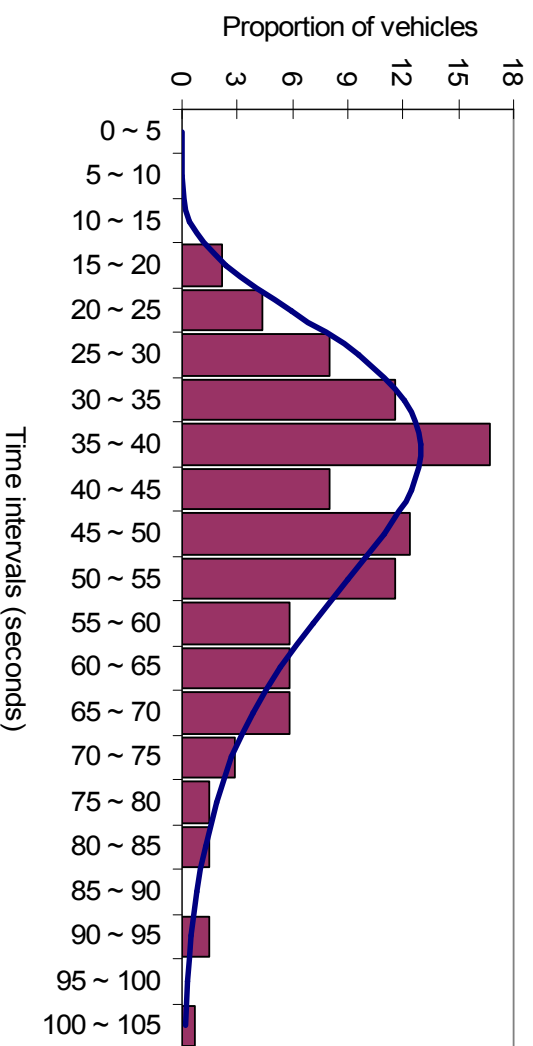 Two tipping locations (recycling floor and tipping floor)

Data Collection
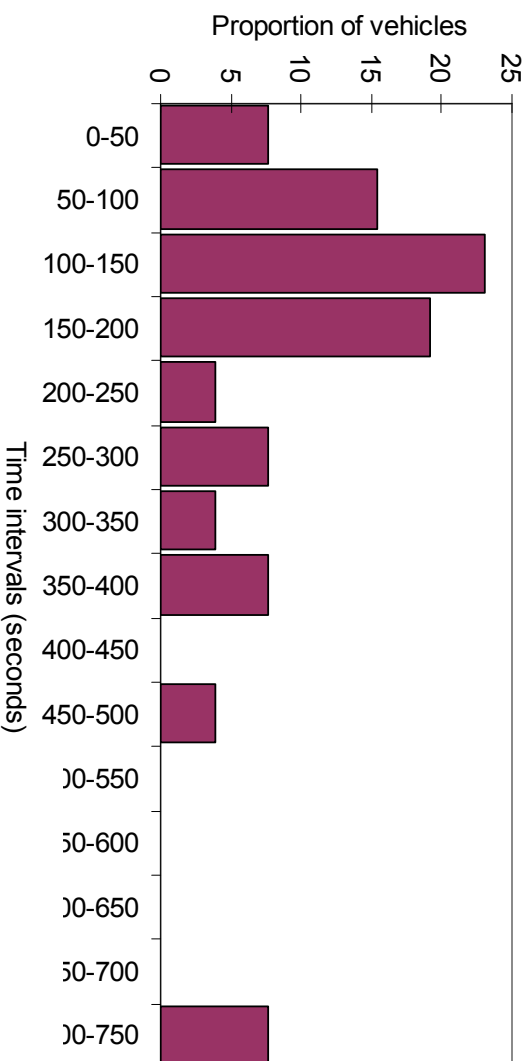
Service times

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Service times at scale house in

Proportion of vehicles

Time intervals

0 ~ 3
3 ~ 6
6 ~ 9
9 ~ 12
12 ~ 15
15 ~ 18
18 ~ 21
21 ~ 24
24 ~ 27
27 ~ 30
30 ~ 33
33 ~ 36
36 ~ 39
39 ~ 42
42 ~ 45
45 ~ 48
48 ~ 51

Scale house out service times
GAMMA(5.509,7.709) shifted by 5.585

Proportion of vehicles

Time intervals (seconds)

0 ~ 5
5 ~ 10
10 ~ 15
15 ~ 20
20 ~ 25
25 ~ 30
30 ~ 35
35 ~ 40
40 ~ 45
45 ~ 50
50 ~ 55
55 ~ 60
60 ~ 65
65 ~ 70
70 ~ 75
75 ~ 80
80 ~ 85
85 ~ 90
90 ~ 95
95 ~ 100
100 ~ 105

Data Collection

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Service times

Container service times

Proportion of vehicles

Time intervals (seconds)

0-50
50-100
100-150
150-200
200-250
250-300
300-350
350-400
400-450
450-500
00-550
50-600
00-650
50-700
00-750

Tipping service times
EXPON(202) shifted by 57 seconds

Proportion of vehicles

Time intervals (seconds)

60-110
110-160
160-210
210-260
260-310
310-360
360-410
410-460
460-510
510-560
560-610
610-660
660-710
710-760
760-810
810-860
860-910
910-960
960-1010
1010-1060
1060-1110
1110-1160
1160-1210
1210-1260
1260-1310
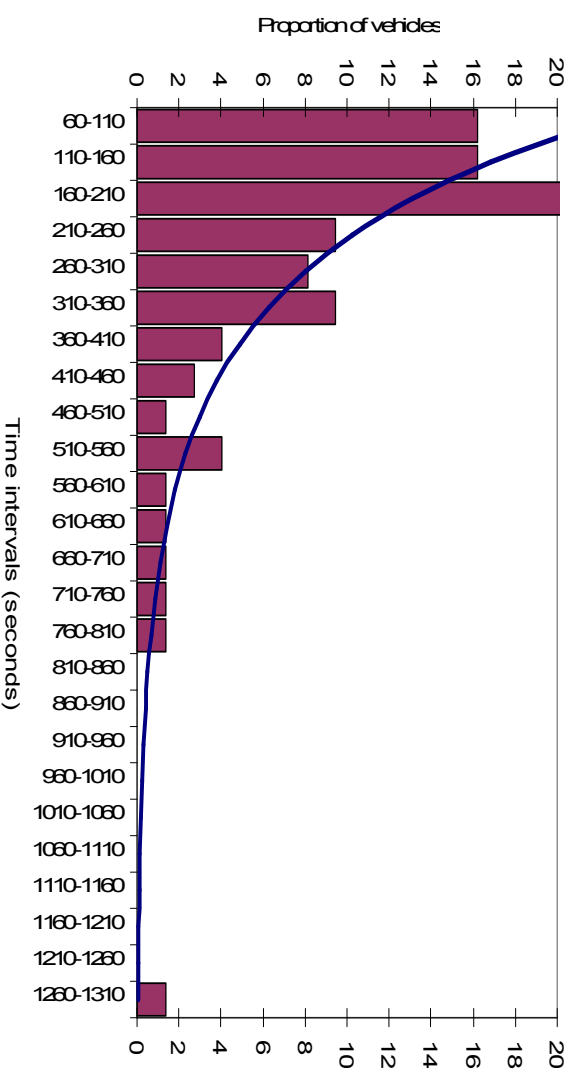
Data Collection

Service times

Paper service times
GAMMA(1.39,137.3) shifted by 43.3

Proportion of vehicles

25 20 15 10 5 0

Time intervals (seco

0-50
50-100
100-150
150-200
200-250
250-300
300-350
350-400
400-450
450-500
500-550
550-600
00-650
50-700
00-750
50-800
00-850
50-900
00-950
0-1000

Garbage service times

Proportion of vehicles

30 25 20 15 10 5 0

Time intervals (seconds)

0-50
50-100
100-150
150-200
200-250
250-300
300-350
350-400
400-450
450-500
500-550
550-600
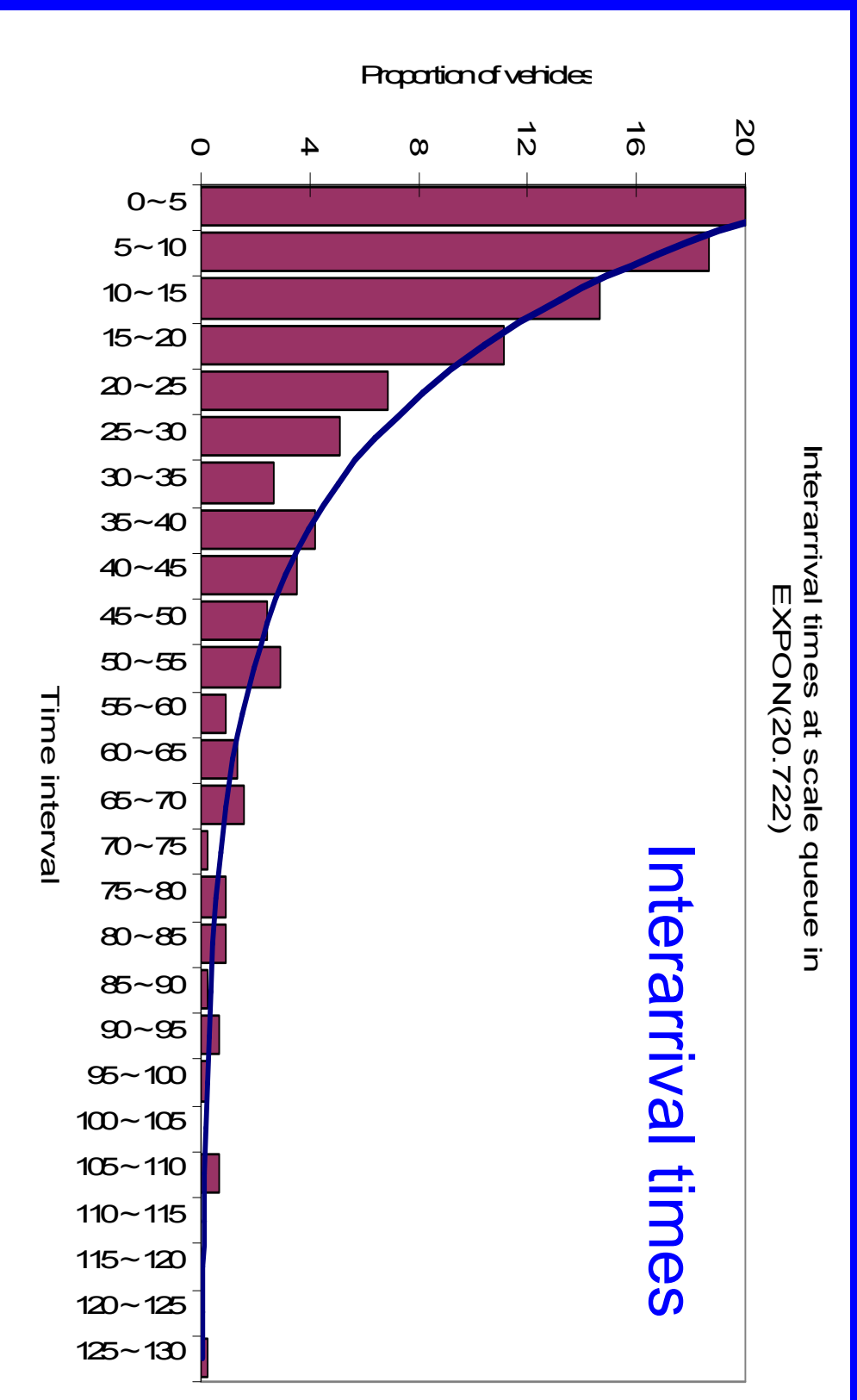600-650
650-700
700-750
750-800
800-850
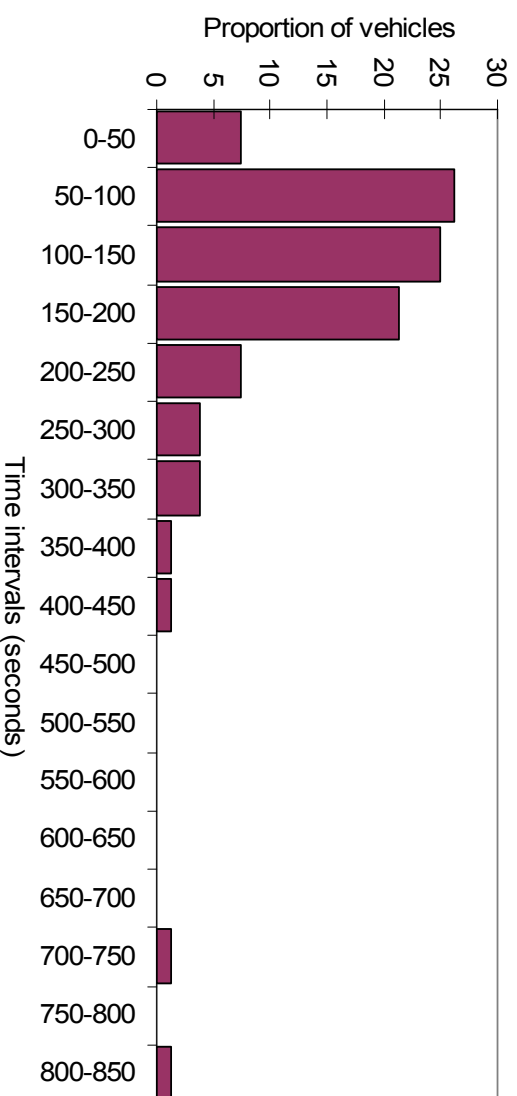
Data Collection

- Interarrival times of the vehicles at the scale house in queue

- Data on how the vehicles make route choices at the main intersection

Paying			% of customers	% of paying
	Garbage		27.59%	47.59%
	Tipping		30.38%	52.41%
		57.97%		
Non paying				% of non paying
	Recycling		0.62%	1.48%
	Drop off			
	Paper		28.38%	67.52%
	Containers		10.03%	23.87%
Yard and Metal			3.00%	7.14%
			100%	4.57%
		42.03%		

Interarrival times

Interarrival times at scale queue in
EXPON(20.722)

Proportion of vehicles

Time interval

Structure of the Model

- List of servers

Location	Shift (sec)	Distribution (sec)	Average service time (sec)
Scale House In	13	Exponential (11.5)	24.5
Containers	17.5	Exponential (194)	221.5
Paper	43.3	Gamma(1.39, 137.3)	234
Garbage	28.4	Gamma(1.31, 101.4)	161
Recycling floor	180	Constant	180
Tipping Floor	57	Exponential(202)	259
Yard Waste	90	Constant	90
Scrap Metal	90	Constant	90
Scale House Out	5.85	Gamma(5.509,7.109)	45

Structure of the Model

- List of queues

Queue	Capacity
Scale Queue In	INF
Queue to Crossing	10
Drop Off Queue In	12
Drop Off Garbage Queue	4
Drop Off Garbage Queue Out	7
Yard and Metal Queue	30
Recycling Queue In	5
Recycling Queue Out	20
Scale Queue Out	8

# Structure of the Model
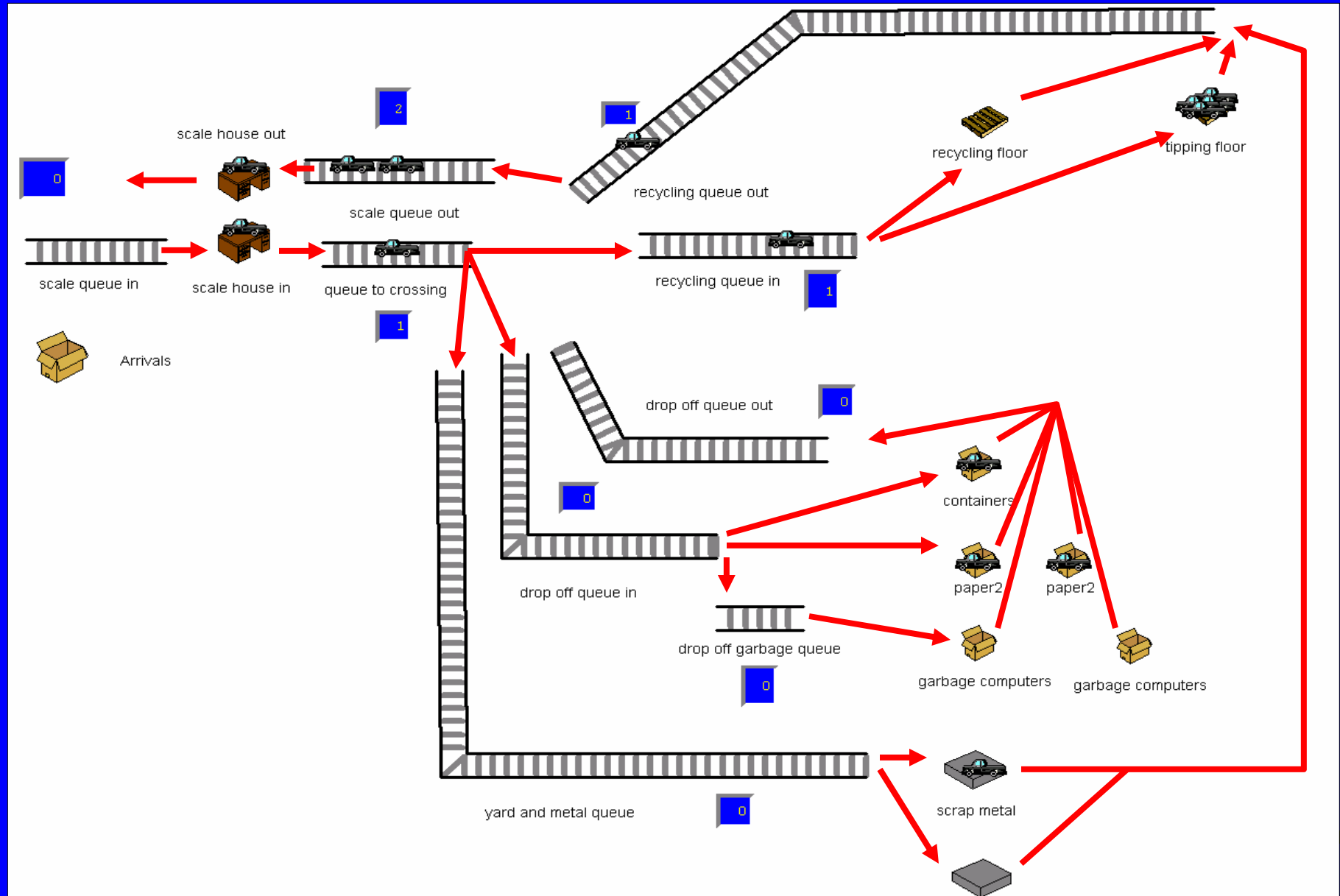
Verification and Validation

- Verification checks if the computer model is bug-free

- Validation checks if the computer model is a valid representation of the reality from the perspective of the purpose of the simulation study

- A very important validation method is to collect output data from the real system and to compare the output of the simulation model with the output data from the real system

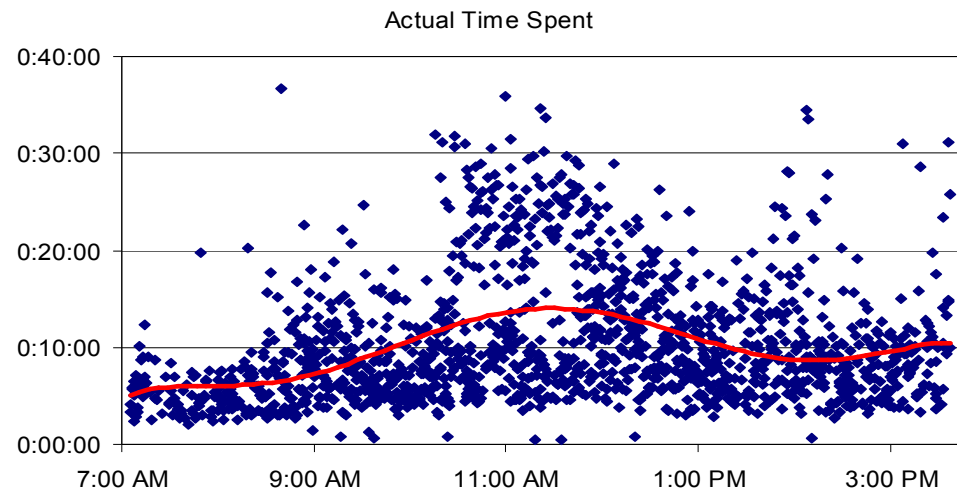# Verification and Validation

- The check-in/check-out system at the scale house keeps track of when a vehicle enters and leaves the facility

- That is, we have data on how much time a vehicle spends in the facility

- We can also estimate how much time a vehicle spends in the facility by using the simulation model

- Compare the estimate from the simulation model with the data from the real system
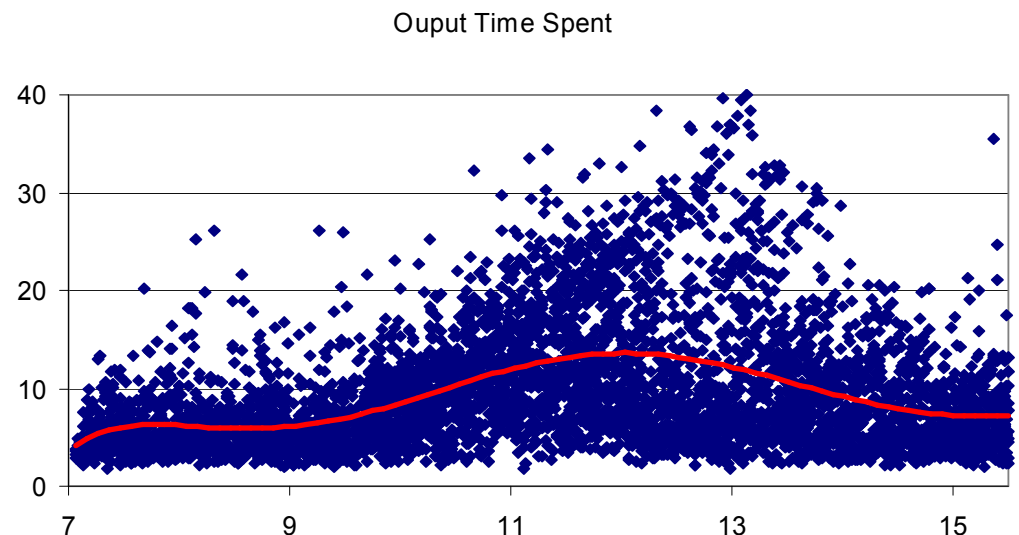
Verification and Validation

Actual Time Spent
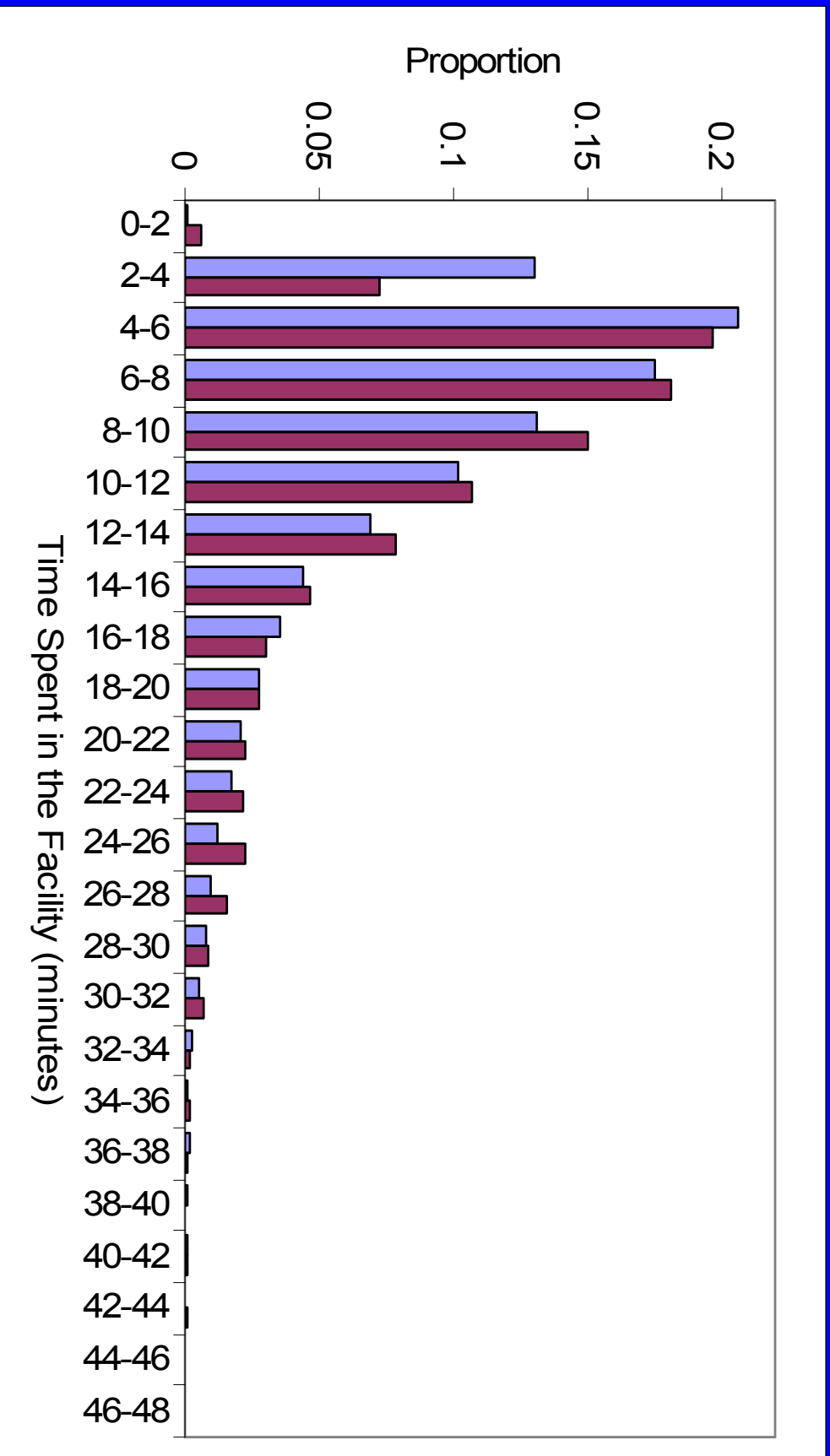
Check how time spent in the system by a vehicle changes over the course of a day
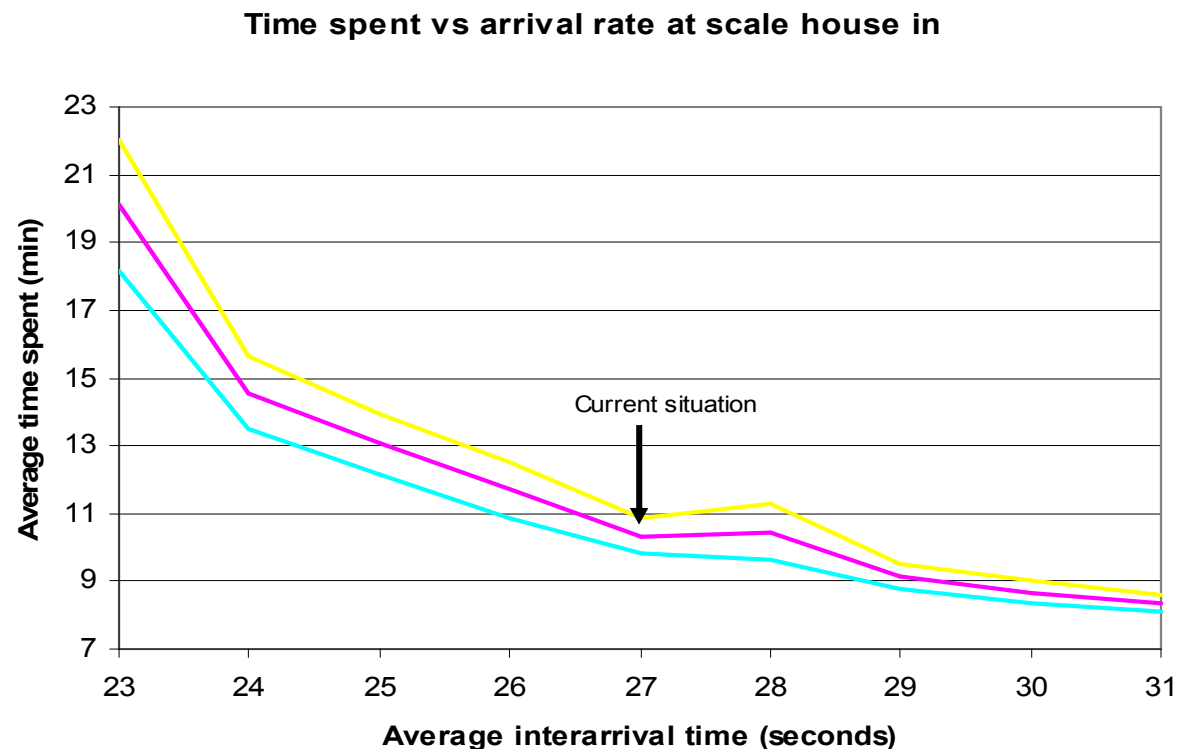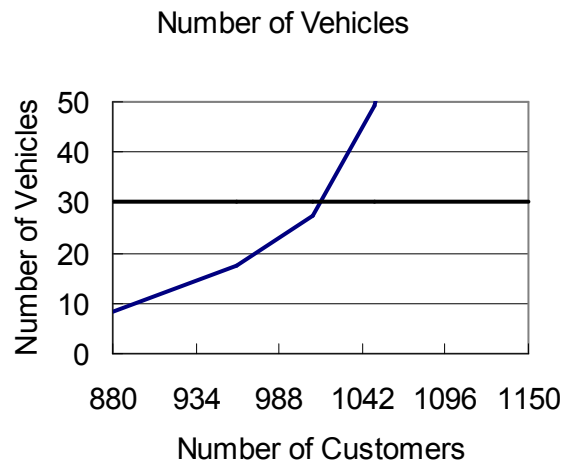

Ouput Time Spent

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Verification and Validation

- Compute what fraction of the time there are a certain number of vehicles at the scale out queue

- We do not have real system data on this queue, but we can show this diagram to the employees and see if they find it agreeable

Cumulative histogram for scale queue out contents
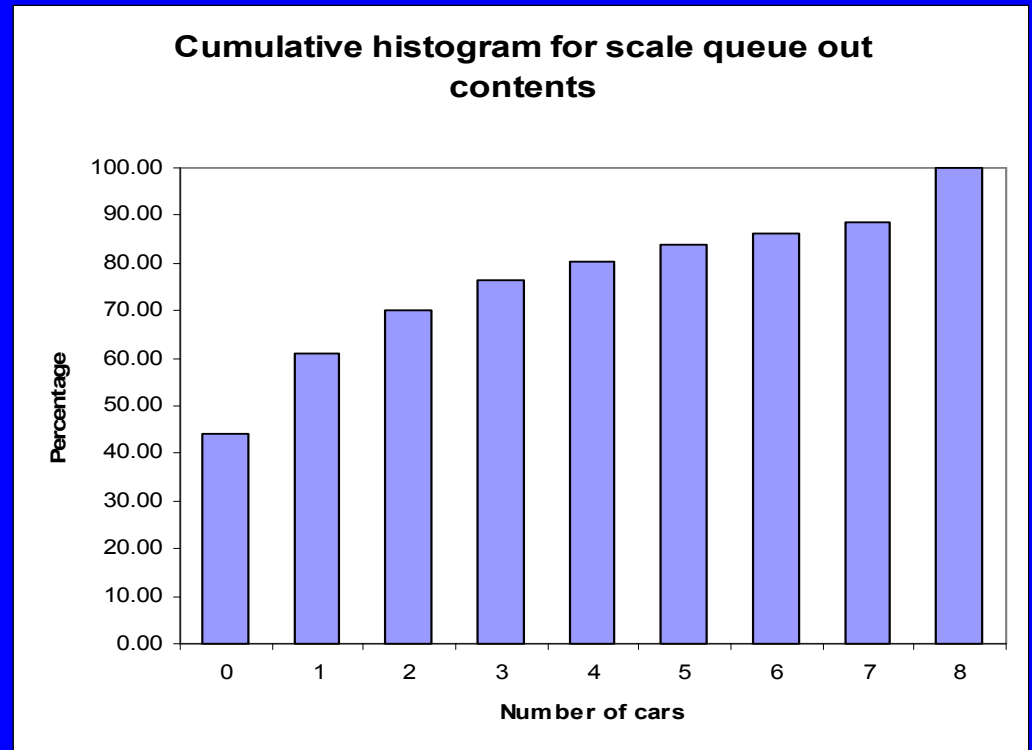
Using the Model

- What is the capacity of the facility?

- Gradually increase the frequency of the vehicle arrivals and check different performance measures

Number of Vehicles

Number of Vehicles vs Number of Customers

Time spent vs arrival rate at scale house in

Average time spent (min) vs Average interarrival time (seconds)

Current situation

Using the Model

- What are the possible alternatives that can increase the throughput of the facility?

  Automated weighing

  Bypass (bypass scale house in, scale house out, both)

  Cars / packers flatbeds / pickups bypass

  Double the capacity of garbage disposal area

  One-way drop off

  Increase the staffing of the scale house

Using the Model

- The model also provided valuable insights on the bottlenecks of the facility

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