Technical Appendix

Introduction

InfraCompass seeks to help countries deliver better infrastructure outcomes by providing policy makers and other users with supporting and enabling information. InfraCompass 2020, which builds on the previous release, provides scores and rankings for 76 countries across eight drivers of infrastructure quality. Underpinning the driver scores are 41 individual metrics that have been selected due to their linkages to efficient and effective infrastructure and grouped by their relevance to each driver.

The purpose of this chapter is to provide a detailed description of the InfraCompass 2020 methodological framework (the Framework), which covers details on the analytical approach to preparing data, shortlisting metrics, estimating weights and developing scores.

Approach

The objective of InfraCompass is to determine the key variables that impact infrastructure outcomes in a country across eight drivers:

Governance	Governance and institutional settings
Regulatory framework	Investment policy and economic regulation
Permits	Clarity and consistency of the permits and land acquisition process
Planning	Planning and infrastructure appraisal processes
Procurement	Efficiency of government contracting and procurement
Activity	The extent and nature of infrastructure investment activity and extent of private sector involvement
Funding capacity	The capacity of countries to invest in infrastructure over time
Financial markets	The availability and cost of funding for infrastructure

The following six steps described in detail in the sections that follow, were undertaken to develop InfraCompass 2020:

- **Defining the dependent (or outcome) variable** – a simplified approach to determine an 'effective' infrastructure market culminated in using Quality of Infrastructure (from WEF Global Competitiveness Index) as a single outcome variable for the statistical modelling.
- **Selecting metrics** – a long list of 80 metrics was refined to a short list of 41 based on five criteria.
- **Selecting countries** – Aligning country coverage with the Global Infrastructure Outlook was the primary determinant. Country data quality and coverage were also considered in selecting the countries to be included.
- **Preparing the data** – data was cleaned and prepared for analysis. This included the imputation of missing values, normalisation and standardisation to ensure comparability of different metrics.
- **Estimating metric weights** – Principal components analysis (PCA) and multivariate linear regression was used as the basis of determining weights for each metric.
- **Deriving index score** – index scores were derived by applying the weights to each metric in each driver.

The cut off period for all data collection was December 2019.

This approach has several advantages, including:

- It is objective, data driven and replicable over time and across countries.
- A dependent variable is used to determine if any of the hypothesised relationships are empirically relevant.
- Metrics are assessed for their relevance to infrastructure outcomes.
- Issues related to correlation are resolved via several statistical techniques.
- Combining variables into a multi-variate modelling framework provides a view on relative importance.

Defining the dependent (or outcome) variable

Key to the framework is to define what an effective infrastructure market means. For most statistical modelling approaches, this reflects the definition of a dependent variable (the outcome variable that is being influenced by the explanatory metrics). The first step in the statistical modelling process is therefore to identify what 'effective' looks like in the context of an infrastructure market. In InfraCompass 2017, the dependent variable was derived applying a fuzzy clustering approach[1] across three series:

01. **Quality of Infrastructure**
    Source: WEF Global Competitiveness Index 2016-17 – Incorporates a range of infrastructure metrics within the overall "Pillar 2" value (Infrastructure).
02. **Total infrastructure expenditure (economic infrastructure only), % of GDP (5 year average)**
    Source: Oxford Economics research based on government and multi-lateral development agency estimates.
03. **Total private sector investment in infrastructure, % of GDP (5 year average)**
    Source: IJ Global research on private transactions reaching financial close.

1. See Global Infrastructure Hub (2017), *Technical Appendix*, InfraCompass.

The dependent variable was defined as the degree of membership (a percentage continuous variable for each of the 76 countries) of the 'optimal cluster' that was most correlated with Quality of Infrastructure.

In InfraCompass 2020, this approach was simplified with only the Quality of Infrastructure used as the dependent variable. This approach was chosen for several reasons:

- Ease of interpretability by stakeholders and users
- Shortlisted 41 metrics had similar and statistically significant correlations with both Quality of Infrastructure and degree of membership variables
- Strong theoretical appeal in Quality of Infrastructure being associated with better infrastructure outcomes. The other two metrics used in InfraCompass 2017 (private infrastructure investment and total infrastructure investment) could be considered as inputs that explain the outcome. Also, the 'total infrastructure investment' metric from InfraCompass 2017 had not been updated.

Selecting metrics

Starting with a longlist of over 80 potential metrics, a series of filtering procedures resulted in a shortlist of 41 metrics for inclusion in the Framework.

Developing a long list of metrics

A longlist of potential metrics was selected for InfraCompass 2017 based on the criteria shown in Table 3 below. The 2017 long list was updated for InfraCompass 2020 using the same criteria, but replacing discontinued metrics and adding new metrics that had been created since 2017. Of the over 80 metrics in the longlist, the vast majority were multi-country and publicly available datasets from international organisations such as the OECD, World Bank, IMF and World Economic Forum.

The process of data collection also revealed gaps in data, for example on project planning and appraisal techniques. To close these gaps, a global survey was conducted with Deloitte in-country infrastructure experts in each region to collect additional information.

Table 3: Criteria for long list of metrics data selection

Metric criteria	Description
Aligned Aligns with The Global Infrastructure Hub Mission Statement	A clear link should exist between metrics and the objectives of the organisation. The metrics should be aligned with strong performance of a country in lowering barriers to investment, preparing quality infrastructure projects and improving supporting policies and processes.
Intertemporal Allows change over time to be detected at regular intervals	The data supporting each metric should be collected and reported at regular intervals over time.
Important Meaningful to, and likely to be perceived as, important by users	Metrics should clearly reflect what matters to users, as noted in literature and consultations.
Quality High quality (statistically appropriate, free of errors, duplications)	Data should have high levels of accuracy and robustness ensuring it is representative of the country's infrastructure market, free from errors, bias, missing records or duplications.
Recurrent Defined and repeatable system and publication intention	The data collection body should have an established system for collecting and reporting metrics.
Comprehensive High coverage of relevant countries	Data supporting metrics should cover a sufficiently high range of countries to support a robust comparison and analysis.

Source: Global Infrastructure Hub

Developing a shortlist of metrics

To further refine the list of metrics, the following five criteria were used to reduce the longlist into a shortlist:

- **Correlation:** The strength of the relationship (positive or negative) and statistical significance with Quality of Infrastructure dependent variable
- **Coverage:** Driver coverage over time (2017 and 2020) and across countries
- **Continuity:** Whether the metric was included in InfraCompass 2017
- **Relevance:** Alignment to the purpose of the Framework and the objective of the drivers
- **Duplicates:** Removal of metrics that provided very similar information to others.

Correlation

Pearson correlation was assessed for each metric in the longlist against the Quality of Infrastructure outcome variable. In general, only the metrics that had the largest magnitude (positive or negative correlation) and statistical significance (p-value), within a driver, were shortlisted. These results are reported in the Table 4.

Coverage

Metrics that had the highest levels of coverage across countries and time were shortlisted. With a view to increasing the accuracy of the InfraCompass 2020 scores, metrics that required a large degree of imputation across countries or that were out-of-date were dropped.

Relevance

To determine the relevance of metrics, the objectives of the Framework, the rationale for each driver and economic theory were all relied upon. Those with low relevance were excluded. Those with high relevance to InfraCompass, but that failed the correlation test (which is typical for discrete variables, such as survey questions in the Planning driver), were included if there was a strong theoretical basis and if the driver had less than four metrics.

Duplicates

To filter out metrics with similar information, cross-correlation tests were completed for all longlisted metrics. In cases where two or more metrics were highly correlated, only metrics that revealed strong correlation with the dependent variable (Quality of Infrastructure) were retained.

The above criteria resulted in 41 metrics being selected for the InfraCompass 2020. Four to six metrics were chosen for each of the eight drivers in the Framework.

Table 4: Correlation between shortlisted metric and Quality of Infrastructure dependent variable

Metric	Correlation with Quality of Infrastructure	P value
Governance		
Rule of law index score	**0.80**	**0.00**
Recovery rate, cents on the dollar	**0.72**	**0.00**
Political stability and absence of violence score	**0.71**	**0.00**
Shareholder governance index	**0.60**	**0.00**
Does the country have a dedicated National or Sub-National Infrastructure or PPP Unit/Agency?	**-0.14**	**0.25**
Does the country do Post-Completion Reviews (Assurance)	**0.14**	**0.24**
Regulatory frameworks		
Regulatory (including competition) quality index	**0.80**	**0.00**
Prevalence of foreign ownership	**0.60**	**0.00**
Product market regulatory score, network sectors	**-0.61**	**0.00**
Strength of insolvency framework index	**0.47**	**0.00**
Effect of taxation on incentives to invest	**0.21**	**0.08**
Does the country have an national agency dedicated to investment promotion and/or trade to attract investment in infrastructure? (Y/N)	**-0.18**	**0.12**
Permits		
Quality of land administration index	**0.78**	**0.00**
Cost to start a business, % of GNI per capita	**-0.54**	**0.00**
Registering property, No. of days	**-0.45**	**0.00**
Time required to start a business (number of days)	**-0.35**	**0.00**
Dealing with construction permits, No. of days	**-0.15**	**0.19**

Metric	Correlation with Quality of Infrastructure	P value
Planning		
Preparation of PPPs, 0-100 (best)	**0.41**	**0.00**
Does the country have a National or Sub-National Infrastructure Plan?	**-0.08**	**0.48**
Do the National and Sub-National Infrastructure Plans contain a list of specific projects (Pipeline)?	**0.09**	**0.46**
Economic analysis assessment (Y/N with methodology)	**-0.07**	**0.53**
Market sounding and/or assessment	**0.08**	**0.51**
Environmental impact analysis	**-0.03**	**0.83**
Procurement		
Degree of transparency in public procurement score	**0.70**	**0.00**
Average procurement duration (in months) – Transaction RFP	**-0.17**	**0.32**
Procurement of PPPs, 0-100 (best)	**0.43**	**0.00**
Does the country publish guidelines for the procurement of infrastructure projects?	**-0.04**	**0.72**
PPP contract management, 0-100 (best)	**0.25**	**0.03**
Activity		
Value of closed infrastructure deals with foreign equity sponsorship, % of GDP	**0.45**	**0.00**
Infrastructure investment, % of GDP	**-0.56**	**0.00**
Value of closed PPP infrastructure deals, % of GDP	**-0.40**	**0.00**
Private finance infrastructure, % of GDP	**-0.21**	**0.08**
Funding		
Summary credit rating	**0.82**	**0.00**
GDP per capita	**0.74**	**0.00**
Long term GDP growth trend	**-0.58**	**0.00**
Gross government debt, % of GDP	**0.32**	**0.01**
Financial		
Financial depth (0-100)	**0.79**	**0.00**
Financing through local equity market	**0.57**	**0.00**
Domestic credit to private sector, % of GDP	**0.67**	**0.00**
Stocks traded, total value, % of GDP	**0.50**	**0.00**
Financial stability (0-100)	**0.47**	**0.00**

Source: Various data sources, Deloitte calculations

Selecting countries

A list of 76 countries was selected to undertake the statistical analysis, which was based on several factors, including:

- **Alignment with Global Infrastructure Outlook**
- **Membership** – membership in various international organisations and sufficient global coverage, so that the analysis is not biased by geographic concentrations or by a specific set of country characteristics such as wealth or size.
- **Data availability** – the availability of data that covers the relevant metrics, since the robustness of statistical analysis is driven by the quality of the underlying data.
- **Data quality** – the quality, consistency and frequency of the data, given that the GI Hub intends to update the Framework on a periodic basis.

The selected countries are detailed below.

Table 5: Countries selected for statistical modelling in InfraCompass 2020

Region/Income Group	Africa	Americas	Asia	Europe	Oceania
High income (economies with a Gross National Income (GNI) per capita, of $12,376 or more in 2018)		Canada Chile United States of America (USA) Uruguay	Japan Korea Qatar Saudi Arabia Singapore United Arab Emirates (UAE)	Austria Belgium Croatia Czech Republic Denmark Finland France Germany Greece Ireland Italy Netherlands Poland Portugal Slovak Republic Slovenia Spain Sweden United Kingdom (UK)	Australia New Zealand
Upper middle income (economies with a GNI per capita between $3,996 and $12,375)	South Africa	Argentina Brazil Colombia Ecuador Guatemala Mexico Paraguay Peru	Azerbaijan China Jordan Kazakhstan Malaysia Thailand Turkey	Romania Russia	Fiji Samoa
Lower middle income (economies with a GNI per capita between $1,026 and $3,995)	Angola Cote d'Ivoire Egypt Ghana Kenya Morocco Nigeria Senegal Tunisia		Bangladesh Cambodia India Indonesia Myanmar Pakistan Philippines Vietnam		Papua New Guinea Solomon Islands Vanuatu
Low income (economies with a GNI per capita of $1,025 or less)	Benin Burkina Faso Chad Ethiopia Guinea Mali Niger Rwanda Tanzania Togo				

*Five additional Pacific Island countries were added following stakeholder consultation, to bring the total number of countries to 81. Data is provided on these five countries, where available, but they are not included in the rankings due to limited data availability and quality issues.

Countries listed in blue indicate the additional countries added to InfraCompass 2020.

Preparing the data

Given the range of data sources and the varying units of measurement, the collected data underwent a rigorous preparation process to assess quality and ensure consistency of unit measurement, facilitating fair comparison and suitability for statistical analysis. The following section summarises this process, starting with the treatment of missing values and then the normalisation of the data.

Imputation

While the selection of metrics and countries was informed by the availability of data, there were still some gaps which required imputation.

The following imputation techniques were applied in the order below, where more accurate techniques have been prioritised. When data requirements for a technique were not met, the next on the list was attempted. This process continued until a value was imputed.

- **Available past or future value** – The value for up to three years prior to 2019 or available values from 2020 were coded as 2019. This technique was applied to metrics that were relatively stable but did not have a long time series. Similar approach was followed for 2016 data.
- **Auto Regressive (AR) or Moving Average (MA) model** – An AR or MA model was used to impute values based on a time series of previous values. This technique was used for data with a relatively long time series, and standard time series criteria (AIC, BIC, Akaike) were applied to derive optimal number of lags.
- **Regional average** – The regional average of member countries was used when a country did not have any data available. Pacific Island countries were not included in these averages.
- **Global average** – The global average was used when there were limited countries with data within a region. Pacific Island countries were not included in these averages.

Like any approach to estimation, this method has limitations and required assumptions to be made about the similarities across countries. However, the scale of the missing data issues is immaterial to the overall outcomes of the analysis. For InfraCompass 2020, less than 6 per cent of all data was imputed.

Table 6: Summary of interpolations for 2019 dataset (76 countries, excluding Pacific Islands[2])

Technique	2019	Share
Actual data	2916	94%
AR or MA	25	1%
Regional Average	165	5%
Global Average	10	0%
Total observations	**3116**	**100%**

Normalisation

Each metric is based on a certain scale or measuring unit. For instance, some metrics are discrete survey responses ("yes" or "no"), while others are continuous integer values or index values.

Data that are expressed using different scales cannot be aggregated to develop comparable metrics without rescaling in an appropriate way. The aggregation process therefore requires that raw data for each metric to be manipulated, such that all data are expressed using the same scale.

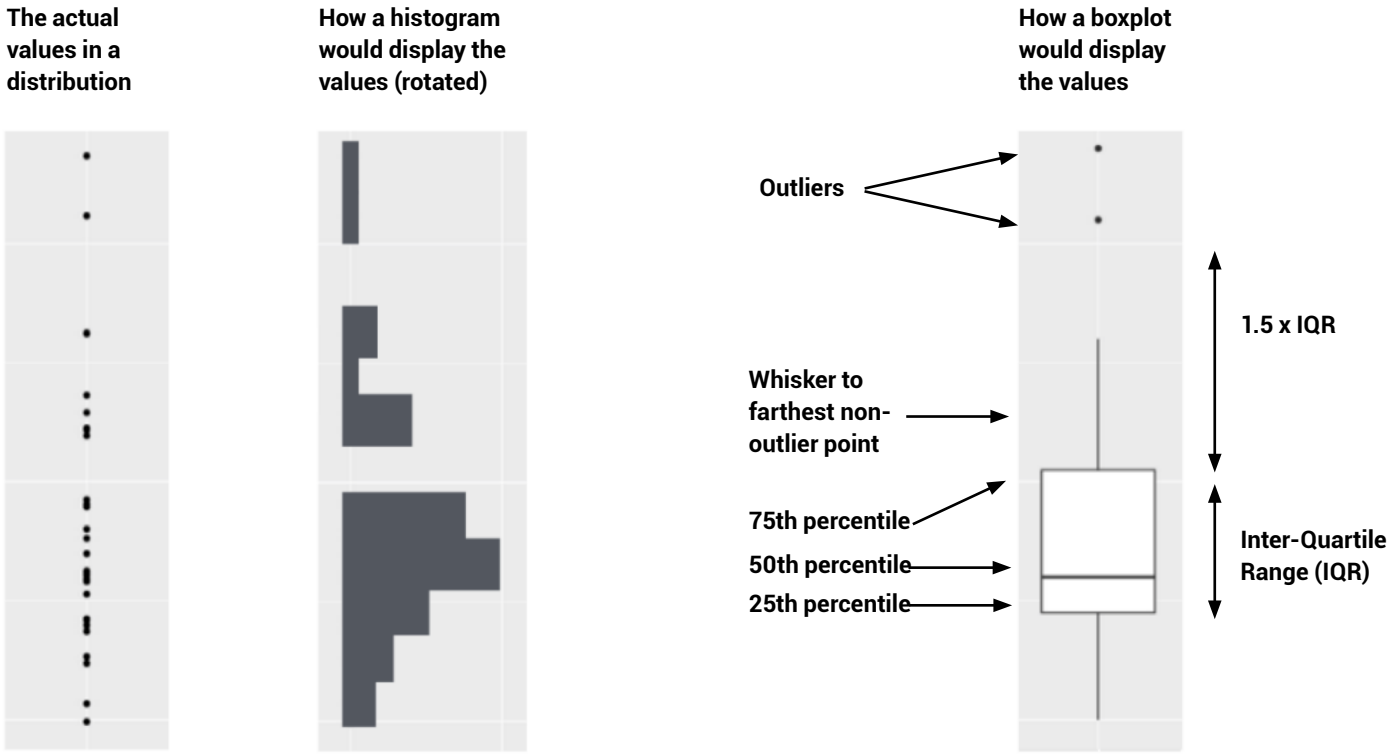
For InfraCompass 2020, all data was rescaled to lie between 0 and 100. For survey questions, 'no' responses were coded as 0, and 'yes' responses as 100. For metrics that had discrete answers (e.g. 1 to 7), they were rescaled to lie between 0 and 100 (e.g. 7 became 100). All continuous metrics were rescaled based on the minimum and maximums of the data over the sample period of 2016 to 2019. For most variables, a lower limit of zero was subsequently set (this applied for variables that cannot be negative, e.g. procedures to start a business).

Treating outliers

Prior to rescaling, where relevant, metrics were adjusted to remove the impact of outliers which can skew the index score ranges. The list of metrics where outliers were recoded is broadly consistent with InfraCompass 2017. Outliers above the median were recoded to be equal to the third quintile plus 1.5 times the interquartile range. Outliers below the median were recoded to be equal to the first quintile minus 1.5 times the interquartile range.

2. For the five Pacific Island countries, we use relevant Income Group metric-averages instead of Regional Averages to impute missing values. Where relevant, other techniques such AR, MA, or Global Averages were also applied. In total, 77/205 Pacific Island observations were interpolated. However, we have included Pacific Islands in Regional (Oceania) and Income Group (Low, Lower-Middle) pages.

Figure 3: Interpretation of outliers



Source: Hadley Wickham

Standardising direction of metrics

Where relevant, some metrics were subsequently inverted after normalisation to standardise all metrics to be strictly increasing in their relationship with Quality of Infrastructure. For example, since lower compliance costs make it easier to invest in infrastructure, the normalised value of 'number of procedures to start a business' was reversed such that, lower numbers for compliance were standardised to be closer to 100, and high numbers closer to 0. In other words, normalised metrics that had negative relationships with Quality of Infrastructure were inverted, so that all metrics had positive relationships with good infrastructure outcomes.

Estimating metric weights

Principal component analysis

A simple approach to determining weights is to regress the chosen shortlist of variables against the dependent variable. However, a multi-variate analysis of this nature will face several challenges:

- **Multicollinearity:** While steps (during short listing) were taken to remove metrics that are correlated, many of the metrics are not statistically independent and will continue to be linearly related, leading to multicollinearity issues in the regression analysis. This would result in unreliable coefficients and metric weights.
- **Degrees of freedom:** Since there are 41 metrics per country, an appropriate econometric approach would be to estimate a panel econometric model to capture country-specific fixed effects. However, this approach is problematic since degrees of freedom would be limited, given the number parameters that need to be estimated. This would compromise the robustness of estimated parameters and standard errors.

There are several statistical techniques that can be used to alleviate these issues. Principal component analysis (PCA) addresses both issues by reducing the number of explanatory variables and controlling for correlation between them.

In InfraCompass 2020, PCA reduced the number of explanatory variables from 41 metrics to 14 principal components.[3] The number of principal components was chosen based on their ability to explain at least 90 percent of the cumulative variance of the dataset. The PCA model was also restricted to non-negative factor loadings to ensure that metric weights are non-negative.

3. Principal component analysis (PCA) is a technique for feature extraction — it groups input variables in a specific way so that it drops the "least important" information in the variables while still retaining the most valuable parts of all of the variables (that are essential in explaining the variability in the outcome variable). The result is that the regression is carried out with a much smaller number of variables and those variables are all independent of one another.

Multivariate Linear Regression

To determine the metric weights, the principal components were regressed against the single dependent variable – Quality of Infrastructure. The regression was restricted to non-negative coefficients to ensure that metric weights are non-negative. The resulting coefficients were then multiplied by the loadings of each metric in each principal component. This resulted in one aggregate weight for each metric. The metric weights were then rescaled to sum to 100, within each driver. As a result, all weights across the eight drivers sum to 800. We also rescaled all estimated weights to ensure a minimum weight of 5%.

The only exception to this approach was the four metrics in the Activity driver (infrastructure investment as a share of GDP, private finance infrastructure investment as a share of GDP, value of closed infrastructure deals with foreign equity sponsorship as share of GDP, value of closed PPP infrastructure deals as share of GDP). The regression results revealed near zero coefficients for these four metrics in explaining Quality of Infrastructure. However, since there is a strong theoretical basis for their inclusion as measures of infrastructure investment activity, and because they align with the objectives of the Framework, we have assigned equal weights for all metrics in the Activity driver (25% each). To provide an alternative to equal weighting of metrics, would be to impose a subjective judgement and artificial bias into the process without any clear supporting evidence.

Deriving index scores

To derive country scores for each driver, the normalised data was multiplied by the derived metric weights. The total driver score is calculated as the sum of the weighted metric scores.

InfraCompass 2020 scored countries separately for two years – 2017 and 2020. The weights were determined using 2020 data and applied to both 2017 and 2020 data to determine the final scores. Testing of weights across multiple sample years revealed relative stability.

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