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TRANSPORT
STRATEGY
CENTRE >

13th February 2023

Cross-Group Benchmarking Review of Recent Activities: Public Report

Contents

Imperial College London
Projects

Overview

This document was initially developed with the purpose of helping operators optimise their response to the COVID-19 pandemic by sharing knowledge and experience from a wide range of organisations globally. As the pandemic situation continues to evolve and large parts of the world have reverted to pre-pandemic life with few restrictions, the overall purpose of this report has shifted and will now also provide a general update on select research topics to support wider learning and information sharing, as well as content related to the COVID-19 pandemic.

Content is sourced from the benchmarking group members and activities within the groups: over 100 metro, rail, bus, light rail and airport operators participate in the international benchmarking groups (see Appendix A for a list of benchmarking groups and members) managed through the Transport Strategy Centre (TSC) at Imperial College London.

In this edition we review the latest developments around public transport ridership recovery and we provide a cross-modal comparison of COVID-19 impacts for metro and bus (as identified in the 2022 Customer Satisfaction Survey). This report also includes a brief overview of digital transformation based on insights from recent studies in the suburban rail and metro benchmarking groups.

ABBG COMET IMRBG ABG
IBBG GOAL ISBERG
RIAMBIG

All information provided is anonymised to respect condentiality rules of the benchmarking groups (unless any information has been sourced publicly).

Full references of relevant literature on COVID-19 in the transport industry are provided at the end of this document, along with a short description for each piece of research.

TSC EDITORIAL

Public transport ridership recovery on track to end strongly for 2022, but there are signs that demand is stabilising - have we reached the "new normal"?

For the most part, the latter half of 2022 shows a continuation of the strong demand recovery that we have been seeing across all regions and public transport modes during the past year. Although there are regional variations in demand returning to public transport, we can see in this report that there are **signs of ridership stabilising** toward the final quarter of the year: this trend is clearly visible and, interestingly, one that generally applies to all regions and modes. The question is whether this flattening out of demand shows that the new travel patterns that have emerged from the pandemic have stabilised and that we have reached the post-pandemic "new normal", at least for now.

This possible "new normal" is supported by findings from the 2022 Customer Satisfaction Survey which suggest that the majority of bus and metro customers (~80% on average) expect to use public transport **the same amount or more** as before the pandemic . We take a more detailed look at survey results from the COVID-19 element of the survey in this report, focusing on a cross-modal comparison of bus (IBBG) and metro (COMET).

In this report, the demand recovery analysis includes data from the airport benchmarking group for the first time. We also review select findings from recent benchmarking activities on the topic of **digital transformation**. As public transport operators continue in their efforts to attract ridership, the advances that the industry is making in this area can only further support this intention as evolving digital technologies and new business models provide opportunities for strengthening the position of public transport. This topic is one that continues to be a strong focus area for benchmarking group members and we will report on further emerging benchmarking research on the topic in future reports.

2022 has seen a global recovery in public transport demand to highest levels since 2019

Recent Metro Demand Trends

Average **metro ridership** by region as a proportion of pre COVID-19 demand *(monthly demand indexed to the corresponding 2019 month)* is shown in Figure 1. The graph is based on daily demand data collected in the COMET metro benchmarking group and shows average ridership across all days of the week.

Following strong trends in ridership recovery experienced globally in 2022, data suggests that there appears to be some stabilisation in metro demand in recent months and across all regions, ranging from around 60% of pre-pandemic demand in North America to nearly 90% in Europe. This trend can be seen in the latest available demand data which is shown in the dotted lines in Figure 1 for each region.

- On average, **European metros** continue to experience the highest demand globally at **89%** of pre COVID-19 levels throughout the week.
- Average metro demand in the **Asia-Pacific** region remains stable at around **83%** of pre COVID-19 levels for recent months.
  - The overall picture for metro demand in the Asia-Pacific region is more variable:
    - » Indian metros have recovered strongly in recent months;
    - » Demand for metro systems in Chinese cities which have been affected by large-scale lockdowns follow the up and down trends of such restrictions (and ridership typically recovers relatively quickly following the end of a lockdown event);
    - » Other cities in the Asia-Pacific region are seeing a more stable trend with demand recovery flattening out.
- In **Latin America** metro demand continues to remain stable at around **70%**. In fact, demand recovery in the region has seen very little change over the second half of 2022.
- Similarly, **North American metro demand** has stabilised at around **60%** of 2019 levels, on average.

Comparison of Recent Multi-Modal Demand Trends

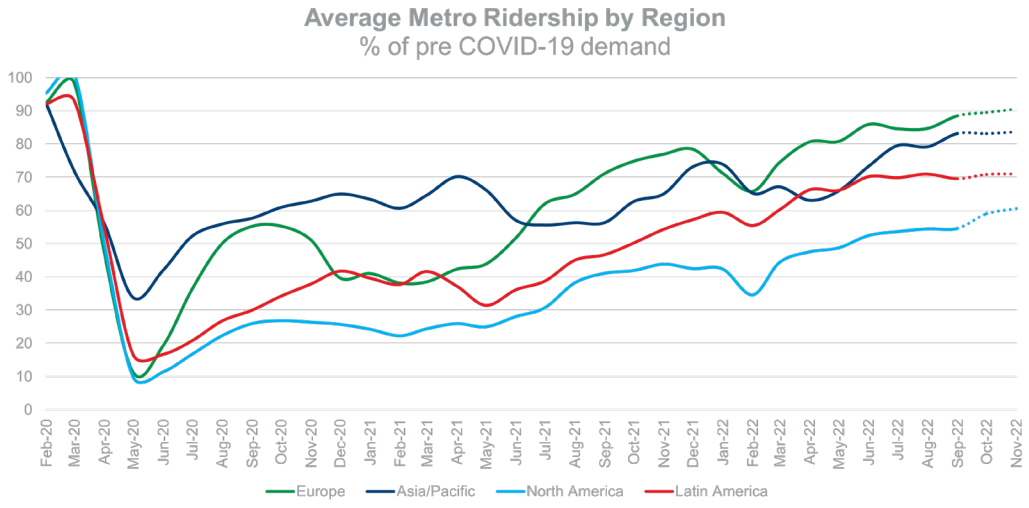
Figure 2 shows average **bus, light rail, suburban rail, and metro ridership** by region *(monthly total demand indexed to pre COVID-19 month, either January/February 2020 or the corresponding 2019 month, depending on the mode)*, based on available data in the benchmarking groups and supplemental data from the US National Transit Database for US operators. In addition, Figure 2 now also includes demand recovery for **North American and European airports** based on available data in the Airports Benchmarking Group (ABG, see Appendix A for the full list of ABG membership).

- Public transport ridership across all modes in the **Asia-Pacific** region has, in recent months, recovered to their highest demand levels since the start of the pandemic. Growth is, however, stabilising based on most recent data, and this is a trend that appears to apply to all modes. On average, metro demand has recovered more strongly than bus and rail modes (approximately 10% higher for metro demand), with bus and rail recovery following a very similar trend throughout much of 2022 and reaching around **75%** of pre-pandemic demand in September. *Note that the metro selection for the Asia/Pacific region now includes metros in China and India (as demand is now more in line with other metros in the region), and the suburban rail and bus demand trends are based on a small sample.*
- In **North America**, multimodal demand across bus, light rail, suburban rail, and metro remain more or less at their highest levels since before the pandemic, and similarly, is showing signs of flattening out.
  - Light rail and bus modes have recovered to similar levels of around **64-68%** of pre-pandemic demand on average in November. Both modes experienced a slight reduction in average demand in October 2022.

Figure 1:

Average metro ridership by region as % of pre COVID-19 demand

Source: TSC/COMET



- Demand for metro and suburban rail recovered to just under **60%** of pre-pandemic demand in September, with metro demand stabilising at this level for October and November.
  - » Suburban rail in this region was primarily used for commuter travel prior to the pandemic and therefore, ridership recovery has, and continues to be, affected by the change in commuting patterns associated with working from home.
- For airports in the region, 2022 has seen a significant boost in passenger demand. Demand was sitting at 46% of pre-pandemic demand in January 2022, first **exceeded 90%** in June 2022, and has remained above 90% since.

- In **Europe**, both bus and metro modes have remained between 80-90% of pre-pandemic demand throughout much of the year with demand stabilising at just under **90%** in recent months.
  - For airports, passenger demand recovery lags behind bus and metro with average demand reaching a high of **80%** of pre-pandemic demand in September and October 2022 (and thereby hitting the 80% threshold for the first time).

Comparison of Recent Service Level Trends

Figure 2 also shows **average service levels by region by mode** as a proportion of pre COVID-19 service *(monthly total service levels indexed to pre COVID-19 month, either January/ February 2020 or the corresponding 2019 month, depending on the mode*). In general, public transport service levels were maintained at high levels throughout the pandemic for various reasons: providing service for essential workers,

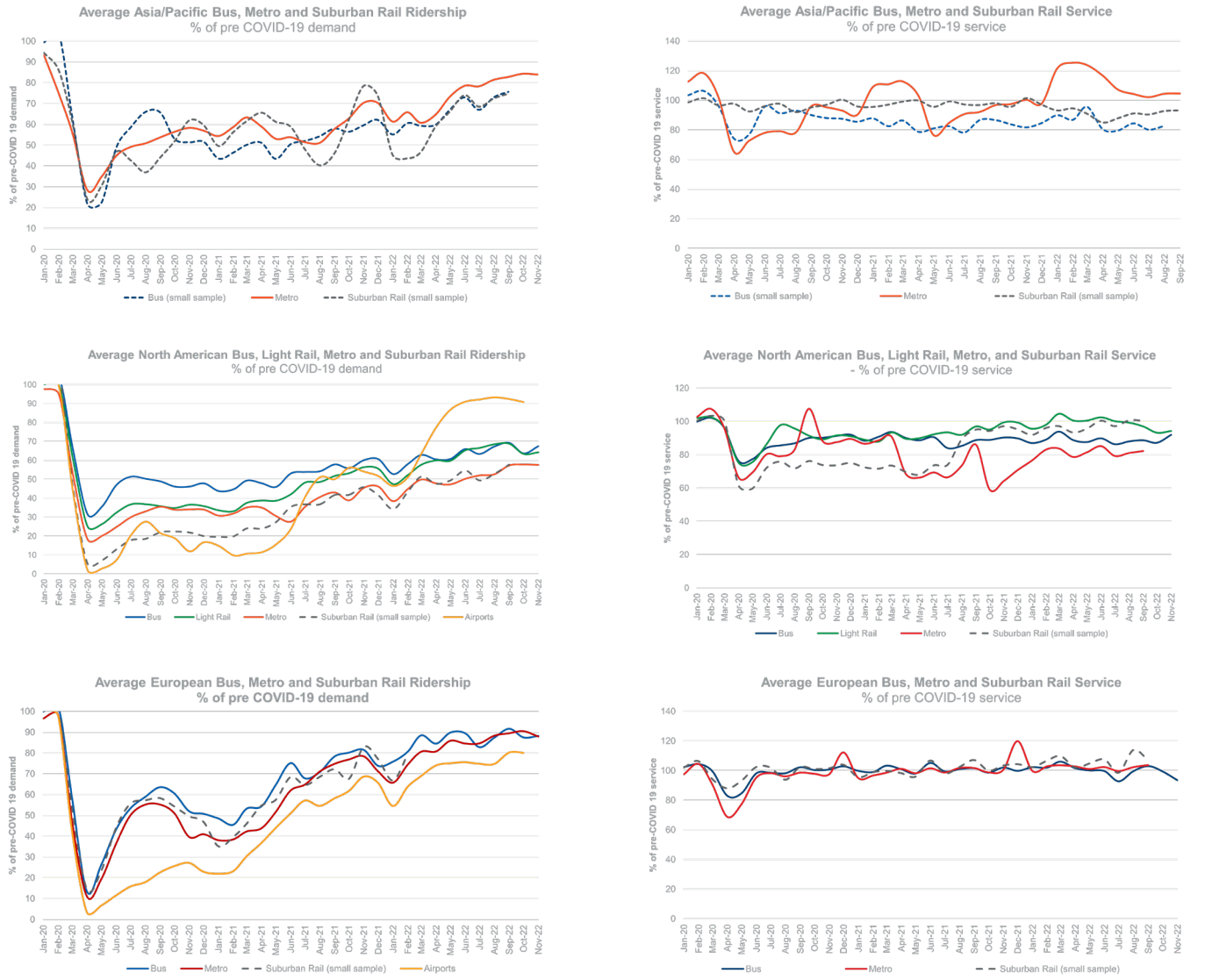


Figure 2:

Average ridership/service by mode/region as % of pre COVID-19 demand/service levels

Source: TSC bus, light rail, suburban rail, metro and airports benchmarking groups / National Transit Database (Federal Transit Administration)

enabling social distancing for passengers, and facilitating ridership recovery. Across the modes, the overall picture largely remains unchanged in recent months, with service levels remaining at high levels.

- In the **Asia/Pacific** region, service levels across bus, rail and metro remain stable in recent months.
  - Bus service levels have remained at **80%** or above on average since April 2022.
  - Average suburban rail service has remained approximately 10% higher than that for bus, sitting at **90%** or above since June 2022.
  - Metro service is highest in the region and averages **105%** of pre-pandemic levels in September 2022. As noted in the previous report, a contributing factor to high metro service in the region is network expansion at several metro systems. *Note that the metro selection for the Asia/Pacific region now includes metros in China and India (as demand is now more in line with other metros in the region), and the suburban rail and bus demand trends are based on a small sample.*
- Public transport modes in the **North America** region have seen service levels flatten throughout much of 2022, although there have been some slight variations from month to month. Based on latest available data for September to November, service levels in the region averaged **82%** (metro), **92%** (bus), **94%** (light rail) and **100%** (suburban rail) of pre-pandemic service.
  - Bus service continues to be affected by the challenging conditions around staff shortages.
  - Metro service in the region has been impacted by operational challenges faced by several metros and which have resulted in a reduced service offer.
- In **Europe**, average service levels in September 2022 for bus, metro and rail were at 100% or above of pre-pandemic levels. Although a slight reduction in average service levels can be seen for the bus mode in October and November, there is a generally stable trend throughout 2022 for European public transport. Europe shows the most stability and consistency between the bus, metro and rail modes when compared to other regions: a possible explanation for this may be the often greater levels of integration between modes in Europe, and which translates to more consistent policies on aspects relating to funding and service level requirments for example.

2022 Customer Satisfaction Survey: Insights on COVID-19 Impacts

In the October report we shared some new insights from the 2022 Customer Satisfaction Survey: customer satisfaction by age and customer satisfaction at journey points.

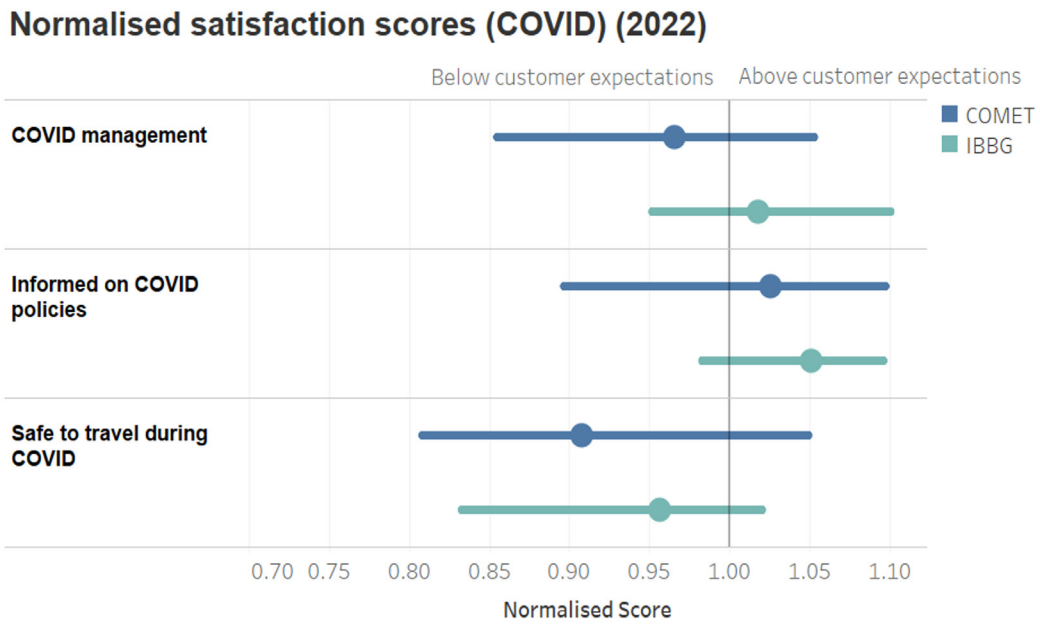
In this report, we are reporting insights into the COVID-19 related questions of the 2022 survey, designed to supplement the standard CSS questions. These supplemental questions were initially introduced in the 2021 survey and developed in consultation with members of all participating benchmarking groups.

Specifically, we summarise **a cross-modal comparison of COVID-19 impacts for COMET and IBBG**, as identified in the 2022 CSS, including perceptions on:

Figure 3:

Compiled COVID-19 Summary for COMET and IBBG

Source: TSC / COMET / IBBG



- whether metro/bus organisations have managed customer safety well,
- whether customers felt well informed,
- whether customers feel safe to travel by metro/bus.

In addition, we report how customers responded to being asked about their previous use of the respective mode and expectations about future use.

As a reminder, the survey took place from 28th March until 1st May 2022 and an academic paper[1] by Trompet et al describes the CSS methodology in detail.

Satisfaction with COVID-19 management of bus and metro passengers

Figure 3 provides a summary of the normalised satisfaction results for all COMET and IBBG members for the three COVID-19 questions on **feeling safe to travel**, **management of customer safety**, and **customer information**:

- The range of COMET (range shown with blue bar) and IBBG (range shown with green bar) normalised scores is displayed. Scores are normalised to overcome problems of cultural bias and differing customer expectations.
  - A score of 1 represents the average score of each members' respective questions.
  - ‹1 refers to below customer overall expectations.
  - ›1 refers to above customer overall expectations.
- The median is labelled with a dot (blue for COMET, green for IBBG).

2022 survey results for COMET across the three areas indicate that:

- Although scores were more distributed this year, the survey suggests that metro customers generally felt that **feeling safe to travel** during COVID-19 and COVID-19 **management** fell **below their expectations**.
- In comparison to 2021 results for these same questions, metro customers' satisfaction with safety to travel and COVID-19 management are, however, **trending upwards**. This is likely a reflection of customers gaining further confidence in returning to travel on metro systems and lower levels of infection risk.
- Overall, customers felt **most satisfied with how operators have kept them informed** about changes in service or policies during the pandemic which applies to both the 2021 and 2022 surveys.

2022 survey results for IBBG across the three areas indicate that:

- Customer expectations were **exceeded** in the majority of IBBG cities for COVID-19 **management**.
- Customer concerns around **safety to travel** on the bus during COVID-19 **remained**.

The IBBG survey results suggest that across all questions, bus passengers were slightly more satisfied than metro passengers, based on median scores. Furthermore, all questions had the same order of satisfaction for both metro and bus modes, again based on median scores. This is consistent with findings from the 2021 survey.

Customer travel pattern redistribution for metro and bus

The survey asked customers questions to better understand **pre-pandemic public transport use vs current use vs intended use in the next 6 months** (noting that the survey largely took place in April). The results for metro and bus are shown in Figure 4:

- Respondents who said they travel on the metro or bus **rarely or very rarely** (in the past, now, or in the future) are shown in orange and red respectively,
- Respondents who said they travel on the metro or bus **sometimes** (in the past, now, or in the future) are shown in light green, and
- Respondents who said they travel **often or very often** (in the past, now, or in the future) are shown in green and dark green respectively.

A review of customers' expectations based on responses to the questions (i.e. the average across members) suggests that:

- Nearly half of metro and bus customers (47% and 48% respectively) were riding very often (i.e. everyday) on average in a pre-pandemic scenario vs. 37% and 47% respectively based on customers' responses for travel in the next 6 months.

Whilst the ranges show that metro customers are expecting **greater reductions** to their travel frequency than bus customers, on average, the distribution is more similar between the modes (displayed below for travel in the next 6 months):

- 37-41% in the "very often" category
- 29-30% in the "often" category
- 19-20% in the "sometimes" category

In response to specific questions relating to pre-pandemic vs post-pandemic travel, the majority of metro customers (**76%** on average) and bus customers (**81%** on average) expect to **travel the same amount (or more)** as before the pandemic.

On average, **13%** of metro customers expect to **travel more** than before the pandemic over the next 6 months. This reflects an increase compared to 2021 survey results, where 10% of customers on average stated that they would travel more.

The public transport sector continues

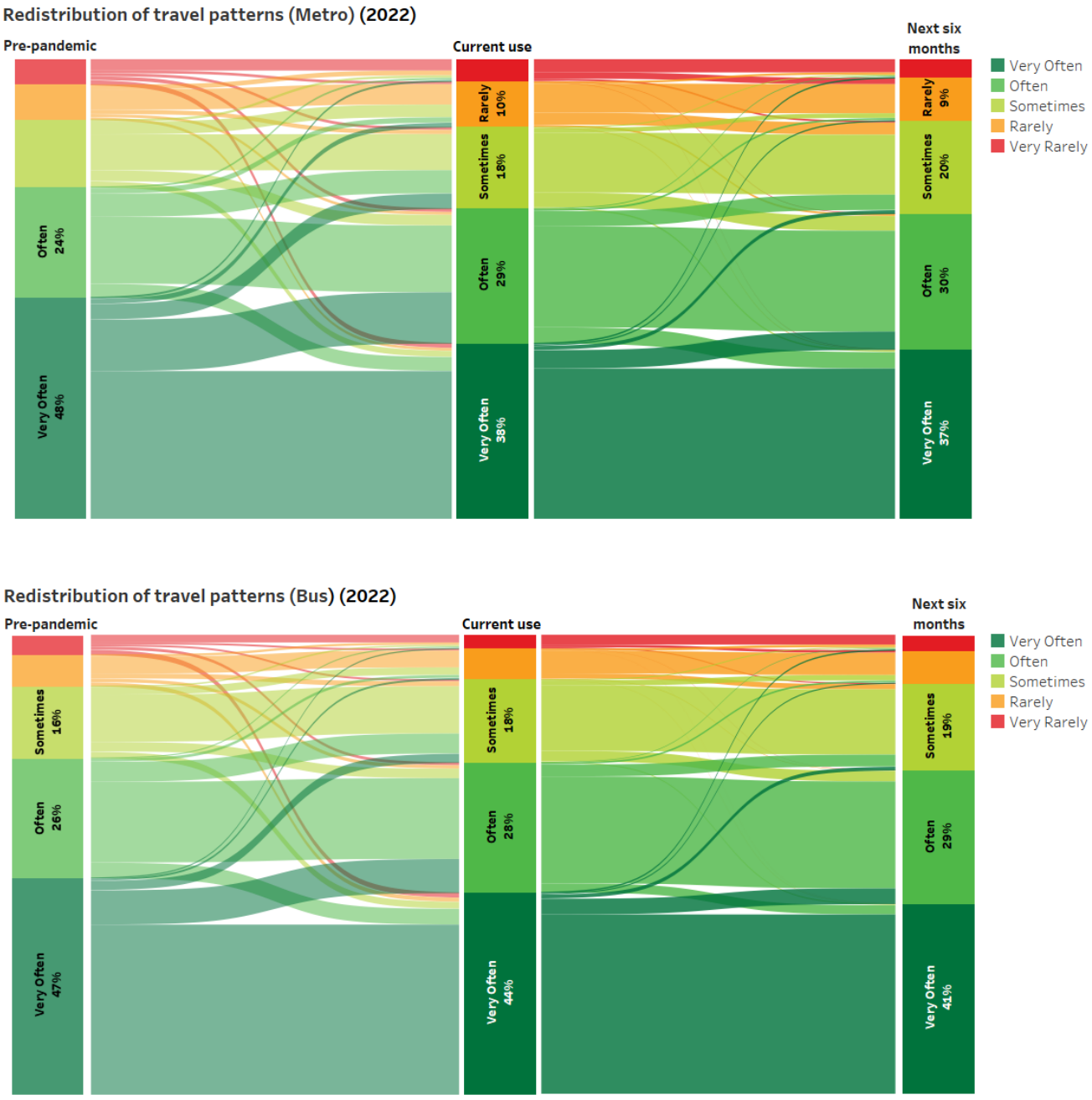


Figure 4:

Compiled COVID-19 Summary for COMET and IBBG

Source: TSC / COMET / IBBG

to adopt digital technologies and practices but opportunities remain

For years now, technological advancement has been on the radar of the public transport industry: digitalisation of practices and approaches to enable greater efficiency in public transport services, to meet customers' evolving expectations, and to enable staff to deliver service in line with these expectations. We have reported in previous reports how specific digital trends (e.g. the use of digital technologies rather than traditional payment methods, static information or staff interactions) were already present prior to the COVID-19 pandemic, and how the pandemic has further accelerated this shift towards digital. Yet, many **opportunities for digital transformation remain** and continue to emerge as technologies evolve and become available in the sector. In the context of COVID-19 and ridership recovery, digitalisation presents opportunities for improvements on the customer side which may contribute toward securing customer loyalty (alongside other benefits such as safety and efficiency).

A recent study within the suburban rail benchmarking group (ISBeRG), identified that railways are generally performing well with **certain aspects of technological advancement** (e.g. updating conventional information sources, processes and channels to improve efficiency, usability and quality), yet there is **scope for development** (e.g. creating new types of information and new ways of delivering information to customers and staff). An explanation for this may be the absence of a **formal digital strategy/innovation plan** or a **dedicated digital taskforce** within organisations which may be resulting in a lack of direction and targeted objectives for digitalisation. This is a common finding within the railways studied, and likely applies to the public transport industry more generally.

Furthermore, **understanding customer expectations** (e.g. preferences for how information is communicated) is imperative to effectively target investment and areas for improvement and yet, is something found to be lacking for the majority of railways studied. In one example, a European railway conducts a major study every 1-2 years to gain an in-depth understanding of customer needs and interaction with customer information channels. The study involves mobile ethnographic studies, interviews and focus groups.

Whilst the benefits and opportunities of digital transformation are wide-ranging and accepted, the **challenges** that are inevitable with innovation need to be acknowledged. These may include managing customer expectations and cybersecurity concerns, with one of the greatest challenges perhaps related to **keeping up with technology** and associated requirements in a rapidly evolving area. For example, issues encountered within the public transport sector may relate to **ensuring a fast enough roll-out of technology** to keep pace with developments and, importantly, the challenges to knowledge, processes, funding and integration that are part and parcel of the fast-paced nature of technological development.

Innovative Examples of Technology Based Monitoring Systems - Metros

Hong Kong MTR uses **robotic underframe inspection equipment:** rotating cameras equipped with image recognition and artificial intelligence check for abnormalities and are able to capture images from multiple angles.

A European metro uses **acoustic technology** to identify sound deviations and detect emerging faults using different filtering techniques. The metro uses this PC-based tool for measuring faults on opening/closing doors and expects to be able to apply the technology to gearboxes in the near future with the installation of additional sensors. This particular metro noted that the technologyy has enabled the development of a more data-driven condition based maintenance vision.

Source: Hong Kong MTR

One area in particular that is identified as potentially benefitting more from digitalisation relates to communications around **service disruption**. There are opportunities to improve the customer experience during incidences of disruption with better information and improved management:

- To ensure timely and accurate information; and
- To provide more specific/individualised information (e.g. communicating disruptions as they apply to different customers, based on personalised service alert settings).

Communication during disruption, however, is especially challenging and something that the public transport industry will continue striving towards improving. Examples of measures to improve in this area include having a **standard protocol** for communicating across different channels to guarantee consistency in the information provided, and creating **dedicated roles** (e.g. in the Operations Control Centre) for delivering timely, consistent and accurate disruption information to customers.

A final point, on the customer side, relates to the availability of 3rd party channels for customer information and the increasing use thereof: customers are increasingly referring to 3rd party apps (e.g. Google Maps) over the channels provided by public transport operators. Given this trend, operators may want to consider the extent to which they support and

encourage **3rd party channels** (and ensure correct use and dissemination of information) vs. restricting data availability or discouraging the use of 3rd party channels, which may contribute to greater levels of inconsistency in information between the different channels.

On the maintenance side of things, technologies to enable digital transformation of **rolling stock maintenance**, for example, are becoming increasingly common and offering better fleet reliability and availability: with the help of technologies such as remote condition monitoring, automated algorithms to rapidly convert data into useful and actionable information for maintenance planning, and the use of digital tools in maintenance workflows, are delivering improvements in maintenance efficiency and labour productivity.

A study within the metro benchmarking group (COMET) identifies that metros' overall objectives of digital transformation of rolling stock maintenance typically focus on three key elements:

- **Fleet availability** (e.g. through reducing service failures, and those related to human error in particular)
- **Asset reliability** (e.g. through increased and improved monitoring and gaining a better understanding of data)
- **Maintenance efficiency** (e.g. through better decision-making and technology driven maintenance practices)

Overall, and not dissimilar to the adoption of digital technologies more broadly, the maintenance study identifies that metros typically face challenges in the areas of **staff competence/management** (staff with multi-disciplinary backgrounds needed: IT, rolling stock engineering and project management), **data management** (low quality data = more time spent on data validation, how to transform data into useable and actionable information), and **financial management** (high initialisation costs and long investment return cycles).

COVID-19 Roundup

This section summarises recent information, trends or developments around COVID-19 policies or practices, strategic decisions, ridership recovery or behaviour.

Milwaukee County Transit System reinstates its mask policy as COVID-19 risk rises

Milwaukee County Transit System (MCTS) **reinstated mandatory mask wearing**[2] on October 14th 2022 in response to an increase in COVID-19 risk in the local community. This follows a change in policy at the start of the month when mask wearing stopped being a mandatory requirement on buses.

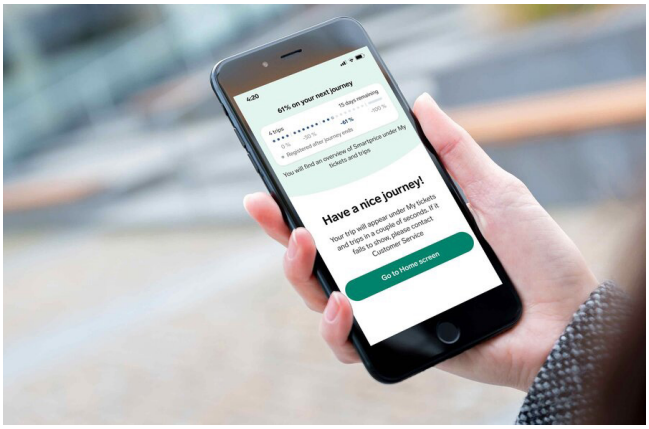
New York City Transit introduces "Weekend Service Czar" as weekend ridership remains strong

New York City Transit (NYCT) has introduced a new position, the "Weekend Service Czar"[3] with overall responsibility for **managing customer experience** for weekend subway service. Passenger demand on the New York Subway has grown to its highest levels of pre-pandemic demand in recent months, with particularly strong weekend ridership growth. Weekend service is often disrupted by a very large and continuous programme of engineering works to carry out maintenance and renewal works due to the system's 24/7 revenue service and major backlog of work. Thus, this dedicated role focuses on weekend demand and oversees how weekend service changes are implemented and communicated to passengers.

Vy launches Smartprice, a discounted ticketing initiative available via mobile application

In Norway, Vy have launched multiple initiatives to welcome new and existing customers back to their rail services. Most notably, **Vy Smartprice**[4] has been their most successful ticketing initiative:

- Smartprice is a discounted ticketing solution available via the Vy app for single ticket purchases over a 30-day period.
- The first four single tickets purchased for a specific route in a month are sold at regular prices, with all further ticket purchases for this route discounted over the remainder of the 30-day period.



Source: Vy

- The discounted tickets are valid for a specific route, however Smartprice can be activated for multiple routes and the same principles apply to each route.
- Total ticket cost amounts to less than the cost of a monthly ticket.
- A new Smartprice period begins at the end of the 30-day period.

Barcelona TMB and FGC offer discounted ticketing with up to 50% off on quarterly/monthly passes

Barcelona metro and suburban rail fares are heavily discounted following a decision by the government to provide some financial relief in the current cost of living crisis. The **temporary fare reductions**[5] apply to quarterly and monthly passes (-50%), with a 30% reduction on all other fare products. The discounted tickets were initially available between 1st September and 31st December 2022. The fare reductions to the quarterly and monthly passes have since been extended until 30th June 2023.

Source: Barcelona TMB

Endnotes

1 https://journals.sagepub.com/doi/10.3141/2351-02

2 https://www.ridemcts.com/who-we-are/news/mcts-reinstates-mask-policy-on-buses-effective-imm

3 https://new.mta.info/press-release/new-york-city-transit-announces-appointment-of-first-weekend-service-czar

4 https://www.vy.se/en/buy-tickets/smartprice

5 https://www.tmb.cat/en/barcelona-fares-metro-bus/single-and-integrated/transport-fares-reduction

References

Relevant COVID-19 Literature

Barbieri DM, Lou B , Passavanti M, Hui C, Hoff I, et al. (2021) Impact of COVID-19 pandemic on mobility in ten countries and associated perceived risk for all transport modes. PLoS ONE 16(2): e0245886.
Description: A cross-country study researching the individual mobility patterns for all transport modes before and during restrictions. The study findings suggest that air and bus travel are perceived by the public to be the riskiest transport modes for COVID-19 transmission, and avoidance of public transport for commuting and non-commuting trips is found across all 10 countries included in the research.

Dai J, Liu Z, Li R (2021) Improving the subway attraction for the post-COVID-19 era: The role of fare-free public transport policy. Transport Policy.
Description: This paper reviews the impact of fare-free policies in three Chinese cities to attract passenger demand. The study identifies that the role of the fare-free policies in helping recover demand is limited and recommends the use of multi-pronged approaches in combination with fare-free policies.

Di Carlo P, Chiacchiaretta P, Sinjari B, Aruffo E, Stuppia L, De Laurenzi V, et al. (2020) Air and surface measurements of SARS-CoV-2 inside a bus during normal operation. PLoS ONE 15(11): e0235943
Description: Air and surfaces of buses in an Italian town were tested during regular operations with average passenger loads of 123 passengers per run. All air and surface samples tested negative for the presence of the Sars-Cov-2 virus, indicating the effectiveness of cleaning, ventilation, and social behaviour policies (i.e. social distancing and wearing of masks). It should be noted that the infection status of passengers at the time of testing was unknown.

Dong H, Ma S, Jia N, Tian J (2021) Understanding public transport satisfaction in post COVID-19 pandemic. Transport Policy, Elsevier.
Description: The aim of this research is to understand passengers' psychological responses to the pandemic over time as public transport begins to resume its operations with the pandemic almost entirely contained in China. A cross-sectional survey was conducted in eight cities of China where the public transport system had been temporarily closed because of the pandemic. The results indicated that (1) passengers' feelings of safety enhanced their overall satisfaction with regard to public transport, (2) state anxiety has a negative effect on perceived safety, (3) state anxiety increases as passengers are psychologically closer to the pandemic, and (4) passengers pay more attention to information that is psychologically closer to the pandemic and perceive lesser safety on public transport. These findings not only reveal the internal mechanisms behind how passengers perceive safety but may also provide insight for future disaster emergency management. Based on the results, some feasible suggestions are proposed to avoid the loss of ridership and help public transport systems recover.

Gkiotsalitis K (2021) Public transport planning adaption under the COVID-19 pandemic crisis: literature review of research needs and directions. Transport Reviews, Volume 41, Issue 3, Taylor and Francis.
Description: This literature review aims to systematically review and synthesise the literature on the impacts of COVID-19 on public transport to identify the need to adjust planning measures, and, on the other hand, the existing methods for public transport planning at the strategic, tactical and operational level. Intervention measures that can support public transport service providers in planning their services in the post-shutdown phase and their respective modelling development requirements are identified. This can support the transition from the initial ad-hoc planning practices to a more evidence-based decision making.

Hörcher, D., Singh, R., Graham, DJ., (2021) Social distancing in public transport: Mobilising new technologies for demand management under the Covid-19 crisis. Transportation.
Description: This paper reviews the literature of five demand management methods to enforce social distancing on public transport and the practical applicability of each method: 1. inflow control with queueing, 2. time and space dependent pricing, 3. capacity reservation with advance booking, 4. slot auctioning, and 5. tradeable travel permit schemes.

Hunt, M. (2020) Covid-19 Transmission Rates on Rail, Technical report, RSSB.
Description: A recent report by the UK Rail Safety and Standards Board (RSSB) estimated the infection risk on UK rail as a function of the inter-personal contact risk, the number of contacts per journey, and any mitigating factors. The risk of infection was estimated to be 1 in 11,000 journeys or 0.009% per journey. The report was published in August 2020, and so infection parameters were based on disease dynamics at that time. Since then, infection dynamics have altered with the introduction of new variants, and the RSSB acknowledges that the quoted infection risk is likely to increase.

Ku, D., Yeon, C., Lee, S., Lee, K., et al. (2021) Safe traveling in public transport amid COVID-19. Science Advances, Volume 7, Issue 43.
Description: Simulation of the exposure to infection on public transport and analysis of the risk of infection in an environment where mandatory prevention measures are in place. The simulation finds that the mandatory wearing of masks provides a similar effect to a 2m social distance in

preventing COVID-19, whereas social distancing with masks during peak hours reduces infection rates by 93.5% and 98.1%, respectively.

Luo, Q. et all (2022) Managing public transit during a pandemic: The trade-off between safety and mobility. Transportation Research Part C.
Description: A network-based analysis framework to understand the trade-off between safety and mobility, and to inform proactive management plans, during a pandemic. A case study based on the COVID-19 pandemic identifies that a system like the New York City subway can sustain 88% of transit flow whilst minimising the risk of disease transmission by 50% relative to a fully-loaded system.

Moreno, T. et al (2021) Tracing surface and airborne SARS-CoV-2 RNA inside public buses and subway trains. Environment International 147 (106326) 1-11.
Description: Air and surfaces of buses and subway trains in Barcelona were tested - 30 out of 82 air and surface samples showed evidence of target RNA genes of the Sars-Cov-2 virus, with surface swabs showing more positive results than air samples. After bus cleaning, there was a reduction in positive surface swab samples, however 4 from 30 samples still yielded positive results. Further testing on the efficacy of cleaning is recommended.

Mutambudzi, M. et al. (2020) Occupation and risk of severe COVID-19: prospective cohort study of 120 075 UK Biobank participants. Occupational and Environmental Medicine.
Description: Research identifies that essential workers have a higher risk of severe illness from COVID-19. Risk to public transport workers is found to be double that of non-essential workers.

Tardivo A , Zanuy AC , and Martin CS (2021) COVID-19 Impact on Transport: A Paper from the Railways' Systems Research Perspective. Transportation Research Record.
Description: Analysis of the impact of the COVID-19 pandemic on the rail sector identifies resilience, return, reimagination, reform, and research, as the necessary steps to provide service and enhance rail competitiveness and resilience in the event of future crises.

Yabe, T., Tsubouchi, K., Fujiwara, N. et al. (2020) Non-compulsory measures sufficiently reduced human mobility in Tokyo during the COVID-19 epidemic. Scientific Reports 10, 18053.
Description: A study of mobility patterns in Japan showed that reductions in mobility (attributed to soft lockdown policies) were associated with reductions in the case reproduction number.

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Contact us

The TSC at Imperial College London

The Transport Strategy Centre (TSC), previously known as The Railway and Transport Strategy Centre, was established in 1992 as a centre of excellence serving the railway industry on strategic, economic and technology issues. Today, the TSC is a globally recognised team specialising in performance benchmarking, research and policy for industry and government.

The Applied Research Team within the TSC works directly with industry to improve performance in public transport worldwide, based on a systematic process managed and facilitated by the TSC through multi-year international benchmarking projects.

Imperial College London is a global university with a world-class reputation in science, engineering, business and medicine. Well known for its excellence in teaching and research, Imperial College London is consistently rated in the top 10 universities worldwide.

Thank you for reading this report.

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Appendix A

List of Benchmarking Groups and Members

COMET
Community of Metros
Benchmarking Group

American Metros

- Metropolitan Atlanta Rapid Transit Authority (Atlanta – United States)
- Emova (Buenos Aires – Argentina)
- Washington Metropolitan Area Transit Authority (Washington DC – United States)
- Honolulu Rail Transit (Honolulu - United States)
- MTA New York City Transit (New York – United States)
- Port Authority Trans-Hudson (New York - United States)
- Ottawa OC Transpo (Ottawa – Canada)
- Metrô Rio (Rio de Janeiro – Brazil)
- Metro de Santiago (Santiago – Chile)
- San Francisco Bay Area Rapid Transit (San Francisco – United States)
- Sistema de Transporte Colectivo (Mexico City - Mexico)
- Société de transport de Montréal (Montréal – Canada)
- Metro São Paulo (São Paulo – Brazil)
- Toronto Transit Commission (Toronto – Canada)
- Vancouver SkyTrain (Vancouver – Canada)

European Metros

- Transports Metropolitans de Barcelona (Barcelona – Spain)
- Berliner Verkehrsbetriebe (Berlin – Germany)
- Société des Transports Intercommunaux de Bruxelles (Brussels – Belgium)
- Docklands Light Railway (London – United Kingdom)
- Metro Istanbul (Istanbul – Turkey)
- Metropolitano de Lisboa (Lisbon – Portugal)
- London Underground Limited (London – United Kingdom)
- Metro de Madrid (Madrid - Spain)
- Tyne and Wear Metro (Newcastle – United Kingdom)
- Oslo Sporveien (Oslo - Norway)
- Régie Autonome des Transports Parisiens Métro (Paris – France)
- Régie Autonome des Transports Parisiens RER (Paris – France)

Asian Metros

- Bangalore Namma Metro (Bangalore – India)
- Bangkok Expressway and Metro Public Company (Bangkok – Thailand)
- Beijing Mass Transit Railway Operation Corp. (Beijing – China)
- Delhi Metro Rail Corporation Ltd (Delhi – India)
- Roads and Transport Authority (Dubai – United Arab Emirates)
- Guangzhou Metro Corporation (Guangzhou – China)
- MTR Corporation Limited (Hong Kong)
- MRT Jakarta (Jakarta – Indonesia)
- Nanjing Metro Operation Corp. (Nanjing – China)
- Seoul Metro (Seoul – South Korea)

- Shenzhen Metro Operation Corp. Ltd (Shenzhen – China)
- Singapore Mass Rapid Transit Corporation Ltd (Singapore)
- Shanghai Shentong Metro Group (Shanghai – China)
- Syarikat Prasarana Negara Berhad (Kuala Lumpur – Malaysia)
- Taipei Rapid Transit Corporation (Taipei – Taiwan)
- Tokyo Metro Co., Ltd. (Tokyo – Japan)
- Sydney Metro (Sydney – Australia)
- Sydney Trains (Sydney – Australia)

ISBERG
International Suburban Rail Benchmarking Group

- Ferrocarrils de la Generalitat de Catalunya (Barcelona – Spain)
- Queensland Rail (Brisbane – Australia)
- S-Tog, Danish State Railways (Copenhagen – Denmark)
- PRASA – Metrorail (Cape Town – South Africa)
- MTR Hong Kong (East Rail, West Rail, Tuen Ma & Tung Chung Lines – Hong Kong)
- MTA Long Island Rail Road (New York – United States)
- London Overground and London Elizabeth Line (London – United Kingdom)
- Metro Trains Melbourne (Melbourne – Australia)
- MTA Metro-North Railroad (New York – United States)
- S-Bahn Munich, Deutsche Bahn (DB) Regio (Munich – Germany)
- Commuter Rail, Vygruppen (Oslo – Norway)
- San Francisco Bay Area Rapid Transit (San Francisco – United States)
- São Paulo ViaMobilidade (São Paulo - Brazil)
- Sydney Trains (Sydney – Australia)

IMRBG
International Mainline Rail Benchmarking Group

- Danish State Railways (Denmark)
- Irish Rail (Ireland)
- Nederlandse Spoorwegen (Netherlands)
- Société nationale des chemins de fer belges (Belgium)
- New South Wales TrainLink (New South Wales, Australia)
- Via Rail Canada (Canada)
- V/Line (Victoria, Australia)

GOAL
Benchmarking Group of North American Light Rail Systems

- Niagara Frontier Transportation Authority (Buffalo – United States)
- Maryland Transit Administration (Baltimore – United States)
- Calgary Transit (Calgary – Canada)
- Charlotte Area Transit System (Charlotte – United States)
- Dallas Area Rapid Transit (Dallas – United States)
- Edmonton Transit System (Edmonton – Canada)
- Hampton Roads Transit (Norfolk – United States)
- Ottawa OC Transpo (Ottawa – Canada)
- Pittsburgh Regional Transit (Pittsburgh – United States)
- Tri-County Metropolitan Transportation District (Portland – United States)
- San Diego Metropolitan Transit System (San Diego – United States)
- Santa Clara Valley Transportation Authority (San Jose – United States)
- Sound Transit (Seattle – United States)
- Toronto Transit Commission (Toronto – Canada)
- Utah Transit Authority (Salt Lake City – United States)

International Bus Benchmarking Group

- Transports Metropolitans de Barcelona (Barcelona – Spain)
- Berliner Verkehrsbetriebe (Berlin – Germany)
- Société des Transports Intercommunaux de Bruxelles (Brussels – Belgium)
- Washington Metropolitan Area Transit Authority (Washington DC – United States)
- Dublin Bus (Dublin – Ireland)
- IETT Isletmeleri Genel Müdürlügü (Istanbul – Turkey)
- Rapid Bus Sdn Bhd (Kuala Lumpur – Malaysia)
- Companhia Carris de Ferro de Lisboa (Lisbon – Portugal)
- London Buses (London – United Kingdom)
- Societe de Transport de Montréal (Montréal – Canada)
- MTA – New York City Transit & MTA Bus (New York – United States)
- Ottawa OC Transpo (Ottawa – Canada)
- Régie Autonome des Transports Parisiens (Paris – France)
- King County Metro Transit (Seattle – United States)
- SMRT Buses (Singapore)
- Coast Mountain Bus Company (Vancouver – Canada)

American Bus Benchmarking Group

- Capital Metropolitan Transportation Authority (Austin – United States)
- Maryland Transit Administration (Baltimore – United States)
- Niagara Frontier Transportation Authority (Buffalo – United States)
- Charlotte Area Transit Systems (Charlotte – United States)
- Dallas Area Rapid Transit (Dallas – United States)
- Des Moines Area Regional Transit Authority (Des Moines – United States)
- Greater Dayton Regional Transit Authority (Dayton – United States)
- Lane Transit District (Eugene – United States)
- Mass Transportation Authority (Flint – United States)
- Foothill Transit (West Covina – United States)
- Hampton Roads Transit (Hampton Roads – United States)
- Jacksonville Transportation Authority (Jacksonville – United States)
- Milwaukee County Transit System (Milwaukee – United States)
- Orange County Transportation Authority (Orange – United States)
- Pittsburgh Regional Transit (Pittsburgh – United States)
- Regional Transit Service (Rochester – United States)
- Rhode Island Public Transit Authority (Rhode Island – United States)
- Greater Richmond Transit Company (Richmond – United States)
- Omnitrans (San Bernardino – United States)
- San Joaquin Regional Transit District (Stockton – United States)
- Pinellas Suncoast Transit Authority (St. Petersburg – United States)
- Spokane Transit Authority (Spokane – United States)
- Utah Transit Authority (Salt Lake City – United States)
- Clark County Public Transportation Benefit Area (Vancouver – United States)

RIAMBiG

Railway Infrastructure Asset Management Benchmarking Group

- Queensland Rail (Brisbane – Australia)
- KiwiRail (New Zealand)
- Public Transport Authority Perth (Perth – Australia)
- Sydney Trains (Sydney – Australia)

ABG

Airport Benchmarking Group

- Amsterdam Airport Schiphol (Amsterdam – the Netherlands)
- Hong Kong International Airport (Hong Kong)
- Heathrow Airport (Heathrow – United Kingdom)
- Los Angeles International Airport (Los Angeles – United States)
- Munich Airport (Munich – Germany)
- Charles de Gaulle Airport (Paris – France)
- San Francisco International Airport (San Francisco – United States)
- Sydney Airport (Sydney – Australia)
- Toronto Pearson International Airport (Toronto – Canada)
- Indira Gandhi International Airport (Delhi – India)