# Balham Station & Crowd Dynamics

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# Introduction

- Cubic Transport Systems (CTS) required analysis of the congestion problem at Balham Station
- Typical Passenger Path:
    - Enter ticket hall from top right
    - Obtain ticket from passenger operated machines (POM) or ticket office
    - Pass through gates and exit through the left
- Number of people averaging 125 during peak period

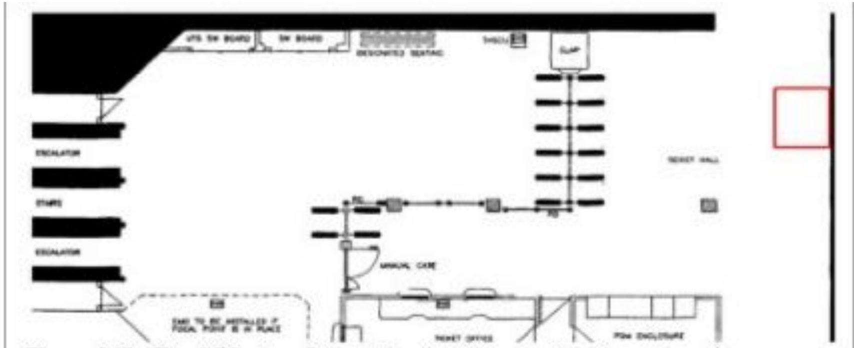

**Figure 139** - The CTS plan of the station (existing guard enclosure in red)

# Accessing Ticket Queues

- Used queuing theory and queuing models to access probable depth of queues at ticket machine and window
- The queueing model was defined by four characteristics
    - The pattern of arrival follows a poisson probability distribution
    - The service time follows an exponential probability distribution
    - The queue discipline is first come, first serve
    - Both waiting lines have a single channel. Patrons use either the machine or manual operator

## Arrivals

$$P(x) = \frac{\lambda^x . e^{-\lambda}}{x!} \qquad \text{For } x = 0, 1, 2, 3, 4, \ldots$$

| | | |
|---|---|---|
| x | = | Number of arrivals in a specific period of time |
| $\lambda$ | = | Average number of arrivals for the specific period of time |
| e | ≈ | 2.71828... (Euler's number) |

## Service Time

$$F(x) = \mu \, e^{-\mu x}$$

| | | |
|---|---|---|
| x | = | service time (time taken to perform some specified function) |
| $\mu$ | = | average number of units that the service facility can handle in a specified period of time. |

# Queueing Model

$\lambda$ = Average arrivals for the specific period of time (mean)

$\mu$ = Expected number of services possible per time period (mean)

For the concourse area we test the arrival range of $\lambda = 75$ to 200 and $\mu = 22$ and 75 second respectively. Using the assumptions of Poisson arrivals and Exponential service times the following quantitative analysis can be applied where the following formulas apply.

1. Probability that the service facility is idle (probability of 0 units in the system)

$$P_0 = 1 - \lambda / \mu$$

2. Probability of n units in the system (waiting time and service time)

$$P_n = (\lambda / \mu)^n . P_0$$

3. Average number of units waiting for service

$$L_q = \lambda^2 / (\mu ( \mu - \lambda ))$$

4. Average time a unit spends in the system (waiting and service)

$$W = W_q + 1 / \mu$$

5. Probability that an arriving unit has to wait for service

$$P_w = \lambda / \mu$$

The values of the mean arrival rate and the mean service rate are clearly important components in the above calculations. We can see that the ratio of these two values, $\lambda / \mu$, is simply the probability that an arriving unit has to wait because the server is busy. Thus $\lambda / \mu$ is often called the utilisation factor. The formulas for determining the characteristics of this type of system are applicable only when the utilisation factor $\lambda / \mu < 1$. This condition occurs when the mean service rate ($\mu$) is greater than the mean arrival rate ($\lambda$) or the system can process the arrivals.

# Spreadsheet modelling

- Performed spreadsheet modelling on queuing model
- Found that queue depth exponentially rises when arrival rate begins to reach service rate
- Found similar results on both ticket machine and manual ticket window

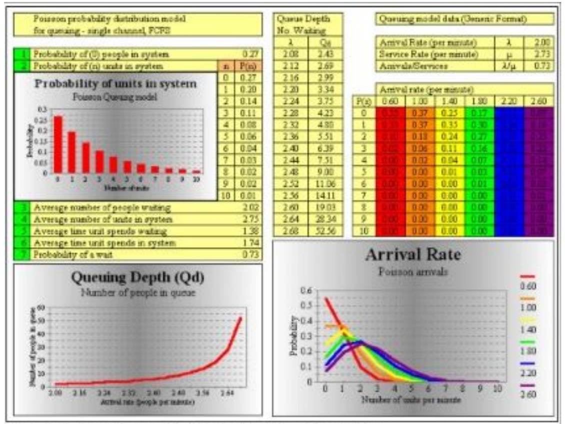

**Figure 141** - Spreadsheet model of the queuing for the ticket machine.

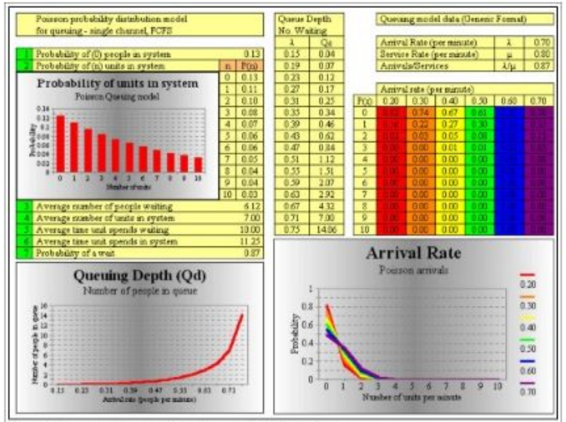

**Figure 142** - spreadsheet model of the manual ticket window.

# The queueing problem

- Missing shape of queues and how they impact passenger travel
- Found that space is adequate during busy periods with two operators
- What leads to congestion in the ticket hall? How and why does it fail?

**Figure 145** - Only one window operating

**Figure 146** - Both windows operating

# Focal Route Analysis

- Needed to examine the effects of focal routes on the mean arrival rates
- Placed sheets of acetate on the monitor screen and tracked peoples head positions
- Analysis showed that the current configuration is not ideal, areas where focal routes cross

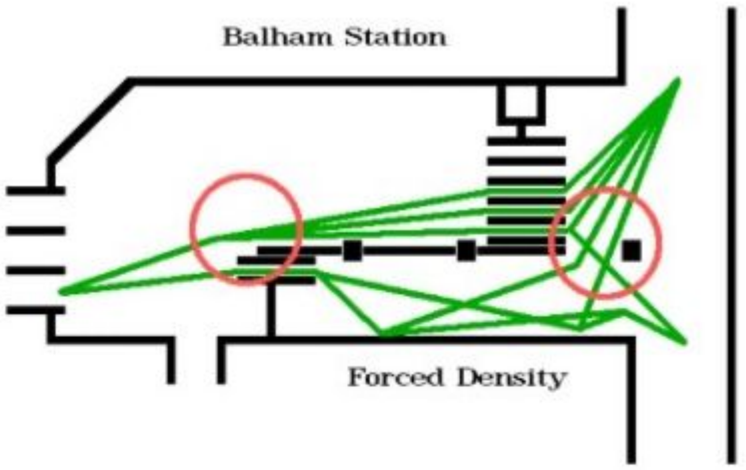


**Figure 148** - Focal route analysis can show the conflict zones.

# Balham Station Simulation and The Legion Model

- Used a virtual reality odel (VEgAS) to visualize queue depth and routes
- Since analysis of crowd dynamics is complex, the combination of queuing theory, focal routes, and the Legion simulation are used
- Manual analysis of focal routes gives a qualitative, not quantitative analysis, so automatic focal route analysis is required

# The “Ant Algorithm”

- To find all the shortest routes in the environment, the “ant algorithm” was used
- Uses dynamic space utilisation map as objective, each entity goes to point of highest space utilisation, thereby reinforcing it
- Timed delay erodes unused trails
- Since some routes are only available during certain times of day, some manual intervention is necessary

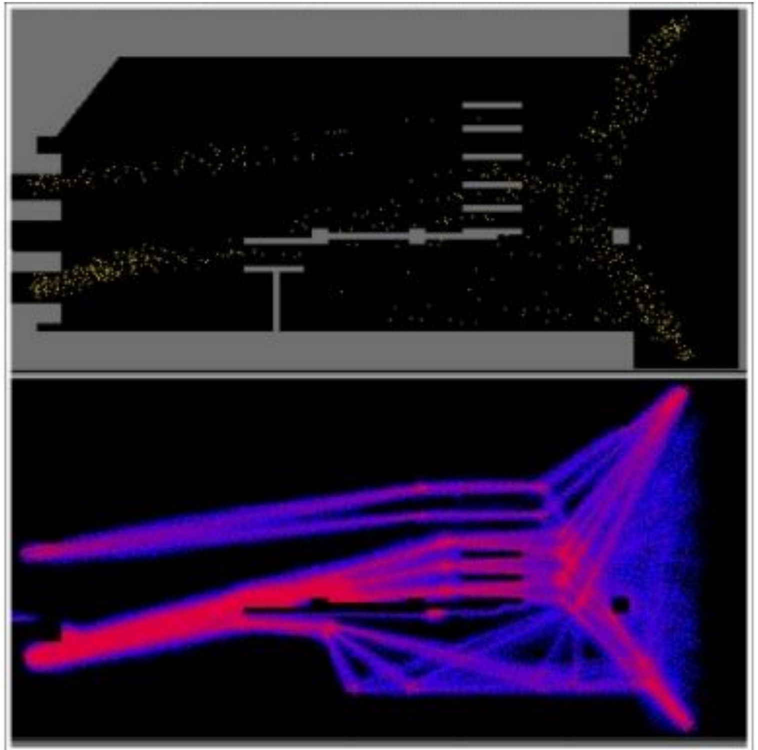

**Figure 150** - The evolution of the automated human trail, the short-cut analysis

# Creating More Space

- A small change to the gate array gave a different set of focal paths
- Based on analysis, there should be sufficient space for queuing without the need to increase space
- In order to figure out issue, they had to figure out where the model and reality differed

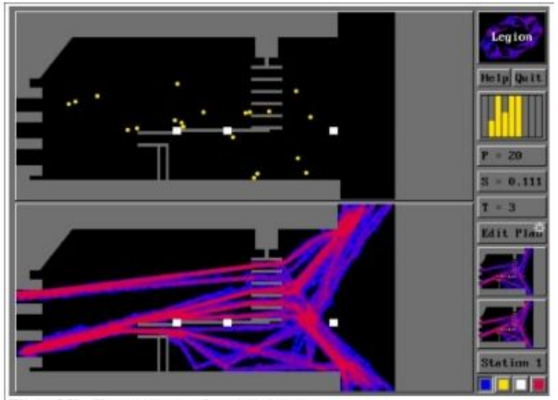

**Figure 151** - Space utilisation for original design

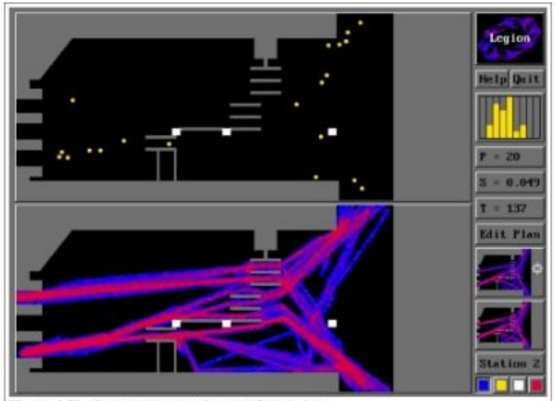

**Figure 152** - Space utilisation for modified design

# A Look at Queueing

Removing guard enclosures had little effect on relieving congestion

Models show enclosures actually have little impact if they are neither on the focal route or queue path

Queues themselves interact with the focal route.

When 1 gets backed up, it affects the others

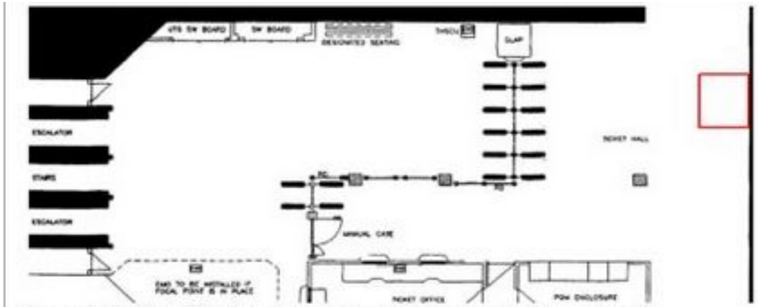


Figure 139 - The CTS plan of the station (existing guard enclosure in red)

# Multiplex Views & Problem Analysis

Multiplexer - combines several camera views into a single image

Allowed researchers to look at the full view of the Ticket Hall at peak operation

Discovered that congestion problem rose when one of the ticket operators took a coffee break during rush hour → solved issue by rescheduling breaks

Defied assumption that competition for space was the main problem

Figure 145 - Only one window operating.

# Crowd Behavior Analysis

Key Understanding: Study of crowd behavior is not the same as an explanation for psychological phenomena like group think

Crowd Dynamics is analyzing influence that density has on flow rates → helps us exploit short-cuts and see the effects of cross flows

# Balham Study Conclusions

Recommendations to improve Balham Station

- Improve crowd flow by staggering the input gates
- Move back gate nearest the escalators toward ticket hall area

Focal route analysis saved  the cost of relocating booths by ‘guess and check’

With frameworks like, Legion, there are many  ways to analyze the smallest influences on a space

# This Work is Out in the World!

Consulting companies like Crowd Dynamics

- Capacity Assessment
- Evacuation Modelling
- Crowd Management
- Shared Space Modelling
- Traffic Enineering
- Much More!

# Questions?