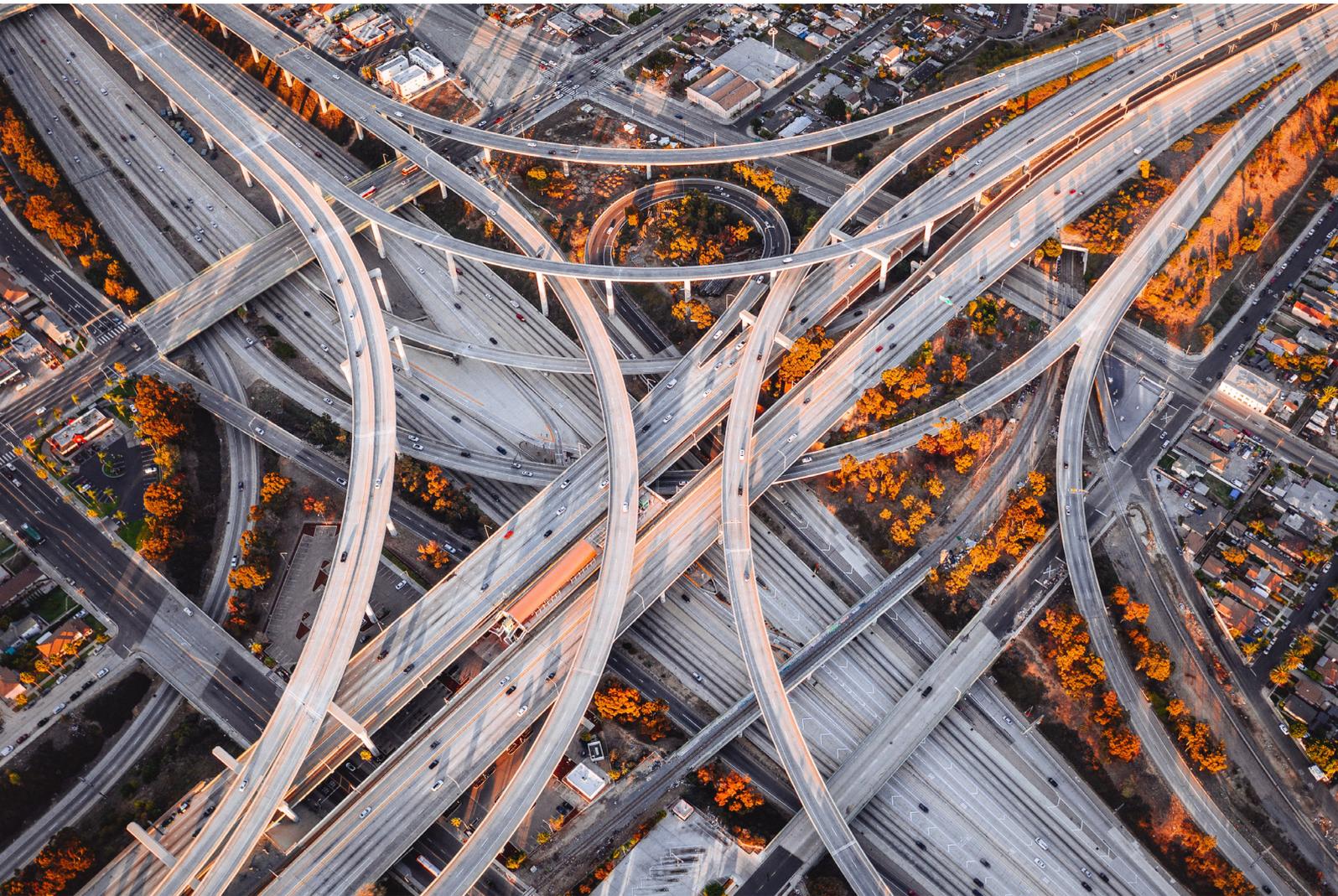




Benchmarking in the infrastructure sector

1st edition, August 2020



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Foreword

In a pre-COVID-19 report produced by Global Construction Perspectives and Oxford Economics¹, it is estimated that the volume of construction output will grow by 85 per cent to \$15.5 trillion worldwide by 2030, with China, the US and India leading the way and accounting for 57 per cent of all global growth. McKinsey Global Institute reports² that keeping up with projected global gross domestic product (GDP) growth will require an estimated \$57 trillion in infrastructure investment between now and 2030. For example, in the US, over the next two decades, the northeast regions capital infrastructure investment is at unprecedented levels as agencies like the New York Metropolitan Transportation Authority and the Port Authority of New York and New Jersey advance their capital plans, rebuild the region's infrastructure and work to transform its legacy assets into modern, world-class facilities capable of meeting 21st -century expectations.

Building a strong project programme – cost, schedule and proven delivery record – is critical for sustained infrastructure investment in the future. A fundamental part of capital planning and programming is to develop a firm understanding of project costs and performance. Benchmarking, the process of comparing projected or actual project cost and performance information against information from similar projects, is key to the development of the plan. Inaccurate estimates can lead to unrealistic expectations and an overinflated programme, which can ultimately lead to selecting and investing in projects that will fail to deliver the expected benefits, often at the expense of investing in other projects and harming confidence in future investment.

Over the past several years, many organisations have established dedicated units with the responsibility to promote and embed best practices, business improvements, lessons learned initiatives and quality assurance across projects. They have also developed consistent approaches to cost and performance benchmarking and monitoring at each stage of a project's life cycle.

Benchmarking is a blueprint for future spending. The process helps both government and industry make more informed and transparent decisions about the future of infrastructure priorities. It provides the evidence and analysis needed for the government to make crucial decisions with greater confidence, ensure value for money for taxpayers and avoid excess costs and missed benefits. Open collaboration and data sharing between organisations is vital to making informed decisions and in making the approach to benchmarking much more consistent across projects in the public sector. Through this insight paper, RICS aims to promote good practice in standardising, classifying and predicting costs across buildings and infrastructure assets.

The global pandemic that started after this paper was initially drafted has changed everything. Now, the world faces health and economic crises that have brought to the forefront endemic social injustices. While governments are providing an immediate response, they are also designing their medium-to-long-term recovery programs. Infrastructure will play a pivotal role in these programs, making the principles and concepts discussed in this paper even more relevant.

We are indebted to our industry colleagues for this paper. I hope you find this paper as informative as I did, as we begin to plan and invest in the future and keep the world moving.

Denise M. Berger, SVP and Chief Operating Officer, AECOM

Abbreviations

Abbreviation	Term/organisation
ASCE	American Society of Civil Engineers
AI	Artificial intelligence
BSC	Balanced scorecard
BCIS	Building Cost Information Service
BPR	Business process re-engineering
CE	Categorical exclusion
CTS	Centre for Transport Studies
CCI	Construction cost index
CII	Construction Industry Institute
CPI	Consumer price index
DOT	Department of Transportation
ENR	Engineering news-record
ESG	Environment, social and governance
EA	Environmental assessment
EIS	Environmental impact statement
FAA	Federal Aviation Administration
FHWA	Federal Highway Administration
FEED	Front-end engineering and design
FEL	Front-end loading
FEP	Front-end planning
GDP	Gross domestic product
IPA	Infrastructure and Projects Authority

Abbreviation	Term/organisation
ICMS	International Construction Measurement Standards
KPIs	Key performance indicators
NCHRP	National Cooperative Highway Research Program
NEPA	National Environmental Policy Act
NHCCI	National Highway Construction Cost Index
PPI	Producer price index
PDRI	Project definition rating index
PPP	Public-private partnership
RCF	Reference class forecasting
ROI	Return on investment
SMEs	Subject matter experts
SNAP	System, network, asset and project
TCRP	Transit Cooperative Research Program
TIC	Transport and Infrastructure Council
TRB	Transportation Research Board
BLS	US Bureau of Labor Statistics
DOD	US Department of Defense
VMT	Vehicle miles travelled
VDOT	Virginia Department of Transportation

1 Introduction

Benchmarking is a strategic tool that helps users make decisions that improve the efficiency and effectiveness of their assets. By impacting the economic, social and environmental outcomes of infrastructure projects, it ensures investments in the sector are effective and significant investments in major global infrastructure projects are prudently and effectively deployed. Benchmarking helps make the most of investments and gives the most value for taxpayers' money by improving the productivity and operational efficiency of the infrastructure sector.

One of the most valuable features of benchmarking is that it can be used for both competitive and collaborative goals³. Benchmarking drives competition by searching for the most innovative solutions to enhance the outcome of a project. This is typically found in private-sector firms that need to improve their standing in the competitive market. At the same time, benchmarking is a collaborative learning process that helps every organisation in the infrastructure sector. The public also benefits from the resulting enhanced efficiency and productivity of the sector.

While benchmarking is not new to the industry, the availability of international standards, including data standards along with numerous data streams, has enhanced its role and effectiveness.

1.1 Aims

This insight paper aims to provide an overview of benchmarking in the infrastructure sector by discussing the types of benchmarking and processes involved. It also outlines the key benefits of benchmarking and the use of data and analytics in modern benchmarking practices. Global case studies in appendix A show the practical relevance of benchmarking.

1.2 Benchmarking

Benchmarking is fundamental to the continuous improvement of organisations, especially those that are project-based. Organisations use benchmarking to:

- measure their performance across several dimensions, such as financial, productivity and quality
- compare their performances with competing organisations
- identify gaps and
- develop an improvement plan to achieve higher performance levels.

The American Productivity and Quality Center⁴ regards benchmarking as a powerful knowledge management tool as it enables identification of knowledge and best practices in an industry sector and provides a platform to share information among organisations participating in the benchmarking process. Benchmarking starts with measuring performance in an organisation and comparing the performance measures with similar organisations, but it does not stop there. It should be a proactive process to continuously engage with similar organisations to identify transferable best practices, examine the reasons for success and define an implementation plan for the targeted performance metrics.

R. C. Camp⁵ regarded benchmarking as the search for finding industry best practices to establish performance targets for excellence in business operation. For example, Xerox Corporation used benchmarking to improve the quality of its business operations, products, services and practices by comparing its performance against that of its competitors and industry leaders. Benchmarking helped them to establish improvement targets and develop a continuous improvement plan.⁴

Benchmarking can also be used internally to compare the performance of projects or divisions within an organisation. It is useful in identifying best practices and replicating this knowledge across the organisation for continuous improvement.

2 Benchmarking in the infrastructure sector

Benchmarking is closely associated with measuring costs and performance at the project level in the infrastructure sector. Most organisations active in infrastructure work are project-based organisations and each project is unique. The goals, objectives, scope, project team, project stakeholders and other internal and external project conditions (e.g. economic and market conditions) change from one project to the next. The complex nature of infrastructure projects makes it challenging for organisations in this industry to improve their project and business operations. For the same reasons, benchmarking is even more critical for public and private infrastructure organisations as they cannot only rely on their own knowledge and experience to improve performance in current or future projects.

For the past 50 years, RICS has been collecting, analysing, modelling and interpreting cost information. This information is easily accessible through the Building Cost Information Service (BCIS) online applications, data licensing and publications. Clients from the public and private sector use BCIS for benchmarking purposes, using data from other completed or ongoing projects to enhance project development and decision-making.

In 2010 the Transportation Research Board (TRB) of the United States National Academy of Sciences believed benchmarking to be a systematic approach to finding best practices in the infrastructure industry to emulate.⁶ A study⁷ benchmarking tunnelling costs and production rates conducted in the UK showed why benchmarking is critical for the infrastructure sector (see case study 3 in appendix A). Without a proper benchmarking system, organisations involved in the infrastructure industry struggle to arrive at reasonable cost estimates for tunnelling projects. The established cost targets are either too conservative or too optimistic, and there is no basis of comparison for cost performance across different project types.

Inaccurate estimation of the cost of major infrastructure projects can have a detrimental effect on government expenditures in public infrastructure. Failure to deliver infrastructure programmes to budget breaks the trust between the public (or legislatures representing the public) and infrastructure agencies. Benchmarking can greatly help parties involved in infrastructure set accurate estimates for project costs, including life cycle costs, and its associated economic benefits.

The Utah Department of Transportation (Utah DOT) used benchmarking in the efficient delivery of its infrastructure projects. The Utah DOT has established a robust relationship with the state legislature because the Utah DOT consistently completes projects to budget and on schedule. To achieve this, the Utah DOT focused on defining the scope of the project early in the project phase, which helped the agency assign the funding clearly to the scope of the project. See case study 5 in appendix A for more detail.

Figure 1 provides a high-level framework for benchmarking in the infrastructure sector. The framework consists of three layers:

- 1** initiating the benchmarking programme
- 2** collecting benchmarking data on an ongoing basis and
- 3** using benchmarking.

It is important to carefully design and implement each of these layers and to document the measures that are part of the benchmarking programme, levels at which these measures are benchmarked and the timescale and geographical spread. Based on this standard data structure, a management system can be agreed. Once these two design decisions have been made, the benchmarking data can be collected on an ongoing basis. When enough data is available, the programme can provide strategic, tactical and operational benchmarks. Several organisations use this software to align benchmarking to their organisational strategies. Commercial software tools are also available. However, they still require organisations to collect and manage large volumes of internal and external project data.

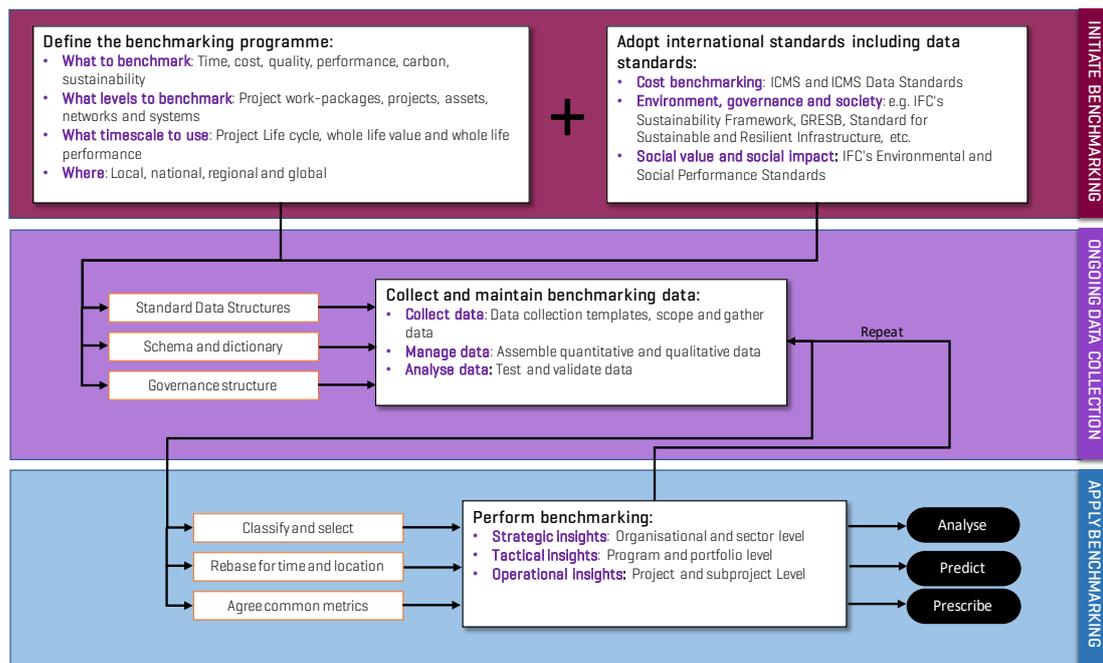


Figure 1: High-level benchmarking framework

2.1 Key characteristics

The first step in designing an effective benchmarking system is to clearly define the focus. Anand and Kodali⁸ presented the following classification for this.

- **Process:** infrastructure development may be viewed as process-based since its delivery is divided into separate processes or activities. Time is a KPI, as the relative delivery times of similar projects can be compared. Other resources, such as financial and human, can also be measured and compared. The primary focus of stakeholders in the infrastructure sector is keeping to the project schedule. For example, the Virginia Department of Transportation (VDOT) has developed a dashboard, which tracks the on-time performance of its projects (see case study 1 in appendix A for more detail).
- **Functional:** infrastructure organisations often want to compare their business units with similar units inside or outside their organisations. Benchmarking based on functionality is used for this comparison. For example, infrastructure design consulting firms routinely compare the profitability of their railroad engineering divisions in different regional locations. Business units can also be benchmarked in non-financial terms, such as end-user satisfaction and meeting deadlines.

- **Performance:** infrastructure benchmarking is traditionally associated with measuring and comparing the outcomes of infrastructure projects. A wide range of performance metrics have been developed to measure and compare the outcome characteristics of infrastructure projects. These metrics are quantifiable in terms of cost, speed, quality, reliability, safety, sustainability and any other relevant measures.
- **Strategic:** at the highest level, infrastructure organisations can compare the effectiveness of their business strategies with each other. The focus of strategic benchmarking is to identify effective best practices, increase market share and improve customer satisfaction. Organisations can also measure and improve their benchmarking capability against industry best practice using the recently released **Benchmarking Capability Tool** by the Infrastructure and Project Authority.

This classification helps infrastructure stakeholders think about the benefits of benchmarking at operational, tactical and strategic levels. Maire et al.⁹ referred to this transition as the evolution of benchmarking in four stages from operational to strategic level (see Figure 2).

- **Stage 1** represents the lowest level of operational performance benchmarking. The focus is on efficiency, i.e. how efficient are day-to-day operations in delivering the service? The object of comparison is the product or service that the organisation produces or delivers, and the performance measurement is purely financial.
- **Stage 2** expands the scope of operational benchmarking to include some non-financial metrics. The nature of benchmarking begins to include the organisational process.
- **Stage 3** goes beyond operational benchmarking and includes non-financial performance metrics and broader measures of customer satisfaction. The focus is on organisational process and internal metrics are developed to measure the efficiency of the organisational workflow.
- **Stage 4** is the highest strategic level of benchmarking. The focus is on identifying best practices, enhancing process efficiency and improving customer relationships.

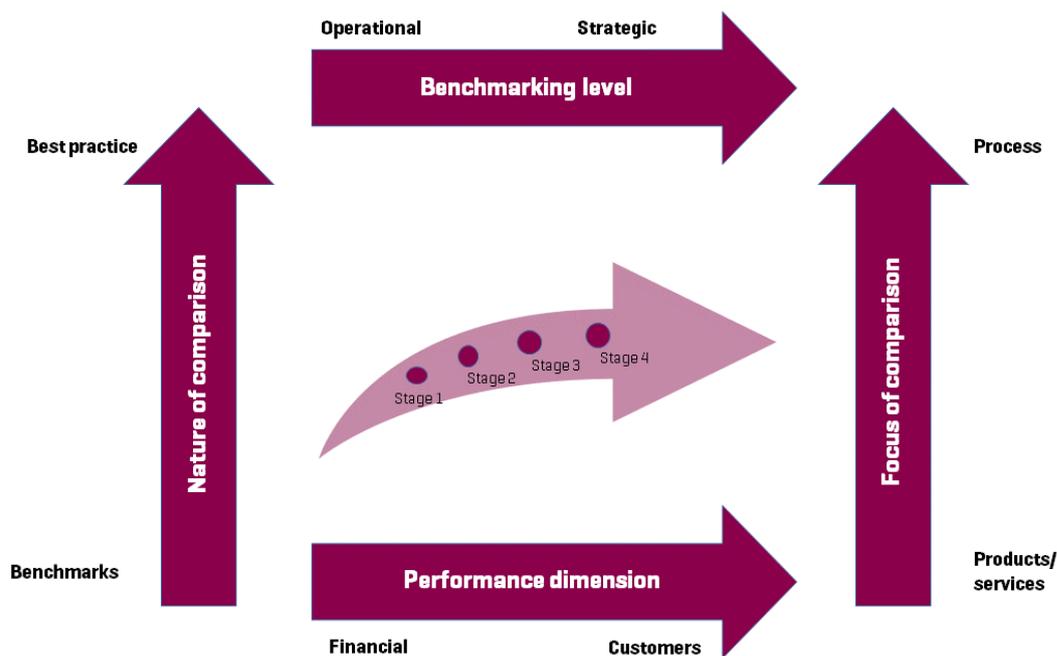


Figure 2: Evolution of benchmarking (adapted from Maire et al. 2005)

The goal of benchmarking at each stage should be to find major areas that can benefit from enhanced decision-making thanks to additional information from the benchmarked data. Several methods have been developed to assist infrastructure organisations in structuring an appropriate benchmarking programme. One of the most widely used methods is input, output, performance, outcome (IOPO). The IOPO methodology establishes a framework to move beyond benchmarking based on resource inputs, such as budget and time. These are used to produce physical outputs, such as new infrastructure systems (e.g. widened roads or replaced bridges). These physical outputs then contribute to improving the performance of the infrastructure network, for example, enhanced capacity or new connections. Ultimately, the investment in the infrastructure leads to tangible outcomes for the public. An example can be reduced congestion (outcomes) as a result of the increased capacity (performance). Figure 3 shows an example of an IOPO model applied to benchmarking of highway projects.



Figure 3: An IOPO model for highway benchmarking (IPA 2019)

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2.2 Internal versus external benchmarking

A National Cooperative Highway Research Program (NCHRP) research report¹⁰ identified two general approaches towards benchmarking in the infrastructure industry.

The first approach is **independent (or internal) benchmarking**. An infrastructure organisation can undertake benchmarking independently, which is relatively low cost as it requires fewer resources and relies on published industry data. Internal benchmarking is flexible and designed to address the concerns of the organisational management team. For example, the Massachusetts Port Authority compared the environmental performance of Logan Airport operations in Boston to those in other airports in the New England region using the published environmental data reports.

The second approach is **external benchmarking** or benchmarking within a network of similar organisations. This approach is more intensive and requires significant investments from the organisations within the network. A set of objective metrics should be agreed to measure organisational performance. Also, there needs to be a common framework for data collection and analysis. External benchmarking is mostly used by government agencies at different levels (local, regional or national) to assess the performance of infrastructure projects.

External benchmarking can also be used in the private sector. The challenge is to incentivise private firms to take part in this initiative as detailed, project-specific information is required to make informed decisions, and not all firms want to share this. One solution can be to use

a third party specialist to oversee benchmarking, or to distribute the benchmarking workload among all stakeholders. Confidentiality should be the top priority in external benchmarking and organisations should stay closely engaged throughout all phases of the benchmarking process.

An excellent example of a benchmarking network can be found in the collaboration between the US Federal Aviation Administration (FAA) and EUROCONTROL, the civil-military air traffic control organisation supporting European aviation. This international network is useful for both sides as each organisation strives to improve the relative performance of their air traffic control systems by considering changes in operating procedures, technology and policy. Despite differences in operating conditions and travel demands in the two regions, a data comparison showed that they have common KPIs.

2.2.1 Benchmarking manager

Benchmarking requires expertise that many organisations may not have, and it needs experienced professionals who have seen different approaches to managing infrastructure projects. An independent (external) benchmarking manager should be hired to lead all benchmarking efforts for organisations participating in the network as independence is key to the success of peer-to-peer comparison. An independent benchmarking manager is in a better position to ensure the confidentiality of collected data and respect the privacy of firms in the benchmarking network. The benchmarking manager explains the rules to the member organisations and establishes a unified data collection platform to compute KPIs across all participating organisations.

Each organisation in the benchmarking network should also consider hiring a dedicated internal benchmarking manager to facilitate efforts to collect the data and represent the organisation in the network. The internal benchmarking manager provides proper links between the internal management team and the independent benchmarking manager.

The independent benchmarking experts oversee the creation of a confidential database of infrastructure projects. They analyse the variability of the performance metrics across different organisations and come up with explanations for the identified variations. The benchmarking consultants also work with the dedicated benchmarking manager in each organisation to define a set of recommended methods for improving the performance of the organisation relative to other peers in the network.

Infrastructure benchmarking is not solely based on 'hard' aspects of benchmarking (e.g. metrics and processes). The 'softer' aspects of benchmarking, with a focus on people, are also important. A good benchmarking manager is a skilled leader who knows how to create an effective environment based on a culture of learning and collaboration (see Appendix B for skills and competencies of a benchmarking manager). The benchmarking manager should make sure that internal and external incentives are in place to encourage the right behaviours, such as willingness to share the data.

2.3 Infrastructure asset management

Infrastructure systems are invaluable resources. Delivered infrastructure projects are a network of interconnected physical assets that provide high-level strategic benefits for society such as job creation and economic growth. In this context, benchmarking is an integrated part of infrastructure asset management.

The major principle of asset management is that a proposed infrastructure project should not be evaluated separately from the overall infrastructure system. Infrastructure owners need to find the best way to invest their limited funds for the greatest overall benefit. The performance of the infrastructure project needs to be evaluated at several levels (strategic, tactical and operational) to make sure that the selected projects provide the best outcome.

The system, network, asset and project (SNAP) method (see Figure 4) is widely-used to encourage the infrastructure industry to continue measuring the performance of infrastructure projects during the operations phase, after the projects are delivered.

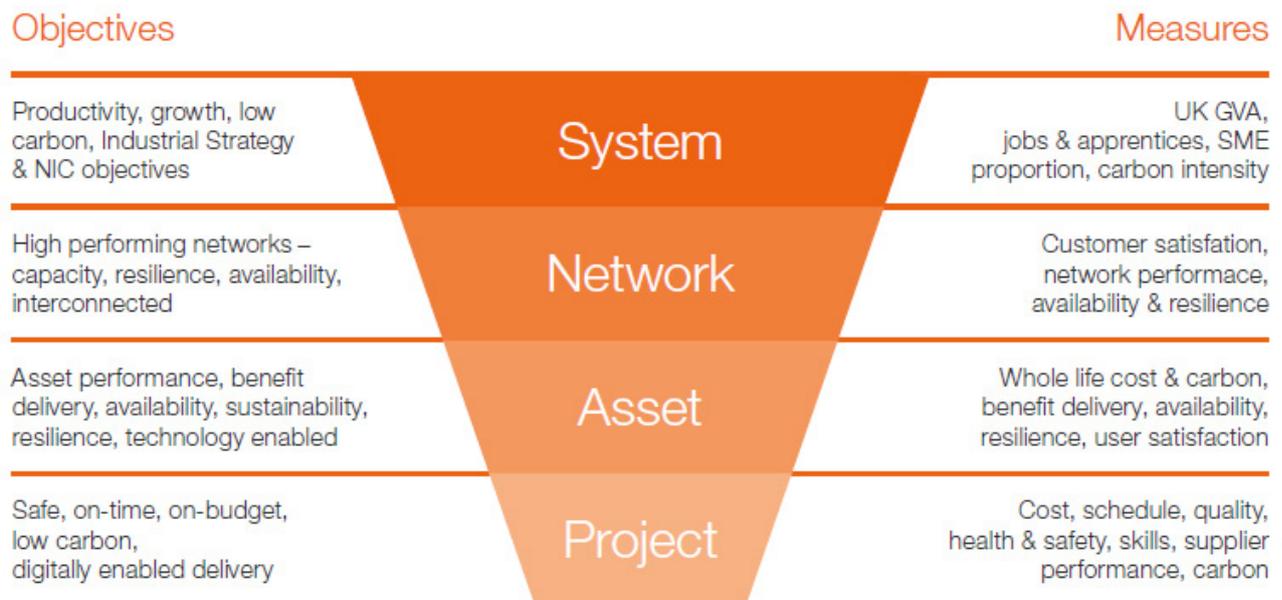


Figure 4: SNAP model for infrastructure benchmarking (©IPA 2019)

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Appropriate performance measures reflect the unique objectives of the project sponsors at each level.

- **System-level:** the focus of system-level benchmarking is high level and strategic. It provides a set of performance indicators to quantify the effects of interconnected assets and networks on economic, social and environmental objectives of the government, e.g. economic growth, job creation, reduced carbon footprints and boosting productivity.
- **Network-level:** the scope of asset benchmarking can be extended to consider interconnected assets at the network level. For example, the operational performance of an improved interchange project can be measured in the context of the road network that the interchange project is part of. Typically, the performance measures used at the network level are similar to those at the asset level, e.g. resiliency, sustainability and customer satisfaction. However, relationships among different infrastructure assets should be modelled in network-level benchmarking.
- **Asset-level:** once the infrastructure project is constructed, the project becomes a crucial physical asset for the owner. Asset-level benchmarking focuses on the operations phase of infrastructure projects and enables systematic measurement of the operational

performance and benefits of the delivered assets. It also identifies best practices to sustain public infrastructure systems and elevate their status in terms of energy efficiency, resiliency and user satisfaction.

- **Project-level:** one of the most popular benchmarking applications is project-level benchmarking and it is a driving force behind improved performance and competitiveness. Owners, designers and builders of infrastructure projects strive to enhance the efficiency of project delivery. Infrastructure project management is based on measuring the performance of an infrastructure project, e.g. schedule, cost, safety and quality. Project-level benchmarking enables the performance measures of an infrastructure project to be compared with those of similar projects to identify the performance gaps and establish improvement targets.

2.4 Levels of benchmarking

Infrastructure benchmarking can be considered at multiple levels in the industry, from an element of the work to the highest level of the industry at regional, national or international levels. For example, the UK government's **Construction cost benchmarking: departmental progress update 2012**¹¹ described principles and methods of cost benchmarking in the following four types.

- **Type 1 benchmarks** involve comparing the total construction costs of delivering a specific quantity of the project in units commonly accepted by the industry, e.g. £/m² of accommodation. Type 1 benchmarks can represent the overall state of the infrastructure industry for a client in a geographical region.
- **Type 2 benchmarks** are functional measures that are specific to a department or a functional unit, e.g. monetary value of flood damage avoided / monetary value of investment made in flood control system. Business outcomes are directly related to the functional measure.
- **Type 3 benchmarks** are also functional measures, but business outcomes are indirectly related to the benchmark measures, e.g. the ratio of right-of-way acquisition cost to total construction cost.
- **Type 4 benchmarks** are focused on the cost of major project components, e.g. foundation costs measured by £/m³ of placed concrete.

Rather than being limited to just one phase of an infrastructure project, a more effective benchmarking system considers the entire life cycle of an infrastructure project, from planning to design, construction and operations. The IPA recommends¹⁴ that organisations go beyond benchmarking typical metrics of infrastructure projects such as cost and schedule. The Australian road construction cost benchmarking (see case study 2 in appendix A) is an example of functional benchmarking for road projects.

The infrastructure industry should embrace broader performance measures related to the outcome of the project, such as economic, environmental and social metrics. A critical challenge for the industry is to establish a unified set of metrics throughout the infrastructure project to measure performance at each phase.

3 Performance measurement

Benchmarking is an integrated part of infrastructure performance management. Performance measures are objective metrics that help the management team to make improvement decisions using the available data. Performance management:

- informs decision-makers about achieving targeted performance goals
- improves overall performance and
- enhances transparency and accountability¹².

The benefits of benchmarking cannot be achieved unless proper performance measures consistent with the strategic goals of the organisation are identified. Consistent data and data collection methods need to be used.

3.1 Balanced scorecard

The balanced scorecard (BSC), originally developed by Kaplan and Norton¹³, is a framework that measures organisational performance using a balanced set of performance measures. The BSC approach considers non-financial strategic measures to ensure long-term success. A fully integrated framework (see Figure 5) was developed to provide a balanced view of organisational objectives. There are four distinct areas helping organisations fulfil their missions. At the highest level is financial performance and the effective use of resources to make profits for shareholders. For organisations in the public sector, such as infrastructure agencies, the high-level objective is not profit, but using taxpayers' money carefully for the greatest economic benefits.

The BSC is based on the argument that an effective organisation needs to design and implement balanced strategies to achieve its short- and long-term financial objectives and sustain its business in the free market. There are three important areas that should be managed effectively by organisations to achieve their financial goals.

First, organisations need to keep investing in critical resources to enable learning, growth and innovation. The most critical resource in any organisation is people. Organisations need to invest in attracting and maintaining talent. A culture of learning, innovation and growth should be created and sustained. Investment in the right information and communications technology should be taken seriously.

Second, organisations need to re-examine the efficiency and productivity of internal business processes. Strategies, such as business process re-engineering (BPR), can help organisations to improve their standing in the industry. BPR is a structured process to identify inefficiencies in an organisation, and design and implement an effective solution to improve workflow.

The third area is customers and stakeholders. All organisational and process improvements should lead to enhanced customer satisfaction and repeat business. The BSC methodology provides a platform to think strategically about business objectives. The key is to align competing strategies while focusing on the overall goal. The BSC balances short- and long-term objectives and enables strategic improvements at all levels.

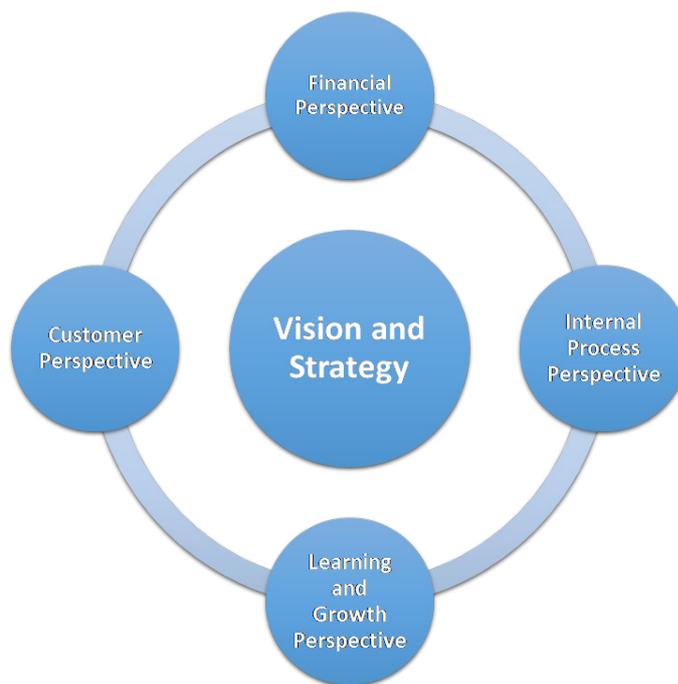


Figure 5: An overview of the BSC (adapted from BPM Institute)

3.2 Key performance indicators

Strategy mapping requires a set of appropriate KPIs to measure and track the success of implementation over time. KPIs provide a systematic measurement system to determine the efficiency of an organisation in several key areas, such as time, cost, quality, safety, productivity, sustainability and resilience. Consistent KPIs help organisations compare performance with similar organisations in the infrastructure. Studying KPIs helps organisations to identify gaps in performance and share success stories.

KPIs need to be meaningful and accessible metrics. The BSC can be used to develop KPIs to facilitate decision-making and policy. A good example of using the BSC method in defining KPIs for infrastructure benchmarking can be found in the IPA's **Best Practice in Benchmarking** guide (2019)¹⁴. The BSC model shows KPIs for a transportation programme in four distinct areas (see Figure 5).

- **Financial:** measured by budget versus forecast and percentage of expenditure standard deviation.
- **Economy:** percentage of contracts per local subject matter expert (SME), cost per local SME and return on investment (ROI) generated.
- **Social:** number of apprenticeships, a square metre of housing land unlocked and number of charities.
- **Sustainability:** percentage of waste to landfill, embodied CO₂ and transport distance.

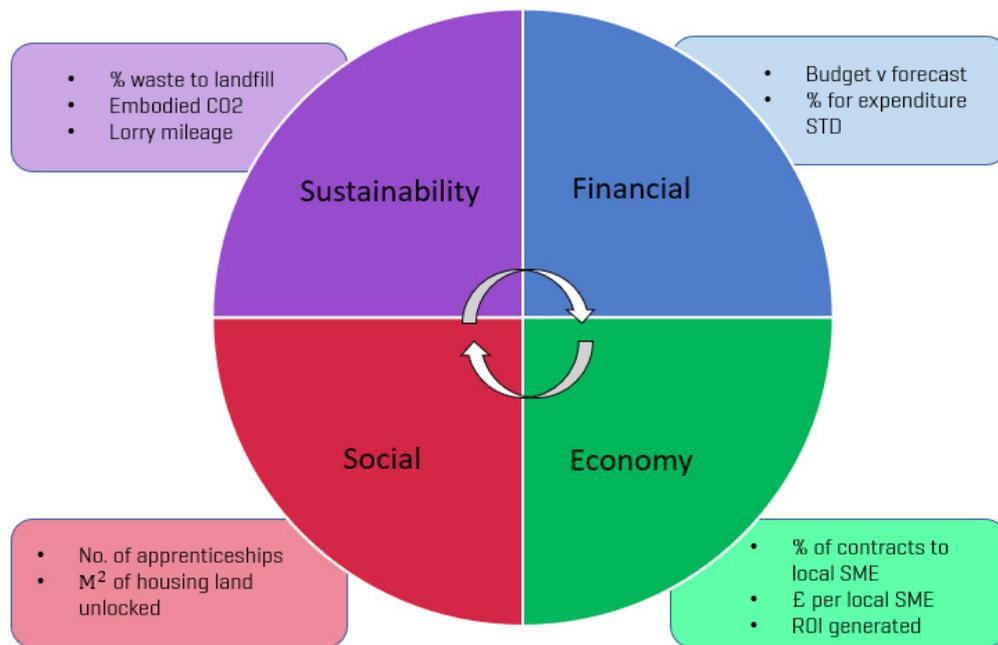


Figure 6: Using the BSC for infrastructure benchmarking (adapted from IPA 2019)

In addition to these areas, schedule/time can be significant for infrastructure stakeholders, especially the public, who would be impacted by delays in the delivery of critical infrastructure projects.

While there is general support for benchmarking infrastructure systems on these four dimensions, there is no global standard for measuring performance in each area. Infrastructure investors use the environment, social and governance (ESG) framework to measure and benchmark investments in infrastructure projects. Each infrastructure project is unique, and each owner has its own set of expectations that need to be addressed in developing appropriate KPIs. The NCHRP provides a list of recommended KPIs for benchmarking environmental performance and performance of non-motorised vehicles in the highway infrastructure industry¹⁰ (see Table 1).

KPIs for environmental benchmarking	KPIs for benchmarking the performance of non-motorised vehicles
<ul style="list-style-type: none"> • fuel consumption per capita • wildlife-vehicle collisions • the National Environmental Policy Act (NEPA) in the US measured three distinct categories of projects based on an environmental impact statement (EIS), an environmental assessment (EA) and categorical exclusion (CE). 	<ul style="list-style-type: none"> • bicycle and pedestrian connectivity [measured via route directness] • bicycle and pedestrian miles travelled estimates • fatalities • vehicle miles travelled • bridge condition • bicycle and walk commute mode share • cyclist fatalities • motor fuel usage

Table 1: Recommended KPIs for benchmarking environmental performance and performance of non-motorised vehicles

There are also several KPIs for benchmarking the cost of infrastructure projects. See case study 3 in appendix A for an example of benchmarking the cost and production rate of tunnelling projects in the UK.

Currency conversions will be required if project costs are compared across different countries. Since currencies fluctuate daily, only yearly or quarterly data may be needed.

3.3 Major databases for performance of infrastructure systems

Public agencies are often legally required to provide the status of public infrastructure systems in a publicly available database. Publishing the latest values of KPIs for public infrastructure systems helps to communicate the value of benchmarking to the public and enhances transparency in the decision-making process for investment. For example, in the US, there are several public databases that provide detailed information about the performance of US transportation infrastructure systems. These are national-level databases that attempt to provide a common framework for comparing projects across different jurisdictions and regions. Consistent guidelines are provided to local decision makers on how to measure and report infrastructure performance.

The following sources are physical performance benchmarks of the US transportation infrastructure assets:

- **The Highway Performance Monitoring System:** a Federal Highway Administration’s (FHWA) national dataset containing information about condition, use and performance of highways across the US.
- **The National Bridge Inventory:** a national database of major characteristics and conditions of all public bridges in the US.

There are two other databases that provide detailed information about travel time and safety for the US highway system:

- **The National Performance Management Research Data Set:** average travel times for five-minute time slices throughout the day on highway sections in the US and 25 Canadian and Mexican border crossings.
- **The Fatality Analysis Reporting System:** traffic fatalities provided by the National Highway Traffic Safety Administration.

4 Infrastructure benchmarking process

A systematic benchmarking methodology has several important steps that are detailed in various guides. The three most notable guides are:

- National Cooperative Highway Research Program (NCHRP) research report 902 (2019)¹⁰
- Transit Cooperative Research Program (TCRP) research report 141¹⁶ and
- IPA, Best Practice in Benchmarking (2019)¹⁴.

The principles of benchmarking and the required steps to implement a benchmarking system are similar in all three guides. These steps are covered in this chapter.

4.1 Establish the context

Infrastructure benchmarking cannot be successfully implemented in any organisation unless the executive leadership team understands its strategic value and provides the necessary support. Organisations should select a team and leader to coordinate all benchmarking activities.

Firstly, the benchmarking team should establish a practice manual explaining infrastructure benchmarking inside the organisation. There should also be a policy manual to define the objectives of benchmarking and how these are aligned with the overall organisational goals. The benchmarking team should reach out to key stakeholders inside the organisation for buy-in and to increase the chance of success. SMEs can provide feedback to help improve the quality of the benchmarking practice manual and identify the areas that would most benefit from benchmarking.

4.2 Identify the levels of benchmarking

Once the context of benchmarking is established, the required levels of benchmarking should be identified, e.g. system, network, asset and project. Appropriate metrics should be developed to measure the performance of the organisation at each level. This is probably the most challenging step in the benchmarking process as it defines what needs to be measured and compared with other organisations. The benchmarking team should use industry standards, such as performance checklists, for this task. For example, normalised performance measures, such as fatalities per million vehicle miles travelled (VMT) or percentage change in fatalities, are widely-accepted performance measures for benchmarking the safety of roadway networks. Unique performance measures limit the application of benchmarking to inside organisations and makes it difficult to set up a reliable comparison with the rest of the industry.

A glossary should be created to clearly define all performance measures and guidance should be provided on how to measure the performance indicators. A step-by-step calculation process is helpful to show how the identified performance indicators are processed. It may be necessary to define which elements or components are included in a metric and which are not. An example of this is buried pipes where fittings and joints are included but valves are not. The information requirements need to be established to develop an effective benchmarking method.

4.3 Select peer organisations for external benchmarking

The results of benchmarking are more useful if organisations can be compared with each other. The following should be considered in identifying peer organisations for benchmarking:

- organisational characteristics, e.g. size, number of full-time employees, revenue, number of projects, market share
- regional differences, e.g. location and climate and
- other specific market characteristics.

For public agencies, socioeconomic characteristics of their service areas (population and its growth rate, GDP and its growth rate, primary industries, job market conditions, etc.) should also be considered.

The main attributes of the entire infrastructure network should be considered to establish a peer-to-peer comparison platform. For example, in benchmarking highway infrastructure systems the NCHRP report 902¹⁰ recommends the following criteria for selecting peer agencies:

- system and service characteristics, e.g. lane miles of urban and rural highway, number of bridges, fleet size and route miles and
- travel demand and usage characteristics, e.g. VMT and transit mode share.

4.4 Collect and processing data

Good benchmarking practices require consistent data and a data collection process. Appropriate templates should be developed to capture data from peer organisations in the benchmarking network. Where possible, industry-standard data frameworks should be used for data collection from different organisations to avoid any discrepancies.

The **International Construction Measurement Standards** (ICMS)¹⁷ provide uniform templates for capturing and reporting several characteristics of infrastructure projects. ICMS provides common attributes across multiple building and infrastructure project types and introduces a consistent level of cost collection and reporting across specific project types. Infrastructure projects can collect data as a complete project or as sub-projects using ICMS; for example, a highway may contain bridges, tunnels, rest areas and roadways. ICMS is based on the data collection from a project life cycle and provides three or four levels of cost reporting based on the complexity of the project data. It provides a global methodology for comparison of similar project types across different countries. Each country can use their native cost reporting system, but it can be mapped to ICMS so that similar project types can be compared. The upcoming RICS professional statement on Cost Prediction discusses benchmarking, amongst other cost prediction methods, for use by practitioners. It embodies ICMS for the collection of data and subsequent reporting, a framework against which construction and life cycle costs are classified, measured, recorded, analysed, and presented.

The templates should not be limited to capturing performance data but other data sources used to examine the biggest variables of infrastructure performance. The collected data needs to be processed before being analysed. Cleaning or conditioning the data is a critical step to ensure the success of the benchmarking exercise as substantial errors in the collected data can lead to unreliable benchmarking results. Conditioning the data relates to unique features or elements that may cause outlier values. For example, in benchmarking

pipeline infrastructure projects, special attention should be given to conditions that require over-excavation due to poor soil conditions or conditions that need more significant pipe foundations. These conditions can be attribute fields or annotated in the notes field. When selecting datasets, these project conditions may help pare down the data for further analysis.

Validating the data is also an essential step in cleaning third-party data that may not contain descriptions and values for all required data fields. Some examples of common data problems are missing values, data entry errors, out-of-range values and impossible data combinations. There are several statistical analysis methods that can be used to facilitate an often manual data cleaning process, e.g. z-score or the extreme value analysis method for outlier detection. An effective data collection method should be able to recognise misleading data points that are deliberately added to the pool to skew the benchmarking results.

4.5 Analyse the data, validate the results and interpret the findings

The measured performance indicators of different projects from the same organisation (internal benchmarking) or different organisations (external benchmarking) should be at the appropriate level. Normalisation should be done to remove the effects of external conditions on performance ranking, e.g. time (escalation), location (area cost factors) and productivity adjustments relating to project complexity. Various cost indices can be used to account for temporal and spatial variations, for example:

- the consumer price index (CPI) provided by the US Bureau of Labor Statistics (BLS)
- the Engineering News-Record (ENR) construction cost index (CCI)
- the FHWA national highway construction cost index (NHCCI) or
- the US Department of Defense (DOD) unit cost/area cost factors.

Adjusting for project complexity is more subjective and requires developing specific criteria for different infrastructure project types.

Using the normalised data, the relative ranking will be provided for infrastructure systems at different tiers. For instance, if the focus of benchmarking is on the project-level cost and schedule, the performance of peer infrastructure projects can be compared at different component levels, e.g. bridge, pavement, foundation, etc. Statistical analysis is useful for understanding the underlying drivers of performance in the infrastructure industry. The benchmarking team needs to verify the calculation process to validate the results.

If the outcomes of benchmarking are surprising, not intuitive or are against the common perceptions of stakeholders, further investigations can help the team understand the fundamental issues in performance. Proper statistical models can be developed to explain the variability of performance among peer organisations. Factors representing external conditions should be used as control variables to determine the main drivers of variations in performance. Most recently, advances in data analytics, such as machine learning and artificial intelligence (AI) algorithms provide promising opportunities for advanced benchmarking. For example, clustering algorithms can be used to classify peers into several groups with similar performance levels.

Forecasting algorithms can be used to predict the trends in benchmarking infrastructure systems. Such algorithms can help improve cost prediction and estimating by strengthening the use of the reference class forecasting (RCF) method. RCF is regaining popularity due to a focus on historical data. It is an approach to estimating based on comparisons with other

projects in the same ‘reference class’¹⁸. It takes an external view of a project estimate based on historical records of similar projects, rather than the more common internal approach where cost estimates are built up from detailed quantity calculations for each project. A reference class is a class of project where the distribution of variances from a forecast have the same statistical distribution within given limits.

4.6 Present and communicate the results

The results of data analysis are shown in different formats. Advances in data visualisation tools should be used to present the quantitative results of the benchmarking to key decision-makers in an easy-to-understand format. Visualisation tools, such as Tableau and Power BI, provide dynamic and interactive ways to work with the benchmarking data. They enable decision-makers to see the performance data from multiple perspectives. A variety of interactive graphs can be used for communicating different dimensions of the data depending on the use case of the performance benchmarking, e.g. bar charts, waterfall diagrams, heat maps and bubble charts.

An example of an effective communication method can be found in the American Infrastructure Report Card¹⁹ from the American Society of Civil Engineers (ASCE). Separate grades are provided for several infrastructure sectors: aviation, ports, bridges, public parks, dams, rail, drinking water, roads, energy, schools, hazardous waste, solid waste, inland waterways, transit, levees and wastewaters. Grades are also provided for each state, to make them more relevant to the general public and policymakers at the local level.

Benchmarking dashboards are the most commonly used tools to show the results of benchmarking to all stakeholders and, in some cases, to the general public. A performance dashboard should illustrate the results of infrastructure benchmarking in a framework that is both easy to interpret and navigate. Decision-makers should be given an opportunity to combine the results to conduct a high-level performance assessment and evaluate the performance at lower levels. For instance, the Virginia Department of Transportation (VDOT) has developed a dashboard that tracks the performance of the entire organisation at multiple layers, including the performance of its project development and delivery (see case study 1 in appendix A). Graphs should be accompanied by descriptions to show how the results can be used to improve business operations in the infrastructure sector. The ASCE report card and VDOT performance dashboards are two good examples of presenting the final efforts of infrastructure benchmarking to the public, who are the ultimate stakeholders of infrastructure projects.

4.7 Identify best practices

Often, the most important outcomes of a benchmarking exercise are not quantitative. Relative rankings of different performance metrics are not as useful as the identification of effective strategies for performance improvement. Lessons learned should be documented and distributed among peer organisations. The proven strategies from organisations participating in the study should be documented as the identified best practices worthy of adoption by other organisations. Peer exchange of effective ideas is one of the most valuable outcomes of a good benchmarking process. Case studies of successful benchmarking programmes are useful for other organisations to understand the barriers of adoption and effective strategies to overcome those barriers.

4.8 Implement the benchmarking strategies

Sometimes, the benchmarking team stays with the organisation to implement the recommended strategies for performance improvement. In this case, a roadmap for implementation should be developed to show changes that need to be made to the existing process. The benchmarking team needs to justify how implementing the identified best practices helps the organisation in several areas, such as efficiency, productivity, quality and safety. Support from leadership is necessary to implement the recommended strategies in the organisation. Proper incentives should be developed to motivate professionals to consider changing their current working practices.

4.9 Monitor the benchmarking process and audit the results

Like any other management practices, implementing benchmarking results need to be controlled. Success measures need to be defined for each implementation phase, and progress should be measured against targets to make timely changes. Once the implementation of best practices is complete, the original benchmarking is repeated. The new results will be tested against targets to see whether the expected improvements have been achieved.

Auditing is considered one of the most critical features of an effective benchmarking programme. Transparency helps build credibility for infrastructure benchmarking experts and this includes demonstrating the performance gains made by implementing a rigorous benchmarking system.

5 Data analytics

Emerging technologies in data analytics provide significant opportunities to advance benchmarking in the infrastructure sector. Data analytics algorithms can be classified as four types (see Figure 7).

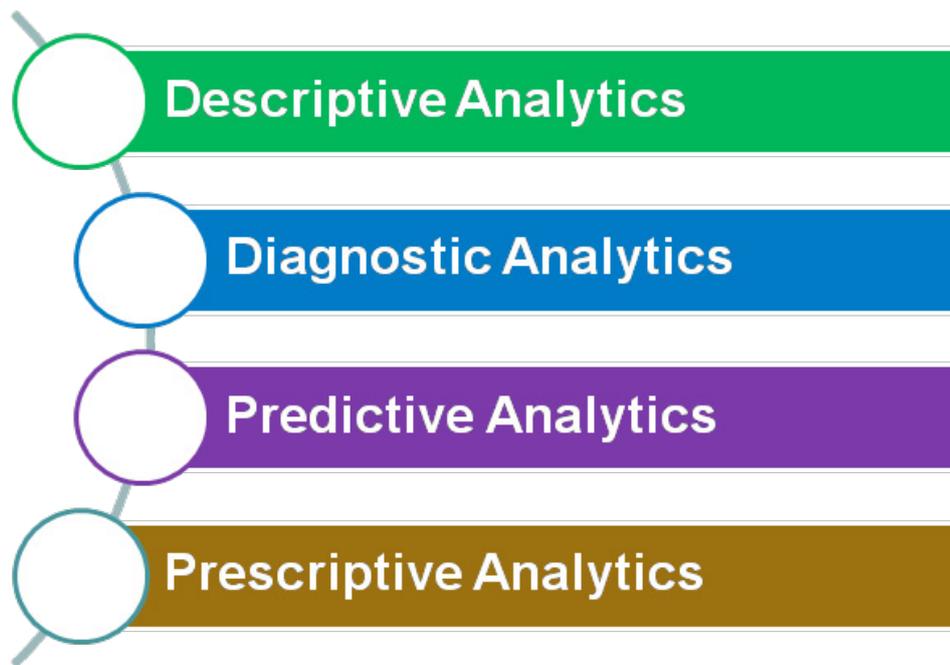


Figure 7: Four types of data analytics

5.1 Descriptive analytics

Descriptive analytics is a time-consuming but necessary step in data analytics to identify the leading indicators of project success. It aims to reshape hard-to-understand quantitative insights across a large dataset into bite-sized descriptions. The primary goal is to examine data to find out what happened. Descriptive analytics is backward-looking and its focus is on descriptions and comparisons, e.g. specific patterns leading to high-performance infrastructure projects. Descriptive analytics can also be used for classification and categorisation, e.g. classifying organisational infrastructure agencies based on similarities and differences across several performance measures.

5.2 Diagnostic analytics

Diagnostic analytics is used to investigate past events and historical trends to try to detect undesirable patterns early in the process. The focus is on identifying the connection between important features and understanding the causal relationships among the key variables. Diagnostics analytics identifies and ranks the most significant variables with the highest power to explain the variability of the outcome. In benchmarking, it helps reveal the variability of performance across different infrastructure projects and can help infrastructure decision-makers identify the underlying reasons for low-performing organisations.

5.3 Predictive analytics

Predictive analytics is used to develop models to forecast future trends and define what the likely outcome is. One of the most common applications of predictive analytics is cost and schedule risk analysis for infrastructure projects. The significant risk factors identified in diagnostic analytics can be used to develop likely scenarios for future outcomes. The Monte Carlo simulation algorithms will then be applied to characterise the risk for the cost and schedule of infrastructure projects. Monte Carlo simulation algorithms are a blend of computational methods that use random sampling to characterise the variability of the outcome of interest. Random values will be drawn from plausible ranges of input variables, in order to obtain potential values for the output. The results will be presented to infrastructure decision-makers as probable distributions of the performance measures. Using the knowledge of the leading indicators, predictive analytics helps decision-makers predict the variability in project outcomes.

5.4 Prescriptive analytics

Prescriptive analytics is about providing a recommended course of actions to improve the performance of infrastructure systems and assets. It informs decision-makers on how to implement the results of benchmarking to mitigate the risk and enhance the performance of an infrastructure organisation.

6 Benefits of benchmarking

The benefits of benchmarking in the infrastructure sector have been documented by several global research studies, including the NCHRP in the US, and IPA, Centre for Transport Studies (CTS) at Imperial College London and benchmarking tunnelling costs and production rates in the UK. Benchmarking is a valuable tool to build understanding and confidence in expected project outcomes from the start. The benefits can be summarised as follows.

6.1 Selection of right infrastructure projects from the onset

If the public have trust and confidence in the expenditures made in public infrastructure, they will continue to invest in it, which is why this is a big concern for all government agencies. Benchmarking is a useful tool to establish accurate estimates for the cost, schedule and benefit of public infrastructure projects, which can help decision-makers select the projects with the greatest economic benefits for the public. Cost benchmarking helps owners of major infrastructure projects find the right price tag for the proposed projects and prepare accurate business cases for the selected projects. Inaccurate cost-benefit analysis leads to inferior projects being selected, which means that limited financial resources cannot be invested in other promising projects. The effective use of benchmarking can avoid under- and over-investment in the infrastructure sector. Public satisfaction in infrastructure projects can be used as another performance benchmarking dimension to increase public support for public infrastructure investment.

6.2 Project initiation

Once a project has been selected, project-based organisations can use benchmarking in project initiation so that the selected project can be primed for success from the start. The quality of project initiation, including the development of the business case and early cost prediction, has been shown to be ‘highly predictive of project success’. Case study 6 in appendix A describes the use of a Project Definition Rating Index (PDRI) to benchmark the quality of the project initiation process. The forthcoming RICS global professional statement Cost prediction, which uses ICMS, will form part of a wider set of global standards in construction, covering project and cost management across buildings and infrastructure.

6.3 Knowledge management

Benchmarking helps the infrastructure industry identify noteworthy practices. An excellent benchmarking exercise encourages project participants to review the completed project and discuss their experience, share knowledge and provide recommendations for future improvements. The identified best practices are analysed and lessons learned shared with the participants in the benchmarking study to help continuous improvement. Discussing bad practices is also useful as it helps stakeholders to avoid making the same mistakes.

6.4 Adoption of innovative solutions

Benchmarking spurs innovation through informing decision-makers about emerging technologies and solutions for major infrastructure problems. There is a need for a comprehensive benchmarking system that identifies the underlying factors driving the

performance trends in infrastructure projects. The lessons learned help the sector better navigate most common challenges and use innovative solutions to tackle the most pressing issues.

6.5 Identification of potential problems over the project life cycle

Benchmarking makes participants think deeper and anticipate infrastructure project delivery and operational challenges. It provides a constructive platform for project stakeholders to rethink assumptions and question whole life aspects of infrastructure development. It creates a better understanding of project strengths and weaknesses, assists infrastructure owners in prioritising their problems and sets ambitious but achievable targets.

6.6 Data-driven decision-making

Benchmarking motivates all industry stakeholders to take data collection seriously and shows the value of investing time and money in collecting performance data. Benchmarking helps establish a common data structure for measuring KPIs in the infrastructure sector. For example, ICMS and the associated data standards promote global consistency in classifying, defining, measuring, recording, analysing, presenting and comparing entire life cycle costs of projects at the regional, state, national or international level. Setting an objective and unbiased data collection practice paves the way for more rigorous decision-making about infrastructure problems.

6.7 Reduced uncertainty in infrastructure development

Infrastructure projects are good examples of highly complex and risky endeavours. At each development phase, projects face significant uncertainties affecting performance, e.g. schedule, cost, safety, quality and economic benefits, which impact the sector output. Benchmarking takes the data from similar projects to provide a range of plausible outcomes for various areas of project performance and helps remove some of the risks from the project and asset operating environment.

6.8 Enhanced transparency and accountability

The public expect government agencies to audit the development of infrastructure projects. An appropriate benchmarking system contains valuable information about the history of infrastructure project development that can also be used for documenting the basis of project decisions. Benchmarking can enable comparative assessment among different infrastructure projects, which helps raise accountability among project stakeholders.

7 Conclusion

Improving benchmarking in the infrastructure industry involves several challenges that should be considered when an organisation is looking to establish a strategic programme for benchmarking.

Finding a reasonably large sample of peer organisations to participate in benchmarking is not easy. Professional bodies representing a wide range of firms should make benchmarking a priority in their efforts to improve efficiency and productivity at the industry level. Governments at a regional level should deploy resources to benchmark infrastructure agencies at a regional level.

Often, benchmarking at project-level may not be possible due to the limited data points from peer organisations with similar project portfolios. External variables also determine the reasonableness of using certain data from projects that are good candidates for peer-to-peer comparison. Sometimes, the focus of benchmarking should be on lower-level components and not the entire projects, for example, comparing the cost of significant elements of highway projects, such as bridges and foundations, across the portfolio of the projects in the benchmarking network.

It is hard to build consensus among SMEs in the industry to come up with a standard data collection platform for measuring performance of infrastructure project delivery. Without a consistent platform to capture the data and measure the performance, benchmarking methods will fail.

Infrastructure benchmarking has become increasingly popular in the industry as there have been several examples of success (see case studies 1, 5 and 6). Lessons learned from the successful implementation of benchmarking show that the infrastructure industry can benefit from the deployment of a rigorous benchmarking system in several areas, such as:

- engagement of the upper management and executive leadership team in understanding the underlying issues for performance inefficiency problems
- independent quality assurance using industry-standard performance data protocols
- continuous business improvement through the identification of innovative solutions
- data-driven decision-making for performance assessment and identification of best practices
- improved transparency in evaluation and selection of infrastructure projects
- knowledge management through capturing and deploying the industry lessons learned
- enhanced accuracy of estimating performance targets for infrastructure projects and
- consistent data and data collection methodologies, such as ICMS.

It is worth noting that infrastructure benchmarking is not just an automated and quantitative study. SME need to be involved in every step. First and foremost, they define the scope of the benchmarking and explain the underlying business problem for performance assessment. The knowledge and experience of SME should be used to define performance indicators to measure different dimensions of performance for delivering and operating infrastructure

systems. Finally, SME provide invaluable insights on how to interpret the benchmarking results and define a plan for implementing the recommended best practices.

Benchmarking is often criticised for a lack of fairness in peer-to-peer comparison, as it is very difficult (or almost impossible) to find two organisations or two projects that are exactly alike. While this concern is valid, the true value of benchmarking goes beyond simple rankings of organisations and projects on a long list of KPIs. Benchmarking provides a collaborative environment to share experiences and avoid repeating the same mistakes. Infrastructure benchmarking, if done correctly, is an effective tool to enhance the strategic objectives of all organisations in the industry, e.g. reduce unnecessary expenses, increase reliability of the services and improve end-user satisfaction. All infrastructure organisations share these common goals, although they have their own strategies to achieve targets. The following case studies show how different infrastructure organisations use benchmarking to improve their working practices and better serve communities in which they deliver infrastructure assets.

Appendix A Case studies

Case study 1: Virginia Department of Transportation

VDOT has developed a benchmarking system to measure, monitor and manage the performance of the project during the development process and construction²⁰. It helps promote responsibility and accountability and increases transparency in the organisation. The dashboard has seven performance dials (see Figure 8).

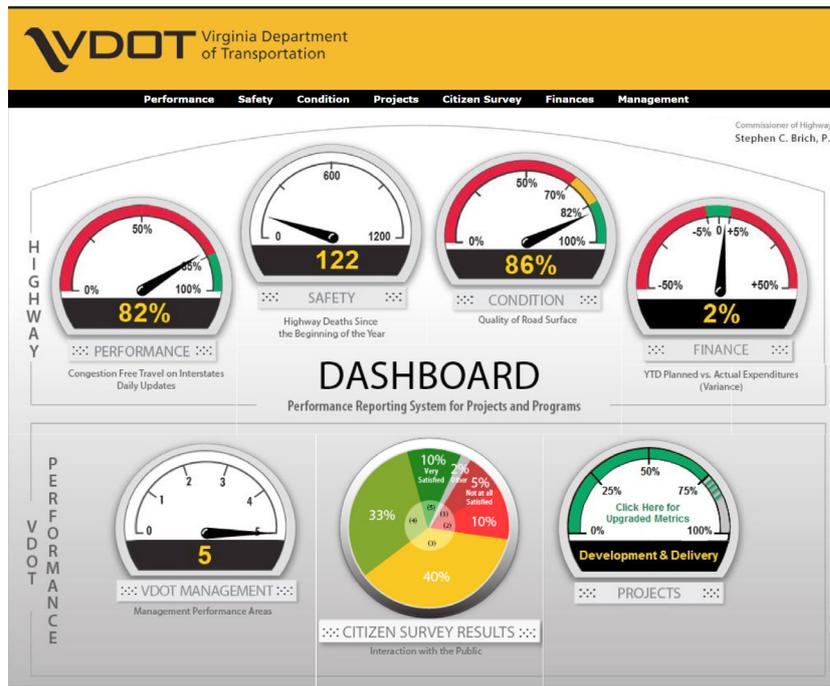


Figure 8: General dashboard (© VDOT)

The seven dials are further defined in Table 2.

Seven dials of VDOT’s dashboard	Description
Highway performance	The performance dial provides valuable data regarding the performance of various projects. The performance can be specific to certain details [e.g. congestion, travel speeds, travel time, incident duration, hours of delay and overall performance].

Seven dials of VDOT's dashboard	Description
Highway safety	The safety dial provides information regarding the number of deaths since the beginning of the year. The detailed information provides a detailed comparison on a month-to-month basis of the current data and past three years' average. It also classifies the accident into several categories.
Highway condition	The condition dial displays the information regarding the quality of the road surface in comparison to the previous years on a percentage basis. The data also includes the condition of the bridges and ride quality on the routes.
Highway finance	The finance dial provides information on planned expenditures versus actual expenditures. The detailed information provides a financial report for the current fiscal year or any fiscal year from the last 13 years.
VDOT management	The VDOT management dial shows the performance of the agency on a scale from 0-5 (5 being the highest). Every agency reports its effectiveness in the five critical areas of emergency preparedness, financial management, government, procurement, human resource and information technology.
Citizen survey results	The citizen survey results dial shows the results based on public satisfaction with the performance of VDOT. Citizen satisfaction is rated on a scale of five, with five being very satisfied and one being not at all satisfied.

Seven dials of VDOT's dashboard	Description
Projects	The dashboard uses performance metrics based on the smart scale business rules developed by the Virginia government. The status of all types of projects is measured on cost and schedule based on common milestones. The dashboard is broadly divided into two sections, including project development and project delivery.

Table 2: Seven dials of VDOT's dashboard

VDOT has developed parameters for measuring the performance of the projects based on schedule, budget and key milestones. The dashboard also provides data regarding the completion and progress for all the projects ranging from the current fiscal year to projects that are planned for completion in the upcoming fiscal years. The dashboard enables projects that are VDOT managed and those that are locally managed to be distinguished.

Case study 2: Australian road construction cost benchmarking

In 2017, the Transport and Infrastructure Council (TIC) were benchmarking highway project costs in Australia²¹. This was the second benchmarking study at a national level in Australia and the findings were compared with the results of the national pilot benchmarking study done in 2015. Seven regions in Australia participated in this benchmarking study by providing cost data on 32 road construction projects and 23 projects in active procurement since mid-2015.

The benchmarking study was conducted for road projects classified using the Austroad's functional road classification. There are nine types of road classes that were classified based on the road location, rural versus urban roads and road types, such as arterial, distributor and local roads. For each class of road projects, cost benchmarking was conducted for the following major components:

- environmental works
- traffic management and temporary works
- public utilities adjustments
- traffic signage
- signals and controls
- retaining walls
- drainage
- tunnels
- client-supplied materials and construction services
- pavements
- finishing works

- bulk earthworks
- supplementary items and
- bridges.

The KPI in the benchmarking study is the whole cost of the road project measured in million Australian dollars per lane kilometre. Figure 9 shows a 'box and whisker plot' of road project costs for different classes of road projects. It also shows variability of the project cost among different road classes and within each road class. A box and whisker plot is a graphical method used in descriptive statistics to show the variability of a factor of interest through identifying the minimum, first quartile, median, third quarter, and maximum.

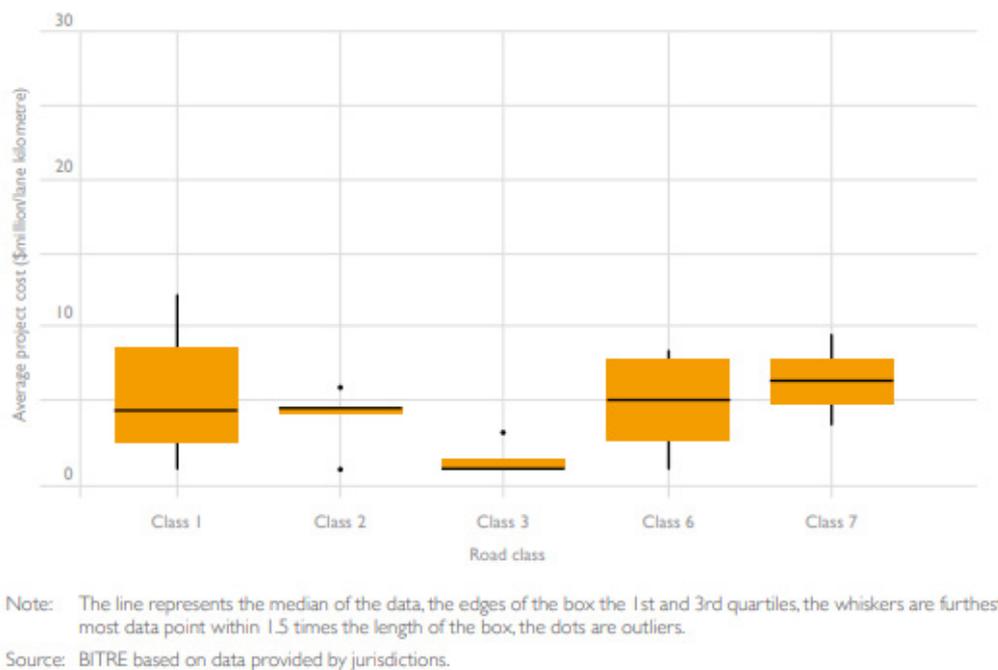
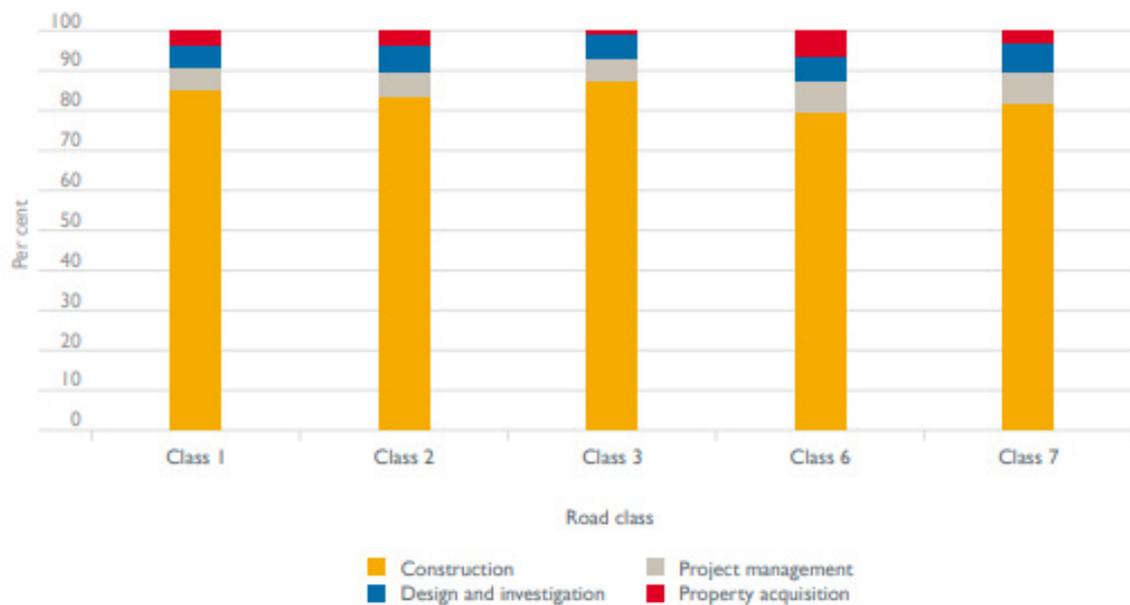


Figure 9: Average project cost for several classes of roadway projects (© BITRE 2017 under the Creative Commons Attribution 3.0 Australia Licence)

The benchmarking study also provides separate comparison for the cost of major project phases, including the costs for project management, design and investigation, property acquisition and construction. Figure 10 shows the proportional share of the cost for different project phases across different classes of road projects.



Source: BITRE based on data provided by jurisdictions.

Figure 10: Proportional share of the cost for different project phases (© BITRE 2017 under the Creative Commons Attribution 3.0 Australia Licence)

This benchmarking study also attempted to examine the differences in the time taken to develop road projects based on the procurement method used to develop the project. The following types of procurement methods were considered in this benchmarking study:

- construct only
- design and construct
- managing contractor
- early contractor involvement
- alliance and
- public-private partnership (PPP).

Benchmarking of the procurement methods was conducted based on the:

- time taken to complete procurement processes and
- time taken in each procurement phase.

The benchmarking study of road projects in Australia faced two great challenges that may be in common with other studies around the world. The sample size was small, especially for some classes of the projects (such as classes four and five) and some types of procurement methods (such as alliance or PPP). Therefore, the benchmarking results were not provided for several groups of projects. This limitation affects the applicability of the benchmarking for special project types. The other challenge was related to the substantial variability of the project cost around its average value. This shows that more investigation is needed to identify the main drivers of road project costs in Australia.

Case study 3: Benchmarking tunnelling costs and production rates in the UK

The IPA recently benchmarked the cost and production rate of tunnelling projects in the UK⁷. As a first step, several structured workshops were organised with SME in the infrastructure community to develop and refine the benchmarking framework in the context of tunnelling in the UK. Industry leaders were invited to share cost and production data from their projects to participate in the benchmarking study. The following KPIs were agreed for use in this benchmarking exercise:

- cost versus diameter for transport projects
- cost versus diameter for utility projects
- comparison of transport projects against utility projects using total tunnel volume
- comparison of transport projects against utility projects using cost per unit volume against tunnel length and
- assessment of tunnel performance or production rates.

The benchmarking team developed a template for data collection based on ICMS to ensure quality data collection and avoid any discrepancies and inconsistencies that can affect the reliability of the benchmarking results. Using ICMS ensures that the cost of tunnelling is separated from the cost of the other items that may be included in the project.

The cost data was adjusted for inflation to allow for the time difference between projects and therefore provide a fairer comparison. The tunnelling benchmarking case study is a good example of using easy-to-understand graphs to communicate the results of benchmarking to industry stakeholders. Several scatter plots were prepared to show the differences among the costs of different transport and utility projects. Total cost or unit cost of tunnelling projects are plotted against key factors that influence the project cost, such as volume of tunnelling, tunnel length or tunnel diameter. Figure 11 plots total tunnelling project cost, measured in cost per metre (£/m), against the volume of tunnelling projects, measured in cubic metres (m³). Two separate comparisons were made between the cost of transport and utility tunnelling projects.

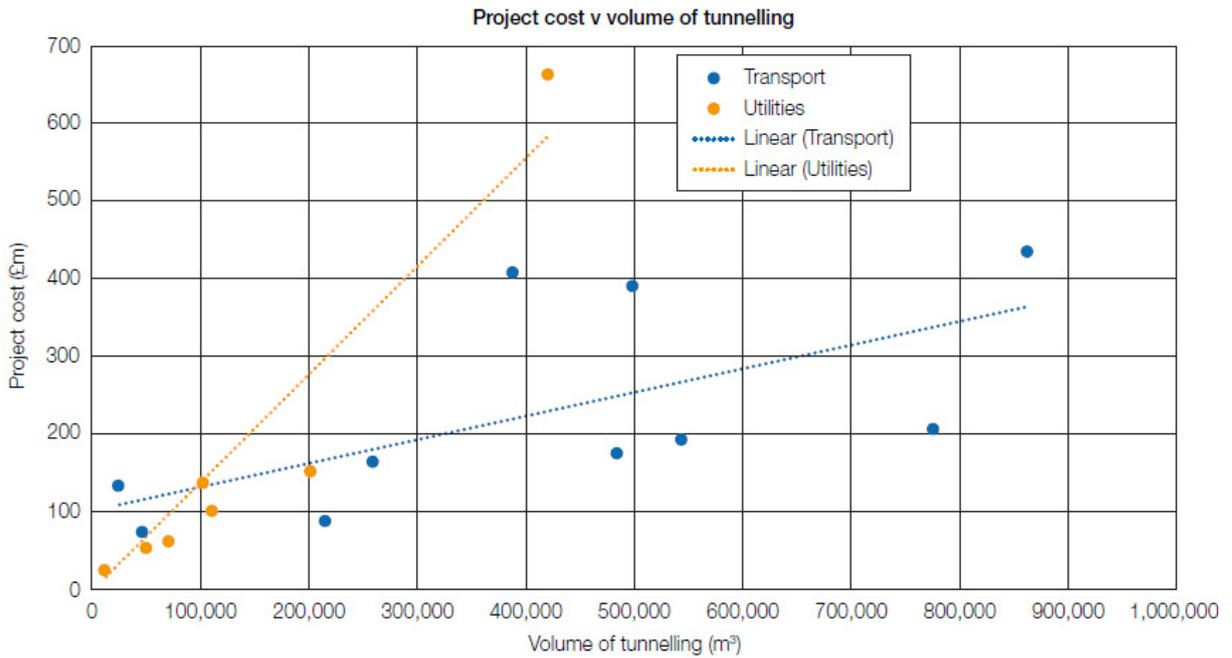


Figure 11: Tunnelling project cost versus tunnel volume (© IPA 2019)

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Figure 12 plots the unit cost of tunnelling projects, measured in cost per metre (£/m), and square metre (m²) of the tunnel face area,) against the tunnel length, measured in kilometres (km). Two separate comparisons were made between the unit cost of transport and utility tunnelling projects.

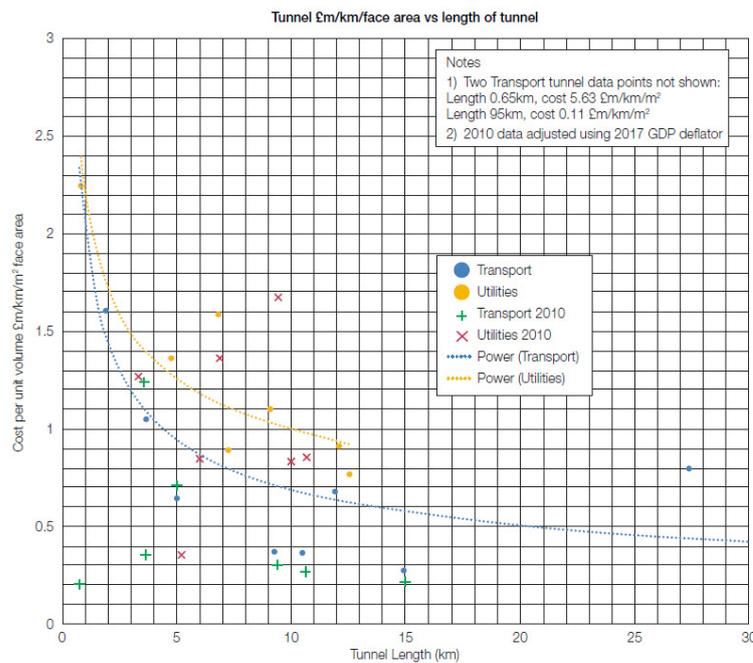


Figure 12: Tunnelling unit cost versus tunnel length (© IPA 2019)

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The results of the benchmarking exercise were presented to the industry participants in a structured workshop. The findings were discussed among industry stakeholders and any lessons learned were reviewed. The notable best practices were defined to set improvement targets. Cost benchmarking is used as a more reliable platform for predicting the cost of new projects, so benchmarking is also useful in improving cost estimation in the transport sector.

Case study 4: Highway construction cost index

The construction cost index (CCI) measures the average change over time in transportation construction material and service prices paid by US infrastructure agencies, most notably state departments of transportation (DOTs), to highway contractors. The highway CCI tracks changes in highway construction costs and helps state DOT officials to consider highway construction cost changes in their economic decision analyses. Many public agencies and organisations publish construction cost indices, including:

- the **FHWA's NHCCI**
- the **Bureau of Reclamation's O&M Cost Index**
- the **Engineering News-Record's (ENR) CCI**
- **RSMMeans' Heavy Construction Cost Index.**

Alongside a national cost index, state DOTs build organisation-wide construction cost indices to suit their needs, including the South Dakota DOT and multiple transportation agencies across the US.

The two types of cost index based on data sources are the input price index and output price index. Input cost indices measure the average costs of inputs to the construction process. For example the Engineering News-Record's (ENR's) CCI is the weighted aggregate index of the 20-city average costs of constant quantities of structural steel, Portland cement, lumber, and common labour in the U.S.

Multiple material suppliers and craft labour providers are used to give information about the costs of materials and labour. The CCI calculation is based on the self-reported costs collected from the suppliers and not the actual costs paid by highway contractors for these services. Input cost indices cannot be used to provide information on price movements for finished construction work because they do not represent the entire range of factors that impact market prices, such as changes in productivity, profit and trade margins of construction contractors and changes in actual market conditions. The trend of real construction prices may differ significantly from the trend of indices compiled based on average labour and material costs.

However, output price indices, such as the NHCCI, measure the price of what is produced. Output price indices track the actual prices of the final products and services as paid by the owners. They measure changes in the outputs of the construction process. Output price indices consider all the items built into the price paid by the owners including materials cost, labour cost, equipment cost, general conditions, overhead and profit. For example, the NHCCI shows trends in actual prices of highway projects as paid by state DOTs across the nation. Market conditions, competition and profit structure of highway contractors are

reflected in the submitted bid prices by contractors and therefore, are implicitly considered in the development of the NHCCI.

Several state DOTs, such as Minnesota, Montana, Iowa, South Dakota, Wisconsin and Ohio, have developed their own construction cost indices to track the purchasing power of their construction dollars. Each state DOT is different in terms of the formula used to calculate the index, frequency of publishing the index, the base year that the index was established or substantially revised and the configuration of their cost items used to construct the index.

State DOTs use construction cost indices for several applications related to economic decision analyses throughout different phases of the project delivery. The CCI has been used for benchmarking to identify opportunities for enhancing efficiency of the design and construction process.

Appropriate construction cost indexes categorised by project type, size and location can help state DOTs track major cost components over time. Any substantial variations will be used to identify areas of improvement that the state DOT needs to target to improve productivity. Cost indices for different DOTs can be compared with each other to track trends in the variability of infrastructure costs from one state to another. States in similar geographical locations with similar infrastructure programmes can use their cost indices to compare the overall cost-effectiveness of their programmes.

Case study 5: Utah Department of Transportation's Program Delivery Dashboard

The Utah DOT has developed a Program Delivery Dashboard²² to evaluate the performance of its projects and programmes at the regional level. The dashboard is used as a benchmarking system to measure, monitor and manage the performance of projects during the project development process and construction within the regions.

The dashboard presents the data in a graph and provides a year-to-year comparison of the regions in meeting the project schedule, budget and scope, including a comparison of the actual letting date and committed letting date for the project. In addition, the dashboard provides a detailed explanation and graphs that explain the performance of the projects in each region compared to the baseline of the projects, current advertising performance and advertising performance history. The dashboard was developed based on a comprehensive set of metrics (see Table 3).

KPI type	KPI metric reported in dashboard	Description
Schedule health	Preconstruction advertising status	Detail for the preconstruction advertising status
	Current advertising performance	Monitoring current advertising performance [85 per cent goal]
	Advertising performance history	Advertising performance trend over the years
	Current preconstruction schedule	Committed versus actual advertising date
	Current preconstruction scoping	Number of projects in the scoping stage, monthly
	Current preconstruction schedule	Number of projects submitted for advertising, monthly
	Preconstruction schedule history	Number of projects advertised each month
	Three-year advertising results	Number of projects advertised each month
	Right time advertising history	Monitoring advertising performance [75 per cent goal]
	Projects that do not advertise	Number of projects that will not advertise

KPI type	KPI metric reported in dashboard	Description
Budget health	Project budget estimate in preconstruction	Current value of various federal obligation and funding categories
	Potential available funds	For projects that have reached substantial completion
	Federal obligation projection	Current value of federal obligation
	Obligation goal status	Current versus remaining obligation status
	Obligations versus de-obligations	Obligations versus de-obligations
	Current year federal estimate	Federal obligations versus federal fiscal year
	Obligation total	Dollars versus federal fiscal year
	Project values	Awarded versus advertised
Scope health	Change orders and overruns versus original contract amount	Measure of maintaining project scope
	Final construction expenditure versus original contract amount trend	State fiscal year versus number of projects

Table 3: Utah DOT's Program Delivery KPIs

The UDOT dashboard page displays two dashboards (a zero fatalities dashboard and a program delivery dashboard) and additional information for factors such as pavement condition, bridge condition and current interstate travel times (see Figure 13).

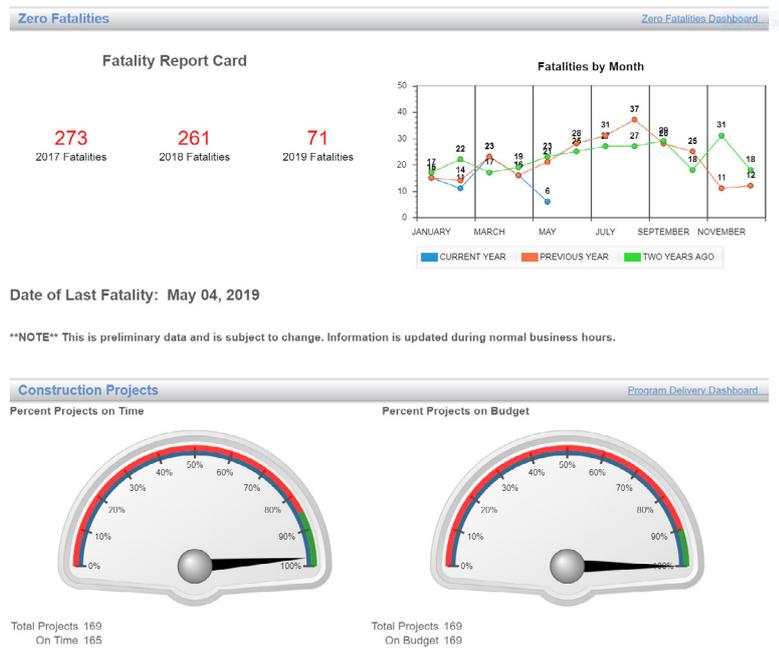


Figure 13: Utah DOT’s Program Delivery Dashboard (© UDOT 2019)

Case study 6: Construction Industry Institute Project Definition Rating Index

Front end planning (FEP) is the process of developing enough strategic information for a project. It is also known as front end loading (FEL), conceptual planning, pre-project planning, feasibility analysis, front end engineering and design (FEED), programming/schematic design and early project planning. Owners and contractors can address risks and decide which resources are needed to maximise the chances of success.

FEP is an owner-driven process that should be closely tied to business goals. It is a complex process that should be adapted to the business needs of the organisation, tailored to specific projects and applied consistently to all projects to gain full benefit. Front end planning is divided into three main phases:

- 1 feasibility
- 2 concept and
- 3 detailed scope.

FEP is a structured process to define the scope of work to:

- identify and mitigate risks
- develop the right scope for a good design basis and
- execute the right project in the right way.

Front end planning is supported by the Construction Industry Institute (CII) Project Definition Rating Index (PDRI). PDRI is a benchmarking tool for infrastructure organisations to use in evaluating the accuracy of the defined scope versus the probability of success on future projects. PDRI elements for infrastructure projects are divided into three sections (basis of

project decision, basis of design, and execution approach), 13 categories and 64 elements as shown in Table 4.

Section	Category	Element
Section I – Basis of project decision	Project strategy	<ul style="list-style-type: none"> • Building use requirements • Business justification • Business plan • Economic analysis • Facility requirements • Future expansion/ alteration • Site selection considerations • Project objectives statement
	Owner/operator philosophies	<ul style="list-style-type: none"> • Reliability philosophy • Maintenance philosophy • Operating philosophy • Design philosophy
	Project requirements	<ul style="list-style-type: none"> • Value-analysis process • Project design criteria • Evaluation of existing facilities • Scope of work overview • Project schedule • Project cost estimate

Section	Category	Element
Section II – Basis of design	Site information	<ul style="list-style-type: none"> • Site layout • Site surveys • Civil/geotechnical information • Governing regulatory requirements • Environmental assessment • Utility sources with supply conditions • Site life safety considerations • Special water and waste treatment requirements
	Building programming	<ul style="list-style-type: none"> • Programme statement • Building summary space list • Overall adjacency diagrams • Stacking diagrams • Growth and phased development • Circulation and open space requirements • Functional relationship diagrams/room by room • Loading/ unloading/storage facility requirements • Transportation requirements • Building finishes • Room data sheets • Furnishings, equipment and built-ins • Window treatment
	Building/project design	<ul style="list-style-type: none"> • Civil/ site design • Architectural design • Structural design • Mechanical design • Electrical design • Building life safety requirements • Constructability analysis • Technological sophistication

Section	Category	Element
	Equipment	<ul style="list-style-type: none"> • Equipment list • Equipment location drawings • Equipment utility requirements
Section III	Procurement strategy	<ul style="list-style-type: none"> • Identify long lead/critical equipment and materials • Procurement procedures and plans
	Deliverables	<ul style="list-style-type: none"> • CADD/model requirements • Documentation/ deliverables
	Project control	<ul style="list-style-type: none"> • Project quality assurance and control • Project cost control • Project schedule control • Risk management • Safety procedures
	Project execution plan	<ul style="list-style-type: none"> • Project organization • Owner approval requirements • Project delivery method • Design/ construction plan and approach • Substantial completion requirements

Table 4: Sections, categories and elements of PDRI

The categories, sections and elements are used to assess individual programmes and add them to the benchmarking database. There are many benefits of using the PDRI for infrastructure benchmarking including:

- assuring alignment of project objectives and stakeholders needs
- ensuring resources are used to maximise value for the time and effort being applied
- verifying the scope in relation to the original project goals
- identifying high priority project deliverables that need to be completed
- helping to eliminate late project surprises
- identifying and planning remaining activities to achieve the level of detail necessary to complete planning and
- facilitating communication across the project team and stakeholders.

Appendix B Skills and competencies of a Benchmarking Manager

The RICS **Project Management, Quantity Surveying and Construction** and **Infrastructure** pathways provide a suite of competencies that are needed to be successful in the role of benchmarking manager.

Multiple mandatory, core and optional competencies provide the necessary knowledge, skills and expertise needed to be a benchmarking manager (see Table 5).

Examples of likely knowledge, skills and experience
Benchmarking from analysed historic data
Advising on data storage system
Advising on data security
Advising on the use of a computerised central project database
Budgeting techniques
Extracting data for inclusion in a database
Forecasting techniques
How project information is stored within your employer's organisation
How technical libraries are set up and used
Legislation applicable to data management and data access
Monitoring performance against budgets
Obtaining data from in-house sources
Obtaining data from published sources for use on a project
Retrieving data from existing records, manual or electronic
Retrieving information from a technical library
Reviewing and understanding analysts' reports on financial statements
Reviewing performance against targets and indicators
Setting performance indicators

Examples of likely knowledge, skills and experience

Setting up and using paper-based or electronic project filing systems

The use of published sources of data

Undertaking cost benefit analysis

Undertaking risk analysis

Table 5: Pathways-based knowledge, skills and experience

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