Imperial College London

The Development of a Performance Indicator to Compare Regularity of Service between Urban Bus Operators

Mr. Mark Trompet from CTS, Imperial College London

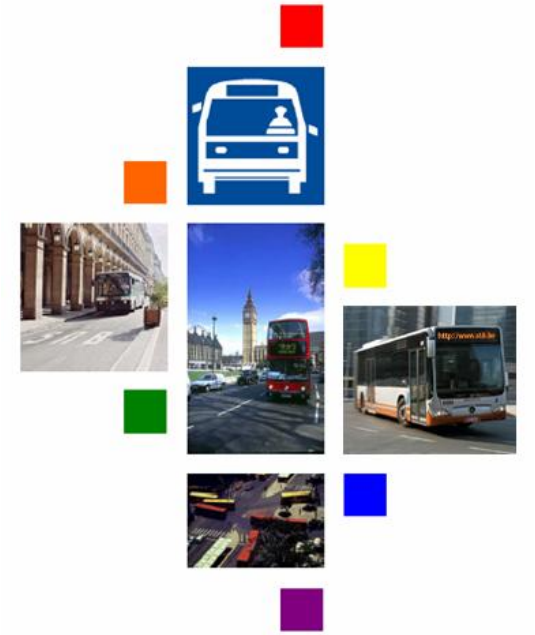
Wednesday, 08 December 2010 - 16:00

Location: Room 610, Skempton (Civil Eng.) Bldg, Imperial College London

Abstract
The work which is presented in this seminar evaluated options for a key performance indicator that comparably illustrates differences in performance with regard to maintaining service regularity on high frequency routes between urban bus operators. The data used for this study was collected by the International Bus Benchmarking Group, facilitated by Imperial College London, and relates to twelve medium to large sized urban bus operators from different countries. Through two annual rounds of data collection, lessons were learned on feasible data characteristics, required sample size and data cleaning processes. The following four key performance indicator alternatives were tested and their strengths and weaknesses described: 'Excess Wait Time', 'Standard deviation of the difference between the scheduled and the actual headway' and % of service within a fixed and relative number of minutes from the scheduled headway, also referred to as respectively 'Wait assessment' and 'Service regularity'. The results suggest that while all four methodologies illustrate a different, interesting view on service regularity performance, the Excess Wait Time methodology is the best option when the key performance indicator should reflect the customer experience of the regularity of service.

Biography
Mark Trompet is a Senior Research Associate of the Railway and Transport Strategy Centre, within the Centre for Transport Studies at Imperial College London. Since 2007 he is the project manager of the International Bus Benchmarking Group (IBBG) and is involved with metro benchmarking projects and other consultancy and research projects in transport strategy, economics and planning.

Development of a Key Performance Indicator to Compare Regularity of Service between Urban Bus Operators



Mark Trompet

CTS Seminar
8th December 2010

Presentation Structure

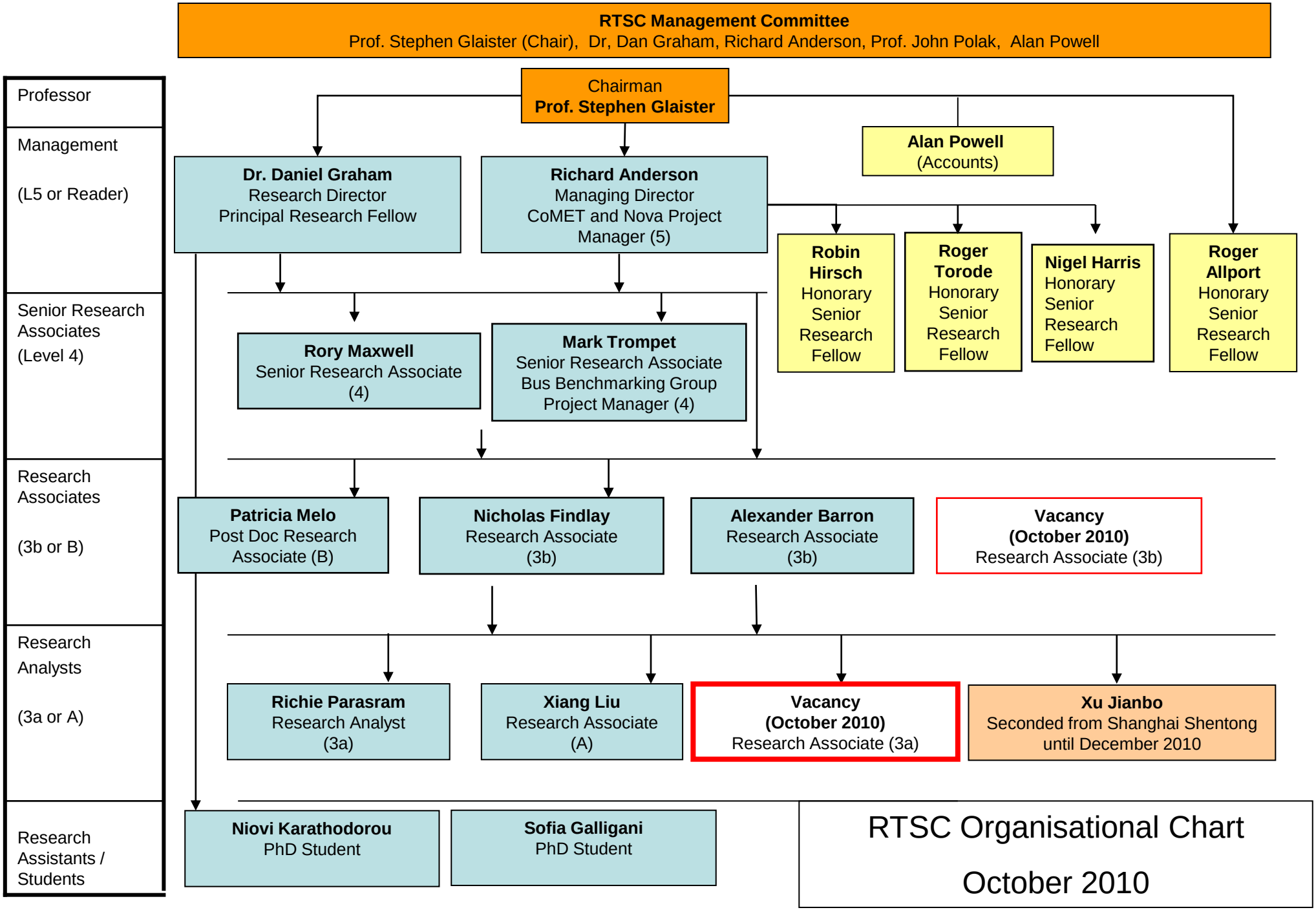
1. Introduction to the Railway and Transport Strategy Centre (RTSC)
2. Introduction to the Benchmarking Work within the RTSC and in specific the International Bus Benchmarking Group (IBBG)
3. Service Regularity Indicators: Literature and Use by Operators
4. Sample size, Data Characteristics and Data Cleaning Methodologies
5. Testing:
   - Excess Wait Time,
   - Standard deviation of the differences between the scheduled and the actual headway,
   - Wait Assessment and
   - Service Regularity.
6. Conclusions

Railway and Transport Strategy Centre

- Established in 1992, the Railway and Transport Strategy Centre (RTSC) at Imperial College London was set up:
  - To serve the transport industry on strategic, technology, economic and policy issues
  - As a research unit within the Centre for Transport Studies,
  - As a commercial unit within the Department of Civil and Environmental Engineering at Imperial College, supporting the academic work of the College.

- Three key research themes:
  - Public transport operations, management and strategy
  - Benchmarking & performance measurement
  - Transport economics & policy

- Activities: applied and academic research, consultancy, teaching


RTSC Management Committee
Prof. Stephen Glaister (Chair), Dr, Dan Graham, Richard Anderson, Prof. John Polak, Alan Powell
Professor
Management
(L5 or Reader)
Senior Research Associates
(Level 4)
Research Associates
(3b or B)
Research Analysts
(3a or A)
Research Assistants / Students
Chairman
Prof. Stephen Glaister
Alan Powell
(Accounts)
Dr. Daniel Graham
Research Director
Principal Research Fellow
Richard Anderson
Managing Director
CoMET and Nova Project Manager (5)
Robin Hirsch
Honorary Senior Research Fellow
Roger Torode
Honorary Senior Research Fellow
Nigel Harris
Honorary Senior Research Fellow
Roger Allport
Honorary Senior Research Fellow
Rory Maxwell
Senior Research Associate
(4)
Mark Trompet
Senior Research Associate
Bus Benchmarking Group
Project Manager (4)
Patricia Melo
Post Doc Research Associate (B)
Nicholas Findlay
Research Associate
(3b)
Alexander Barron
Research Associate
(3b)
Vacancy
(October 2010)
Research Associate (3b)
Richie Parasram
Research Analyst
(3a)
Xiang Liu
Research Associate
(A)
Vacancy
(October 2010)
Research Associate (3a)
Xu Jianbo
Seconded from Shanghai Shentong until December 2010
Niovi Karathodorou
PhD Student
Sofia Galligani
PhD Student
RTSC Organisational Chart
October 2010

2. Introduction to the Benchmarking Work within the RTSC

2. Definition of Benchmarking

- **A systematic process of continuously measuring, comparing and understanding organisations' performance and change in performance**
  - of a diversity of key business processes
  - against comparable peers anywhere else in the world
  - to gain information which will help the participating organisations to improve their performance

- *Adapted from the definition by Lema and Price*

2. Imperial College London are World Leaders in the Field of Public Transport Benchmarking

Sixteen year history of benchmarking projects facilitated by Imperial College London

1994 Group of Five heavy metros formed (incl. NYCT)

1996 *Community of Metros (CoMET)* founded (9 of the world's largest 12 metros)

1998 Success of *CoMET* leads to formation of *Nova* group for medium-sized metros

2004 *International Bus Benchmarking Group* established

2005 *Nova* grows to 14 members, *CoMET* to 12

2010 *Suburban Rail Benchmarking Group* established

Significant benefits have driven continued participation:

NYCT is a member for CoMET for 16 years and the IBBG for 6 years

2. 27 Metros Compare Performance to Identify and Share Best Practices

2. Thirteen Bus Benchmarking Group members

2. Ten members in the Suburban Rail Benchmarking Group

DSB S-Tog (Copenhagen)

London Rail

Metro Trains (Melbourne)

S-Bahn (Munich)

JR East (Tokyo)

Metro-North (New York)

CPTM (Sao Paulo)

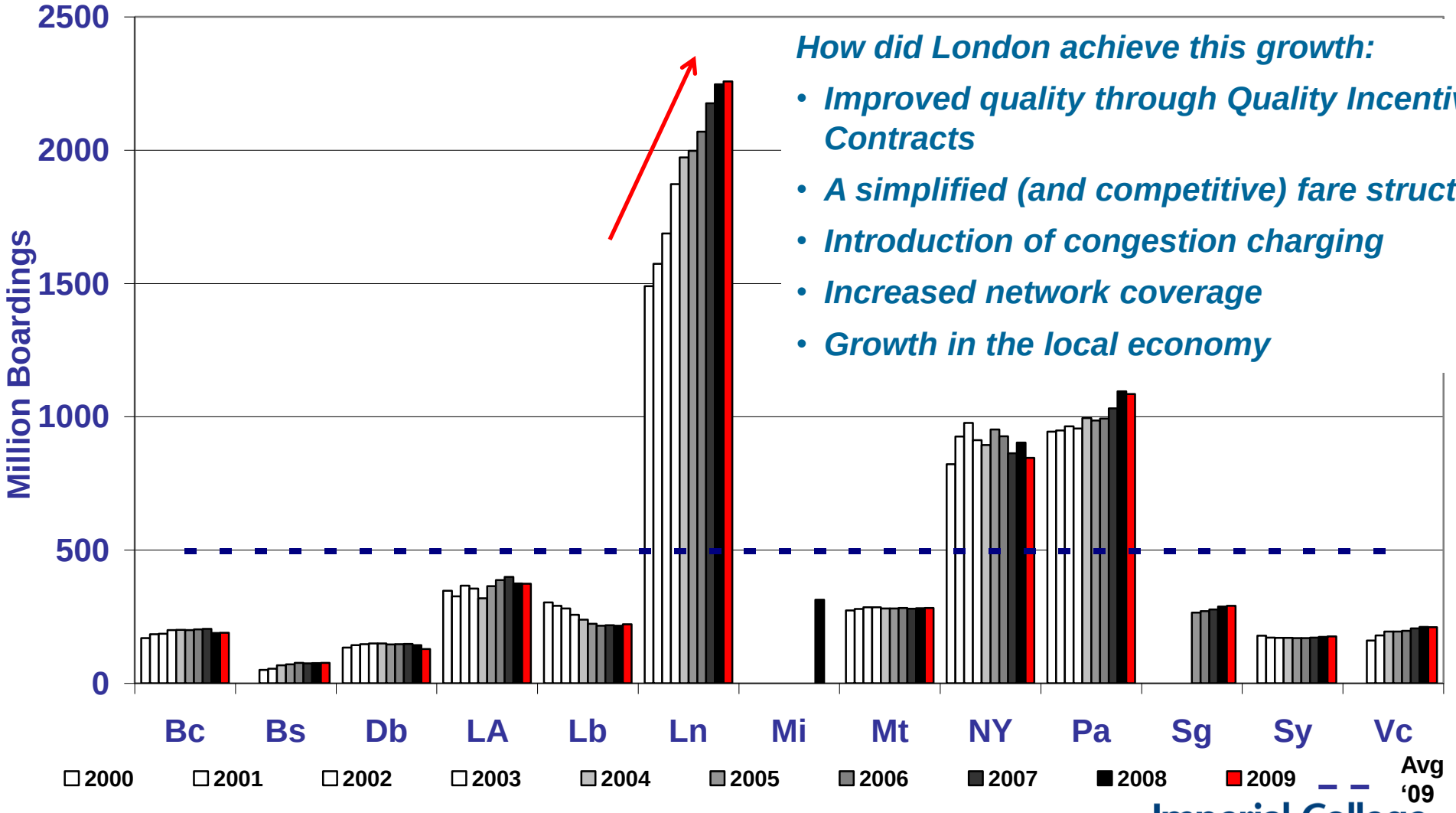
LIRR (New York)

NSB (Oslo)

BART (San Francisco)

2. IBBG Member Size: Passenger Boardings – Trends Possible to Compare Agencies of Different Sizes

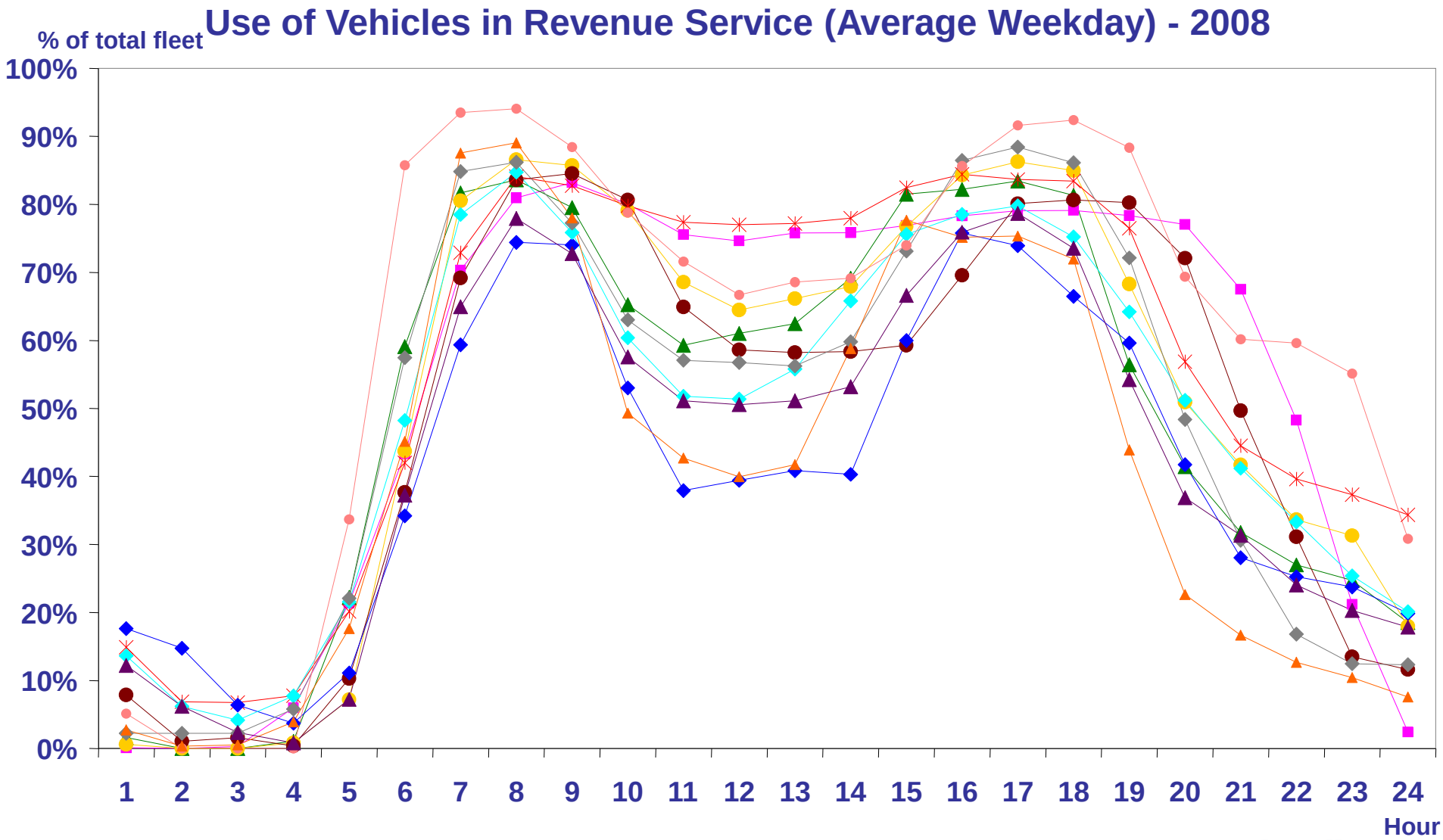
GA: Annual Passenger Boardings - Trends



How did London achieve this growth:

- ***Improved quality through Quality Incentive Contracts***
- ***A simplified (and competitive) fare structure***
- ***Introduction of congestion charging***
- ***Increased network coverage***
- ***Growth in the local economy***

2. Background Information example: Supply profile differences help to understand differences in performance



2. Bus Benchmarking Group KPIs

Growth & Learning

G1 Passenger Boardings
G2 Vehicle Kilometres
G3 Staff Training (categories)

Customer

C1 Passenger km / Revenue capacity km
C2 Actual / Scheduled revenue km & hour
c3 dynamic customer information
c4 low floor buses
C5 % buses on-time (Punctuality)
C6 Regularity (Excess Wait Time)
C7 Customer satisfaction

Internal Processes

P1 % of fleet used in peak (not used split by cause)
p2 revenue / total vehicle km & hour
P3 Total vehicle hours per labour hour
p4 staff absenteeism rate (categories)
P5 Mean distance between failures
p6 lost vehicle km (internal/external causes)

Safety & Security

S1 Number of vehicle accidents per vehicle km & hour
S2 Number of staff accidents per million staff hours
S3 Number of passenger accidents per boarding
S4 Number of 3rd party accidents
S5 Incidences of on-board crime

Financial

F1 Total cost per total vehicle km & hour
F2 Total operating cost per total vehicle km & hour
(F3 service operation, F4 maintenance, F5 administration)
F6 Service operation cost per revenue vehicle km & hour
F7 Total fare revenue / Total operating cost
F8 Total operating cost per passenger boarding/kilometre
F9 Fare revenue per passenger boarding/kilometre

Environmental

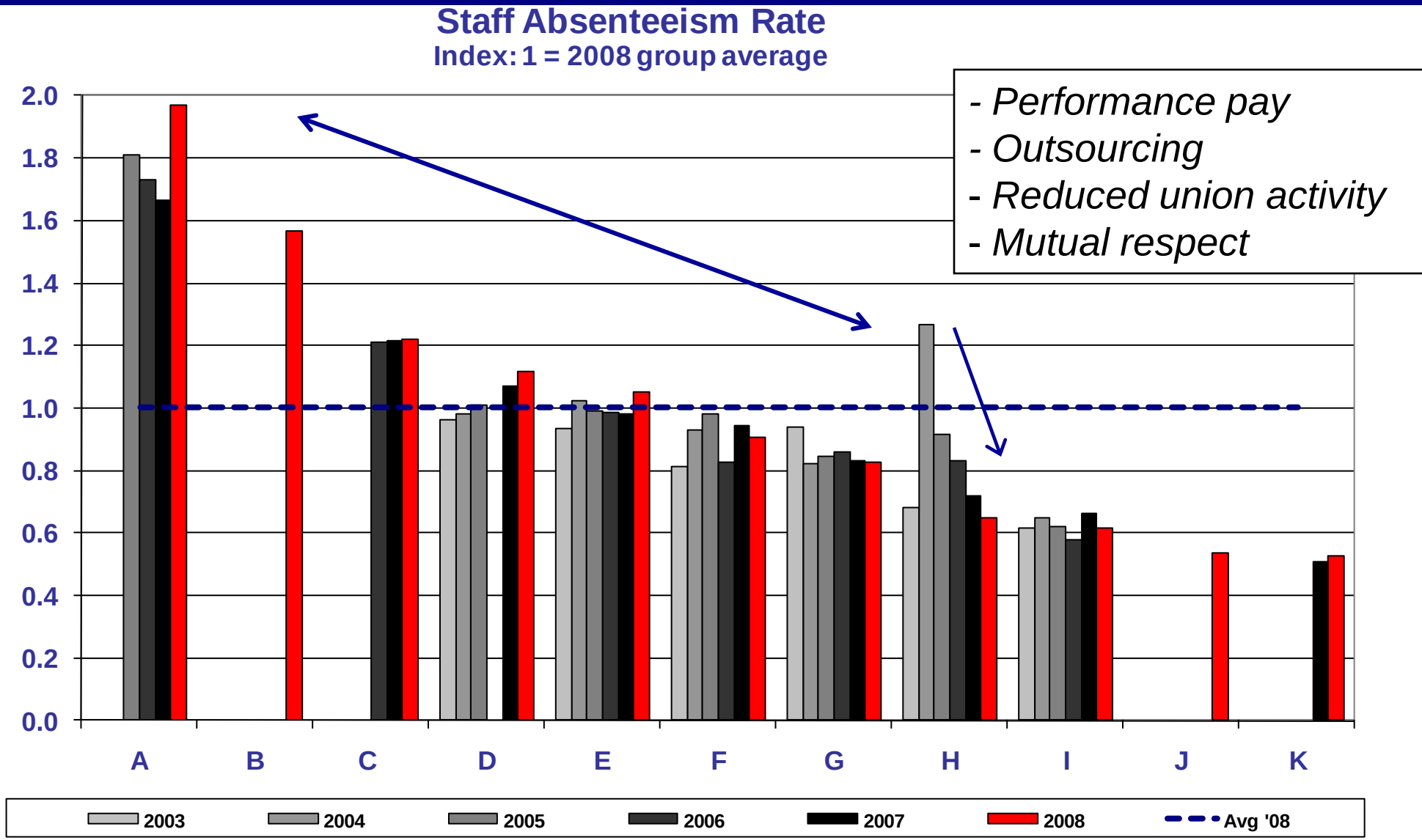
E1 Diesel/CNG fuel consumption per 100 total vehicle km
E2 Diesel/CNG fuel consumption per passenger kilometre
E3 Diesel/CNG fuel consumption per total vehicle tonne km
e4 % of fleet meeting EURO emissions categories
E5 CO2 emissions per passenger km & vehicle km

2. The Key Performance Indicator (KPI) System – Purpose and Use of KPIs

- **Benchmarking is NOT merely a comparison of data or a creation of rankings.**

- The structured KPI comparisons can be used for:
  - Stimulating productive “why” questions / identifying lines of inquiry.
  - Identifying high priority problems, strengths and weaknesses.
  - Identifying trends: performance can be monitored over time; identify organizations which have truly improved performance over time.
  - Internal motivation – setting targets for improved performance.
  - Supporting dialogue with government, authorities, media and other stakeholders (confidentiality permitting).

2. KPI example: Staff absenteeism - Bus organisation 'A' now realised absenteeism is too high relatively to peers, info used with talks to unions



2. Studies: KPIs can identify major differences between organisations, justifying more detailed examination

- About Detailed **Case Studies** (>80 completed studies in the three groups)
  - Proposed by metros and voted for at the Management Meeting
  - Detailed analysis by RTSC to determine best practices
  - 2-4 Studies per year per group. Lead time – 6 to 9 months
  - Wide-ranging, practical, emphasis on improving service quality & efficiency

- **Clearinghouse study**: Member initiated exchange of information on a specific topic (> 160 completed in the three groups)
  - Lead-time 1-2 months
  - Member performs the analysis, RTSC facilitates
  - Used to inform strategy, business case and option development….To identify best practices

- **Forum question**: Member post a short specific question on the website
  - Lead-time 2 weeks, More than 700 questions posted in 5.5 years

2. Examples of types of benefits

1. Using benchmarking results to understand where productivity improvements can / must be made, setting realistic targets:

- Understanding service control productivity differences
  - 33 Buses per controller versus 170 buses
  - Case study showed that some members could improve productivity

2. Using benchmarking results in communication with stakeholders (Government, Authority, Media, Passengers etc):

- A member showed unions that driver absenteeism is 200% higher than the Group average
  - Provided the member with a better position in their negotiations

3. No need to ‘re-invent the wheel’, saving consultancy resources

3. Service Regularity Indicators: Literature and Use by Operators

3. Time based Performance Indicators: Punctuality and Regularity

Punctuality, Regularity and Availability are perceived as top priority ‘service quality areas’ by customers

- Punctuality is measured for low frequency routes (~ 4 buses or less/hour)
  - Passengers look at timetable
  - % of services arriving within -1 to +3 minutes / 0 to +5 minutes of published schedule
- Regularity is measured for high frequency services (~ 5 or more/hour)
  - ‘Turn up and go’ services
- Research focussed on the perception of the customer

3. Objectives– Regularity as a ‘customer’ KPI

- The research questions are:
  - Which indicators could be used in comparing regularity of service between operators in different cities?
  - What and which quantity of data is necessary to calculate the indicator?
  - How do anomalies in the dataset need to be addressed before analysis?
  - What are the strengths and weaknesses of different regularity key performance indicators when used in benchmarking?

3. Regularity Indicators in Literature

- We could not find evidence of published research on regularity indicators specifically used in benchmarking
  - This research aims to add knowledge to this area.
  - However, much research has been published with regards to regularity measures in general.

- The most common used metric is the average passenger waiting time (A.W.T) proposed by Osuna and Newell.
- Assuming uniform passenger arrival, the A.W.T is derived as the sum of one half of the average headway and the ratio of headway variance to twice the average headway, i.e.

$$E(A.W.T)=0.5E(headway)+V(Headway)/2E(Headway).$$

AWT = part of the Excess Wait Time methodology used in London

EWT = AWT – SWT (scheduled wait time)

3. Regularity Indicators in Literature: The TCRP 'Guidebook for Developing a Transit Performance Measurement System'

- The TCRP Guidebook presents five possible regularity indicators:
  - **Headway Adherence**: Coefficient of variation of headway deviations divided by the average scheduled headway
  - **Service Regularity**: The percentage of headways that deviate no more than a specified percentage from the scheduled interval.
  - **Wait Assessment.** The percentage of headways that deviate no more than a specified number of minutes from the scheduled interval.
    - used by European quality certification institutions
  - **Headway ratio**: the observed headway divided by the scheduled headway, multiplied by 100.
    - Scheduled headways need to be constant over the measurement period.
    - In reality, as also the IBBG pilot has shown, this is very uncommon, which makes this indicator less applicable for benchmarking purposes.
  - **Headway regularity index** using Gini's ratio.
    - Performs well in identifying vehicle bunching, however that the indicator is difficult to visualize and or explain.

3. Current regularity indicators in use by IBBG bus operators

- The table below gives a summary overview of regularity indicators and thresholds in use amongst IBBG members

Bus Operator	Regularity Indicator Type	Definition of Service Regularity (i = scheduled headway)
Barcelona TMB	Wait Assessment	i-1 to i+3
Brussels STIB	Wait Assessment	i to i+2
Dublin Bus	None, measures on time terminal departures	NA
Los Angeles LACMTA	None, measures en route on time performance	NA
Lisbon Carris	Service regularity	i-20% to i+20%
London Buses	Excess Wait Time	Route dependant minimum performance, EWT: 0.5 - 2
Milan ATM	Wait Assessment	i-3 to i+3
Montreal STM	None, measures en route on time performance	NA
New York NYCT	Wait Assessment	i to i+3 (peak), i to i+5 (off-peak)
Paris RATP	Wait Assessment	i to i+2
Singapore SMRT	Wait Assessment	i-5 to i+5
Sydney Buses	None, measures on time terminal departures	NA
Vancouver CMBC	Wait Assessment / Service regularity	i-2 to i+4, i-20% to i+20%

3. Which indicators should be tested?

- Benchmarking results are generally comprised of high level performance indicators that are presented to senior management or at board level

- Benchmarking results could, when fully anonymised, be used to inform external stakeholders.

- Good reliability indicators should therefore be clear, easily understandable and useful to the audience.

Hence, the IBBG pilot aimed to find indicators that were either:

- Expressed in (wait) minutes and/or percentages of service delivered.
- A focus was on indicators that are already in use by IBBG members.

3. The Four Regularity Methodologies Tested for Benchmarking Suitability

- Methods tested to compare regularity between members are:
- Excess Wait Time (EWT)
  - Normalised AWT
- Standard Deviation (SD) of the difference between scheduled and actual headway
  - Headway Adherence, not normalised, but expressed in minutes
- Wait Assessment (WA)
  - Used by most operators
  - Used by European certification agencies
- Service Regularity (SR)
  - Normalised WA, used by some operators

3. Suitability for benchmarking: criteria

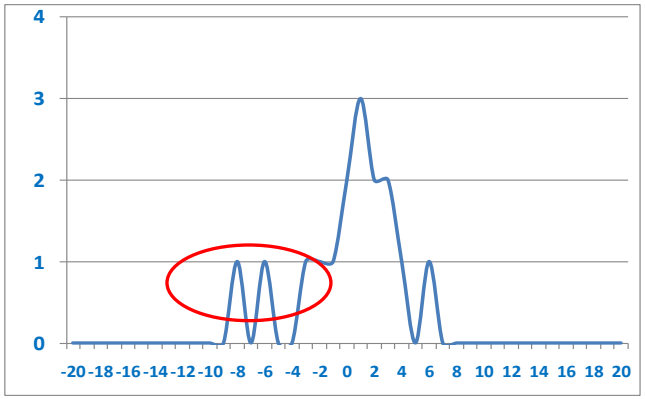
- Suitability for benchmarking is according to the authors determined by:
  - ‘ease of communication’,
  - the ‘customer view’ expressed (i.e. are all customers taken into account, are long gaps penalised),
  - data ‘condition requirements’ (e.g. similar scheduled headways between datasets, normal distribution) and
  - the ‘objectivity’ of the KPI output (e.g. the output cannot be manually influenced by changing regularity thresholds).

4. Sample size, Data Characteristics and Data Cleaning Methodology

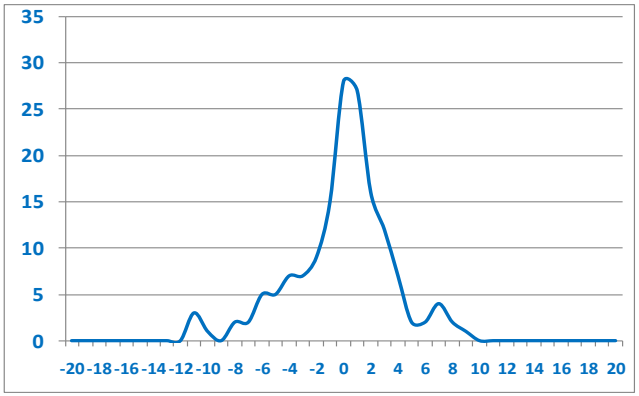
4. Data Collection – Number of Data Points Required

- How many data points are needed?
  - The more the better!
  - The below graphs (TMB 2010 data) reveal the distribution of the difference between actual headway and scheduled headway.

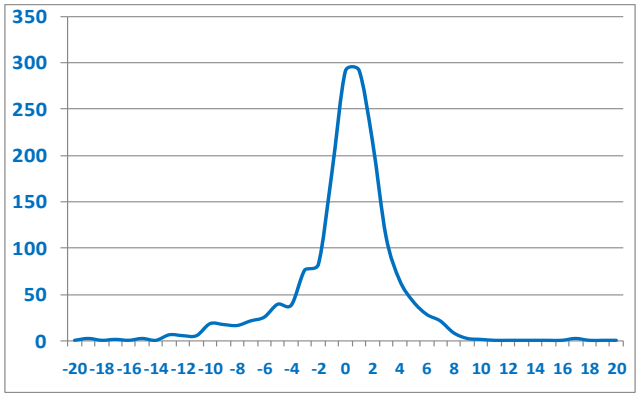
20 data points



200 data points



2000 data points



- The graphs show that > 200 observations can increase the normal distribution, which will make the results more reliable.

4. Data Collection – Data Requested

Members agreed to collect the following data:

- For their 3 busiest high frequency bus routes in terms of passenger boardings
  - peak hour scheduled headway should not be more than 12 minutes
- Actual and scheduled arrival times from one typical bus stop in the middle section of the route (one unique stop per route),
- For the morning peak period (2-3 hours)
- For 5 weekdays within a ‘complete’ week in the Spring
  - Weekend days were excluded last year due to longer headways

4. Data Collection – Data Requested (continued)

- For each stop, members agreed to report:
  1) scheduled arrival times, and
  2) actual arrival times
  3) 'hh:mm:ss' format

- Sample data from London Buses
  - 21 scheduled arrival times & 21 actual arrival times provided per day/route
  - From this, 20 scheduled headways & 20 actual headways can be calculated

Scheduled arrival time	Scheduled headway	Actual arrival time	Actual headway
08:11:00		08:03:56	
08:16:00	00:05:00	08:05:47	00:01:51
08:21:00	00:05:00	08:11:07	00:05:20
08:26:00	00:05:00	08:17:18	00:06:11
08:31:00	00:05:00	08:20:17	00:02:59
08:36:00	00:05:00	08:26:19	00:06:02
08:40:00	00:04:00	08:28:06	00:01:47
08:45:00	00:05:00	08:38:03	00:09:57
08:50:00	00:05:00	08:44:17	00:06:14
08:55:00	00:05:00	08:46:02	00:01:45
09:00:00	00:05:00	08:52:13	00:06:11
09:04:00	00:04:00	08:54:06	00:01:53
09:09:00	00:05:00	09:00:36	00:06:30
09:14:00	00:05:00	09:03:39	00:03:03
09:19:00	00:05:00	09:09:55	00:06:16
09:24:00	00:05:00	09:22:45	00:12:50
09:29:00	00:05:00	09:24:45	00:02:00
09:34:00	00:05:00	09:30:17	00:05:32
09:39:00	00:05:00	09:32:08	00:01:51
09:44:00	00:05:00	09:36:55	00:04:47
09:49:00	00:05:00	09:57:26	00:20:31

4. Data Received – Synthesis

In total, 12 bus companies provided data for this phase, up from 10 last year.
The table below summarises the characteristics of the 2010 data set:

	Bc	Bs	Db	LA	Lb	Ln	Mi	NY	Pa	Sg	Sy	Vc
Scheduled arrival time	✔	✔	✔	✔	✔	✔	✔	✔	✔	✔	✔	✔
Actual arrival time	✔	✔	✔	✔	✔	✔	✔	✔	✔	✔	✔	✔
Actual arrival time format	seconds	seconds	seconds	seconds	seconds	seconds	seconds	**minutes**	seconds	seconds	seconds	seconds
Scheduled headway range	4'-9'	3'-11'	4'-12'	2'-12'	6'-10'	2'-8'	1'-8'	2'-10'	3'-12'	1'–12'	1'-12'	1'-9'
Total valid data points	285	340	207	329	209	491	491	398	429	323	404	511
Missing data points	14	20	0	21	0	0	0	0	4	0	10	6
Same routes for 2009 and 2010?	Y	Y	Y	2010 only	Y	Y	2010 only	Y	Y	2010 only	Y	2/3

4. Data Received – Problems

- Members supplied data in their original recorded form. This needed to be processed and filtered in order to make comparisons.

- Data anomalies that were found in the dataset include:
  - Missing data (buses actually ran but failed to be recorded, either through human error or transmission equipment failure)
  - Cancelled service (bus did not run)
    - due to driver / bus unavailability
    - or as a measure to regulate service
  - Breakdown (bus did not make it to the measure point)
  - Overtaking (a bus or several buses arrived out of sequence)

4. Data Processing – Customer Orientation

- In standardising and cleaning the dataset, the perspective of the customer has been the main focus.

- From the service provider point of view, “the scheduled bus” is as important as “a bus”
  - To know whether the service is running as planned, and
  - To look for ways of improving matches between the scheduled and actual arrival times of each bus

  This is outside the scope of the study

- From the customer point of view:
  - Regularity is an important component of customer satisfaction, and so the analysis should be “customer oriented”
  - Passengers don’t know, or care, whether the “scheduled bus” arrives, as long as “a bus” comes

4. Data Processing – Procedures for missing data

- Missing data - buses actually ran but failed to be recorded, either through human error or equipment failure.
- Two options were considered: remove data completely or estimate missing data
- It is decided to remove the missing data completely:

Data Anomaly	Scheduled arrival	Actual arrival	Re-arranged actual arrival
Missing Data	08:00:00	08:00:23	08:00:23
	08:05:00	08:21:42	08:09:57
	08:10:00	08:09:57	08:14:48
	~~08:15:00~~	missing	missing
	08:20:00	08:20:05	08:21:42
	08:25:00	08:24:52	08:24:52

- However, removing one missing data point, would lead to losing two headways for calculation purposes

4. Data Processing – Procedures for cancelled services

- Cancelled service - scheduled buses did not run due to driver or bus unavailable, service control measures (Paris).
- 'The passenger experience' procedure
  - The non-existing actual arrival time is replaced with the next actual arrival time. In case of subsequent cancellations, all are replaced by this next actual arrival time:

Scheduled arrival	Actual arrival
8:00:00	8:01:35
8:05:00	*cancelled*
8:10:00	*cancelled*
8:15:00	8:16:03

This is replaced by

Scheduled arrival	Actual arrival
8:00:00	8:01:35
8:05:00	*8:16:03*
8:10:00	*8:16:03*
8:15:00	8:16:03

scheduled buses are assigned the next actual arrival time, matching the passenger experience

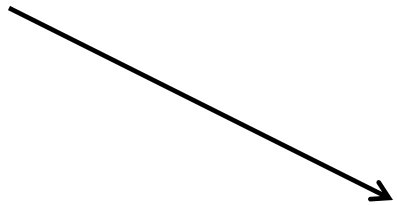
2. Data Processing – Procedures for breakdowns

- Breakdown / serious delay - bus did not make it to the measure point (within the sample period).
  - This was very rare in the data received, but where it occurs, the data was treated with the same procedure as a cancelled service

2. Data Processing – Procedures for overtaking

- With ‘overtaking’, the actual arrival data was rearranged to reflect the order in which customers experienced the bus arriving.

Scheduled arrival	Actual arrival	Re-arranged actual arrival
08:00:00	08:00:23	08:00:23
08:05:00	**08:21:42**	*08:09:57*
08:10:00	08:09:57	*08:14:48*
08:15:00	08:14:48	*08:20:05*
08:20:00	08:20:05	***08:21:42***
08:25:00	08:24:52	08:24:52



- It can be observed that scheduled service of 08:05:00 has been overtaken by 3 services

5. Testing:

- Excess Wait Time
- Standard deviation of the differences between the scheduled and the actual headway
- Wait Assessment
- Service Regularity

5.1 Results of the First Methodology: Excess Wait Time

5. Introduction – Excess Wait Time (EWT)

- Excess wait time - method used by London Buses.
  - SWT (Scheduled wait time)

$$SWT = \frac{\sum_{i=1}^{N} SHway_i^{\,2}}{2 \times \sum_{i=1}^{N} SHway_i}$$

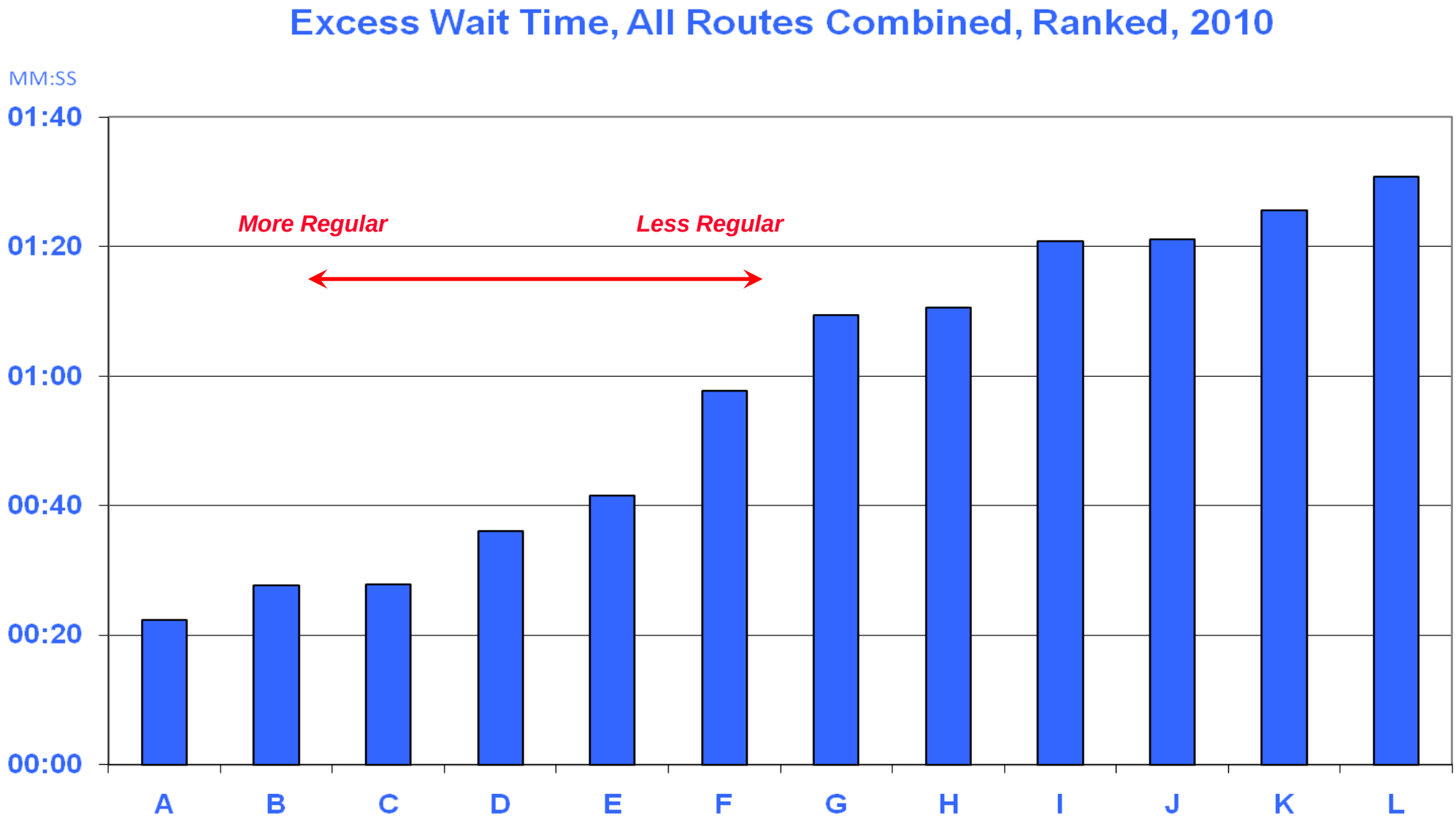
  - AWT (Actual wait time)

$$AWT = \frac{\sum_{i=1}^{N} AHway_i^{\,2}}{2 \times \sum_{i=1}^{N} AHway_i}$$

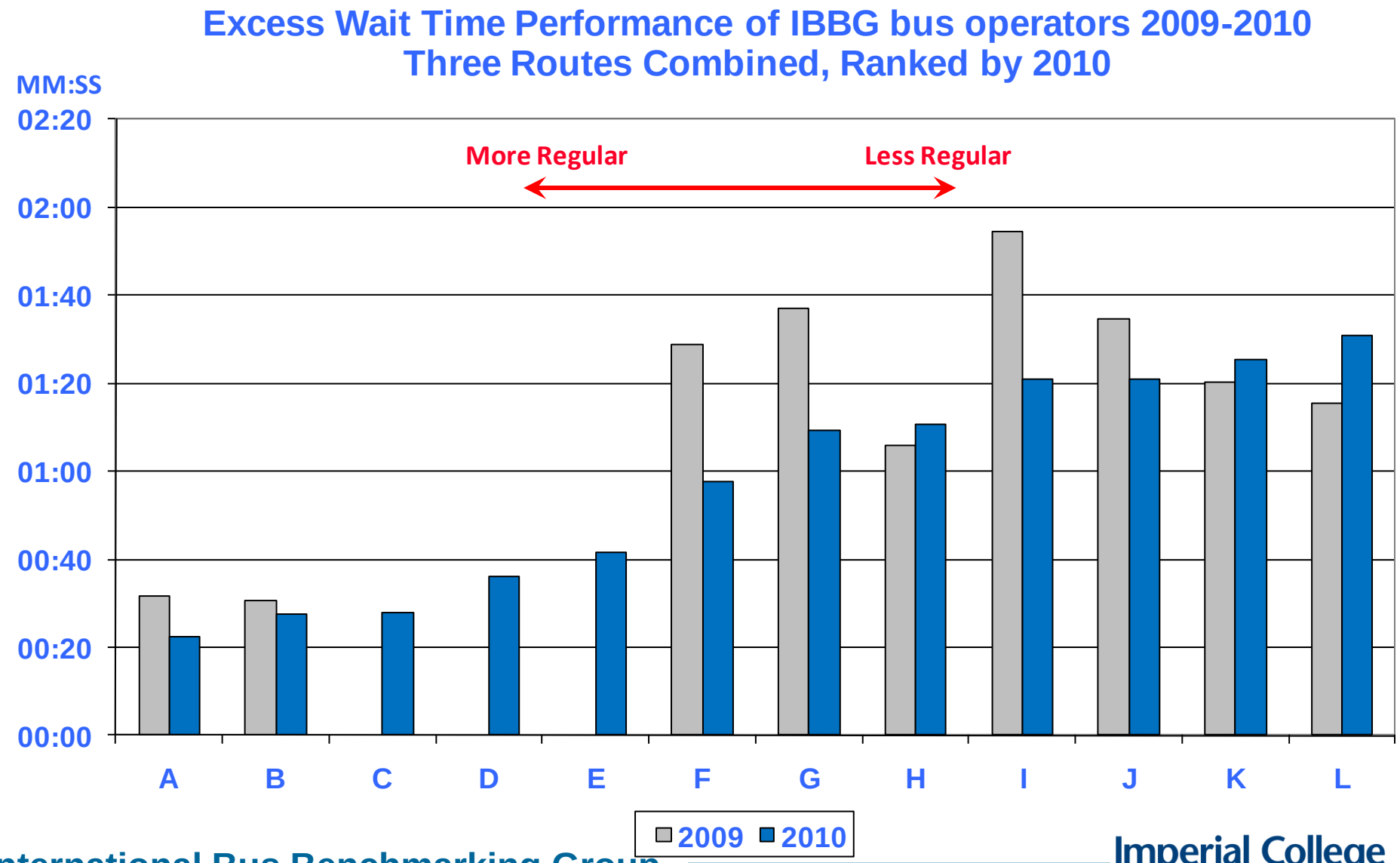
  - Excess wait time: $EWT = AWT - SWT$

  - EWT is a measure of perceived regularity, measuring the average additional waiting time passengers experience as compared to the waiting time they expect
  - The lower the EWT, the more likely it is that passengers will not wait more than scheduled and perceive the service as regular
  - E.g. a 10-min headway route has a SWT of 5 min. An EWT of 1 min means customers are likely to wait 6 min instead of the expected 5 min

5. Result – Excess Wait Time, All Routes Combined, 2010 Result



5. Result – Excess Wait Time, All Routes Combined, Ranked by 2010 Result



5. Discussion on Excess Wait Time

Advantages

- Objective measurement
- Easy to communicate (expressed in minutes)
- Uses all data in the calculation (including extremes)
- Focuses on the customer point of view

Disadvantages

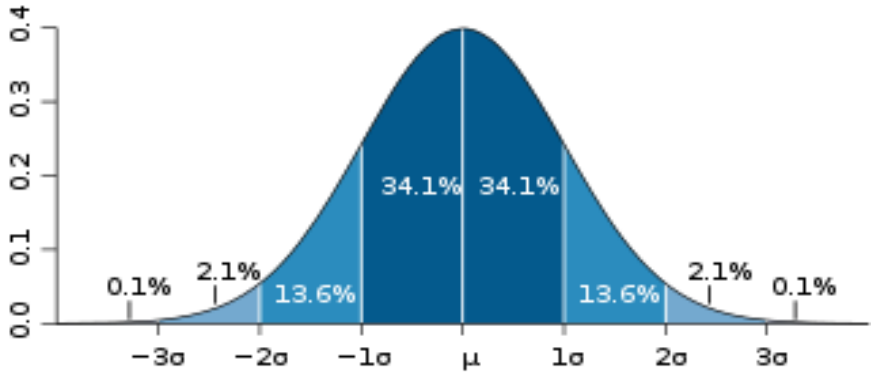
- Irregular/uneven scheduled headways may skew the results
- Works best with longer periods of observation – shorter periods can show artificially good results if the last bus in the sample arrives early

5.2 Results of the Second Methodology: Standard Deviation

5. Introduction – Standard Deviation (SD)

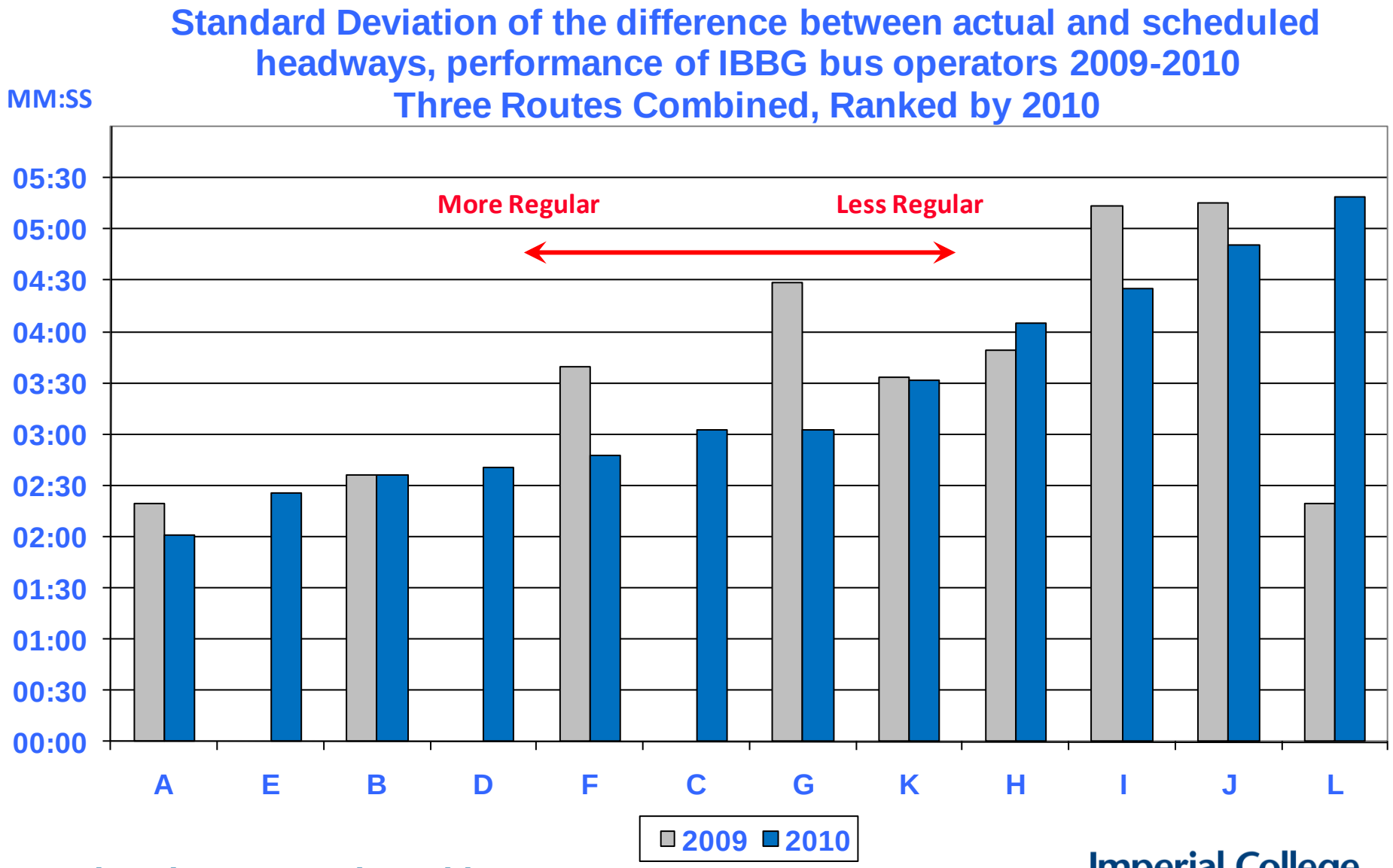
- Definition of Standard Deviation

$$\sigma = \sqrt{\frac{1}{N}\sum_{i=1}^{N}\left(AHway_i - SHway_i\right)^2}$$



- If data follows a Normal Distribution, then
  - 1 x Standard deviation relates to 68% of the population
- If SD=2 Min, then 68% of the actual headways are within +/- '2' minutes of the scheduled headway

5. Result – Standard Deviation, All Weekday Routes Combined, Ranked by 2010 Result



4. Discussion on Standard Deviation

Advantages

- Objective measurement
- Easy to understand (expressed in minutes)
- Uses all data in the calculation (including extremes), however it only outputs the experience of approximately 68% of the passengers

Disadvantages

- Difficult to communicate and interpret
- Assumes generally normal distribution of data – typically requires suitably large number of data points
- Heavily affected by very long headways 'gaps'
- Doesn't normalise for differences in scheduled headways

5. Discussion on Standard Deviation: Outlier Example

- Standard Deviation Example:
  - Scheduled Headway: 10 min
  - All actual headways are within ±1 minute of the scheduled headway except one long headway of 19 minutes
  - Standard Deviation of this sample with the single long headway is three times as much as without it
- The “penalty” for the long headway may be too great – particularly as most customers experience a regular service

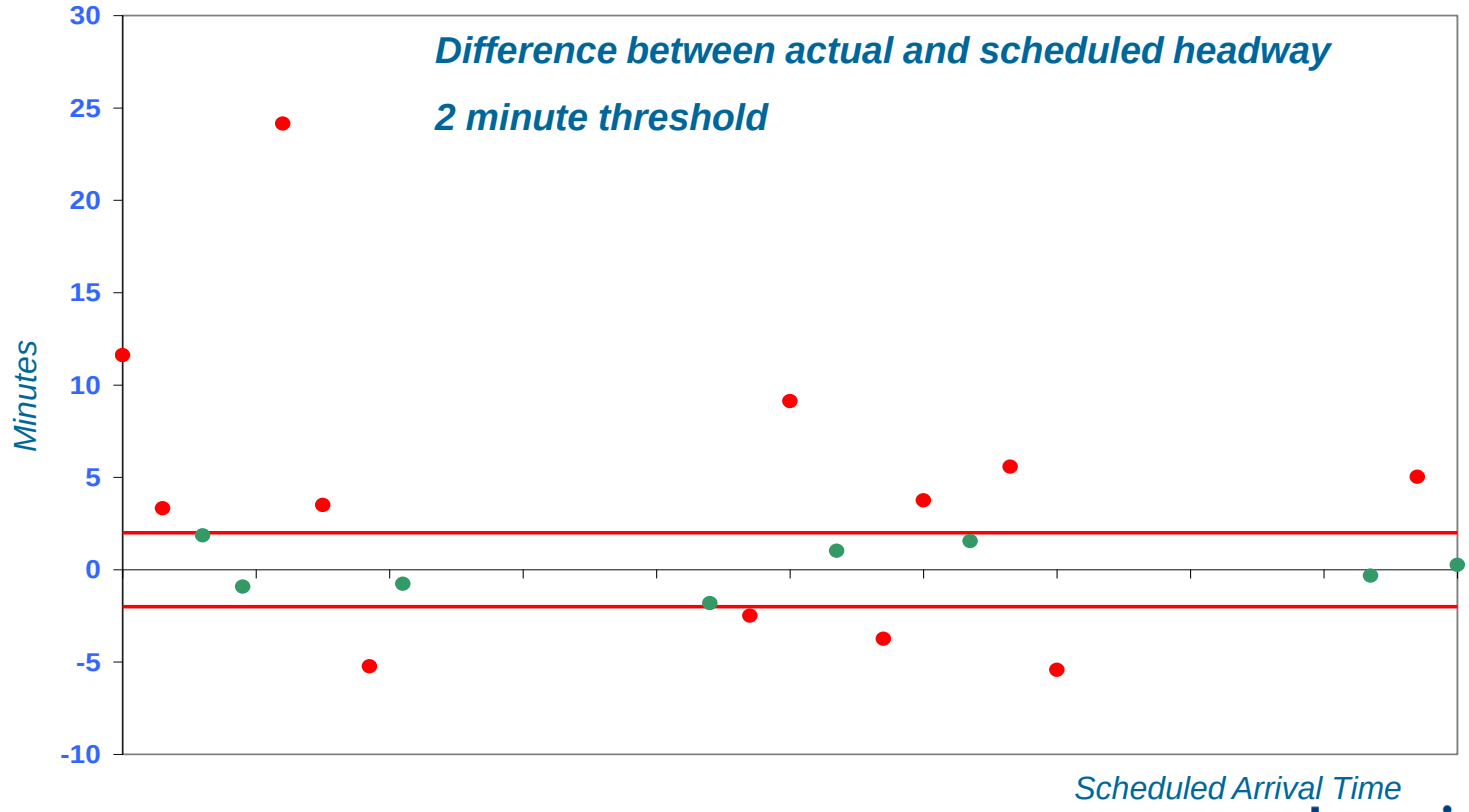
SAT	SHW	AAT	AHW
13:08:00	------	13:08:06	------
13:18:00	10:00	13:18:58	10:52
13:28:00	10:00	13:27:36	08:38
13:38:00	10:00	13:38:16	10:40
13:48:00	10:00	13:47:54	09:38
13:58:00	10:00	13:57:36	09:42
14:08:00	10:00	14:08:33	10:57
14:18:00	10:00	14:19:26	10:53
14:28:00	10:00	14:38:55	19:29
14:38:00	10:00	14:47:36	08:41
14:48:00	10:00	14:57:00	09:24
14:58:00	10:00	15:07:58	10:58
15:08:00	10:00	15:17:57	09:59
15:18:00	10:00	15:27:36	09:39
15:28:00	10:00	15:36:52	09:16
15:38:00	10:00	15:47:30	10:38
15:48:00	10:00	15:58:28	10:58
SD for entire sample:			**02:30**
SD without outlier:			**00:51**

SAT/SHW: Scheduled Arrival Time / Headway
AAT/AHW: Actual Arrival Time / Headway

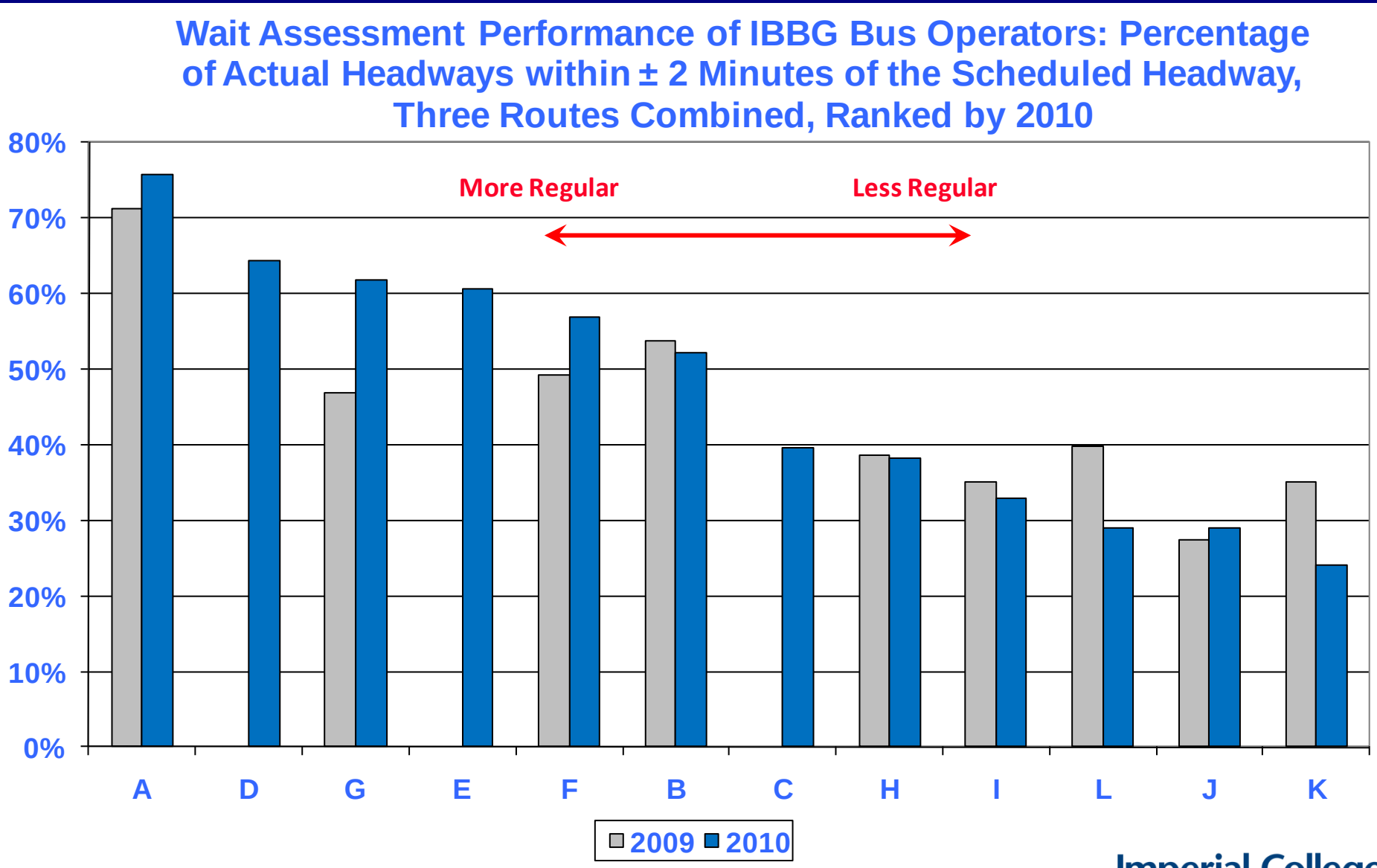
5.3 Results of the Third Methodology: Absolute Regularity Band

5. Introduction – Regularity within Absolute Band

- Regularity within absolute band (2 minutes)
  - The percentage of actual headway that is within ±2 minutes of scheduled headway. This is the percentage of green dots to the total number of dots.
  - The higher the percentage, the more regular the service



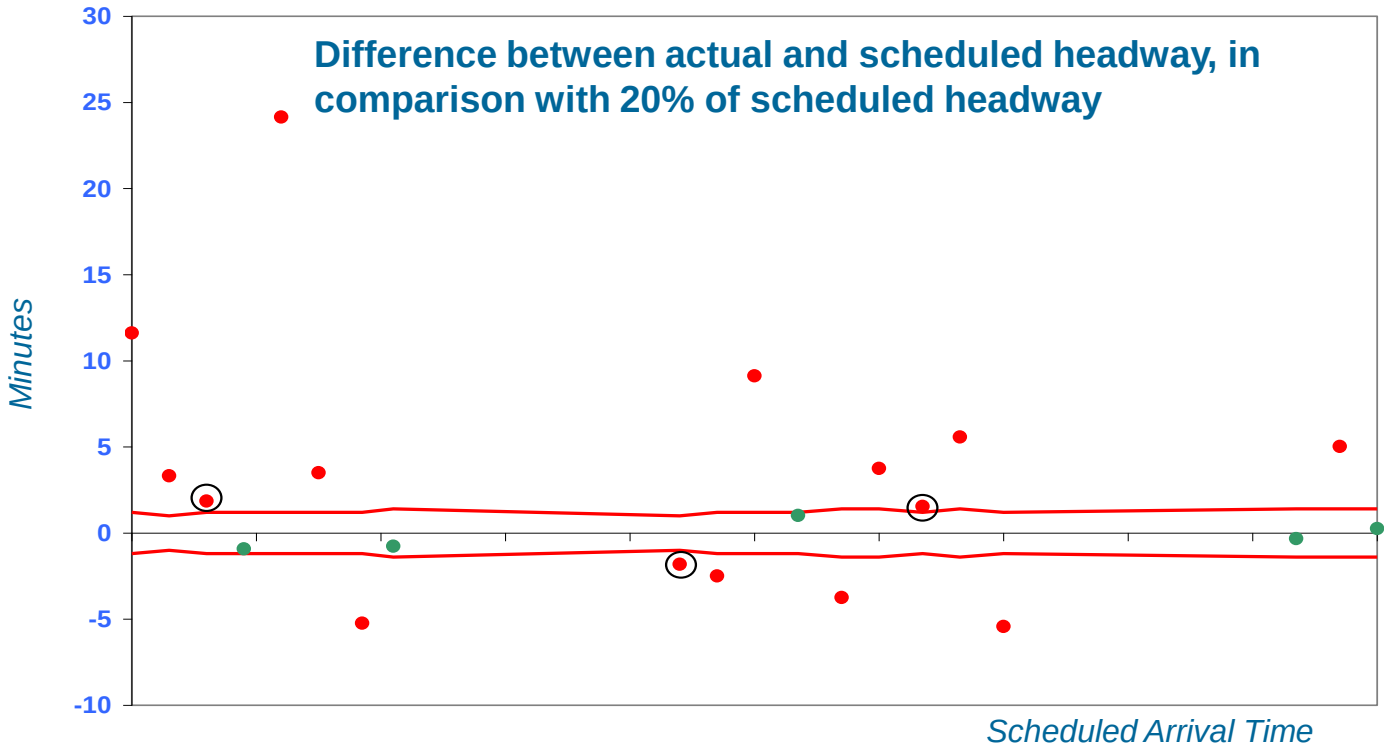
5. Result – Wait Assessment (Absolute Band), All Routes Combined, 2009-2010



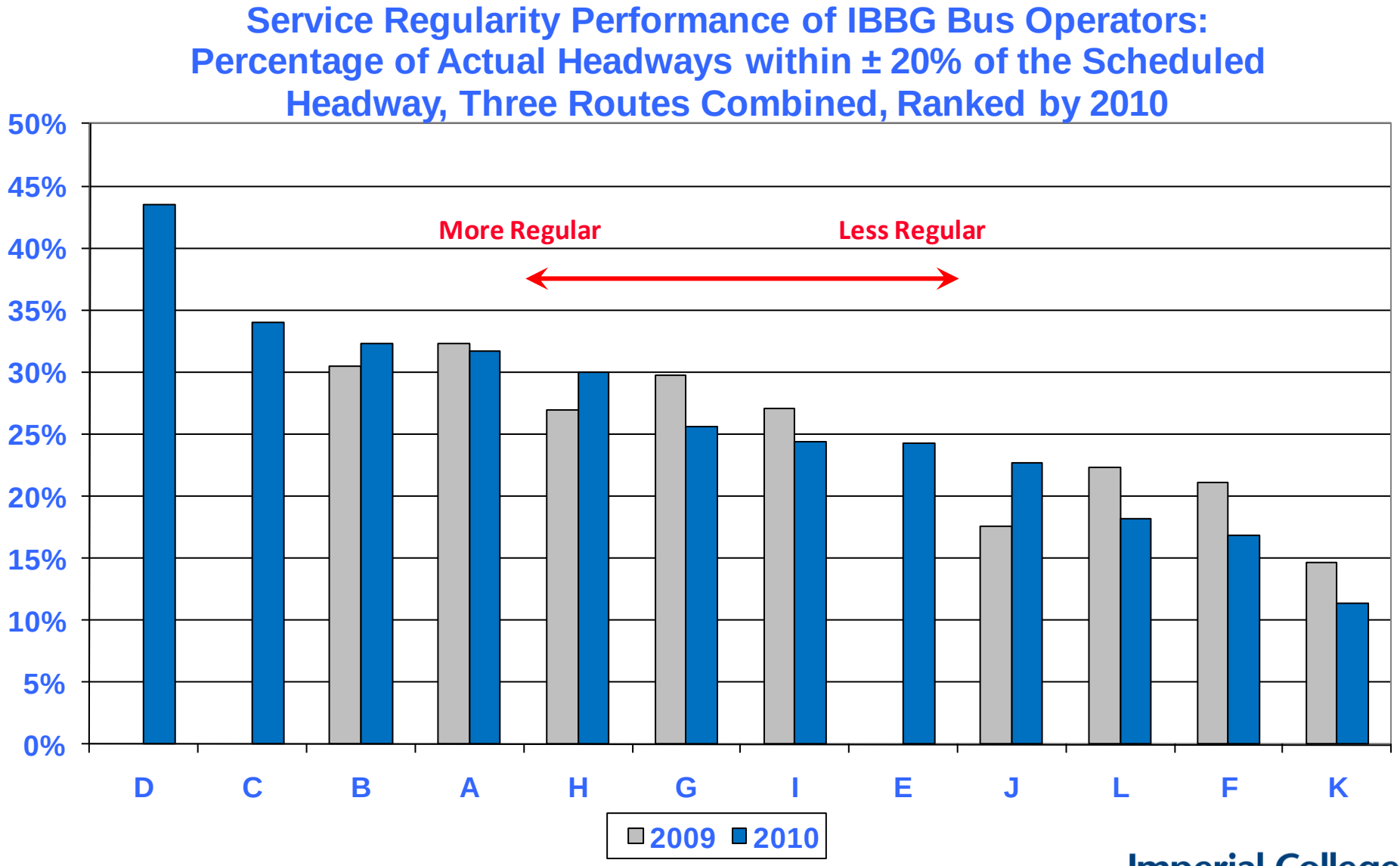
5.4 Results of the Fourth Methodology: Relative Regularity Band

5. Introduction – Regularity within Proportional Band

- Regularity within proportional band (20% of Scheduled Headway)
  - The percentage of actual headways within ±20% of scheduled headway are shown in green.
  - The higher the percentage, the more regular the service.
  - The width of the proportional band may vary if the scheduled headway is not constant.



5. Result – Service Regularity (Proportional Band), All Routes Combined, 2009-2010



6. Discussion – Wait Assessment and Service Regularity

Advantages

- Very easy to understand and communicate (expressed in % of headways matching criteria)
- Simple calculations, ability to set multiple thresholds (i.e. % within 1 min, % within 3 min, % within 5 min, etc.)

Disadvantages

- Subjective measurement – threshold of ±2 minutes (absolute) or ±20% of scheduled headway (relative) is arbitrary
- Focus more on service operation than customer experience – each data point is either in or out of the band, causing very long headways to have the same effective "penalty" as headways just beyond the threshold

6. Discussion – Wait Assessment and Service Regularity

- Absolute regularity bands (wait assessment) strongly favour frequent services, while relative regularity bands penalise them
  - Within the IBBG chosen thresholds, services with 10-minute headways have the same results for either methodology

	Wait Assessment		Service regularity	
Bus Service Headway	% of headway *(result range)*	Absolute band *(minutes)*	Relative band *(% of headway)*	Absolute *(result range)*
3 Minutes	67%	±2 minutes	20%	±36 seconds
5 Minutes	40%	±2 minutes	20%	±1 minute
10 Minutes	20%	±2 minutes	20%	±2 minutes
12 Minutes	17%	±2 minutes	20%	±2.4 minutes

6. Conclusions

6. Regularity Results 2010 – Summary Table.
Members regularity performance: 1 = best / 12 = worst

All four potential Service Regularity KPIs produce different service regularity rankings amongst members. In summary:

Bus Operator	Excess Wait Time	Standard deviation of difference between actual and scheduled headways	Wait Assessment +/- 2 minutes of scheduled headway	Service Regularity +/- 20% of scheduled headway
A	1	1	1	4
B	2	3	7	3
C	3	6	6	2
D	4	4	2	1
E	5	2	4	8
F	6	5	5	12
G	7	7	3	6
H	8	9	9	5
I	9	10	10	7
J	10	11	12	10
K	11	8	8	9
L	12	12	11	11

6. Conclusions – Summary of characteristics

- All four regularity indicators have both advantages and disadvantages.
- However, Excess Wait Time is only 'true' customer oriented method.

	Excess Wait Time	Standard deviation of different between actual and scheduled headways	Wait Assessment +/- 2 minutes of scheduled headway	Service Regularity +/- 20% of scheduled headway
Ease of communication	**Good**	Marginally	**Very good**	**Very good**
Subjective/ Objective	**Objective**	**Objective**	*Subjective*	*Subjective*
Customer representation	**All**	Input all, Output only 68%	*% who experience regular service*	*% who experience regular service*
Condition requirements	*Regular scheduled headways*	*Normal distribution* *Similar scheduled headways*	Headways at least longer than regularity threshold	*Similar scheduled headways*
Penalises very long headways	**Yes**	Significantly	*No*	*No*

6. Regularity KPI: conclusions

- This research shows that it is feasible to comparably benchmark the service regularity performance of bus operators, however there are challenges to overcome.
- Regardless of the regularity indicator chosen, a challenge lies with both data collection (sample size) and data cleaning.
  - Irregular scheduled and differences in 'Headway range' provided cause comparability problems.
- The difference in regularity performance for 2009 and 2010 is quite substantial for some organisations.
- The chosen minimum sample size of 200 observations is too small to provide meaningful performance (trend) data for benchmarking purposes.

6. Regularity KPI: conclusions – Sample size

- For all four indicators tested, the results of the individual routes also differ significantly in most bus organisations.
  - This is due to route specific traffic and dwell time conditions.

- Members agreed to increase the data sample. A proposal from London Buses is:

  Data for not less than seven and not more than ten routes, provided on a turn-up-and-go basis covering both peak and interpeak and not measured at the terminus. It could be a requirement that the routes' total patronage on a weekday should exceed 2.5% of the organisation's total patronage.

- Recent discussions (last week!) resulted in an all or nothing agreement:
  - Full system AVL data used for calculations, or no KPI
  - Testing phase of ‘data cleaning’ macros

Thank you