## Visualising Infrastructure Performance: A Review of Data Visualisation Techniques in UK Highway Management

##### Introduction

Transportation and infrastructure are heavily reliant on data visualisation as an indispensable tool. It is used to effectively present findings to help with decision making, management of operations, and public engagement. The evolution of technological tools has adapted how transport data is analysed and presented, with less of a reliance on static charts, paper maps and lists, to communicate traffic flow and congestion (ADEPT, 2021).

Data Visualisation has been adopted to improve operational efficiency and planning of infrastructure in major UK organisations such as National Highways, Local Highway Authorities, and contractors such as Marlborough Highways. As a Performance Analyst at Marlborough Highways, I have seen first-hand, the benefits of using dashboards and predictive modelling in regular monitoring of performance. Using these tools gives better foresight into surface conditions, and makes reviewing resource allocations and service delivery much more effective (GeoPlace, 2023).

Given increasing public scrutiny and accountability requirements, intelligible and accessible displays of road maintenance performance has become a necessity. An area where this is particularly relevant is in public sector procurement and contract performance evaluation; visual reporting of key performance indicators (KPIs) helps in complying to service-level agreements (SLA) and supporting funding cases.

There does still remain challenges in integrating dissimilar datasets, as is it difficult to maintain accuracy and ensure stakeholders have complete accessibility. Due to the different levels of IT literacy across this sector, there needs to be a balance between automation and human interpretability to ensure confident decision making. In this literature review, we delve into and examine the tools, techniques and best practices of the visualisation of transport data across the UK highways sector, as a specific focus. We also look into emerging trends and challenges that road maintenance organisations face.

##### Background and Context

From the UK’s road infrastructure alone, there is a significant amount of performance related data, from maintenance logs to traffic flow metrics and surface condition testing. It is the job of highway authorities, including National Highways, to not only manage assets, but ensure that roads are kept safe and useable in a cost-effective way. Highways maintenance contractors are now being asked to use the data they have to prove they are meeting targets and keep their approach and delivery transparent, evidencing everything they do (House of Commons Transport Committee, 2019).

Historically, these organisations made decisions based on static data retrieved from condition surveys and manual reporting, which caused major lag in processes and inaccuracies in decision-making situations. However, there are now connected technologies and cloud-based systems in place, to help remove these delays, as data is retrieved and sent efficiently, occasionally in real-time or through predictions. To allow data from these sources, different visualisation approaches are demanded, ensuring the likes of SCANNER surveys, GPS-enabled vehicles and asset databases, are utilised together and are displayed to facilitate long-term planning and timely interventions (ADEPT, 2021).

Different systems record data in different formats, which are often incompatible with each other. This causes data fragmentation, which is a key challenge that reduce the reliability of performance metrics and makes integration much more difficult. Furthermore, visualisations must be tailored to match the needs of stakeholders of different levels, ranging from operations managers to members of councils. For this reason, it is crucial that visualisations are clear and functional (GeoPlace, 2023).

There are several areas of data visualisation which must be considered when assessing performance:

* **Condition Monitoring:** Mapping and scoring systems are used to assess and prioritise roads which require repairing.
* **Resource Allocation:** Team performance, spending and asset coverage is tracked and monitored by employing interactive dashboards.
* **Maintenance Scheduling:** Planning resurfacing and reactive repairs requires time-series graphs to programme works.

To meet service standards and improve transparency, the UK government, through the Department for Transport (DfT), is encouraging digital transformation in highways management, with data-led planning being a concentrated area for improvement, which also helps to improve public accountability (National Highways, 2023). National objectives such as sustainability of infrastructure and resilience when faced with climate-related pressures are also met by these efforts.

##### Techniques for Data Visualisation in Transport Performance Analysis

Data visualisation plays a crucial role in simplifying complex findings in the UK highways sector, supporting decision-making and analysing performance. Different visual approaches are used by both contractors and authorities, depending on what the data is showing and who their audience is (ADEPT, 2022).

1. **Geospatial Mapping**  
   GIS mapping is still essential in order to show road networks and maintenance activity. ArcGIS and QGIS are tools which allow users to monitor asset condition, safety inspection info and live job works, overlayed onto interactive maps. This setup allows asset managers and engineers to monitor patterns in deterioration, plan inspection routes, and keep stakeholders in the loop with their plans. Local Transport Plans (LTPs) are being supported by many councils, who have chosen to adopt GIS dashboards and make insights accessible to the public.
2. **Condition Scoring Visualisations**  
   Highways authorities rely on specific UK-based systems for condition scores, such as SCANNER, CVI and SCRIM. The visualisations used here are often heat maps, colour-coded charts showing deterioration, or performance summaries of different sections. These visualisations assist planners in the prioritisation of resurfacing schemes (ADEPT, 2021). When paired with historical trends, these scores can be used as evidence when requesting funding for works or justification when reprioritising a scheme when mid-cycle.
3. **Dashboards for Operational Monitoring**  
   Dynamic dashboards let contractors, such as Marlborough Highways, monitor KPIs in adherence to HMEP and DfT reporting requirements. Utilising the likes of “drill-down” features, helps to showcase findings across defect response times, programme adherence and works completion rates (Marlborough Highways, 2023). An effective dashboard would make comparisons between contracts and boroughs much easier, with performance framework-supporting analysis.
4. **Time-Series Trend Analysis**  
   Time-based visual analysis can demonstrate pressures caused by seasonal demands, service resilience and recommend actions. Maintenance data can be plotted to show trends over time and assess improvements in pothole repairs, inspection intervals and spend profiles. The visualisations created from this type of analysis typically helps to plan long-term investments and to benchmark performance (ADEPT, 2022).
5. **Predictive Modelling Visualisations**  
   Deterioration modelling, cost prediction and other predictive analytics tools can generate charts which simulate future scenarios, providing insights and outputting decision trees. The visual outputs from this sort of analysis helps management to stay proactive, predicting times of needed intervention based on historical patterns and trends (CIHT, 2023). Planning can also be future proofed, by utilising tools to model deterioration based on climate rate and other conditions.
6. **Route Optimisation and Scheduling Tools**  
   Route optimisation tools calculate efficient journeys using algorithms which consider the weather, congestion and road classification, and can be especially useful for operational delivery during defect inspections and maintenance in the winter months. Not only do these tools enhance efficiency and safety, they also help to improve environmental performance (TfWM, 2025). One for the future, is dynamic mapping based on live weather warnings or road closures.
7. **KPI Scorecards and RAG Ratings**  
   Across performance dashboards, it is common to use a traffic light system colour scheme (RAG - Red, Amber, Green) to show the status of compliance metrics, including customer service target, completion rates across inspections and health and safety. Contract managers express the need for easy, quick-glance visuals involving simple colours and shapes, over a bombardment of values and formulas, to present overall performance (Highways Magazine, 2025). The same techniques tend to be used in monthly reporting to external clients.

If combinations of these techniques are utilised correctly, it can be made relatively easy to have data-led conversations between different levels of transport organisations, no matter the level of mathematical understanding or IT literacy. Despite the large amounts of data, the correct visualisations can enhance transparency, reduce cognitive load, and transform decision-making.

##### Tools for Data Visualisation

There are several tools in the UK which have specific performance monitoring capabilities in data capture, integration and visualisation. It is vital that these tools produce strategy-based outputs to tackle and support planning and day-to-day maintenance works, no matter the operational complexity of infrastructures (CIHT, 2023).

1. **ArcGIS and QGIS**Local authorities tend to adopt these GIS platforms to help present findings in planned works, maintenance history and asset conditions. ArcGIS supports geospatial mapping of a high-quality to identify intervention areas. In their public-facing web portals, councils are embedding ArcGIS dashboards, in an attempt to encourage community engagement and be more transparent across the board.
2. **Power BI**  
   When in need for highly tailored performance dashboards, look no further than Microsoft’s Power BI. It allows for integration of multiple sources of data, in this sector that could be defect logs, scheduling data or asset inventories. Where different boroughs value different KPIs and client promises, or maybe prefer specific reporting formats, Power BI’s flexibility is especially valuable. At my current role as a Performance Analyst at Marlborough, I visualise trends in inspection intervals, resource allocation and track job budgets using power BI. Its embedding ability using DAX logic is particularly useful when it is necessary to work with more complex calculations and custom KPIs.
3. **Confirm and Alloy**  
   Confirm, a system which is widely used by councils, shows workflow tracking and map overlays, which are helpful when managing a team (Highways Magazine, 2017). Alloy allows and encourages use of IoT devices, facilitating integration of sensor data to enable proactive maintenance planning by monitoring data such as gulley sensors and grit bin levels. Both these asset management systems help to visualise asset attributes, inspection logs and road networks.
4. **Symology Insight**  
   Known in the industry for its usage in permitting and compliance, Symology uses live maps and analysis of permit breaches, works statuses, reinstatement history, and more, all presented visually (Symology, 2023). At Marlborough Highways, I have worked extensively with Symology, pulling data to support our defect permit compliance dashboards. It can also be useful when trying to identify trends in delays and non-compliance, and make decisions to correct actions, using visual summaries of performance-based metrics.
5. **Microsoft Excel**  
   Despite the progression of other platforms on this list, Excel is still vital for early-stage exploration, reports and basic visualisations. Before loading data into Power BI or GIS, Marlborough Highways’ SOP (Standard Operating Procedure) is to conduct preliminary analysis and create swift visuals for internal stakeholders whose preference is to work with Excel (Marlborough Highways, 2025).
6. **Palisade DecisionTools Suite**  
   Used by asset managers to assess uncertainty and monitor long-term costs/investments; tools such as @Risk and PrecisionTree use decision trees and risk maps to support the prioritisation of investments (CIHT, 2023). Stakeholders are able to use these tools to compare the outcomes of different strategies using visual scenario analysis.

When tool selection is done correctly, depending on a variety of conditions, these platforms together can translate large amounts of complex data into clear insights, which strengthen compliance, help with long-term planning, and ultimately drive efficiency.

##### Best Practices for Effective Data Communication

Providing insights is crucial to get right, as the wrong technique can invalidate findings for clients, causing a negative effect on decision-making, justification, and expectations at all levels. Here are some of the current best principles and practice guidance (ADEPT, 2021; ADEPT, 2022):

1. **Audience-Relevant Design**  
   When presenting findings, it is important to tailor the visualisations and summaries to your audience’s needs and their technical ability. Using a layered dashboard can be an appropriate way of allowing users to show both summarised and detailed views of findings, depending on the stakeholders’ expertise.
2. **Standardised Visual Elements**  
   Sticking to a consistent colour scheme for visual elements of a presentation, such as RAG indicators, is recommended by National Highways; this goes for symbols, colours and shapes. In addition to the colour scheme, the use of linear route maps and performance gauges improves usability, which is especially valuable when reporting to a client, benchmarking consistency across all levels of authority.
3. **Accessible Design**  
   It is important to ensure all visualisations adhere to the UK Government Digital Service accessibility guidance (GDS, 2021), such as clear labelling, colour contrast ratios and alternative text. Furthermore, giving the option to download CSV files makes sure users who rely on raw data interpretation or screen readers are accommodated for.
4. **Clarity and Integrity**  
   When reporting performance, transparency is crucial. It is important not to misrepresent any findings by accidental labelling, incorrect chart types, truncated axes or lack of contextual data. Errors in presenting visualisations can also make you lose integrity which is considered very unprofessional.

Following these common best practices improves outputs and strengthens approaches to planning, compliance and decision-making.

##### Conclusion

Data visualisation has a huge effect on the UK’s highways infrastructure sector. Organisations can effectively manage assets and report performance, through the use of tools such as GIS mapping, predictive modelling and dynamic dashboards. If built with clarity and integrity, visualisations can be used to help technical and non-technical stakeholders to collaborate. Despite challenges in data integration, the introduction of IoT devices and predictive modelling over recent years, has improved its role to live decision reporting. Maintaining the UK’s transport infrastructure can be approached with much smarter techniques and more accountable approaches due to these advancements in technology.

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