



Developing Aoristic Network Analysis on London's Transport System

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Transport for London

Introduction

- **Why needed?**
- **Where to start?**
- **Current analytical capability**
- **Progress to date**
- **Limitations to be overcome**
- **Future developments**



Why Needed?

- **It's a busy system!**
- **Nature of offending**
 - **Static v Non-Static events**
 - **% of offences that occur without defined location**
 - **High volume (e.g. Theft)**
- **Expanding network & population thereby increasing the challenge**



Where to start?

- **Multi-modal approach?**
- **Develop proof of concept**
 - **Start small**
 - **Underground**
 - **Smallest Network**
 - **Supplementary information**
 - **Theft**
 - **Highest volume offence**
 - **Lowest detected offence**
 - **On train / on route offending**
 - **Opening of European borders**
 - **Possible change of offending**



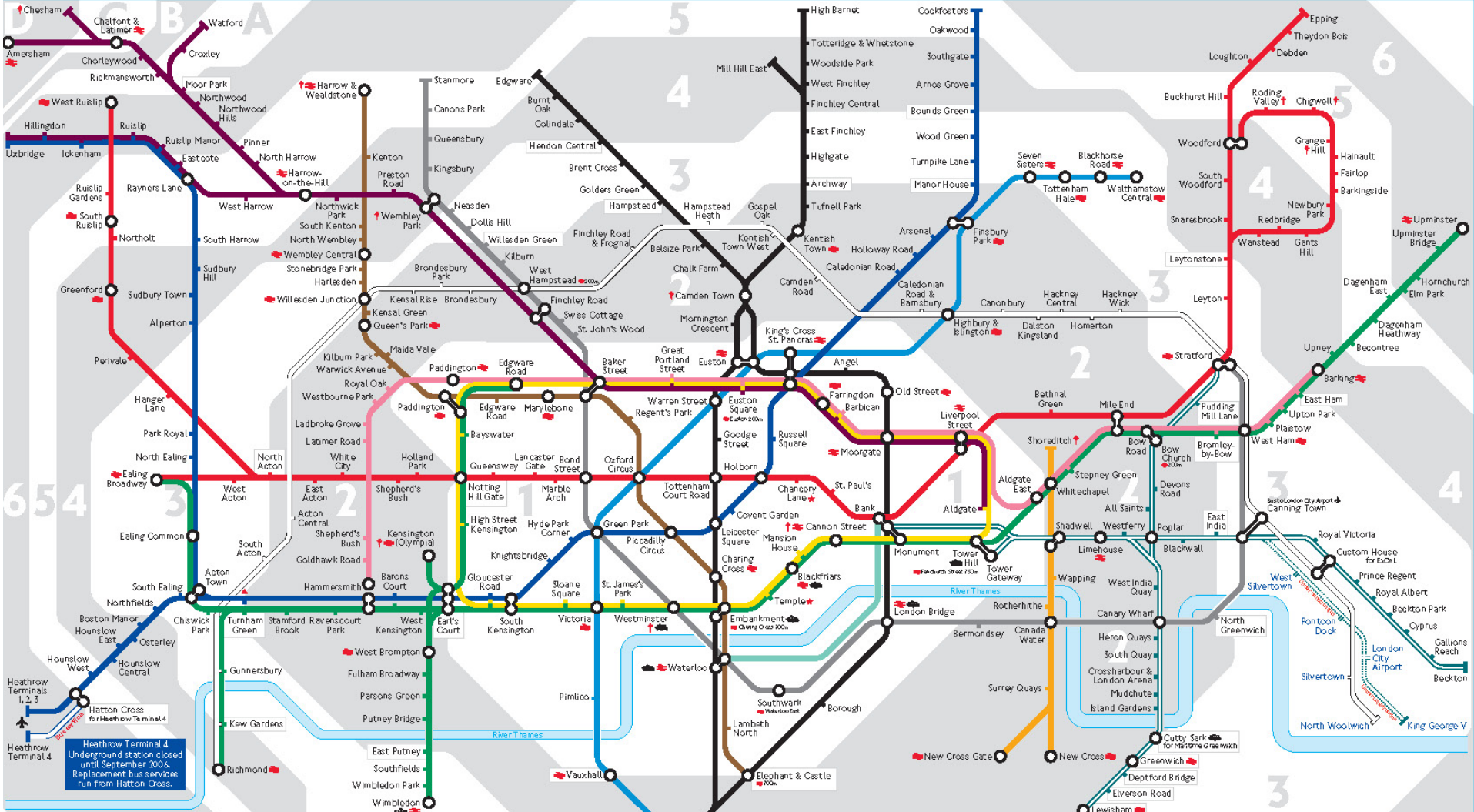
Where to start?



How is this currently analysed?

- **Fortnightly tasking meetings**
- **Manual process**
 - ~150 offences per week (almost 8,000 p.a.)
- **Start / End stations reporting**
 - E.g. Edinburgh to London Victoria
- **Limitations**
 - Time-consuming
 - No consideration of supplementary factors
 - Lack of specialist spatial analysis capability within BTP





Key to lines and symbols

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Explanation of zones

- | | | | |
|---|-----------------------|--|---------------------------|
| D | Station in Zone D | | Points to remember |
| C | Station in Zone C | | |
| B | Station in Zone B | | |
| A | Station in Zone A | | |
| 6 | Station in Zone 6 | | |
| 5 | Station in Zone 5 | | |
| 4 | Station in Zone 4 | | |
| 3 | Station in both zones | | |
| 2 | Station in Zone 2 | | |
| 1 | Station in Zone 1 | | |

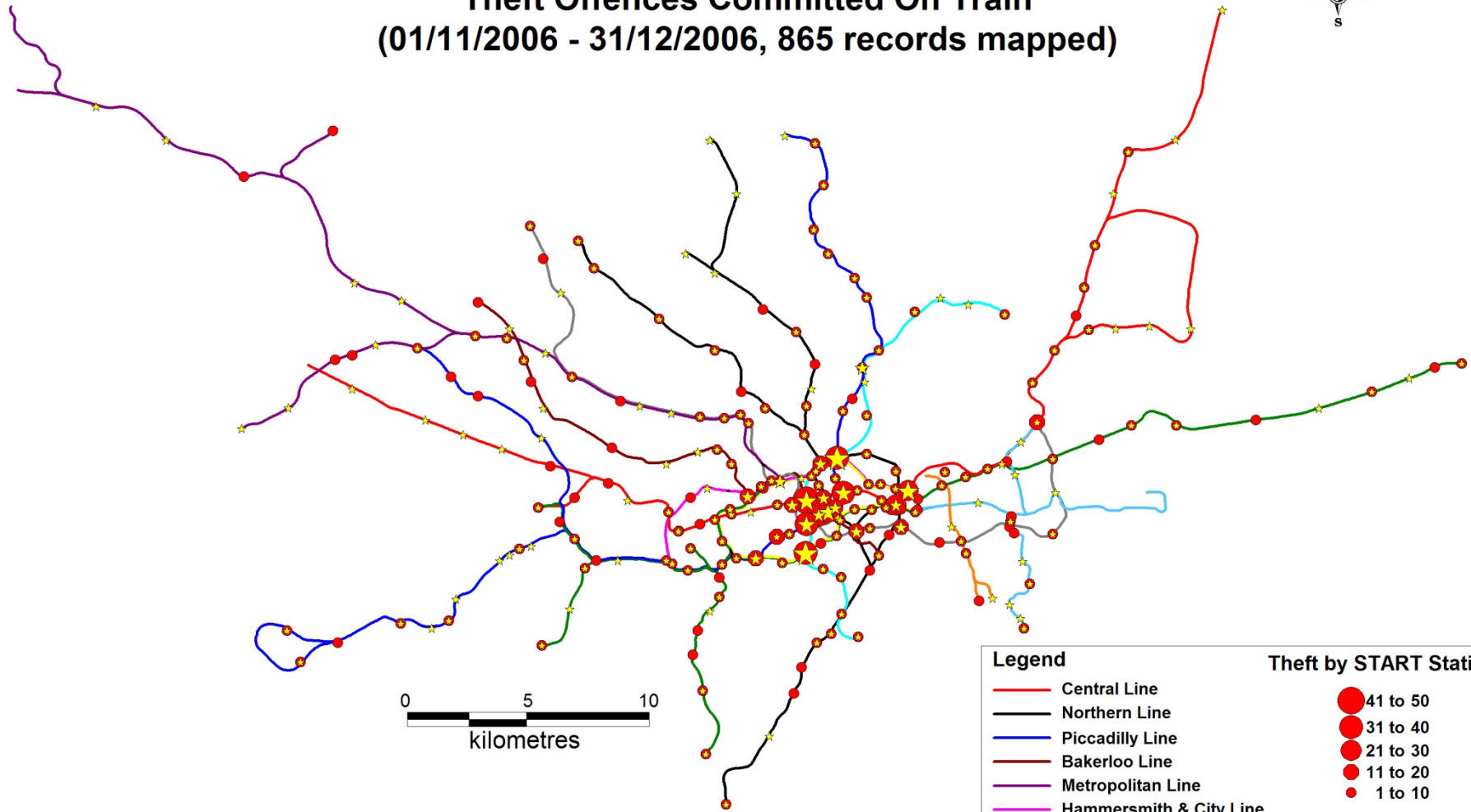
Points to remember

- : No service Whitechapel - Barking early morning or late evening Mondays to Saturdays or all day Sundays. For Chesham changes at Chalfont & Latimer on most trains.
- : On Sundays between 1800 and 1730, Camden Town is open for interchanges and exit only. No service Uxbridge - Rayners Lane in the early mornings.
- : Replacement bus services between Herton Cross and Heathrow Terminal 4, Heathrow Terminal 4 Underground station closed until September 2006.
- : 0615 to 2100 Mondays to Fridays, 0900 to 1630 Saturdays. Closed Sundays.

Certain stations are closed on public holidays.



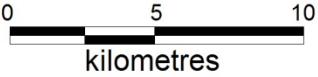
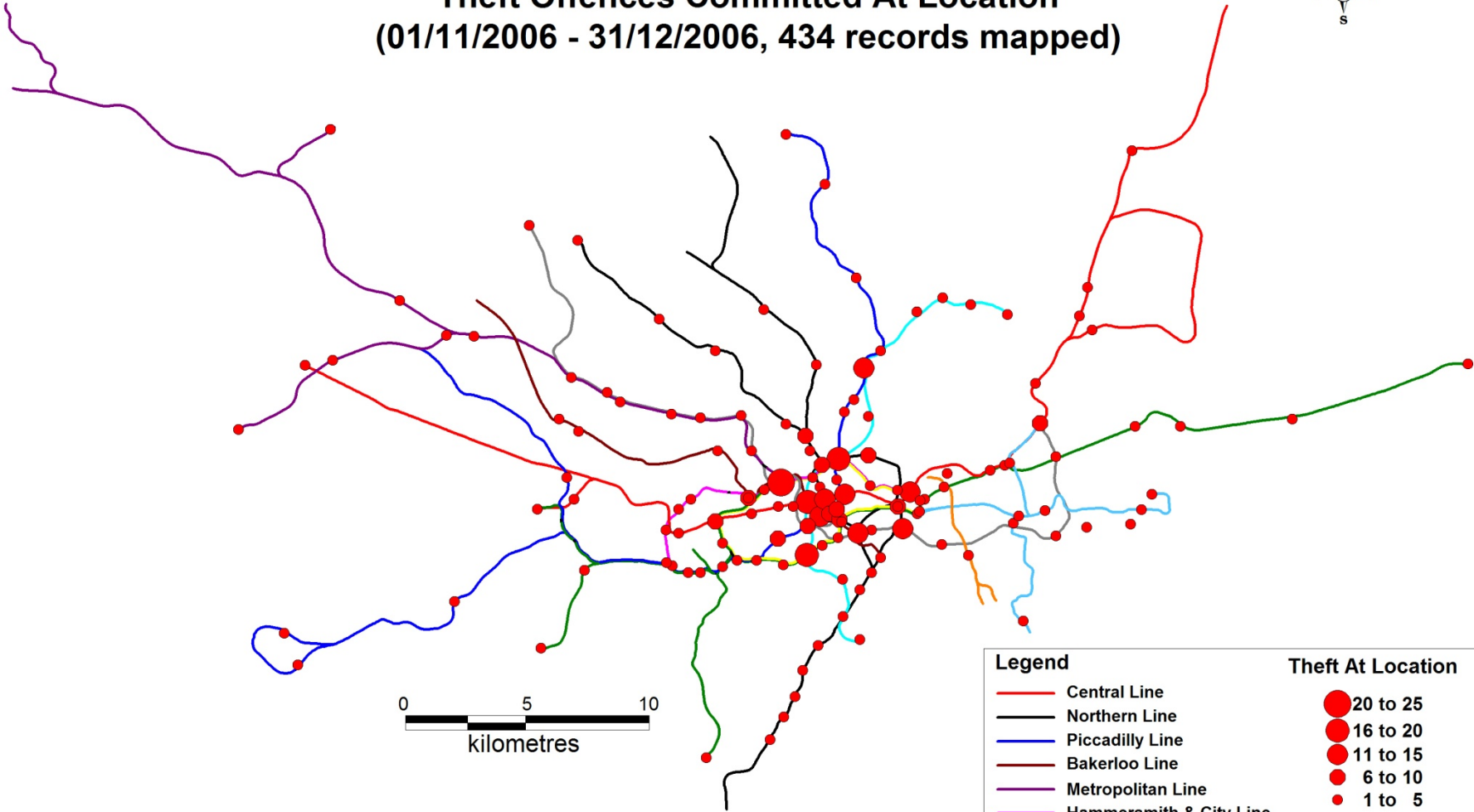
London Underground & DLR Theft Offences Committed On Train (01/11/2006 - 31/12/2006, 865 records mapped)



Legend		Theft by START Station	
—	Central Line	●	41 to 50
—	Northern Line	●	31 to 40
—	Piccadilly Line	●	21 to 30
—	Bakerloo Line	●	11 to 20
—	Metropolitan Line	●	1 to 10
—	Hammersmith & City Line	★	41 to 50 (2)
—	District Line	★	31 to 40 (2)
—	Jubilee Line	★	21 to 30 (3)
—	East London Line	★	11 to 20 (12)
—	Circle Line	★	1 to 10 (173)
—	Victoria Line		
—	Docklands Light Railway		



London Underground & DLR Theft Offences Committed At Location (01/11/2006 - 31/12/2006, 434 records mapped)



Legend	Theft At Location
— Central Line	● 20 to 25
— Northern Line	● 16 to 20
— Piccadilly Line	● 11 to 15
— Bakerloo Line	● 6 to 10
— Metropolitan Line	● 1 to 5
— Hammersmith & City Line	
— District Line	
— Jubilee Line	
— East London Line	
— Circle Line	
— Victoria Line	
— Docklands Light Railway	



What is Aoristic Analysis?

- “Aoristic is from the Greek term *Aorist*, defined in the Shorter Oxford English Dictionary as “without defined occurrence in time.”
- “One of the problems with analysing crime is achieving **temporal** accuracy **when** the exact **time and date** of many crimes is unknown. This can occur if a family goes on holiday for two weeks and return to find their home burgled. Not knowing the exact date can be a problem for analysing crime accurately, but an aoristic search can help, and can also reveal different patterns not seen in other types of analyses.”

What is *Aoristic* Network Analysis?

- “One of the problems with analysing crime is achieving *spatial* accuracy *where* the exact *location* of many crimes *upon a network* is unknown.”



Time spans

START
date/time

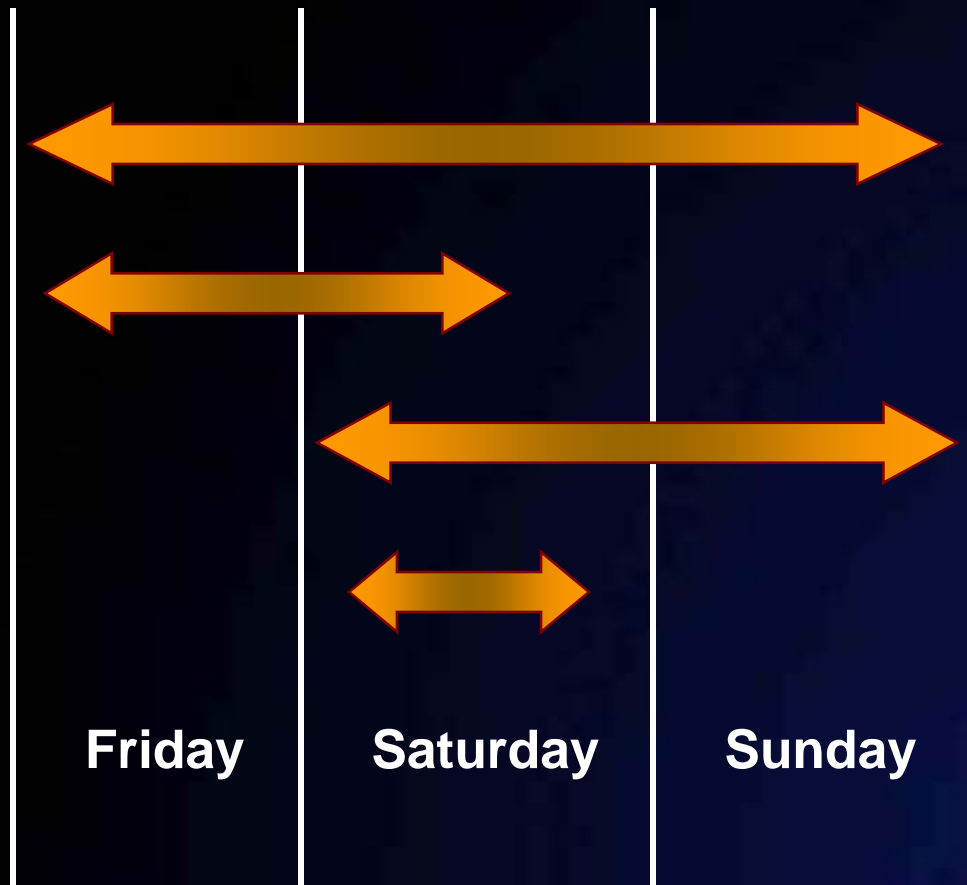
END
date/time



Time span



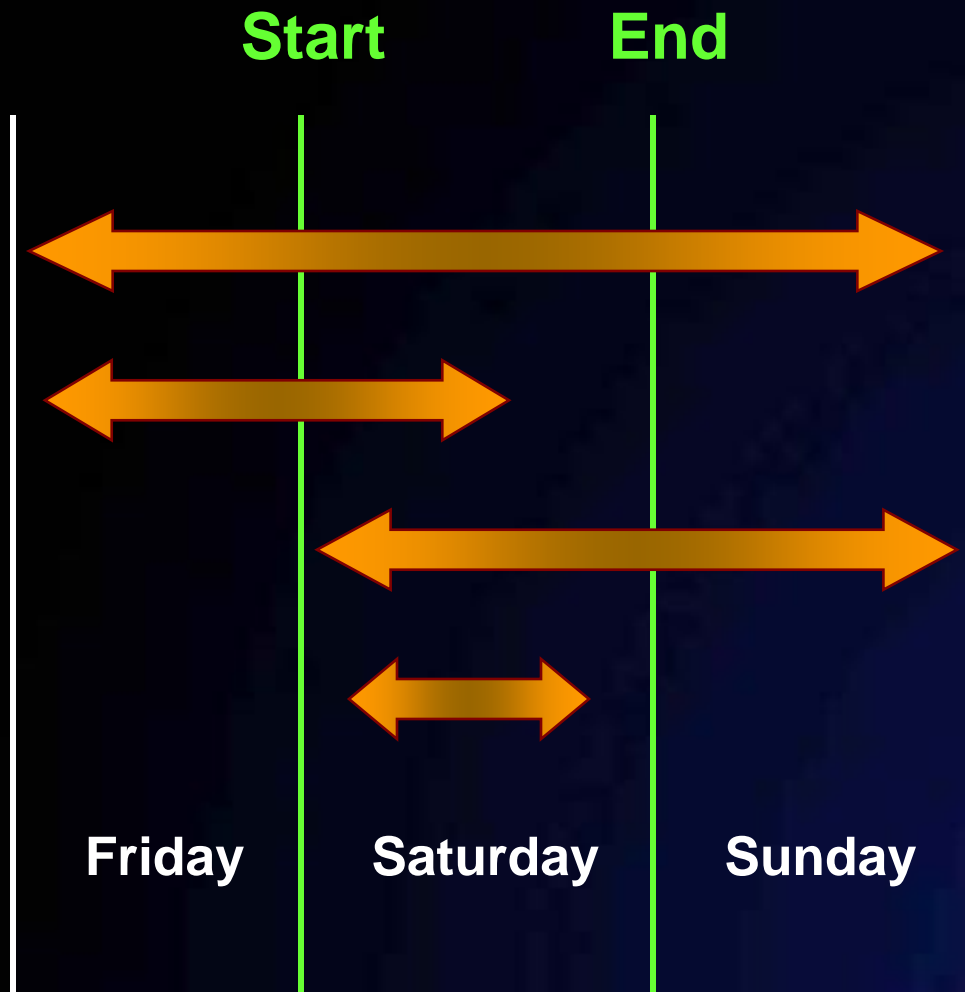
Temporal options



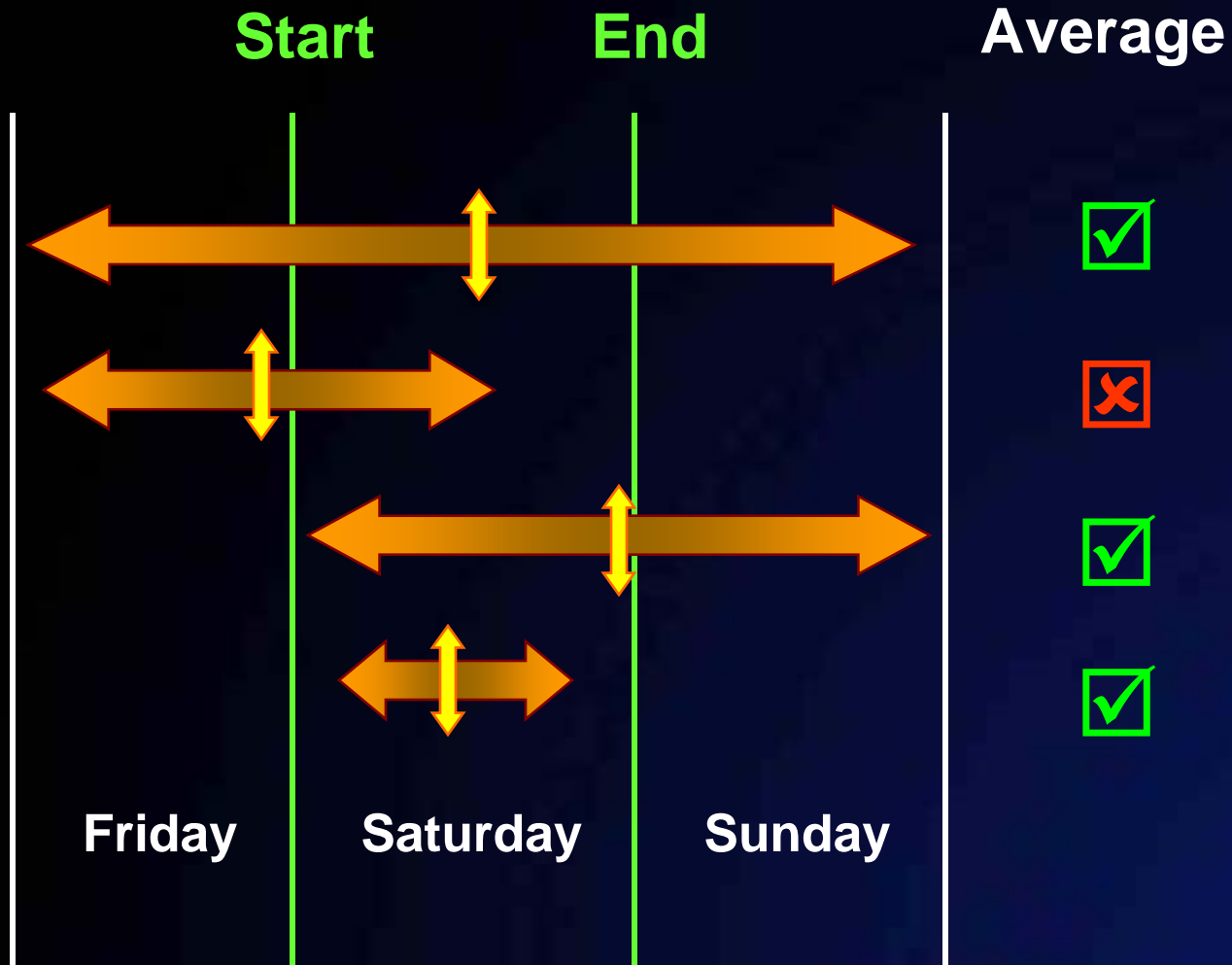
**Which
burglaries
occurred on
Saturday?**



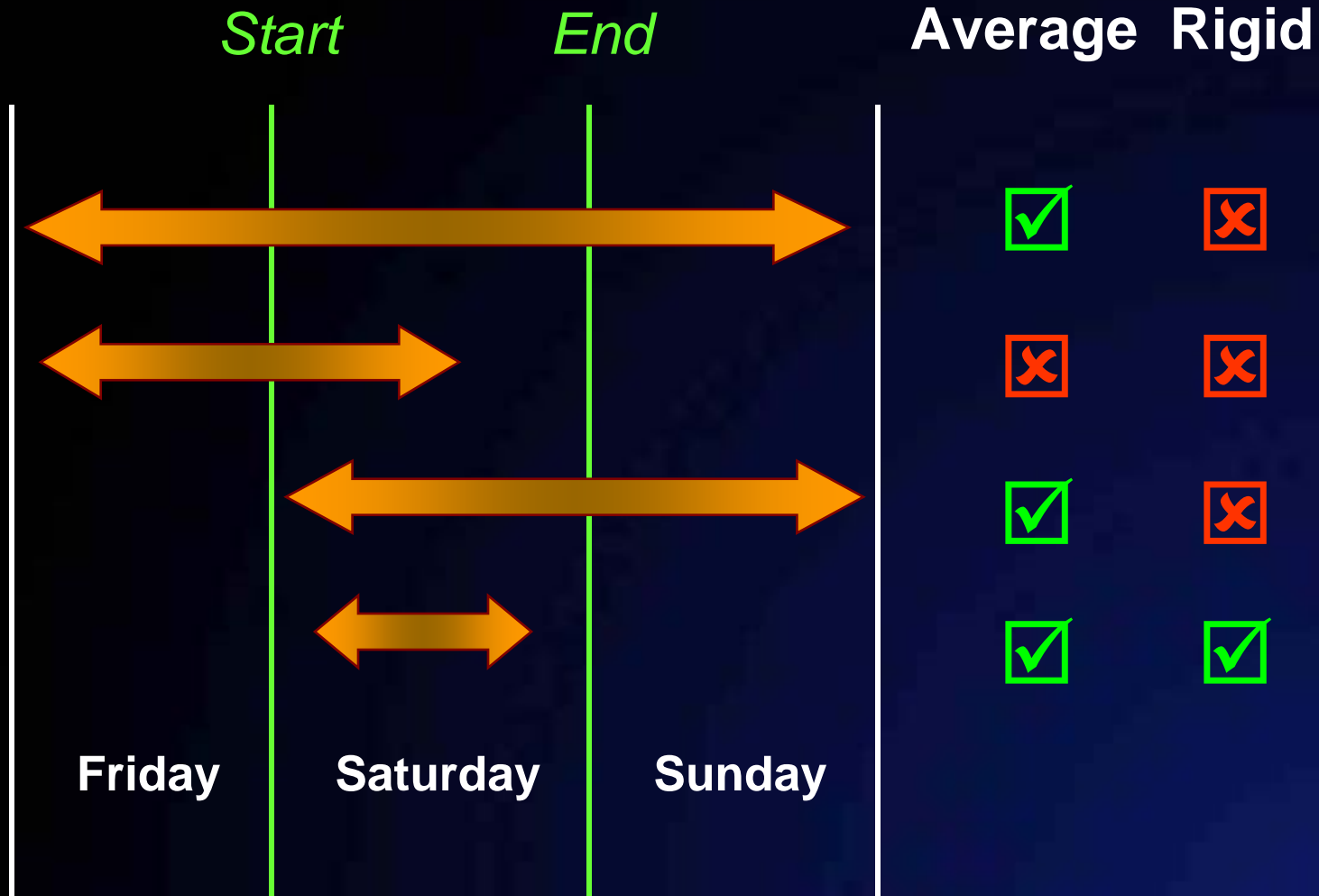
Temporal options



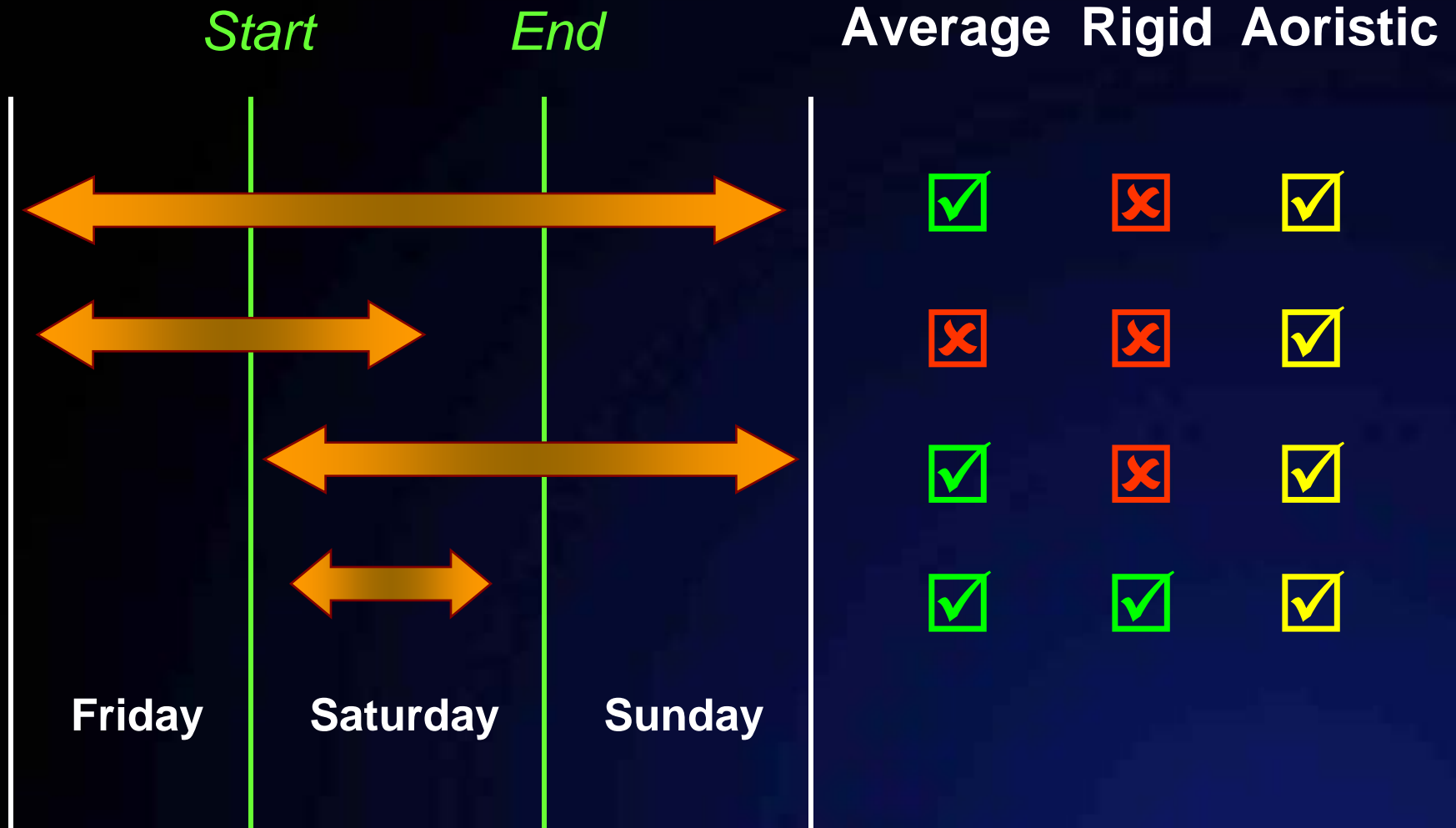
Temporal options



Temporal options

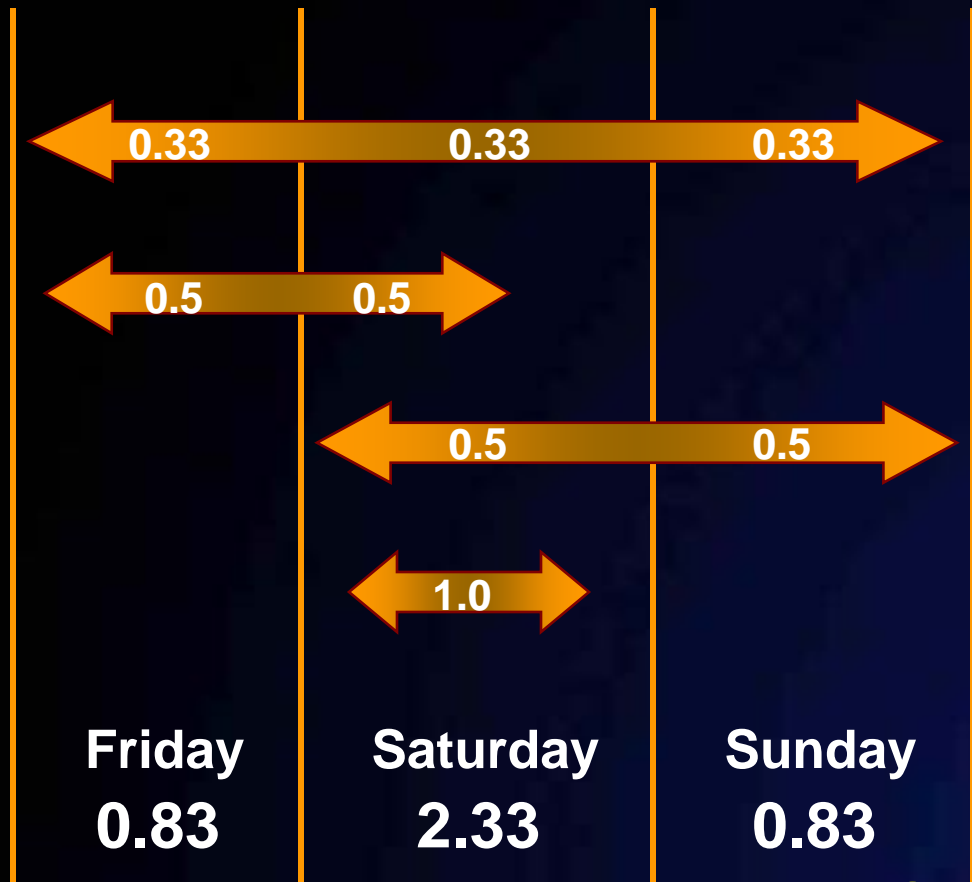


Temporal options



Aoristic values

Kings X Euston Warren Street Oxford Circus



Friday Saturday Sunday
0.83 2.33 0.83
Kings X Euston Warren St
to to to
Euston Warren St Oxford Circus

Extends ? Segments	Each day segment value
3	0.33
2	0.5
2	0.5
1	1.0

Aoristic value

What is Aoristic Network Analysis?

- **Doesn't make sense to analyse by**
 - **Specifically defined sections of the underground**
 - **Average / mid-point of the journey**
 - **Start / end locations**



What is Aoristic Network Analysis?

- **Aoristic value (AV)**

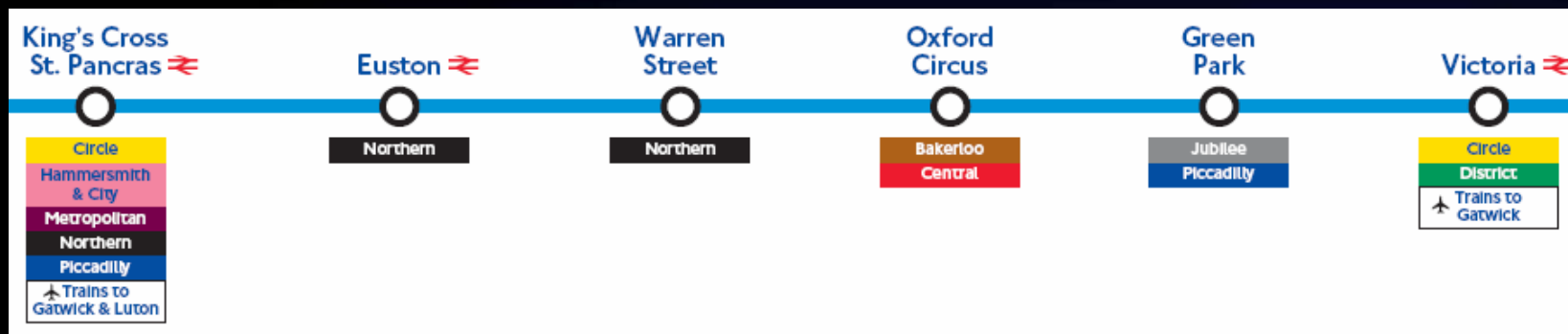
$$AV = \textit{journey} / \textit{total segments}$$

- **My journey to work**
- **Kings Cross to Victoria (Victoria Line)**
 - *6 stations with 5 segments, therefore*
 - *Value per segment = 1 / 5*
= 0.2



What is Aoristic Network Analysis?

Route



Network	Segment 1	Segment 2	Segment 3	Segment 4	Segment 5
Aoristic Value	0.20	0.20	0.20	0.20	0.20

- **But is this truly reflective?**
 - Time taken to travel on a segment
 - Number of passengers travelling a segment
 - Time of day / day of week

What is Aoristic Network Analysis?

- **Aoristic value (additional factors)**

$$AV = (\textit{journey/no. of segments}) \times T \times P$$

- ***Where***

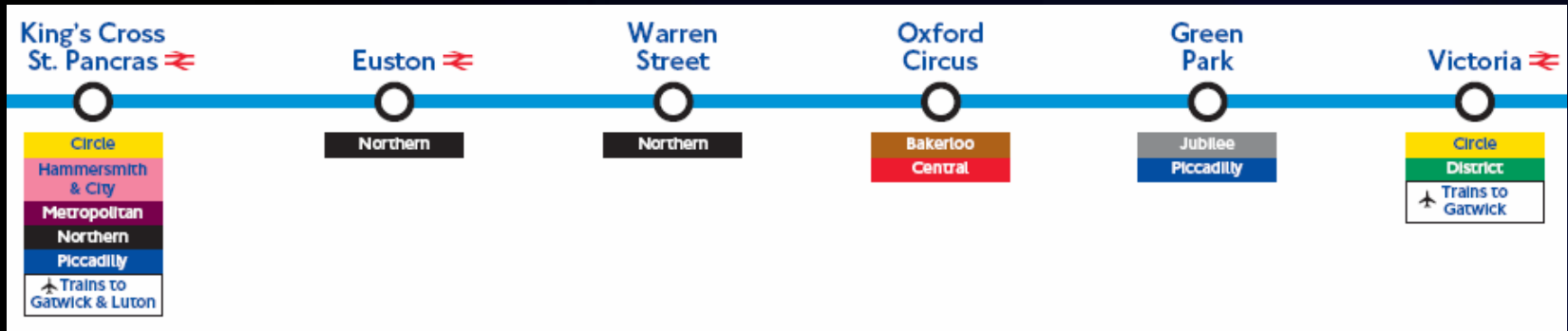
T = time taken to travel the segment

P = passengers travelling the segment



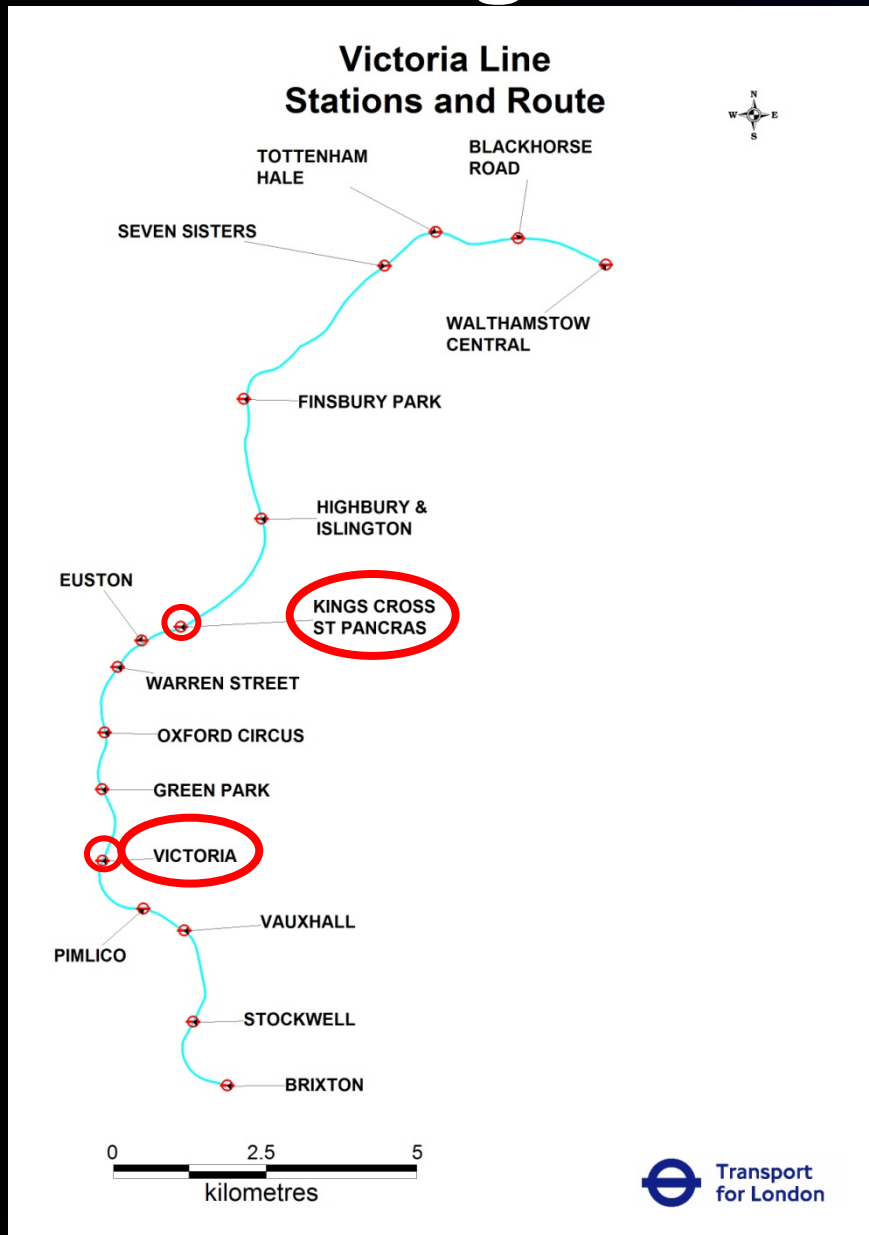
What is Aoristic Network Analysis?

Route



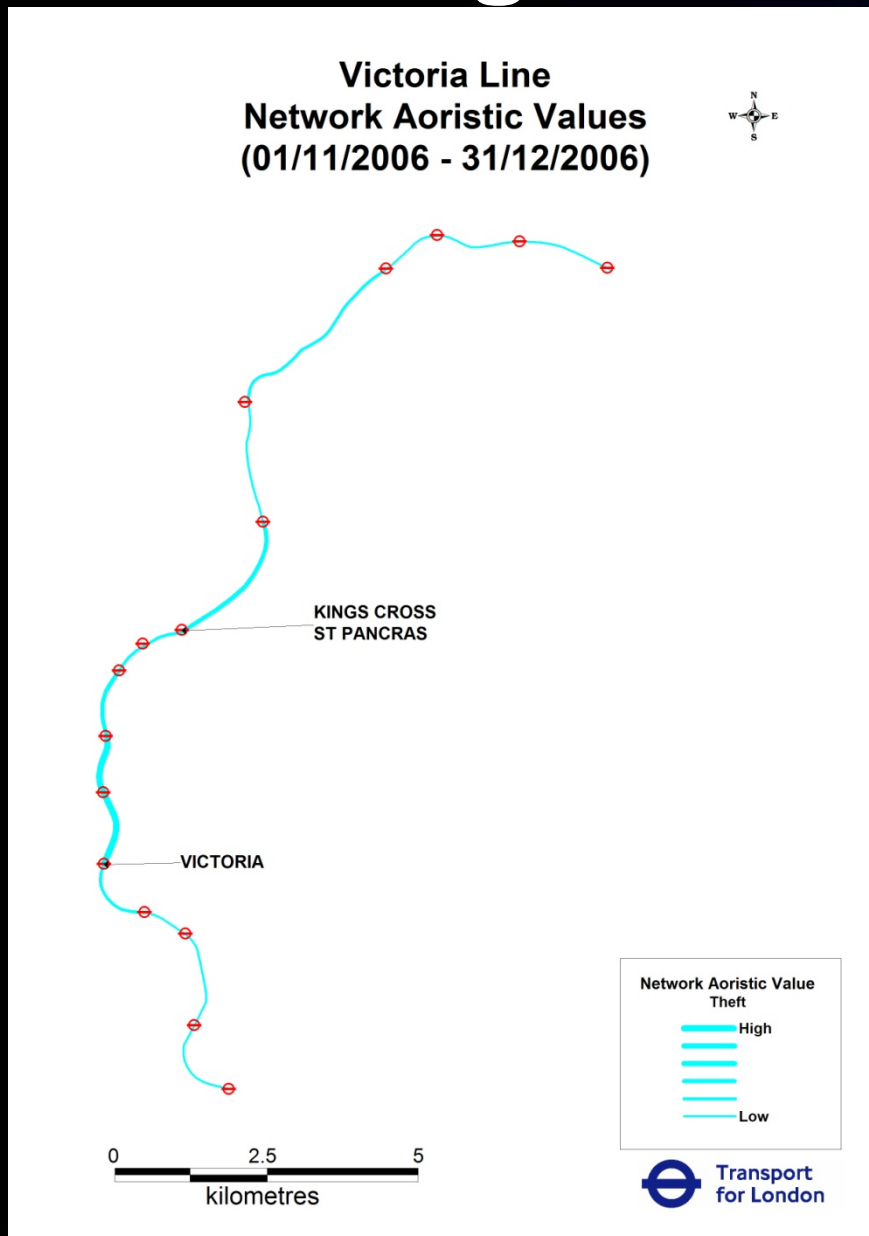
	Segment 1	Segment 2	Segment 3	Segment 4	Segment 5
Aoristic Value	0.20	0.20	0.20	0.20	0.20
Time Weight	1	2	2	2	2
Passenger Weight	19.9	11.1	49.7	21.1	54.3
Network Aoristic Value	3.98	4.44	19.88	8.44	21.72

Visualising Aoristic Network Values



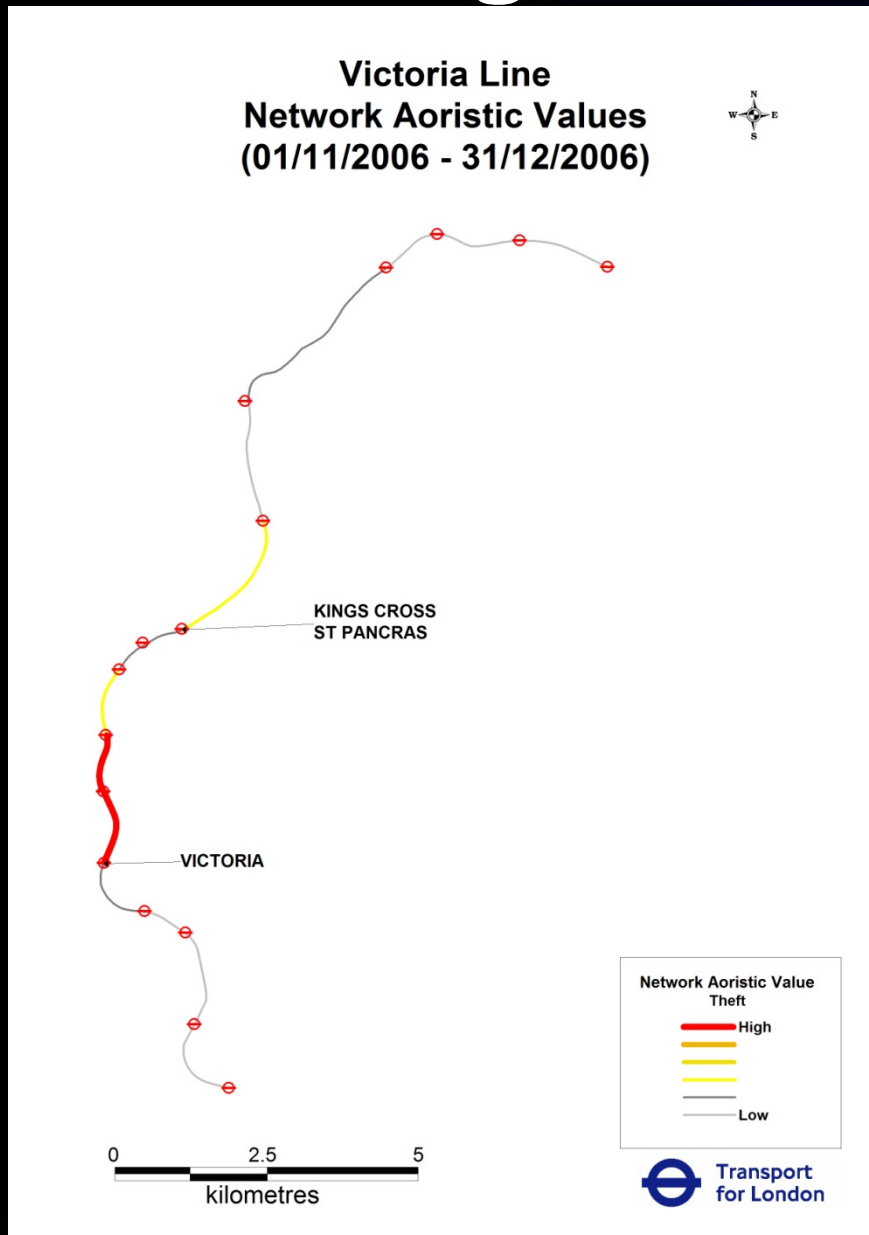
- My journey to work
- Thematic line map indicating weighted network of where offences occurred

Visualising Aoristic Network Values



- My journey to work
- Hmm looking less safe....

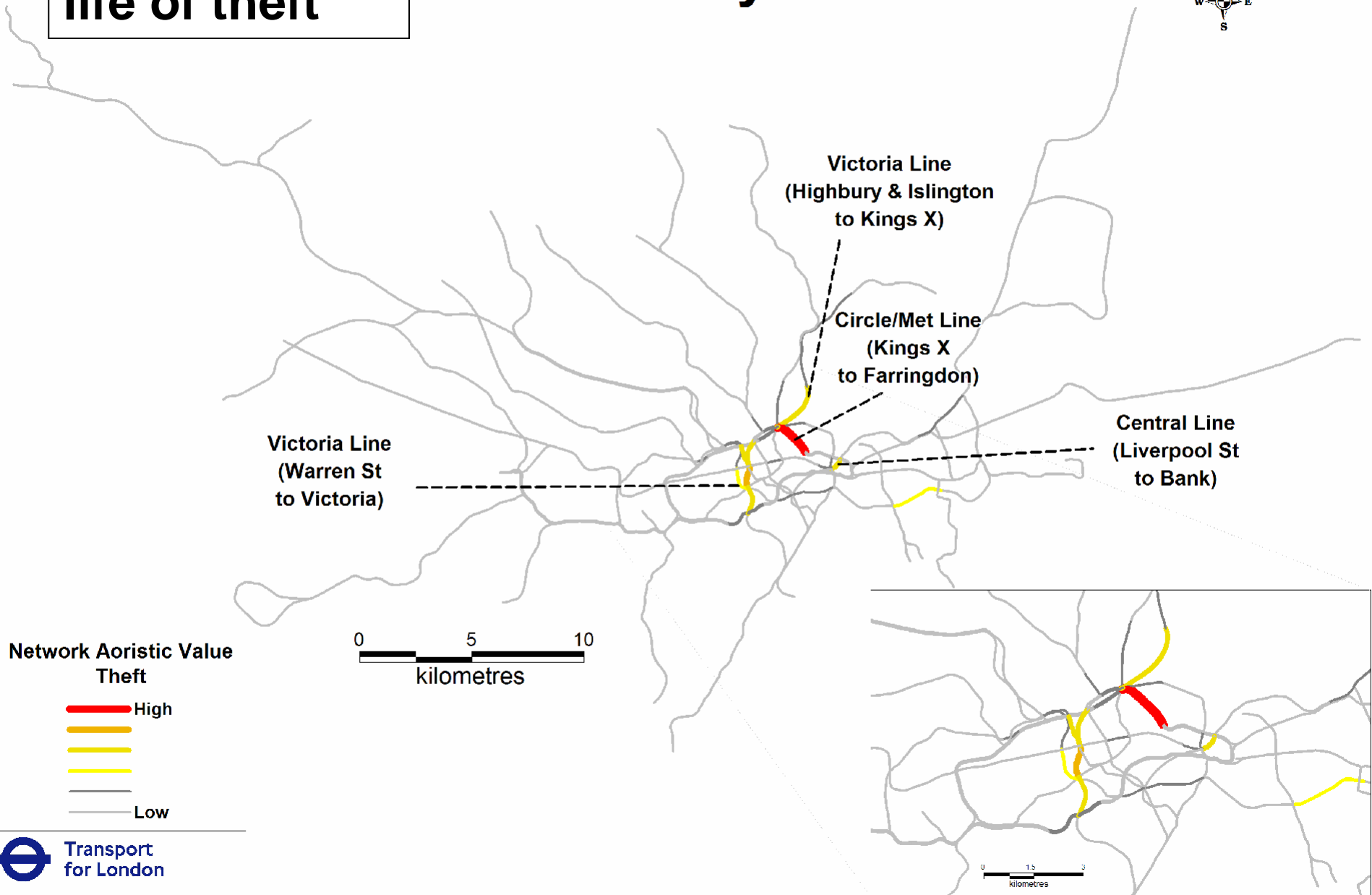
Visualising Aoristic Network Values



- My journey to work
- I'd better watch my pockets!

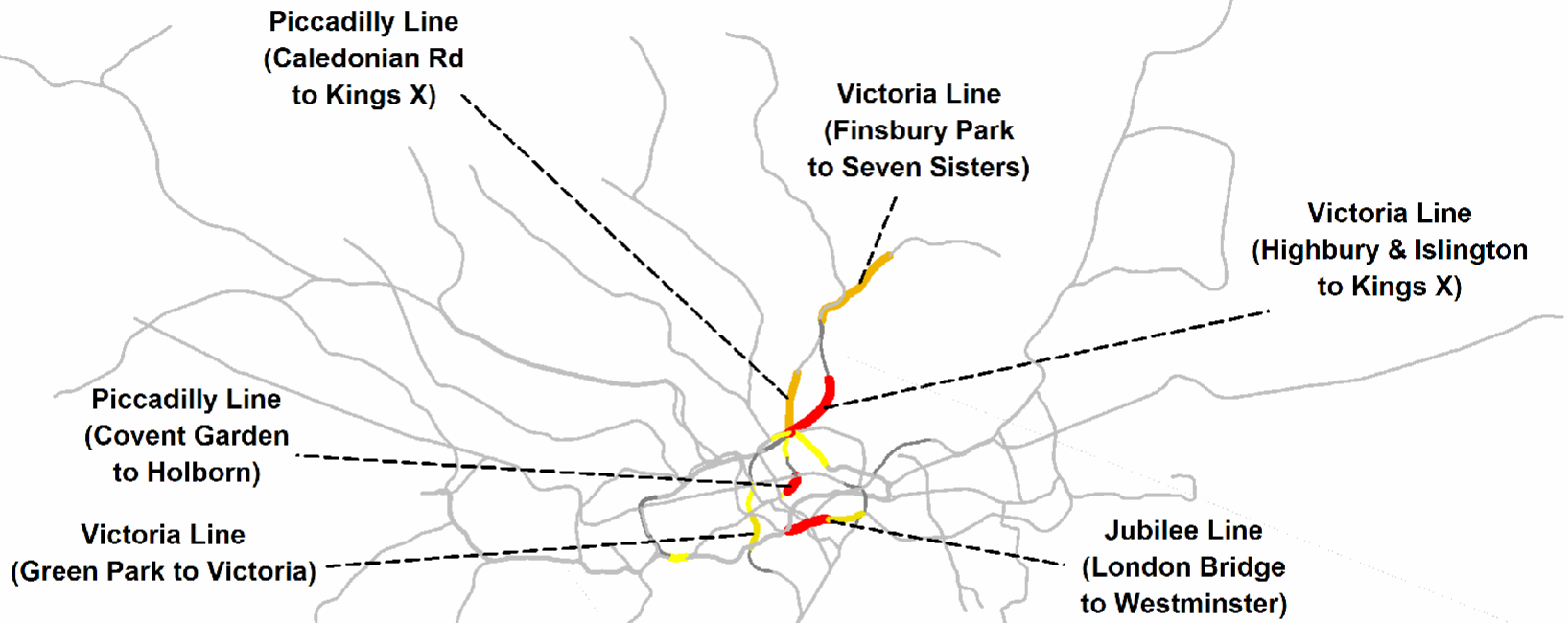
A week in the life of theft

Monday

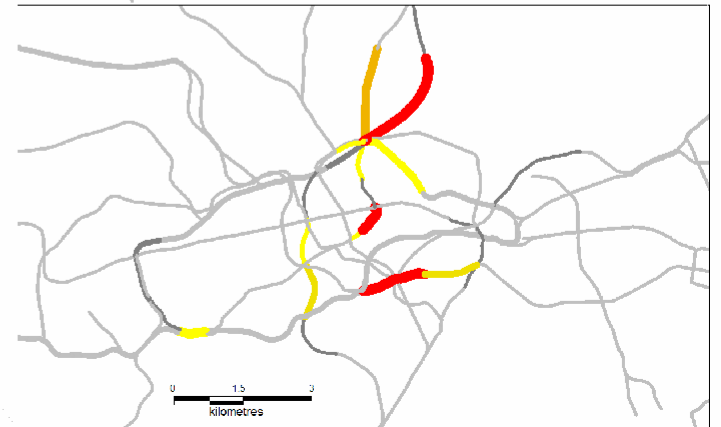
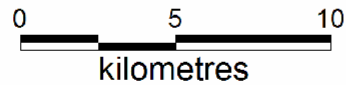


A day in the life of theft

00:00 - 00:59



Network Aoristic Value Theft



Limitations

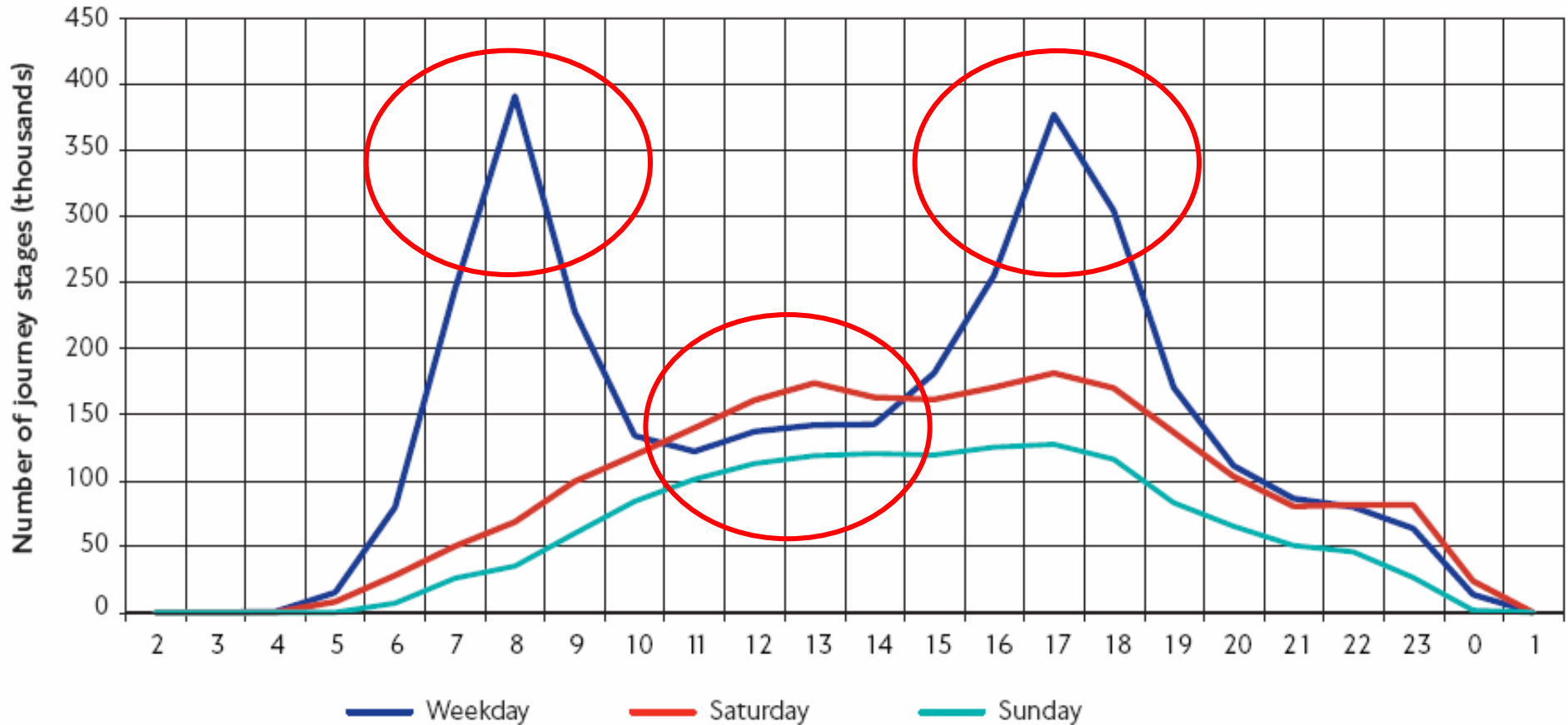
- **Not automated**
- **Untested**
- **Not multi-directional**
- **Segment time data**
- **Passenger data**



Passengers

Chart 2.4.4 Weekday and weekend Underground journey stages by hour of departure (2005/06)

Source: LUL Entry Counts
Enquiries: 020 7918 4492



Benefits

- **Complements intelligence / analysis**
- **Other offences besides theft**
- **Feedback mechanism – data quality**
- **Refined understanding of crime**



Evaluation

- **Automated tool**
- **BTP to deploy officers against suggested areas**
- **Refinement of process**



Future Developments

- **Phase 1: Underground**
- **Phase 2: Overground network**
 - *BTP policed also*
 - *But adds complexity*
- **Phase 3: Bus network**
 - *Not as easy to utilise as due to non-landmark nature of bus stops and multiple bus services operating along same route/roads.*



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Thank You

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Useful Links

Jerry Ratcliffe

www.jratcliffe.net

Andrew Newton

<http://wcr.sonoma.edu/v5n3/manuscripts/newton.pdf>



www.tfl.gov.uk

9th Crime Mapping Research Conference

