Methodology for Data Analysis of Digital Transformation

Jongsur Park
Seunghwa Jun
Jeong Yoon Kim
Disclaimer: The views expressed in the Asia-Pacific Information Superhighway Working Paper Series should not be reported as representing the views of the United Nations, but as views of the author(s). Working papers describe research in progress by the author(s) and are published to elicit comments for further debate. They are issued without formal editing. The United Nations bears no responsibility for the availability or functioning of URLs. Opinions, figures and estimates set forth in this publication are the responsibility of the author(s) and should not necessarily be considered as reflecting the views or carrying the endorsement of the United Nations. Any errors are the responsibility of the author(s). Mention of firm names and commercial products does not imply the endorsement of the United Nations.

Available at: http://www.unescap.org/kp

Tracking number ESCAP / 5-WP / 47

About the authors: Dr. Jongsur Park is a Professor of Econometrics in the Economics Department at Sunmoon University, Republic of Korea. Prior to his professorship, he conducted research in the field of telecommunications demand prediction at the Korea Telecom Economic Management Research Institute and established a big data policy in the local government of the Republic of Korea.

Dr. Seunghwa Jun is a senior information and communications technology (ICT) consultant with 18 years of strategy development and market analysis experience in the ICT industry and 4 years of teaching experience in digital economics and strategic management at Korea University. She is the author of the book, “Phono Sapiens Economics: The New Human-Centered Digital Economics”, and writes columns about the Fourth Industrial Revolution.

Jeong Yoon Kim is a consultant of the ICT and Development Section, ICT and Disaster Risk Reduction Division of the United Nations Economic and Social Commission for Asia and the Pacific (ESCAP).
# Table of Contents

ABSTRACT 5

1. INTRODUCTION 6

2. LITERATURE REVIEW 7

3. DATA AND METHODOLOGY 10

4. DTI RESULT ANALYSIS 17

5. CONCLUSION AND IMPLICATIONS 41

REFERENCES 43
Abstract

Considering the deeply unequal global landscape, diagnosing the status of digital transformation at a country level in Asia and the Pacific is urgently needed. Thus, this paper discusses a study that has built a country-level model for digital transformation diagnosis and developed a new index to benchmark leading countries. As existing digital-related indices have been limited to specific fields or have encompassed the overall economy, their analyses have not focused on digital transformation. The study has therefore constructed a framework for the Digital Transformation Index in a dynamic manner and focused on the evolutionary nature of digital transformation. Leveraging macroeconomic analysis tools such as the political, economic, social, technological, environmental and legal (PESTEL) analysis and the circular flow model, the digital transformation framework incorporates five thematic pillars. The results of the Digital Transformation Index through more in-depth analysis are expected to be useful guidelines for countries included in the analysis to not only understand their level of achievements in digital transformation, but also develop plans to further accelerate digital transformation.

Keywords: Digital Transformation
1. Introduction

DIGITAL TECHNOLOGY IS NOW FULLY INTEGRATED INTO PEOPLE’S LIVES

Governments and businesses are utilizing digital technologies to bring innovation and create new values across diverse areas. The so-called “Digital Transformation” has become more than just a keyword that represents an era. It is playing an integral role in determining the survival of a company and the future of a country. The gaps in national competitiveness between countries that have recognized the need and prepared for digital transformation and those that have not, are widening, as socioeconomic systems continue to be digitalized at an accelerated rate. The World Economic Forum (WEF) estimates that 70 per cent of the new economic value will be created on digitally-enabled platforms over the next decade, and socioeconomic changes brought about during the COVID-19 pandemic are expected to further accelerate digital transformation around the world. Digital transformation strategies, therefore, lie at the core of the national agenda for economic growth and COVID-19 recovery across countries, and an important task has emerged to accurately diagnose the status of digital transformation and establish a balanced digital strategy.

A variety of approaches and frameworks has been developed by international organizations and private consulting firms to measure national competitiveness from various angles.

These indices, however, are either based on economic performance or offer a narrow focus on digital-related achievements.

This working paper discusses a study that has developed a new Digital Transformation Index (DTI). The new framework reflects the dynamics over time by dividing digital transformation into three stages – Foundation, Adoption and Acceleration. Furthermore, considering that digital transformation is a comprehensive process across a country’s economy, society and industry, the new framework includes five thematic pillars – Network/Infrastructure, Government, Business, People and Ecosystem, based on the political, economic, social, technological, environmental and legal (PESTEL) analysis and the circular flow model.

The study aims to measure the DTI as a new standard to diagnose the degree of digital divide among countries and identify the factors causing this digital divide. The study also attempts to derive meaningful implications to be used for establishing national digital transformation strategies by selecting benchmarking countries based on the results of the DTI. The results of the DTI through more in-depth analysis are expected to be useful guidelines for countries included in the analysis to not only understand their level of achievements in digital transformation, but also develop plans to further accelerate digital transformation.
2. Literature Review

2.1 Definition of Digital Transformation

The definition of digital transformation in the business sector is focused on businesses that improve productivity by using digital technologies in the process of simplifying and automating the business operating environment. This definition, however, extends to a composite set of social and cultural phenomena where an organization introduces new and innovative methods, such as emerging technologies and digital tools that lead to an improvement of existing models or substitution for new ones. A number of existing literature and research show that the definition of digital transformation varies depending on the perspective or the organization to which the term is applied.

Fitzgerald, M., Kruschwitz, N., Bonnet, D., and Welch, M. (2014) define digital transformation as: “The use of new digital technologies (social media, mobile, analytics or embedded devices) to enable major business improvements (such as enhancing customer experience, streamlining operations or creating new business models)”. Their definition can be viewed as a purpose-oriented definition to improve major business sectors by using emerging digital technologies. Berghaus, S., and Back, A. (2016) emphasize the role of digital transformation in improving the efficiency and productivity of corporate operations, and illustrate that: “Digital transformation encompasses both process digitization with a focus on efficiency, and digital innovation with a focus on enhancing existing physical products with digital capabilities”. Meanwhile, Demirkan, H., Spohrer, J. C., and Welser, J. J. (2016) expand the horizon on the role and scope of digital transformation, describing digital transformation as: “The profound and accelerating transformation of business activities, processes, competencies and models to fully leverage the changes and opportunities brought by digital technologies and their impact across society in a strategic and prioritized way”. Haffke, I., Kalgovas, B. J., and Benlian, A. (2016) explain that: “Digital transformation encompasses the digitization of sales and communication channels, which provide novel ways to interact and engage with customers, and the digitization of a firm’s offerings (products and services), which replace or augment physical offerings. Digital transformation also describes the triggering of tactical or strategic business moves by data-driven insights and the launch of digital business models that allow new ways to capture value”. Moreover, Nwankpa, J. K., and Roumani, Y. (2016) suggest that: “Within an enterprise, digital transformation is defined as an organizational shift to big data, analytics, cloud, mobile and social media platform. Whereas organizations are constantly transforming and evolving in response to changing business landscape, digital transformation are the changes built on the foundation of digital technologies, ushering unique changes in business operations, business processes and value creation". Vial, G. (2019), after analysing 23 different definitions of digital transformation, presents a more comprehensive definition of digital transformation as: “A process where digital technologies create disruptions triggering strategic responses from organizations that seek to alter their value creation paths while managing the structural changes and organizational barriers that affect the positive and negative outcomes of this process”.

In general, the definition of digital transformation revolves around the business sector, which raises the need to define digital transformation from a national perspective and apply a new definition to future national development strategies. However, there have been few studies that define and analyse digital transformation from a national or government perspective. A few research have
explored the impacts of introducing digital technologies in public management. For example, Asgarkhani, M. (2005) examines the effectiveness and value of digital government as a strategic tool for public management reform. The research also addresses differing views and perceptions of the implications of digital government and elaborates on the "digital divide" and its impact on the success of digital government. Furthermore, the Network Readiness Index 2020 claims that the four types of digital transformation presented by McKinsey – business process, business model, domain and culture / organization – are mostly used when defining digital transformation at a country level. That being said, McKinsey's classification can be translated into the following four categories: (1) the "regalian" functions of a sovereign state (e.g., fiscal matters, laws and regulations, national security); (2) the day-to-day organization and delivery of public services (health, education, justice, and most government services); (3) the proper functioning of the economy and society according to some set of accepted rules (typically a constitution), a particular economic system, as well as a set of cultural and confessional values; and (4) the overall efficiency and performance of the national economy as a whole, as it competes on the international scene.

2.2 DIGITAL INDICES

A summary of the main indices used in the study is provided in Table 1.

The Institute for Management Development (IMD) is an independent academic institution in Switzerland, and publishes the IMD World Digital Competitiveness ranking that analyses and measures the extent of countries’ adoption and exploration of digital technologies for digital transformation in government practices, business models and society in general. While the rankings of national digital competitiveness are primarily determined by the level of digital transformation at enterprise level, they also highlight that digital transformation is taking place across all social sectors, including governments and countries. Rankings are based on three major factors – Knowledge, Technology and Future Readiness – each of which is divided into three subfactors. A total of nine subfactors comprise 52 criteria and each subfactor has the same weight. Criteria can be either hard data or soft data, with hard data given a weight of 2/3 and soft (survey) data given a weight of 1/3 due to its reliability and validity issues.

Cisco, recognizing the role of advanced digital technologies in creating education, health and employment opportunities, has released the Digital Readiness Index to measure the level of digital maturity of countries. Rather than solely focusing on a technology aspect, the Digital Readiness Index takes a more holistic approach that includes seven components – Basic Needs, Business and Government Investment, Ease of Doing Business, Human Capital, Startup Environment, Technology Infrastructure, and Technology Adoption.

As digital disruption has become the new normal and countries embrace digital technologies to prepare for the future, the Network Readiness Index, annually published by the Portulans Institute, assesses how countries are leveraging information and communications technologies (ICTs) to be future-ready. It is based on four fundamental dimensions of Technology (Access, Content, Future Technologies), People (Individuals, Businesses, Governments), Governance (Trust, Regulation, Inclusion) and Impact (Economy, Quality of Life, Sustainable Development Goal (SDG) Contribution).

The Global Competitiveness Index (GCI) 4.0 has been developed by WEF to provide guidance for long-term growth. The GCI 4.0 framework consists of 12 pillars – Institutions, Infrastructure, ICT Adoption, Macroeconomic Stability, Health, Skills, Product Market, Labour Market, Financial System, Market Size, Business Dynamism and Innovation Capability – as main drivers of productivity. The GCI has
103 indicators across the 12 pillars and places more focus on the factors that contribute to the Fourth Industrial Revolution – human capital, agility, resilience and innovation.

**Table 1: Main references used in the study**

<table>
<thead>
<tr>
<th>Report</th>
<th>Source</th>
<th>Factors</th>
<th>Weight</th>
</tr>
</thead>
</table>
| Digital Readiness Index (2019)               | Cisco                      | • Number of indicators: 25  
• 7 pillars: Basic Needs, Business and Government Investment, Ease of Doing Business, Human Capital, Startup Environment, Technology Adoption, Technology Infrastructure | Total score from 0 to 25                                              |
| Network Readiness Index (2020)               | Portulans                  | • Number of indicators: 60  
• 4 pillars: Technology, People, Governance, Impact  
• 3 subpillars under each pillar                               | Each pillar is given a weight of 25%                              |
| World Digital Competitiveness Rankings (2020) | IMD                        | • Number of indicators: 52  
• 3 pillars: Knowledge, Technology, Future Readiness  
• 3 subpillars under each pillar                               | Hard data represents a weight of 2/3 in the overall ranking whereas soft survey data represents a weight of 1/3 |
| Government Artificial Intelligence Readiness (2020) | Oxford Insights            | • Number of indicators: 33  
• 3 pillars: Government, Technology Sector, Data and Infrastructure                                          | All indicators, dimensions and pillars are weighted equally          |
| The Inclusive Internet Index (2021)          | Economist                  | • Number of indicators: 83 (59 + 24 background indicators)  
• 4 pillars: Availability, Affordability, Relevance, Readiness                                         | Availability (40%)  
Affordability (30%)  
Relevance (20%)  
Readiness (10%)                                             |
| Global Competitiveness Index (2019)          | WEF                        | • Number of indicators: 103  
• 4 areas: Enabling Environment, Human Capital, Markets, Innovation Ecosystem  
• 12 pillars: Institutions, Infrastructure, ICT Adoption, Macroeconomic Stability, Health, Skills, Product Market, Labour Market, Financial System, Market Size, Business Dynamism, Innovation Capability | Each pillar is given a weight of 8.3%                               |
| Global Innovation Index (2021)               | World Intellectual Property Organization | • Number of indicators: 81  
• 7 pillars: Institution, Human Capital and Research, Infrastructure, Market Sophistication, Business Sophistication, Knowledge and Technology Outputs, Creative Outputs |                                                                                                                                 |
3. Data and Methodology

3.1 DTI FRAMEWORK

This working paper describes the building of a country-level model of digital transformation diagnosis and the development of a new index to benchmark the leading countries. As digital transformation is the process of implementing and adopting digital technologies, the DTI applies three different digital maturity stages – Foundation, Adoption and Acceleration. Additionally, in consideration of the macroeconomic analysis tools such as the PESTEL analysis and the circular flow model, the following five thematic pillars of the DTI are used – Network / Infrastructure, Government, Business, People and Ecosystem. The DTI with a total of 105 indicators (see Appendix) incorporates data from 107 different countries worldwide, among which 29 are member States of the United Nations Economic and Social Commission for Asia and the Pacific (ESCAP).

3.2 SELECTING THE INDICATORS

The DTI framework has a total of 15 domains, comprising five pillars and three stages. Domains consist of indicators that best represent the theme of each domain, and the level of importance of each domain is primarily reflected through the number of indicators. Out of 105 indicators in total, Network and Government have eight indicators, Business has seven indicators, and People and Ecosystem have six indicators, at each stage of Foundation, Adoption and Acceleration.

The indicators have been selected from the latest available data or indicators from existing national datasets or digital-related indices developed by various organizations. In some cases, data has been directly collected and processed from the individual datasets. One of the principal considerations for the selection of indicators is whether the data is relevant to and representative of the theme of each domain. For instance, as the Network–Foundation domain focuses on the aspect of basic infrastructure, the indicators in this domain include basic networks or facilities necessary to provide digital services, such as access to electricity, ease of getting electricity and the number of wired Internet users. On the other hand, the indicators in the Network–Acceleration domain are based on the data related to technology necessary to provide more advanced services such as 5G connections or public cloud. With these considerations, the DTI is thus differentiated from other digital-related indices in that it attempts to capture the dynamic features of digital transformation.

As is the case in many other indices, the DTI includes quite a few indicators that are based on survey data, despite the difficulty to maintain objectivity and reliability. The survey responses inevitably depend on the subjectivity of the responders, which sometimes leads to biases or distorts the reliability for many reasons, including different baselines by countries or backgrounds. However, the reason the DTI has included those survey data is because there are some important factors that cannot be quantified or inferred from the numbers, such as the level of intellectual property protection, the extent of the burden of government regulations, trust in online privacy and so forth. In these cases, survey data based on well-designed questionnaires with sufficient number of responses can be useful tools. The DTI includes 34 survey data in total, which accounts for 32 per cent of the entire dataset.

In order to deal with the inherent problem of the objectivity of survey data, the study halved the
weight of survey data in the DTI by setting the maximum point for qualitative data at 50, whereas the maximum point for quantitative data is 100. Table 2 provides an overview of the selected indicators by each stage and pillar.

**Figure 1: The DTI framework**

![Digital Transformation Index Framework Diagram]

(Total: 105 indicators)

3 Stages

<table>
<thead>
<tr>
<th>5 Pillars</th>
<th>DT Foundation</th>
<th>DT Adoption</th>
<th>DT Acceleration</th>
</tr>
</thead>
<tbody>
<tr>
<td>NW / Infra</td>
<td>Network Availability and Affordability</td>
<td>Quality Connectivity</td>
<td>Inclusive Connectivity</td>
</tr>
<tr>
<td>Government</td>
<td>Investment and Regulation</td>
<td>Applications and Services</td>
<td>Inclusive Competitiveness</td>
</tr>
<tr>
<td>Business</td>
<td>ICT Market</td>
<td>Digital Market</td>
<td>Innovation Market</td>
</tr>
<tr>
<td>People</td>
<td>Basic Skills and Education</td>
<td>Digital Skills and Literacy</td>
<td>Digital Capacity and Creativity</td>
</tr>
<tr>
<td>Ecosystem</td>
<td>Macroeconomic Stability</td>
<td>Diversity and Dynamism</td>
<td>Environmental Sustainability</td>
</tr>
</tbody>
</table>

Notes: DT = Digital Transformation; NW = Network; and Infra = Infrastructure.

Source: Elaborated by the author, based on secondary sources such as WEF, IMD, Economist, Global System for Mobile Communications Association, World Intellectual Property Organization, Cisco, World Bank, etc.

**Table 2: Indicators by stage and pillar**

<table>
<thead>
<tr>
<th>Pillar / Stage</th>
<th>Foundation</th>
<th>Adoption</th>
<th>Acceleration</th>
</tr>
</thead>
<tbody>
<tr>
<td>Network / Infrastructure</td>
<td>Network Availability and Affordability</td>
<td>Quality Connectivity</td>
<td>Inclusive Connectivity</td>
</tr>
<tr>
<td></td>
<td>Total electricity access</td>
<td>Smartphone penetration</td>
<td>5G coverage</td>
</tr>
<tr>
<td></td>
<td>Days to get electricity</td>
<td>Average revenue per user</td>
<td>5G deployment</td>
</tr>
<tr>
<td></td>
<td>Mobile subscribers</td>
<td>Average fixed-broadband download speed</td>
<td>Public cloud services spending</td>
</tr>
<tr>
<td></td>
<td>Fixed-line broadband subscribers</td>
<td>Mobile download speed</td>
<td>Gender equality in mobile phone access</td>
</tr>
</tbody>
</table>

1 The assignment of different weights is an approach that acknowledges the researchers’ subjectivity and interpretations. For example, while IMD gives a weight of 1/3 to survey data, the DTI assigns 50 per cent.
# Methodology for Data Analysis of Digital Transformation (version 1)

<table>
<thead>
<tr>
<th><strong>Internet users</strong></th>
<th><strong>Average mobile latency</strong></th>
<th><strong>Gender equality in Internet use</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Mobile tariff affordability</strong></td>
<td><strong>Tablet possession</strong></td>
<td><strong>Government effort to promote 5G</strong></td>
</tr>
<tr>
<td><strong>Fixed-line broadband affordability</strong></td>
<td><strong>4G coverage</strong></td>
<td><strong>Government initiatives to make Wi-Fi available</strong></td>
</tr>
<tr>
<td><strong>Handset prices affordability</strong></td>
<td><strong>Servers per population</strong></td>
<td><strong>Private sector initiatives to make Wi-Fi available</strong></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th><strong>Investment and Regulation</strong></th>
<th><strong>Applications and Services</strong></th>
<th><strong>Inclusive Competitiveness</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Ease of doing business</strong></td>
<td><strong>e-Government Index</strong></td>
<td><strong>National artificial intelligence policies</strong></td>
</tr>
<tr>
<td><strong>Intellectual property protection</strong></td>
<td><strong>e-Participation Index</strong></td>
<td><strong>Publication and use of open data</strong></td>
</tr>
<tr>
<td><strong>ICT regulatory environment</strong></td>
<td><strong>Online Service Index</strong></td>
<td><strong>Artificial Intelligence Readiness Index</strong></td>
</tr>
<tr>
<td><strong>Privacy regulation</strong></td>
<td><strong>Legal framework's adaptability to digital business models</strong></td>
<td><strong>Open data policies</strong></td>
</tr>
<tr>
<td><strong>Burden of government regulation</strong></td>
<td><strong>National digital identification system</strong></td>
<td><strong>Trust in online privacy</strong></td>
</tr>
<tr>
<td><strong>Business and government investment</strong></td>
<td><strong>Government effectiveness</strong></td>
<td><strong>Trust in government websites and apps</strong></td>
</tr>
<tr>
<td><strong>Research and development expenditure by government and higher education</strong></td>
<td><strong>Government's responsiveness to change</strong></td>
<td><strong>Online security</strong></td>
</tr>
<tr>
<td><strong>Government promotion of investment in emerging technologies</strong></td>
<td><strong>e-Commerce legislation</strong></td>
<td><strong>Future orientation of government</strong></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th><strong>ICT Market</strong></th>
<th><strong>Digital Market</strong></th>
<th><strong>Innovation Market</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Foreign direct investment net flow</strong></td>
<td><strong>Computer software spending</strong></td>
<td><strong>Startup environment</strong></td>
</tr>
<tr>
<td><strong>Research and development expenditures by business</strong></td>
<td><strong>Venture capital availability</strong></td>
<td><strong>Robot density</strong></td>
</tr>
<tr>
<td><strong>Business environment</strong></td>
<td><strong>Mobile apps development</strong></td>
<td><strong>Use of big data analytics</strong></td>
</tr>
<tr>
<td><strong>High-tech exports</strong></td>
<td><strong>Digital content (news) in local languages</strong></td>
<td><strong>Innovation capability</strong></td>
</tr>
<tr>
<td><strong>Medium- and high-tech industry</strong></td>
<td><strong>e-Government services in local languages</strong></td>
<td><strong>Adoption of emerging technologies</strong></td>
</tr>
<tr>
<td><strong>Labour productivity per employee</strong></td>
<td><strong>Business use of digital tools</strong></td>
<td><strong>Number of tech unicorns</strong></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th><strong>People</strong></th>
<th><strong>Basic Skills and Education</strong></th>
<th><strong>Digital Skills and Literacy</strong></th>
<th><strong>Digital Capacity and Creativity</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Basic Skills and Education</strong></td>
<td><strong>Digital Skills and Literacy</strong></td>
<td><strong>Digital Capacity and Creativity</strong></td>
<td></td>
</tr>
</tbody>
</table>
### 3.3 SELECTING COUNTRIES FOR ANALYSIS AND HANDLING MISSING DATA

Currently, the United Nations has 193\(^2\) member States. The researchers tried to include as many countries as possible in the DTI for comparative analysis among countries and regions, but countries with insufficient data to diagnose their digital transformation status were inevitably excluded from the DTI. A total of 183 countries out of 193 were originally included in the DTI, but countries that did not meet the 80 per cent of data availability across 105 indicators were excluded from the final analysis. Therefore, a total of 107 countries, including Hong Kong, were included in the DTI. One of the most conspicuous findings of the DTI is that most of the countries excluded from the DTI due to limited data availability are low-income countries.

---

\(^2\) Although Hong Kong is not counted as a member State in the United Nations, it is included in this study as a separate country as Hong Kong is an associate member of ESCAP and has many distinct features that are different from China. Thus, the total number of countries in this study is 194.
Surprisingly, more than 49 per cent of middle-income countries did not have enough data for the 105 indicators related to digital transformation. On the contrary, 78 per cent of high-income countries had sufficient data to examine their digital transformation status.

Considering that 45 per cent of United Nations member States did not have enough data to diagnose the progress of digital transformation, building data infrastructure for these countries must be prioritized.

Although the number of ESCAP member States in the DTI was originally 29, only 25 countries – excluding France, Netherlands, United Kingdom and United States of America – were treated as ESCAP member States in order to focus the analysis on countries that geographically belong to the Asia-Pacific region.

### 3.4 HANDLING MISSING VALUES

A significant number of missing values were found across the 107 countries and 105 indicators, and those missing values were calculated through imputation. In general, the missing values were estimated with coefficients obtained through regression analysis on neighbouring countries with similar attributes.

While this method reflects various information and thus, improves the accuracy in predicting the actual value of the missing data, the method also causes inefficiency due to the need to perform regression analysis for estimating each missing value. To resolve the issue of inefficiency, the study first normalized the raw data and replaced the missing values with the average value of the data of countries with similar income levels in the same region. For example, if a mobile subscription data of one of the low-income countries in Latin America was missing, the missing data was replaced with the average value of mobile subscription data from neighbouring countries with the same income level.

### 3.5 NORMALIZATION AND CALCULATION OF DTI

The data used to calculate the DTI had distinct characteristics for each indicator. Those characteristics include not only differences in scale and the existence of outliers, but also their representation (usually as a few integers such as 1, 2, 3, 4 or 5) in the case of survey data. Hence, data was normalized to ensure that all data points were reflected in the same scale. Min-max normalization and z-score normalization are two of the most commonly used normalization methods. The min-max normalization brings all data points into the range between 0 and 100. For example, if a raw
data has the maximum value of 60 and the minimum value of 25, these two values are normalized to become 100 and 0, respectively. A specific data value of X can be normalized using the following formula:

\[(X – MIN) * 100 / (MAX – MIN)\]

The z-score normalization converts data values into Z-scores, where the data value of X will have a normalized value by using the following formula:

\[(X – \text{average}) / \text{standard deviation}\]

If a value of X coincides with the mean, then it is normalized to 0. A normalized value is positive if the value of X lies above the mean, and negative if it lies below the mean. And the size of those positive and negative numbers is determined by the standard deviation of the original feature.

Since each of the normalization methods has its pros and cons, it is important to understand what they are. One of the limitations of min-max normalization is that it does not handle outliers very well, while the z-score normalization has a disadvantage of not producing normalized data within the same interval.

In this study, the min-max normalization was applied. To handle outliers, the distribution's skewness and kurtosis of the indicator data were first examined and when the absolute values of each exceed 3 and 7, then those were considered as outliers and thus, need to be processed. In addition, interquartiles were used to detect outliers. First, the quartile deviation was defined as \([Q3-Q1]\), a low outlier was defined as a value smaller than \([Q1-1.5*\text{quartile deviation}]\), and a high outlier was defined as a value higher than \([Q3+1.5*\text{quartile deviation}]\) to detect outliers. Then, high outliers were replaced with the maximum value of the normal range, and low outliers with minimum value of the normal range. The number of indicators with outlier treatment in this study was 4 for high outliers and 3 for low outliers.

Another consideration when sorting the data is that some data are represented in a reverse order, which must be aligned when reflected in the indicators. For example, as the Handset Price Affordability expresses the price level of mobile devices in each country, the country with a lower number (price) should be converted into a higher score in the DTI. Therefore, for these indicators, the min-max normalization should be performed in a reversed way as shown in the following formula:

\[(MAX - X) * 100 / (MAX – MIN)\]

### 3.6 Calculation of Total Scores

The total DTI score for each country was calculated as follows. First, the raw data values of the hard data were normalized on a scale of 0 to 100, and the survey data on a scale of 0 to 50. Second, the missing values in the normalized dataset were imputed with methods described above and each sum of the 15 domains was calculated. Third, as the sum of each domain varies by the number of indicators in the domains, the sums were again normalized on a scale of 0 to 100. Fourth, the weights were given to each of the normalized domains: 0.3 to Foundation, 0.3 to Adoption and 0.4 to Acceleration (stages); \(^3\) and 0.3 to Network, 0.2 to Government, 0.2 to Business, 0.15 to People and 0.15 to Ecosystem (pillars). \(^4\) assigns a higher weight to the Acceleration stage.

\(^3\) Each stage is introduced to represent or measure the extent of basic infrastructure, utilization and potential for advancing digital transformation. In consideration of the future-oriented approaches of digital transformation, the DTI assigns a higher weight to the Acceleration stage.

\(^4\) The weights are assigned in consideration of the area's relation to digital transformation or need for digitalization. As
For instance, for the Network–Foundation domain, 0.09 (0.3 to Network * 0.3 to Foundation) was given as a weight and a new value for the Network–Foundation domain was calculated. Fifth, with the tallying of all new values of weighted domains, the total score was again normalized on a scale of 0 to 100 and the rank was determined.
4. DTI Results Analysis

4.1 OVERALL RANKING ANALYSIS

DTI Ranking and Grade Level by Country

Table 3 shows the final rankings and total scores of DTI 2022 by country. The DTI scores have been calculated by combining the weighted scores of each stage and pillar. In addition, the countries analysed through this DTI framework have been grouped into five Grades – S (above 80), A (above 60), B (above 40), C (above 20) and D (below 20), based on their DTI scores.

Table 3: DTI rankings, scores and grade levels by country

<table>
<thead>
<tr>
<th>Rank</th>
<th>Country</th>
<th>Region</th>
<th>DTI score</th>
<th>ESCAP</th>
<th>Income group</th>
<th>Grade</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>United States of America</td>
<td>Northern America</td>
<td>88.45</td>
<td></td>
<td>High</td>
<td>S</td>
</tr>
<tr>
<td>2</td>
<td>Switzerland</td>
<td>Western Europe</td>
<td>86.97</td>
<td></td>
<td>High</td>
<td>S</td>
</tr>
<tr>
<td>3</td>
<td>United Kingdom of Great Britain and Northern Ireland</td>
<td>Northern Europe</td>
<td>86.33</td>
<td></td>
<td>High</td>
<td>S</td>
</tr>
<tr>
<td>4</td>
<td>Singapore</td>
<td>South-East Asia</td>
<td>83.83</td>
<td>Y</td>
<td>High</td>
<td>S</td>
</tr>
<tr>
<td>5</td>
<td>Germany</td>
<td>Western Europe</td>
<td>83.81</td>
<td></td>
<td>High</td>
<td>S</td>
</tr>
<tr>
<td>6</td>
<td>Sweden</td>
<td>Northern Europe</td>
<td>83.62</td>
<td></td>
<td>High</td>
<td>S</td>
</tr>
<tr>
<td>7</td>
<td>Denmark</td>
<td>Northern Europe</td>
<td>82.01</td>
<td></td>
<td>High</td>
<td>S</td>
</tr>
<tr>
<td>8</td>
<td>Netherlands</td>
<td>Western Europe</td>
<td>81.83</td>
<td></td>
<td>High</td>
<td>S</td>
</tr>
<tr>
<td>9</td>
<td>Republic of Korea</td>
<td>East and North-East Asia</td>
<td>80.25</td>
<td>Y</td>
<td>High</td>
<td>S</td>
</tr>
<tr>
<td>10</td>
<td>Finland</td>
<td>Northern Europe</td>
<td>80.21</td>
<td></td>
<td>High</td>
<td>S</td>
</tr>
<tr>
<td>11</td>
<td>Canada</td>
<td>Northern America</td>
<td>79.89</td>
<td></td>
<td>High</td>
<td>S</td>
</tr>
<tr>
<td>12</td>
<td>Australia</td>
<td>Pacific</td>
<td>79.44</td>
<td>Y</td>
<td>High</td>
<td>A</td>
</tr>
<tr>
<td>13</td>
<td>Austria</td>
<td>Western Europe</td>
<td>78.03</td>
<td></td>
<td>High</td>
<td>A</td>
</tr>
<tr>
<td>14</td>
<td>Hong Kong, China</td>
<td>East and North-East Asia</td>
<td>77.12</td>
<td>Y</td>
<td>High</td>
<td>A</td>
</tr>
<tr>
<td>15</td>
<td>Luxembourg</td>
<td>Western Europe</td>
<td>76.90</td>
<td></td>
<td>High</td>
<td>A</td>
</tr>
<tr>
<td>16</td>
<td>Ireland</td>
<td>Northern Europe</td>
<td>75.29</td>
<td></td>
<td>High</td>
<td>A</td>
</tr>
<tr>
<td>17</td>
<td>Japan</td>
<td>East and North-East Asia</td>
<td>74.86</td>
<td>Y</td>
<td>High</td>
<td>A</td>
</tr>
<tr>
<td>18</td>
<td>Norway</td>
<td>Northern Europe</td>
<td>74.58</td>
<td></td>
<td>High</td>
<td>A</td>
</tr>
<tr>
<td>19</td>
<td>France</td>
<td>Western Europe</td>
<td>74.46</td>
<td></td>
<td>High</td>
<td>A</td>
</tr>
<tr>
<td>20</td>
<td>New Zealand</td>
<td>Pacific</td>
<td>73.05</td>
<td>Y</td>
<td>High</td>
<td>A</td>
</tr>
<tr>
<td>21</td>
<td>Israel</td>
<td>Western Asia</td>
<td>72.12</td>
<td></td>
<td>High</td>
<td>A</td>
</tr>
<tr>
<td>22</td>
<td>Belgium</td>
<td>Western Europe</td>
<td>71.95</td>
<td></td>
<td>High</td>
<td>A</td>
</tr>
<tr>
<td>23</td>
<td>Spain</td>
<td>Southern Europe</td>
<td>70.77</td>
<td></td>
<td>High</td>
<td>A</td>
</tr>
<tr>
<td>24</td>
<td>United Arab Emirates</td>
<td>Western Asia</td>
<td>69.42</td>
<td></td>
<td>High</td>
<td>A</td>
</tr>
<tr>
<td>25</td>
<td>Estonia</td>
<td>Northern Europe</td>
<td>68.41</td>
<td></td>
<td>High</td>
<td>A</td>
</tr>
<tr>
<td></td>
<td>Country</td>
<td>Region</td>
<td>Index</td>
<td>Level</td>
<td>Grade</td>
<td></td>
</tr>
<tr>
<td>---</td>
<td>---------------</td>
<td>-------------------------</td>
<td>-------</td>
<td>--------------</td>
<td>-------</td>
<td></td>
</tr>
<tr>
<td>26</td>
<td>Qatar</td>
<td>Western Asia</td>
<td>66.84</td>
<td>High</td>
<td>A</td>
<td></td>
</tr>
<tr>
<td>27</td>
<td>Iceland</td>
<td>Northern Europe</td>
<td>66.68</td>
<td>High</td>
<td>A</td>
<td></td>
</tr>
<tr>
<td>28</td>
<td>China</td>
<td>East and North-East Asia</td>
<td>66.54</td>
<td>Y</td>
<td>Upper-middle</td>
<td>A</td>
</tr>
<tr>
<td>29</td>
<td>Italy</td>
<td>Southern Europe</td>
<td>65.41</td>
<td>High</td>
<td>A</td>
<td></td>
</tr>
<tr>
<td>30</td>
<td>Czech Republic</td>
<td>Eastern Europe</td>
<td>63.64</td>
<td>High</td>
<td>A</td>
<td></td>
</tr>
<tr>
<td>31</td>
<td>Malaysia</td>
<td>South-East Asia</td>
<td>63.60</td>
<td>Y</td>
<td>Upper-middle</td>
<td>A</td>
</tr>
<tr>
<td>32</td>
<td>Portugal</td>
<td>Southern Europe</td>
<td>62.87</td>
<td>High</td>
<td>A</td>
<td></td>
</tr>
<tr>
<td>33</td>
<td>Lithuania</td>
<td>Northern Europe</td>
<td>61.24</td>
<td>High</td>
<td>A</td>
<td></td>
</tr>
<tr>
<td>34</td>
<td>Slovakia</td>
<td>Eastern Europe</td>
<td>59.05</td>
<td>High</td>
<td>B</td>
<td></td>
</tr>
<tr>
<td>35</td>
<td>Saudi Arabia</td>
<td>Western Asia</td>
<td>58.65</td>
<td>High</td>
<td>B</td>
<td></td>
</tr>
<tr>
<td>36</td>
<td>Poland</td>
<td>Eastern Europe</td>
<td>58.35</td>
<td>High</td>
<td>B</td>
<td></td>
</tr>
<tr>
<td>37</td>
<td>Chile</td>
<td>South America</td>
<td>58.05</td>
<td>High</td>
<td>B</td>
<td></td>
</tr>
<tr>
<td>38</td>
<td>Latvia</td>
<td>Northern Europe</td>
<td>57.20</td>
<td>High</td>
<td>B</td>
<td></td>
</tr>
<tr>
<td>39</td>
<td>Hungary</td>
<td>Eastern Europe</td>
<td>55.52</td>
<td>High</td>
<td>B</td>
<td></td>
</tr>
<tr>
<td>40</td>
<td>Romania</td>
<td>Eastern Europe</td>
<td>54.60</td>
<td>High</td>
<td>B</td>
<td></td>
</tr>
<tr>
<td>41</td>
<td>Bahrain</td>
<td>Western Asia</td>
<td>54.52</td>
<td>High</td>
<td>B</td>
<td></td>
</tr>
<tr>
<td>42</td>
<td>Bulgaria</td>
<td>Eastern Europe</td>
<td>52.92</td>
<td>Upper-middle</td>
<td>B</td>
<td></td>
</tr>
<tr>
<td>43</td>
<td>Russian Federation</td>
<td>North and Central Asia</td>
<td>52.46</td>
<td>Y</td>
<td>Upper-middle</td>
<td>B</td>
</tr>
<tr>
<td>44</td>
<td>Uruguay</td>
<td>South America</td>
<td>52.23</td>
<td>High</td>
<td>B</td>
<td></td>
</tr>
<tr>
<td>45</td>
<td>Oman</td>
<td>Western Asia</td>
<td>51.76</td>
<td>High</td>
<td>B</td>
<td></td>
</tr>
<tr>
<td>46</td>
<td>Thailand</td>
<td>South-East Asia</td>
<td>50.56</td>
<td>Y</td>
<td>Upper-middle</td>
<td>B</td>
</tr>
<tr>
<td>47</td>
<td>Mexico</td>
<td>Central America</td>
<td>50.02</td>
<td>Upper-middle</td>
<td>B</td>
<td></td>
</tr>
<tr>
<td>48</td>
<td>Greece</td>
<td>Southern Europe</td>
<td>49.77</td>
<td>High</td>
<td>B</td>
<td></td>
</tr>
<tr>
<td>49</td>
<td>Turkey</td>
<td>South and South-West Asia</td>
<td>49.72</td>
<td>Y</td>
<td>Upper-middle</td>
<td>B</td>
</tr>
<tr>
<td>50</td>
<td>Kuwait</td>
<td>Western Asia</td>
<td>49.57</td>
<td>High</td>
<td>B</td>
<td></td>
</tr>
<tr>
<td>51</td>
<td>Brazil</td>
<td>South America</td>
<td>48.88</td>
<td>Upper-middle</td>
<td>B</td>
<td></td>
</tr>
<tr>
<td>52</td>
<td>South Africa</td>
<td>Southern Africa</td>
<td>48.74</td>
<td>Upper-middle</td>
<td>B</td>
<td></td>
</tr>
<tr>
<td>53</td>
<td>Costa Rica</td>
<td>Central America</td>
<td>47.29</td>
<td>Upper-middle</td>
<td>B</td>
<td></td>
</tr>
<tr>
<td>54</td>
<td>Indonesia</td>
<td>South-East Asia</td>
<td>47.19</td>
<td>Y</td>
<td>Upper-middle</td>
<td>B</td>
</tr>
<tr>
<td>55</td>
<td>Croatia</td>
<td>Southern Europe</td>
<td>47.07</td>
<td>High</td>
<td>B</td>
<td></td>
</tr>
<tr>
<td>56</td>
<td>India</td>
<td>South and South-West Asia</td>
<td>46.79</td>
<td>Y</td>
<td>Lower-middle</td>
<td>B</td>
</tr>
<tr>
<td>57</td>
<td>Argentina</td>
<td>South America</td>
<td>46.48</td>
<td>Upper-middle</td>
<td>B</td>
<td></td>
</tr>
<tr>
<td>58</td>
<td>Philippines</td>
<td>South-East Asia</td>
<td>46.32</td>
<td>Y</td>
<td>Lower-middle</td>
<td>B</td>
</tr>
<tr>
<td>59</td>
<td>Ukraine</td>
<td>Eastern Europe</td>
<td>44.78</td>
<td>Lower-middle</td>
<td>B</td>
<td></td>
</tr>
<tr>
<td>60</td>
<td>Colombia</td>
<td>South America</td>
<td>44.57</td>
<td>Upper-middle</td>
<td>B</td>
<td></td>
</tr>
<tr>
<td>61</td>
<td>Azerbaijan</td>
<td>North and Central Asia</td>
<td>44.56</td>
<td>Y</td>
<td>Upper-middle</td>
<td>B</td>
</tr>
<tr>
<td></td>
<td>Country</td>
<td>Region</td>
<td>GDP</td>
<td>Status</td>
<td>Group</td>
<td></td>
</tr>
<tr>
<td>---</td>
<td>-------------------------------</td>
<td>---------------------------------</td>
<td>-------</td>
<td>----------</td>
<td>-------</td>
<td></td>
</tr>
<tr>
<td>62</td>
<td>Kazakhstan</td>
<td>North and Central Asia</td>
<td>43.54</td>
<td>Y</td>
<td>B</td>
<td></td>
</tr>
<tr>
<td>63</td>
<td>Viet Nam</td>
<td>South-East Asia</td>
<td>43.28</td>
<td>Y</td>
<td>B</td>
<td></td>
</tr>
<tr>
<td>64</td>
<td>Panama</td>
<td>Central America</td>
<td>42.07</td>
<td></td>
<td>B</td>
<td></td>
</tr>
<tr>
<td>65</td>
<td>Jordan</td>
<td>Western Asia</td>
<td>42.04</td>
<td>Upper</td>
<td>B</td>
<td></td>
</tr>
<tr>
<td>66</td>
<td>Peru</td>
<td>South America</td>
<td>41.21</td>
<td>Upper</td>
<td>B</td>
<td></td>
</tr>
<tr>
<td>67</td>
<td>Jamaica</td>
<td>Caribbean</td>
<td>38.31</td>
<td></td>
<td>C</td>
<td></td>
</tr>
<tr>
<td>68</td>
<td>Morocco</td>
<td>Northern Africa</td>
<td>38.13</td>
<td></td>
<td>C</td>
<td></td>
</tr>
<tr>
<td>69</td>
<td>Trinidad and Tobago</td>
<td>Caribbean</td>
<td>38.12</td>
<td>High</td>
<td>C</td>
<td></td>
</tr>
<tr>
<td>70</td>
<td>Egypt</td>
<td>Northern Africa</td>
<td>37.87</td>
<td>Lower</td>
<td>C</td>
<td></td>
</tr>
<tr>
<td>71</td>
<td>Tunisia</td>
<td>Northern Africa</td>
<td>37.61</td>
<td>Lower</td>
<td>C</td>
<td></td>
</tr>
<tr>
<td>72</td>
<td>Dominican Republic</td>
<td>Caribbean</td>
<td>37.49</td>
<td>Upper</td>
<td>C</td>
<td></td>
</tr>
<tr>
<td>73</td>
<td>Iran (Islamic Republic of)</td>
<td>South and South-West Asia</td>
<td>36.22</td>
<td>Y</td>
<td>C</td>
<td></td>
</tr>
<tr>
<td>74</td>
<td>Kenya</td>
<td>Eastern Africa</td>
<td>35.73</td>
<td>Low</td>
<td>C</td>
<td></td>
</tr>
<tr>
<td>75</td>
<td>Ecuador</td>
<td>South America</td>
<td>35.66</td>
<td>Low</td>
<td>C</td>
<td></td>
</tr>
<tr>
<td>76</td>
<td>Lebanon</td>
<td>Western Asia</td>
<td>34.40</td>
<td>Low</td>
<td>C</td>
<td></td>
</tr>
<tr>
<td>77</td>
<td>Botswana</td>
<td>Southern Africa</td>
<td>34.21</td>
<td>Low</td>
<td>C</td>
<td></td>
</tr>
<tr>
<td>78</td>
<td>Mongolia</td>
<td>East and North-East Asia</td>
<td>33.91</td>
<td>Y</td>
<td>C</td>
<td></td>
</tr>
<tr>
<td>79</td>
<td>Sri Lanka</td>
<td>South and South-West Asia</td>
<td>32.46</td>
<td>Y</td>
<td>C</td>
<td></td>
</tr>
<tr>
<td>80</td>
<td>Paraguay</td>
<td>South America</td>
<td>31.14</td>
<td>Low</td>
<td>C</td>
<td></td>
</tr>
<tr>
<td>81</td>
<td>Ghana</td>
<td>Western Africa</td>
<td>30.77</td>
<td>Low</td>
<td>C</td>
<td></td>
</tr>
<tr>
<td>82</td>
<td>Namibia</td>
<td>Southern Africa</td>
<td>28.14</td>
<td>Low</td>
<td>C</td>
<td></td>
</tr>
<tr>
<td>83</td>
<td>Rwanda</td>
<td>Eastern Africa</td>
<td>27.66</td>
<td>Low</td>
<td>C</td>
<td></td>
</tr>
<tr>
<td>84</td>
<td>Guatemala</td>
<td>Central America</td>
<td>26.55</td>
<td>Low</td>
<td>C</td>
<td></td>
</tr>
<tr>
<td>85</td>
<td>Senegal</td>
<td>Western Africa</td>
<td>26.38</td>
<td>Low</td>
<td>C</td>
<td></td>
</tr>
<tr>
<td>86</td>
<td>Algeria</td>
<td>Northern Africa</td>
<td>25.97</td>
<td>Low</td>
<td>C</td>
<td></td>
</tr>
<tr>
<td>87</td>
<td>El Salvador</td>
<td>Central America</td>
<td>25.63</td>
<td>Low</td>
<td>C</td>
<td></td>
</tr>
<tr>
<td>88</td>
<td>Cambodia</td>
<td>South-East Asia</td>
<td>25.52</td>
<td></td>
<td>C</td>
<td></td>
</tr>
<tr>
<td>89</td>
<td>Lao People's Democratic Republic</td>
<td>South-East Asia</td>
<td>25.44</td>
<td>Y</td>
<td>C</td>
<td></td>
</tr>
<tr>
<td>90</td>
<td>Bangladesh</td>
<td>South and South-West Asia</td>
<td>25.35</td>
<td>Y</td>
<td>C</td>
<td></td>
</tr>
<tr>
<td>91</td>
<td>Pakistan</td>
<td>South and South-West Asia</td>
<td>25.03</td>
<td>Y</td>
<td>C</td>
<td></td>
</tr>
<tr>
<td>92</td>
<td>Honduras</td>
<td>Central America</td>
<td>24.25</td>
<td></td>
<td>C</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Country</td>
<td>Region</td>
<td>DTI</td>
<td>Grade</td>
<td>Type</td>
<td></td>
</tr>
<tr>
<td>---</td>
<td>-----------------------------</td>
<td>-------------------------</td>
<td>------</td>
<td>-------</td>
<td>-------</td>
<td></td>
</tr>
<tr>
<td>93</td>
<td>Uganda</td>
<td>Eastern Africa</td>
<td>24.06</td>
<td>Low</td>
<td>C</td>
<td></td>
</tr>
<tr>
<td>94</td>
<td>Nepal</td>
<td>South and South-West Asia</td>
<td>23.91</td>
<td>Y</td>
<td>Lower-middle</td>
<td>C</td>
</tr>
<tr>
<td>95</td>
<td>Nigeria</td>
<td>Western Africa</td>
<td>23.09</td>
<td></td>
<td>Lower-middle</td>
<td>C</td>
</tr>
<tr>
<td>96</td>
<td>Côte d'Ivoire</td>
<td>Western Africa</td>
<td>22.22</td>
<td></td>
<td>Lower-middle</td>
<td>C</td>
</tr>
<tr>
<td>97</td>
<td>United Republic of Tanzania</td>
<td>Eastern Africa</td>
<td>20.72</td>
<td></td>
<td>Lower-middle</td>
<td>C</td>
</tr>
<tr>
<td>98</td>
<td>Zambia</td>
<td>Eastern Africa</td>
<td>19.63</td>
<td></td>
<td>Lower-middle</td>
<td>C</td>
</tr>
<tr>
<td>99</td>
<td>Zimbabwe</td>
<td>Eastern Africa</td>
<td>18.95</td>
<td></td>
<td>Lower-middle</td>
<td>D</td>
</tr>
<tr>
<td>100</td>
<td>Cameroon</td>
<td>Middle Africa</td>
<td>17.99</td>
<td></td>
<td>Lower-middle</td>
<td>D</td>
</tr>
<tr>
<td>101</td>
<td>Benin</td>
<td>Western Africa</td>
<td>17.62</td>
<td></td>
<td>Lower-middle</td>
<td>D</td>
</tr>
<tr>
<td>102</td>
<td>Mali</td>
<td>Western Africa</td>
<td>13.60</td>
<td></td>
<td>Low</td>
<td>D</td>
</tr>
<tr>
<td>103</td>
<td>Malawi</td>
<td>Eastern Africa</td>
<td>12.50</td>
<td></td>
<td>Low</td>
<td>D</td>
</tr>
<tr>
<td>104</td>
<td>Burkina Faso</td>
<td>Western Africa</td>
<td>12.22</td>
<td></td>
<td>Low</td>
<td>D</td>
</tr>
<tr>
<td>105</td>
<td>Madagascar</td>
<td>Eastern Africa</td>
<td>10.75</td>
<td></td>
<td>Low</td>
<td>D</td>
</tr>
<tr>
<td>106</td>
<td>Mozambique</td>
<td>Eastern Africa</td>
<td>10.60</td>
<td></td>
<td>Low</td>
<td>D</td>
</tr>
<tr>
<td>107</td>
<td>Angola</td>
<td>Middle Africa</td>
<td>7.89</td>
<td></td>
<td>Lower-middle</td>
<td>D</td>
</tr>
</tbody>
</table>

Figure 3 displays the DTI rankings of countries on a world map for a global overview of the level of digital transformation. Only 11 countries – United States of America, Switzerland, United Kingdom, Singapore, Germany, Sweden, Denmark, Netherlands, Republic of Korea, Finland and Canada – are classified as Grade S, and all of them except Singapore and Republic Korea are located in Europe and North America. These countries have consistently ranked high across various digital-related indices and national competitiveness indices, forming a leading group in digital transformation at an international level. The countries classified as Grade B, or the middle-ranked countries, are mostly the upper-middle- or lower-middle-income countries and they are evenly located throughout South-East Asia, Eastern Europe and South America. The countries in Grade D or the lowest-ranked countries are primarily the low-income countries in Africa.
**Figure 3: The world map of DTI 2022**

**DTI Grade by Income Level**

The DTI finds a clear correlation between a country’s income level and its level of digital transformation. Figure 4 presents the distribution of countries within the same income level by grade. The high-income countries are distributed from Grade S to Grade C, the upper-middle-income countries – Grades A, B and C, the lower-middle-income countries – Grades B, C, D, while the low-income countries are distributed only in Grades C and D. The average DTI scores consistently decrease with income levels, and the difference in the average DTI scores between high-income countries and upper-middle-income countries is greater than those between upper-middle-income and lower-middle-income countries, or between lower-middle-income and low-income countries.

Even though the study replaces the missing values with the average value of the data of countries with similar income levels in the same region, the number of missing values replaced is very small, and thus, the high correlation between the income levels and the DTI stands valid.
analysis on these superior-performing countries can generate insights that contribute to their better performance and provide good practices for other countries in the same income level.

**Figure 4: DTI scores and number of countries by income and grade level**

Table 4 summarizes the number of countries by each grade and income level, and identifies the superior-performing countries with relatively higher scores and the inferior-performing countries with relatively lower scores in the same income level. Among the high-income countries, 11 countries with Grade S are the superior-performing countries and Trinidad Tobago scores low in DTI compared to its income level. While most of the upper-middle-income countries are classified as Grade B, China and Malaysia are graded as A, displaying excellent performance in digital transformation within the same income level. On the other hand, the countries with Grade C – Botswana, Dominican Republic, Ecuador, Guatemala, Iran, Jamaica, Lebanon, Namibia and Paraguay – exhibit relatively lower DTI scores in this income level. For the lower-middle-income group, India, Philippines, Ukraine and Viet Nam are identified as the superior-performing countries, whereas Angola, Benin, Cameroon and Zimbabwe are identified as the inferior-performing countries. All countries in the low-income group are categorized into Grades C and D.
### Table 4: Countries by income and grade level

<table>
<thead>
<tr>
<th></th>
<th>High</th>
<th>Upper-Middle</th>
<th>Lower-Middle</th>
<th>Low</th>
</tr>
</thead>
<tbody>
<tr>
<td>S</td>
<td>USA, Switzerland, UK, Singapore, Germany, Sweden, Denmark, Netherland, Republic of Korea, Finland, Canada</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Australia, Austria, Hong Kong, Luxembourg, Ireland, Japan, Norway, France, New Zealand, Israel, Belgium, Spain, United Arab Emirates, Estonia, Qatar, Iceland, Italy, Czech Republic, Portugal, Lithuania</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>A</td>
<td></td>
<td>China, Malaysia</td>
<td></td>
<td></td>
</tr>
<tr>
<td>A</td>
<td></td>
<td>Bulgaria, Russian Federation, Thailand, Mexico, Turkey, Brazil, South Africa, Costa Rica, Indonesia, Argentina, Colombia, Azerbaijan, Kazakhstan, Jordan, Peru</td>
<td></td>
<td></td>
</tr>
<tr>
<td>B</td>
<td>Slovakia, Saudi Arabia, Poland, Chile, Latvia, Hungary, Romania, Bahrain, Uruguay, Oman, Greece, Kuwait, Croatia, Panama</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>B</td>
<td></td>
<td>India, Philippines, Ukraine, Viet Nam</td>
<td></td>
<td></td>
</tr>
<tr>
<td>B</td>
<td></td>
<td>Morocco, Egypt, Tunisia, Kenya, Mongolia, Sri Lanka, Ghana, Senegal, Algeria, El Salvador, Cambodia, Lao PDR, Bangladesh, Pakistan, Honduras, Nepal, Nigeria, Côte d'Ivoire, United Republic of Tanzania, Zambia</td>
<td></td>
<td></td>
</tr>
<tr>
<td>C</td>
<td>Trinidad and Tobago</td>
<td>Jamaica, Dominican Republic, Iran, Ecuador, Lebanon, Botswana, Paraguay, Namibia, Guatemala</td>
<td></td>
<td></td>
</tr>
<tr>
<td>C</td>
<td></td>
<td>Rwanda, Uganda</td>
<td></td>
<td></td>
</tr>
<tr>
<td>D</td>
<td></td>
<td>Zimbabwe, Cameroon, Benin, Angola</td>
<td></td>
<td></td>
</tr>
<tr>
<td>D</td>
<td></td>
<td>Mali, Malawi, Burkina Faso, Madagascar, Mozambique</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Figure 5 compares the DTI scores of ESCAP member States in the Asia-Pacific region with those of other countries in other regions by income level, which shows that the average DTI scores of ESCAP member States are 20 per cent higher than those of other countries across all income levels.

Figure 5: Comparison of DTI scores of ESCAP and Non-ESCAP countries by income level

DTI by Region

The comparative analysis of the average DTI scores by region has been conducted at two levels: (1) regional comparison at a global level; and (2) subregional comparison among ESCAP member States in the Asia-Pacific region. Due to the geographical locations, four ESCAP member States – France, Netherlands, United Kingdom and United States of America – have been excluded from the subregional comparison of ESCAP member States.

As inferred from the DTI ranking in Table 3, North America and Western Europe have high average DTI scores, whereas most of the countries in Africa record low DTI scores. The average DTI score of the Asia-Pacific is lower than that of North America and Western Europe but higher than that of Africa and Latin America.

For subregional comparison within the Asia-Pacific region, the Pacific, which only comprises Australia and New Zealand in the DTI, has the highest DTI score, followed by East and North-East Asia, South-East Asia, North and Central Asia, and South and South-West Asia. One of the highlights in the comparative analysis is that the Asia-Pacific is the most digitally divided region in the world. While the average DTI score of the developed countries in the region is as high as that of Western Europe, the DTI scores of the rest of the countries in the region are lower than the world’s average. Moreover, there is more than a 40-point difference between the highest and lowest DTI scores among the rest of the countries. Within the Asia-Pacific region, the digital divide is most significant in South-East Asia. These findings underscore the urgent need to develop and implement measures to bridge the digital divide in the Asia-Pacific region.
4.2 STAGE AND PILLAR ANALYSIS

Stage and Pillar Ranking

Table 5 presents the rankings by stage and pillar for each country along with the overall country ranking. The results indicate that there are some countries with significant gaps among the stages and pillars. For instance, India is the country with the largest standard deviation of 16.8 among 107 countries included in the DTI. India, with the overall DTI rank of 56, has ranked 34th in Business but 79th in People, implying huge gaps in the level of digital transformation among the stages and pillars. On the other hand, Switzerland, ranked second in the overall DTI, has the smallest standard deviation of 2.1, demonstrating strong results evenly balanced across almost all stages and pillars. This table is expected to provide a useful baseline for governments in identifying key priority areas or challenges to accelerate digital transformation.
<table>
<thead>
<tr>
<th>Overall ranking</th>
<th>Country</th>
<th>Stage</th>
<th>Pillar</th>
<th>Standard deviation</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>United States of America</td>
<td>6</td>
<td>3</td>
<td>3</td>
</tr>
<tr>
<td>2</td>
<td>Switzerland</td>
<td>2</td>
<td>2</td>
<td>5</td>
</tr>
<tr>
<td>3</td>
<td>United Kingdom</td>
<td>10</td>
<td>12</td>
<td>1</td>
</tr>
<tr>
<td>4</td>
<td>Singapore</td>
<td>1</td>
<td>1</td>
<td>19</td>
</tr>
<tr>
<td>5</td>
<td>Germany</td>
<td>3</td>
<td>13</td>
<td>2</td>
</tr>
<tr>
<td>6</td>
<td>Sweden</td>
<td>4</td>
<td>7</td>
<td>8</td>
</tr>
<tr>
<td>7</td>
<td>Denmark</td>
<td>5</td>
<td>4</td>
<td>12</td>
</tr>
<tr>
<td>8</td>
<td>Netherlands</td>
<td>9</td>
<td>6</td>
<td>6</td>
</tr>
<tr>
<td>9</td>
<td>Republic of Korea</td>
<td>11</td>
<td>18</td>
<td>7</td>
</tr>
<tr>
<td>10</td>
<td>Finland</td>
<td>7</td>
<td>5</td>
<td>17</td>
</tr>
<tr>
<td>11</td>
<td>Canada</td>
<td>17</td>
<td>8</td>
<td>9</td>
</tr>
<tr>
<td>12</td>
<td>Australia</td>
<td>12</td>
<td>20</td>
<td>4</td>
</tr>
<tr>
<td>13</td>
<td>Austria</td>
<td>13</td>
<td>14</td>
<td>11</td>
</tr>
<tr>
<td>14</td>
<td>Hong Kong, China</td>
<td>8</td>
<td>10</td>
<td>22</td>
</tr>
<tr>
<td>15</td>
<td>Luxembourg</td>
<td>21</td>
<td>9</td>
<td>10</td>
</tr>
<tr>
<td>16</td>
<td>Ireland</td>
<td>16</td>
<td>19</td>
<td>13</td>
</tr>
<tr>
<td>17</td>
<td>Japan</td>
<td>14</td>
<td>24</td>
<td>16</td>
</tr>
<tr>
<td>18</td>
<td>Norway</td>
<td>22</td>
<td>11</td>
<td>15</td>
</tr>
<tr>
<td>19</td>
<td>France</td>
<td>15</td>
<td>23</td>
<td>18</td>
</tr>
<tr>
<td>20</td>
<td>New Zealand</td>
<td>19</td>
<td>22</td>
<td>23</td>
</tr>
<tr>
<td>21</td>
<td>Israel</td>
<td>18</td>
<td>16</td>
<td>24</td>
</tr>
<tr>
<td>22</td>
<td>Belgium</td>
<td>20</td>
<td>21</td>
<td>20</td>
</tr>
<tr>
<td>23</td>
<td>Spain</td>
<td>27</td>
<td>29</td>
<td>14</td>
</tr>
<tr>
<td>24</td>
<td>United Arab Emirates</td>
<td>25</td>
<td>17</td>
<td>30</td>
</tr>
<tr>
<td>25</td>
<td>Estonia</td>
<td>23</td>
<td>26</td>
<td>26</td>
</tr>
<tr>
<td>26</td>
<td>Qatar</td>
<td>32</td>
<td>27</td>
<td>29</td>
</tr>
<tr>
<td>27</td>
<td>Iceland</td>
<td>26</td>
<td>15</td>
<td>32</td>
</tr>
<tr>
<td>28</td>
<td>China</td>
<td>29</td>
<td>31</td>
<td>25</td>
</tr>
<tr>
<td>29</td>
<td>Italy</td>
<td>31</td>
<td>36</td>
<td>21</td>
</tr>
<tr>
<td>30</td>
<td>Czech Republic</td>
<td>24</td>
<td>34</td>
<td>28</td>
</tr>
<tr>
<td>31</td>
<td>Malaysia</td>
<td>33</td>
<td>25</td>
<td>34</td>
</tr>
<tr>
<td>32</td>
<td>Portugal</td>
<td>30</td>
<td>30</td>
<td>27</td>
</tr>
<tr>
<td>33</td>
<td>Lithuania</td>
<td>28</td>
<td>33</td>
<td>33</td>
</tr>
<tr>
<td>34</td>
<td>Slovakia</td>
<td>35</td>
<td>42</td>
<td>31</td>
</tr>
<tr>
<td>35</td>
<td>Saudi Arabia</td>
<td>39</td>
<td>32</td>
<td>41</td>
</tr>
<tr>
<td>36</td>
<td>Poland</td>
<td>34</td>
<td>41</td>
<td>38</td>
</tr>
<tr>
<td>37</td>
<td>Chile</td>
<td>37</td>
<td>37</td>
<td>35</td>
</tr>
<tr>
<td></td>
<td>Country</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>---</td>
<td>--------------------</td>
<td>----</td>
<td>----</td>
<td>----</td>
</tr>
<tr>
<td>38</td>
<td>Latvia</td>
<td>36</td>
<td>38</td>
<td>36</td>
</tr>
<tr>
<td>39</td>
<td>Hungary</td>
<td>38</td>
<td>45</td>
<td>37</td>
</tr>
<tr>
<td>40</td>
<td>Romania</td>
<td>45</td>
<td>46</td>
<td>40</td>
</tr>
<tr>
<td>41</td>
<td>Bahrain</td>
<td>52</td>
<td>28</td>
<td>56</td>
</tr>
<tr>
<td>42</td>
<td>Bulgaria</td>
<td>47</td>
<td>40</td>
<td>46</td>
</tr>
<tr>
<td>43</td>
<td>Russian Federation</td>
<td>43</td>
<td>50</td>
<td>43</td>
</tr>
<tr>
<td>44</td>
<td>Uruguay</td>
<td>41</td>
<td>43</td>
<td>49</td>
</tr>
<tr>
<td>45</td>
<td>Oman</td>
<td>48</td>
<td>35</td>
<td>59</td>
</tr>
<tr>
<td>46</td>
<td>Thailand</td>
<td>46</td>
<td>49</td>
<td>51</td>
</tr>
<tr>
<td>47</td>
<td>Mexico</td>
<td>49</td>
<td>59</td>
<td>39</td>
</tr>
<tr>
<td>48</td>
<td>Greece</td>
<td>40</td>
<td>53</td>
<td>55</td>
</tr>
<tr>
<td>49</td>
<td>Turkey</td>
<td>51</td>
<td>48</td>
<td>52</td>
</tr>
<tr>
<td>50</td>
<td>Kuwait</td>
<td>50</td>
<td>39</td>
<td>65</td>
</tr>
<tr>
<td>51</td>
<td>Brazil</td>
<td>59</td>
<td>62</td>
<td>45</td>
</tr>
<tr>
<td>52</td>
<td>South Africa</td>
<td>58</td>
<td>55</td>
<td>47</td>
</tr>
<tr>
<td>53</td>
<td>Costa Rica</td>
<td>42</td>
<td>47</td>
<td>60</td>
</tr>
<tr>
<td>54</td>
<td>Indonesia</td>
<td>57</td>
<td>51</td>
<td>50</td>
</tr>
<tr>
<td>55</td>
<td>Croatia</td>
<td>44</td>
<td>61</td>
<td>58</td>
</tr>
<tr>
<td>56</td>
<td>India</td>
<td>66</td>
<td>63</td>
<td>44</td>
</tr>
<tr>
<td>57</td>
<td>Argentina</td>
<td>62</td>
<td>57</td>
<td>54</td>
</tr>
<tr>
<td>58</td>
<td>Philippines</td>
<td>69</td>
<td>58</td>
<td>42</td>
</tr>
<tr>
<td>59</td>
<td>Ukraine</td>
<td>64</td>
<td>52</td>
<td>57</td>
</tr>
<tr>
<td>60</td>
<td>Colombia</td>
<td>67</td>
<td>64</td>
<td>48</td>
</tr>
<tr>
<td>61</td>
<td>Azerbaijan</td>
<td>63</td>
<td>44</td>
<td>66</td>
</tr>
<tr>
<td>62</td>
<td>Kazakhstan</td>
<td>61</td>
<td>54</td>
<td>62</td>
</tr>
<tr>
<td>63</td>
<td>Viet Nam</td>
<td>56</td>
<td>60</td>
<td>64</td>
</tr>
<tr>
<td>64</td>
<td>Panama</td>
<td>53</td>
<td>72</td>
<td>63</td>
</tr>
<tr>
<td>65</td>
<td>Jordan</td>
<td>76</td>
<td>56</td>
<td>53</td>
</tr>
<tr>
<td>66</td>
<td>Peru</td>
<td>60</td>
<td>73</td>
<td>61</td>
</tr>
<tr>
<td>67</td>
<td>Jamaica</td>
<td>68</td>
<td>67</td>
<td>73</td>
</tr>
<tr>
<td>68</td>
<td>Morocco</td>
<td>65</td>
<td>66</td>
<td>76</td>
</tr>
<tr>
<td>69</td>
<td>Trinidad and Tobago</td>
<td>55</td>
<td>70</td>
<td>79</td>
</tr>
<tr>
<td>70</td>
<td>Egypt</td>
<td>72</td>
<td>68</td>
<td>70</td>
</tr>
<tr>
<td>71</td>
<td>Tunisia</td>
<td>70</td>
<td>75</td>
<td>69</td>
</tr>
<tr>
<td>72</td>
<td>Dominican Republic</td>
<td>71</td>
<td>74</td>
<td>71</td>
</tr>
<tr>
<td>73</td>
<td>Iran</td>
<td>75</td>
<td>81</td>
<td>68</td>
</tr>
<tr>
<td>74</td>
<td>Kenya</td>
<td>77</td>
<td>69</td>
<td>67</td>
</tr>
<tr>
<td>75</td>
<td>Ecuador</td>
<td>79</td>
<td>65</td>
<td>75</td>
</tr>
<tr>
<td>76</td>
<td>Lebanon</td>
<td>82</td>
<td>71</td>
<td>74</td>
</tr>
<tr>
<td>77</td>
<td>Botswana</td>
<td>54</td>
<td>91</td>
<td>72</td>
</tr>
<tr>
<td>78</td>
<td>Mongolia</td>
<td>74</td>
<td>78</td>
<td>80</td>
</tr>
<tr>
<td>79</td>
<td>Sri Lanka</td>
<td>83</td>
<td>76</td>
<td>77</td>
</tr>
<tr>
<td>80</td>
<td>Paraguay</td>
<td>78</td>
<td>82</td>
<td>82</td>
</tr>
<tr>
<td>81</td>
<td>Ghana</td>
<td>81</td>
<td>80</td>
<td>78</td>
</tr>
<tr>
<td>82</td>
<td>Namibia</td>
<td>73</td>
<td>85</td>
<td>81</td>
</tr>
</tbody>
</table>
The stage rankings of ESCAP member States are displayed in Table 6. The stage rankings help to understand the evolution of infrastructure level, service utilization and growth potential in promoting digital transformation from the perspectives of past, present and future. For example, Singapore ranks first in the Foundation and Adoption stages but ranks fourth in the Acceleration stage, which indicates the degree of digital preparation for the future. By examining the domains and the indicators that lower its ranking in the Acceleration stage, it is shown that Singapore records a relatively low score in the Acceleration–Network domain, which results from its low public cloud services spending or low 5G coverage. Meanwhile, India ranks higher in the Acceleration stage than other stages because of relatively high scores in its national artificial intelligence policies and future orientation of government indicators in the Acceleration–Government domain. Australia also has a higher rank in the Acceleration stage than in any other stages.
Table 6: Stage rankings of ESCAP member States

<table>
<thead>
<tr>
<th>Rank</th>
<th>Foundation</th>
<th>Adoption</th>
<th>Acceleration</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Singapore</td>
<td>Singapore</td>
<td>Australia</td>
</tr>
<tr>
<td>2</td>
<td>Hong Kong, China</td>
<td>Hong Kong, China</td>
<td>Republic of Korea</td>
</tr>
<tr>
<td>3</td>
<td>Republic of Korea</td>
<td>Republic of Korea</td>
<td>Japan</td>
</tr>
<tr>
<td>4</td>
<td>Australia</td>
<td>Australia</td>
<td>Singapore</td>
</tr>
<tr>
<td>5</td>
<td>Japan</td>
<td>New Zealand</td>
<td>Hong Kong, China</td>
</tr>
<tr>
<td>6</td>
<td>New Zealand</td>
<td>Japan</td>
<td>New Zealand</td>
</tr>
<tr>
<td>7</td>
<td>China</td>
<td>Malaysia</td>
<td>China</td>
</tr>
<tr>
<td>8</td>
<td>Malaysia</td>
<td>China</td>
<td>Malaysia</td>
</tr>
<tr>
<td>9</td>
<td>Russian Federation</td>
<td>Azerbaijan</td>
<td>Philippines</td>
</tr>
<tr>
<td>10</td>
<td>Thailand</td>
<td>Turkey</td>
<td>Russian Federation</td>
</tr>
<tr>
<td>11</td>
<td>Turkey</td>
<td>Thailand</td>
<td>India</td>
</tr>
<tr>
<td>12</td>
<td>Viet Nam</td>
<td>Russian Federation</td>
<td>Indonesia</td>
</tr>
<tr>
<td>13</td>
<td>Indonesia</td>
<td>Indonesia</td>
<td>Thailand</td>
</tr>
<tr>
<td>14</td>
<td>Kazakhstan</td>
<td>Kazakhstan</td>
<td>Turkey</td>
</tr>
<tr>
<td>15</td>
<td>Azerbaijan</td>
<td>Philippines</td>
<td>Kazakhstan</td>
</tr>
<tr>
<td>16</td>
<td>India</td>
<td>Viet Nam</td>
<td>Viet Nam</td>
</tr>
<tr>
<td>17</td>
<td>Philippines</td>
<td>India</td>
<td>Azerbaijan</td>
</tr>
<tr>
<td>18</td>
<td>Mongolia</td>
<td>Sri Lanka</td>
<td>Iran (Islamic Republic of)</td>
</tr>
<tr>
<td>19</td>
<td>Iran (Islamic Republic of)</td>
<td>Mongolia</td>
<td>Sri Lanka</td>
</tr>
<tr>
<td>20</td>
<td>Sri Lanka</td>
<td>Iran (Islamic Republic of)</td>
<td>Mongolia</td>
</tr>
<tr>
<td>21</td>
<td>Nepal</td>
<td>Pakistan</td>
<td>Pakistan</td>
</tr>
<tr>
<td>22</td>
<td>Lao PDR</td>
<td>Bangladesh</td>
<td>Cambodia</td>
</tr>
<tr>
<td>23</td>
<td>Bangladesh</td>
<td>Lao PDR</td>
<td>Bangladesh</td>
</tr>
<tr>
<td>24</td>
<td>Cambodia</td>
<td>Cambodia</td>
<td>Lao PDR</td>
</tr>
<tr>
<td>25</td>
<td>Pakistan</td>
<td>Nepal</td>
<td>Nepal</td>
</tr>
</tbody>
</table>

Ranking of ESCAP Member States by Pillar

Figure 7 illustrates the pillar rankings of ESCAP member States. The differences in ranking by pillar among the middle-income group are larger than those either among the high-income group or the low-income group. For example, the difference in ranking between the highest ranked pillar (#1 in Government) and the lowest (#19 in People) in Singapore is only 18, whereas India shows a 34-rank difference between the Business Pillar and the People Pillar. This suggests that the levels of investments or concentration vary by each pillar in the middle-income group’s process towards digital transformation, and gaps among the pillars will narrow as it progresses into a more mature level of digital transformation. The graph provides insights to understand the degree of a country's competitiveness across the pillars. Among the middle-income group, China scores higher in the Business Pillar, and the Russian Federation in the People Pillar than any other pillars. For pillars with relatively lower scores, Turkey and Iran score lowest in Ecosystem, India in Network and People, and the Philippines in Network.
Stage and Pillar Ranking by Grade and Income Level

Based on the scores by stage and pillar, the countries have been divided into two groups – the leaders and the laggards. The leaders consist of 33 countries with Grade S and the laggards include nine countries with Grade D. Figure 8 shows the scores of the leaders and the laggards, as well as the average score by stage and pillar. There are large differences between the leaders and the laggards, with relatively large differences between the Government and Ecosystem pillars. The results of the analysis on stage rankings also demonstrate large differences between the leaders and the laggards. The average ratios of the laggards to the leaders in the Acceleration, Adoption and Foundation stages are 23 per cent, 16 per cent and 12 per cent, respectively, confirming that the gaps are large. The difference between the leaders and the laggard in each stage is greatest in the Acceleration stage, meaning that the gaps among countries get only wider over time.
As shown in Figure 9, the difference in each stage was not significant among the high-income group. However, the lower the income level, the greater the gap between stages. The ratio of Acceleration to Foundation is 93 per cent for high-income countries, while it is 54 per cent for low-income countries. The findings indicate that the level of digital transformation in low-income countries declines as they enter Adoption and Acceleration stages.
Stage and Pillar Ranking by Income Level in Asia and the Pacific

The results of the same analysis for ESCAP member States are shown in Figure 10. Among the 25 ESCAP member States included in the DTI, there is no low-income country, and thus, the countries are divided into three groups – high, upper-middle and lower-middle.

By examining the achievements in each pillar, the differences between each income group appear to be minimal in the Network and Government pillars, but the Ecosystem and the Business pillars reveal significant differences between the high-income group and the middle-income groups. The score ratio of the middle-income groups to the high-income group in the People pillar is 50 per cent, whereas in the Ecosystem pillar, it is 33 per cent. This is because the score differences in the Ecosystem–Foundation and the Ecosystem–Adoption domains are relatively larger for the middle-income groups than in the high-income group, which is attributed to the gaps in income-related indicators in the domains.

The results of stage score analysis on ESCAP member States, however, do not indicate significant differences in scores across the stages by income level. In other words, it is found that the difference between the high-income group and the two middle-income groups is relatively small across all three stages.

Figure 10: Gaps in the five pillars and three stages by income group in ESCAP member States

4.3 OVERALL RANKING ANALYSIS

The distribution of scores by each domain for each income group in 107 countries shows the constant differences across four income groups in the Network–Foundation, Network–Adoption and People–Foundation domains. In the Government–Foundation domain, however, there is no significant difference in scores among the upper-middle-, lower-middle- and low-income groups, while the high-income group displays a significantly higher score than the other three groups. This tendency is also found in the Ecosystem–Foundation and Ecosystem–Adoption domains, which implies that progress in these domains is not made gradually, but rather, requires a certain level of national income.
In the same analysis for ESCAP member States, as shown in Figure 12, domains with significant differences between the high-income group and the upper-middle- and lower-middle-income groups are Ecosystem–Foundation, Ecosystem–Adoption and Ecosystem–Acceleration. In other words, in the Ecosystem pillar, the average scores of the upper-middle- and lower-middle-income groups are similar, while the difference between these two groups and the high-income group is considerably large.
This section analyses the competitiveness of 25 ESCAP member States by stage and pillar.

Singapore has a relatively low ranking in the Acceleration stage, which is due to the low 5G coverage as mentioned in the previous section. The Republic of Korea is found to have strengths in the Network pillar because of its relative advantages in mobile download speed and 5G coverage, but ranks low in the Ecosystem pillar due to its relatively lower score in the diversity of workforce and the gross domestic product (GDP) per unit of energy use indicators. Australia displays a relatively strong position in the People pillar as it ranks at the top in indicators such as adult literacy, basic skills and schools with Internet access, whereas the Business pillar appears to be relatively weak due to its low high-tech export. Hong Kong, an associate member of ESCAP, ranks 11th in the Government pillar, exposing its weakness in the indicators related to obtaining trust in government websites and apps, and national artificial intelligence policies. Japan records relatively low score in the People pillar. New Zealand and China have relative strengths in the People and Business pillars. Malaysia has a relatively even distribution in ranking across the eight areas. The Russian Federation is particularly vulnerable in the Government pillar, which is attributed to the business and government investment, and the trust in government websites and apps indicators. Thailand reveals its weak performance in the People pillar, due to its relatively inferior achievement in the support for digital literacy indicator. Turkey ranks lowest in the environmental treaties in force indicator, and records a relatively low ranking in the Ecosystem pillar. Indonesia ranks low in the Network pillar, which results mainly from the very low number of fixed-line broadband subscribers. In India, the Network and People pillars are found to be relatively inferior pillars due largely to its low number of fixed-line broadband subscribers and low average revenue per user. The Philippines reveals its weakness in the Network pillar while shows relatively excellent performance in the Acceleration stage. Azerbaijan, Viet Nam and Sri Lanka do not have a pillar in a particularly inferior position. Iran is found to be particularly vulnerable in the Ecosystem pillar as it ranks at the bottom for the GDP per unit of energy use indicator. Generally, the low-ranking member States also have low rankings across the stages and pillars. For more meaningful inferences, further analysis should be conducted by reflecting on country-specific features such as the developmental status.
Among the 25 ESCAP member States, seven countries exhibiting relatively excellent performance in their income group have been selected for further analysis. This includes two countries with Grade S from the high-income group, two countries with Grade A from the upper-middle-income group and three countries with Grade B from the lower-middle-income group (Table 8).

Based on the rankings by each pillar of the seven countries, the pillars with higher rankings compared to their overall DTI ranks have been examined to identify the indicators that drive higher ranks of the pillars. The analysis reveals that Singapore records high scores in the government investment and government efficiency indicators, and the Republic of Korea, with its reputation as a network powerhouse, is far ahead in the number of Internet users and smartphone penetration rate. Meanwhile, China ranks high in the Business pillar compared to other pillars, showcasing its high number of unicorn companies and high-tech exports. Malaysia demonstrates excellent performance in the People pillar with the pupil to teacher ratio in primary education and the skills of workforce indicators as key drivers.

<table>
<thead>
<tr>
<th>Country</th>
<th>DTI rank</th>
<th>ESCAP rank</th>
<th>Foundation</th>
<th>Adoption</th>
<th>Acceleration</th>
<th>Network</th>
<th>Government</th>
<th>Business</th>
<th>People</th>
<th>Ecosystem</th>
<th>Standard deviation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Singapore</td>
<td>4</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>4</td>
<td>4</td>
<td>1</td>
<td>1</td>
<td>3</td>
<td>2</td>
<td>1.27</td>
</tr>
<tr>
<td>Republic of Korea</td>
<td>9</td>
<td>2</td>
<td>3</td>
<td>3</td>
<td>2</td>
<td>1</td>
<td>2</td>
<td>2</td>
<td>4</td>
<td>6</td>
<td>1.45</td>
</tr>
<tr>
<td>Australia</td>
<td>12</td>
<td>3</td>
<td>4</td>
<td>4</td>
<td>1</td>
<td>2</td>
<td>4</td>
<td>6</td>
<td>1</td>
<td>3</td>
<td>1.62</td>
</tr>
<tr>
<td>Hong Kong, China</td>
<td>14</td>
<td>4</td>
<td>2</td>
<td>2</td>
<td>5</td>
<td>3</td>
<td>7</td>
<td>3</td>
<td>5</td>
<td>1</td>
<td>1.87</td>
</tr>
<tr>
<td>Japan</td>
<td>17</td>
<td>5</td>
<td>5</td>
<td>6</td>
<td>3</td>
<td>6</td>
<td>3</td>
<td>5</td>
<td>8</td>
<td>4</td>
<td>1.58</td>
</tr>
<tr>
<td>New Zealand</td>
<td>20</td>
<td>6</td>
<td>6</td>
<td>5</td>
<td>6</td>
<td>5</td>
<td>7</td>
<td>2</td>
<td>5</td>
<td>3</td>
<td>1.36</td>
</tr>
<tr>
<td>China</td>
<td>28</td>
<td>7</td>
<td>7</td>
<td>8</td>
<td>7</td>
<td>8</td>
<td>4</td>
<td>9</td>
<td>8</td>
<td>1</td>
<td>1.39</td>
</tr>
<tr>
<td>Malaysia</td>
<td>31</td>
<td>8</td>
<td>8</td>
<td>7</td>
<td>8</td>
<td>8</td>
<td>6</td>
<td>6</td>
<td>7</td>
<td>1</td>
<td>0.83</td>
</tr>
<tr>
<td>Russian Federation</td>
<td>43</td>
<td>9</td>
<td>9</td>
<td>12</td>
<td>10</td>
<td>11</td>
<td>13</td>
<td>12</td>
<td>7</td>
<td>12</td>
<td>1.85</td>
</tr>
<tr>
<td>Thailand</td>
<td>46</td>
<td>10</td>
<td>10</td>
<td>11</td>
<td>13</td>
<td>10</td>
<td>11</td>
<td>10</td>
<td>15</td>
<td>14</td>
<td>1.85</td>
</tr>
<tr>
<td>Turkey</td>
<td>49</td>
<td>11</td>
<td>11</td>
<td>10</td>
<td>14</td>
<td>9</td>
<td>12</td>
<td>11</td>
<td>14</td>
<td>17</td>
<td>2.44</td>
</tr>
<tr>
<td>Indonesia</td>
<td>54</td>
<td>12</td>
<td>13</td>
<td>13</td>
<td>12</td>
<td>17</td>
<td>10</td>
<td>13</td>
<td>13</td>
<td>11</td>
<td>1.92</td>
</tr>
<tr>
<td>India</td>
<td>56</td>
<td>13</td>
<td>16</td>
<td>17</td>
<td>11</td>
<td>19</td>
<td>9</td>
<td>9</td>
<td>19</td>
<td>9</td>
<td>4.27</td>
</tr>
<tr>
<td>Philippines</td>
<td>58</td>
<td>14</td>
<td>17</td>
<td>15</td>
<td>9</td>
<td>18</td>
<td>16</td>
<td>14</td>
<td>10</td>
<td>10</td>
<td>3.28</td>
</tr>
<tr>
<td>Azerbaijan</td>
<td>61</td>
<td>15</td>
<td>15</td>
<td>9</td>
<td>17</td>
<td>12</td>
<td>14</td>
<td>16</td>
<td>12</td>
<td>16</td>
<td>2.52</td>
</tr>
<tr>
<td>Kazakhstan</td>
<td>62</td>
<td>16</td>
<td>14</td>
<td>14</td>
<td>15</td>
<td>13</td>
<td>15</td>
<td>18</td>
<td>11</td>
<td>18</td>
<td>2.22</td>
</tr>
<tr>
<td>Viet Nam</td>
<td>63</td>
<td>17</td>
<td>12</td>
<td>16</td>
<td>16</td>
<td>14</td>
<td>17</td>
<td>15</td>
<td>16</td>
<td>15</td>
<td>1.45</td>
</tr>
<tr>
<td>Iran</td>
<td>73</td>
<td>18</td>
<td>19</td>
<td>20</td>
<td>18</td>
<td>15</td>
<td>19</td>
<td>20</td>
<td>17</td>
<td>23</td>
<td>2.20</td>
</tr>
<tr>
<td>Mongolia</td>
<td>78</td>
<td>19</td>
<td>18</td>
<td>19</td>
<td>20</td>
<td>16</td>
<td>22</td>
<td>17</td>
<td>18</td>
<td>20</td>
<td>1.79</td>
</tr>
<tr>
<td>Sri Lanka</td>
<td>79</td>
<td>20</td>
<td>20</td>
<td>18</td>
<td>19</td>
<td>20</td>
<td>21</td>
<td>19</td>
<td>21</td>
<td>13</td>
<td>2.42</td>
</tr>
<tr>
<td>Cambodia</td>
<td>88</td>
<td>21</td>
<td>24</td>
<td>24</td>
<td>22</td>
<td>24</td>
<td>23</td>
<td>24</td>
<td>23</td>
<td>21</td>
<td>1.05</td>
</tr>
<tr>
<td>Lao People’s Democratic Republic</td>
<td>89</td>
<td>22</td>
<td>22</td>
<td>23</td>
<td>24</td>
<td>21</td>
<td>25</td>
<td>22</td>
<td>20</td>
<td>24</td>
<td>1.58</td>
</tr>
<tr>
<td>Bangladesh</td>
<td>90</td>
<td>23</td>
<td>23</td>
<td>22</td>
<td>23</td>
<td>24</td>
<td>20</td>
<td>24</td>
<td>24</td>
<td>22</td>
<td>1.30</td>
</tr>
<tr>
<td>Pakistan</td>
<td>91</td>
<td>24</td>
<td>25</td>
<td>21</td>
<td>21</td>
<td>25</td>
<td>18</td>
<td>21</td>
<td>25</td>
<td>19</td>
<td>2.62</td>
</tr>
</tbody>
</table>

Table 7: Stage and pillar rankings of ESCAP member States
India scores high in the number of unicorn companies and the renewable energy indicators, and the Philippines in the ease of finding skilled employees. Viet Nam shows strengths in the Network pillar, especially through the fixed-line broadband affordability and smartphone penetration indicators.

Table 8: List of key indicators driving high rankings in selected countries

<table>
<thead>
<tr>
<th>Country</th>
<th>Grade</th>
<th>ESCAP rank</th>
<th>Pillar rank</th>
<th>Indicators driving high ranks</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>Network</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Government</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Business</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>People</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Ecosystem</td>
<td></td>
</tr>
<tr>
<td>Singapore</td>
<td>S</td>
<td>3</td>
<td>6</td>
<td>Government • Business and government investment • Government effectiveness</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Republic of Korea</td>
<td>S</td>
<td>5</td>
<td>3</td>
<td>Network • Days to get electricity • Internet users • Smartphone penetration</td>
</tr>
<tr>
<td>China</td>
<td>A</td>
<td>11</td>
<td>12</td>
<td>Business • High-tech exports • Number of tech unicorns</td>
</tr>
<tr>
<td>Malaysia</td>
<td>A</td>
<td>12</td>
<td>12</td>
<td>People • Pupil-to-teacher ratio in primary education • Skills of future workforce</td>
</tr>
<tr>
<td>India</td>
<td>B</td>
<td>17</td>
<td>13</td>
<td>Business • Number of tech unicorns • Renewable energy regulation • Environmental treaties in force</td>
</tr>
<tr>
<td>Philippines</td>
<td>B</td>
<td>18</td>
<td>20</td>
<td>People • Ease of finding skilled employees • Environmental treaties in force • GDP per unit of energy use</td>
</tr>
<tr>
<td>Viet Nam</td>
<td>B</td>
<td>21</td>
<td>18</td>
<td>Network • Average mobile latency • Fixed-line broadband affordability</td>
</tr>
</tbody>
</table>

4.5 CORRELATION ANALYSIS

DTI Overall Score vs. Indicators

This section aims to identify factors affecting digital transformation by analysing correlations between the total DTI score and each pillar, stage, domain and indicator. First, all correlation coefficients between 105 indicators and the total DTI score are computed, and the number of indicators and the cumulative values for each correlation coefficient interval are displayed in Figure 13. As illustrated in the graph, the number of indicators with a correlation coefficient of 0.6 or higher is 72, which accounts for 67 per cent of the total number of indicators, and the number of indicators with a very high correlation coefficient of 0.8 or higher reaches 38.
Table 9 lists 22 indicators whose correlation coefficients are more than 0.85. The comparative analysis on the correlation coefficients of all 105 indicators reveals that the indicators in the Business and Government pillars and in the Adoption and Acceleration stages are more relevant than in other pillars and stages, respectively. The findings suggest that the DTI is more related to the use of digital technologies or the introduction of emerging technologies than the basic infrastructures, in achieving digital transformation. The indicator with the highest correlation coefficient with the total score is the Government Artificial Intelligence Readiness Index whose correlation coefficient is 0.97. Other indicators with correlation coefficients of 0.9 or higher include innovation capability, adoption of emerging technologies, the e-Government Index, government effectiveness and mobile apps development.

Table 9: Correlation coefficients between total score and indicators

<table>
<thead>
<tr>
<th>Rank</th>
<th>Indicator</th>
<th>Pillar</th>
<th>Stage</th>
<th>Correlation coefficient</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Government Artificial Intelligence Readiness Index</td>
<td>Government</td>
<td>Acceleration</td>
<td>0.967</td>
</tr>
<tr>
<td>2</td>
<td>Innovation Capability</td>
<td>Business</td>
<td>Acceleration</td>
<td>0.935</td>
</tr>
<tr>
<td>3</td>
<td>Adoption of Emerging Technologies</td>
<td>Business</td>
<td>Acceleration</td>
<td>0.930</td>
</tr>
<tr>
<td>4</td>
<td>e-Government Index</td>
<td>Government</td>
<td>Adoption</td>
<td>0.929</td>
</tr>
<tr>
<td>5</td>
<td>Government Effectiveness</td>
<td>Government</td>
<td>Adoption</td>
<td>0.924</td>
</tr>
<tr>
<td>6</td>
<td>Mobile Apps Development</td>
<td>Business</td>
<td>Adoption</td>
<td>0.918</td>
</tr>
<tr>
<td>7</td>
<td>Business Environment</td>
<td>Business</td>
<td>Foundation</td>
<td>0.899</td>
</tr>
<tr>
<td>8</td>
<td>Labour Productivity per Employee</td>
<td>Business</td>
<td>Foundation</td>
<td>0.895</td>
</tr>
<tr>
<td>9</td>
<td>Fixed-line Broadband Subscribers</td>
<td>Network</td>
<td>Foundation</td>
<td>0.888</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>---</td>
<td>--------------------------------</td>
<td>----------</td>
<td>----------------</td>
<td>---------</td>
</tr>
<tr>
<td>10</td>
<td>Servers per Population</td>
<td>Network</td>
<td>Adoption</td>
<td>0.884</td>
</tr>
<tr>
<td>11</td>
<td>Tablet Possession</td>
<td>Network</td>
<td>Adoption</td>
<td>0.879</td>
</tr>
<tr>
<td>12</td>
<td>ICT-enabled Organizational Model Creation</td>
<td>Business</td>
<td>Adoption</td>
<td>0.878</td>
</tr>
<tr>
<td>13</td>
<td>Gross National Income per Capita</td>
<td>Ecosystem</td>
<td>Foundation</td>
<td>0.875</td>
</tr>
<tr>
<td>14</td>
<td>Business Use of Digital Tools</td>
<td>Business</td>
<td>Adoption</td>
<td>0.870</td>
</tr>
<tr>
<td>15</td>
<td>Environmental Performance</td>
<td>Ecosystem</td>
<td>Acceleration</td>
<td>0.869</td>
</tr>
<tr>
<td>16</td>
<td>Handset Prices Affordability</td>
<td>Network</td>
<td>Foundation</td>
<td>0.863</td>
</tr>
<tr>
<td>17</td>
<td>Mobile Download Speed</td>
<td>Network</td>
<td>Adoption</td>
<td>0.863</td>
</tr>
<tr>
<td>18</td>
<td>Skills of Future Workforce</td>
<td>People</td>
<td>Acceleration</td>
<td>0.862</td>
</tr>
<tr>
<td>19</td>
<td>International Co-inventions</td>
<td>Ecosystem</td>
<td>Adoption</td>
<td>0.859</td>
</tr>
<tr>
<td>20</td>
<td>Ease of Doing Business</td>
<td>Government</td>
<td>Foundation</td>
<td>0.854</td>
</tr>
<tr>
<td>21</td>
<td>Basic Skills</td>
<td>People</td>
<td>Foundation</td>
<td>0.854</td>
</tr>
<tr>
<td>22</td>
<td>Corruption Perceptions Index</td>
<td>Ecosystem</td>
<td>Foundation</td>
<td>0.853</td>
</tr>
</tbody>
</table>

**Correlation Coefficients between DTI Overall Score and Stage / Pillar**

Among the correlation coefficients between the total DTI scores and each stage and pillar, it is found that the Business pillar and the Acceleration stage have the highest correlation coefficients. These findings are in line with the results from the analyses on the individual indicators.

**Figure 14: Correlation coefficients between total score and stages / pillars**
Correlation Coefficients between DTI Overall Score and the Domains

With regard to the correlation coefficients between the total score and the domains, the Network–Adoption domain has the highest correlation coefficient followed by the Business–Adoption and Business–Acceleration domains. The Business pillar has a correlation coefficient of 0.9 or higher across all stages, and the correlation coefficients of domains related to the People and Ecosystem pillars are relatively low.

Figure 15: Correlation coefficients between total score and domains

![Correlation Coefficients](image_url)

Notes: NW = Network; GOV = Government; BIZ = Business; PEO = People; and ECO = Ecosystem.

Correlation Coefficients between Stages and Pillars

The analysis on correlations between the total score of each stage and the scores of the pillars within that stage discovers that the pillars with the highest correlation with the Foundation stage are the Ecosystem and Business pillars, and the Network and Government pillars have relatively low correlations. The pillars with the highest correlation coefficients with the total score of the Adoption stage are the Network and Business pillars, while the pillars with highest correlation coefficients with the total score of the Acceleration stage are the Business and Government pillars. The Business pillar is confirmed to be highly correlated with all stages.
Meanwhile, the analysis of the correlation coefficients between the total score of each pillar and the scores of stages of that pillar reveals that the Adoption stage has the highest correlation coefficient with the Network pillar, and the Acceleration stage with the Business and Government pillars. In addition, the Business and the People pillars are highly correlated with the Acceleration stage, and the Ecosystem pillar with the Foundation stage.

Notes: NW = Network; GOV = Government; BIZ = Business; PEO = People; and ECO = Ecosystem.

Notes: NW = Network; GOV = Government; BIZ = Business; PEO = People; and ECO = Ecosystem.
5. Conclusion and Implications

THE PURPOSE OF THE STUDY IS TO UNDERSTAND THE LEVEL OF DIGITAL TRANSFORMATION OF THE COUNTRIES THROUGH THE DTI FRAMEWORK

This study aims to explore the digital divides between countries by region and income level, and identify the drivers for digital transformation. The study developed the DTI in the attempt to overcome limitations of previous digital-related indices by including various aspects and reflecting the dynamics of digital transformation in the DTI framework. The results of the DTI and the analyses on the correlations between each value derive the following implications:

5.1 The income gap between countries is a major cause of the digital divide.

While 97.8 per cent of high-income countries are graded B or above, every low-income country is categorized into Grade C or D.

5.2 In low-income countries, the gap between each Foundation, Adoption and Acceleration stage gets wider.

The ratio of the Acceleration score to the standardized Foundation score is 93 per cent for the high-income group and 54 per cent for the low-income group.

5.3 Gaps in the level of digital transformation exist between regions, and this regional digital divide can be exacerbated due to the absence of the peer effect.

Gaps in the level of digital transformation exist within regions as well. For ESCAP member States, countries with high levels of digital transformation are concentrated in North-East Asia, while countries with low levels of digital transformation are concentrated in South-East Asia.

5.4 The pillar with the highest discriminatory power on the DTI is the Business pillar.

The Business pillar has the highest correlation coefficient of 0.971 between the total score and each pillar. For the correlation coefficients between each domain and the total DTI score, all three domains related to the Business pillar out of 15 domains are included in the top five correlation coefficients.

5.5 The difference in rankings between the pillars in each country decreases as the countries rank higher.

The average standard deviation of the pillar rankings is 4.5 for Grade S countries, whereas it reaches 8 for Grade B and C countries.

5.6 Forty-five per cent of the world’s countries do not have sufficient data to measure the DTI.

The results of this study suggest the existence of digital divides between countries and regions, as summarized above. Given the essential role of digital transformation on the future of a country’s economy, it is imperative to develop strategies and enhance international cooperation to improve the overall level of digital transformation. The DTI framework can serve as an important benchmark for countries to identify priorities for digital transformation, as well as manage and improve the performance of indicators. It is also expected to assist digital-related international organizations and intergovernmental bodies in identifying areas for mutual cooperation to establish...
support plans for less developed countries. Moreover, one of the main challenges revealed in the process of developing the DTI is the lack of data availability. There is an urgent need to provide policy, technology and financial support for countries whose level of digital transformation cannot even be assessed due to the limited availability of data and the inadequate data infrastructure.

The selection of valid indicators in modelling the DTI framework is one of the most crucial tasks for improving the objectivity and reliability of the DTI. The indicators included in the DTI have been selected through rigorous review based on the criteria of importance and reliability. Yet, there are some indicators that lack objectivity like surveys. Therefore, the selection of indicators is a task that requires continuous reviews and updates to address the limitations of this study. In addition, although the study utilizes recent data to capture the current status of digital transformation, the DTI is not good for predicting the future by comparing the past and the present due to the absence of time series data. Despite the limitations, however, the study contributes to providing meaningful implications and inferences on digital transformation by developing the framework in a multi-dimensional way to reflect the dynamics of digital transformation.
References


J. P. Morgan (2020). What Will the Recovery Look Like From the COVID-19 Recession?


Kline, T. J. (2005). *Psychological testing: A
practical approach to design and evaluation. Sage Publications.


(2020). How COVID-19 has pushed companies over the technology tipping point—and transformed business forever.


Divides.


Visual Capitalist (2021). This Simple Chart Reveals the Distribution of Global Wealth.


World Economic Forum (2020). Are we experiencing a K shaped recovery from COVID-19?


(2020). ‘Untact’: South Korea’s plan for a contact-free society.
_______ (2021). COVID-19 exposed the digital divide. Here's how we can close it.

Appendix: DTI Indicators

A. Network Pillar

1.1 Foundation Stage

1.1.1 Total electricity access (per cent of population)

The percentage of population with access to electricity. Electrification data is collected from industry, national surveys and international sources.

Source: World Bank Global Electrification Database

1.1.2 Days to get electricity

The number of days to obtain a permanent electricity connection. This indicator captures the median duration that the electricity utility and experts indicate is necessary in practice, rather than required by law, to complete a procedure.

Sources: World Bank and Doing Business Project

1.1.3 Mobile subscribers (per 100 inhabitants)

The sum of active handset-based and computer-based mobile-broadband subscriptions to the public Internet, where users have accessed the Internet in the last three months. It covers actual subscribers, not potential subscribers, even though the latter may have broadband-enabled handsets.

Source: International Telecommunication Union

1.1.4 Fixed-line broadband subscribers

Fixed-line broadband subscriptions per 100 inhabitants. The higher the number of subscriptions, the greater the level of Internet connectivity.

Source: International Telecommunication Union

1.1.5 Internet users (per cent of household)

The number of people who have used the Internet in the past 12 months. A higher number of people using the Internet indicates greater connectivity.

Source: International Telecommunication Union

1.1.6 Mobile tariff affordability

This indicator is based on the Mobile Tariffs Subindex that is included in the Affordability pillar of the Mobile Connectivity Index published by the Global System for Mobile Communications Association (GSMA). The subindex relates to the cost of three different basket profiles (100MB, 500MB and 1GB) that are partly distinguished by monthly usage allowance. The tariffs are given as a percentage of monthly gross domestic product (GDP) per capita. The main source for the data is Tarifica (https://tarifica.com/).

Source: GSMA Mobile Connectivity Index 2019

1.1.7 Fixed-line broadband affordability (per cent of monthly gross national income (GNI) per capita)

The price of fixed-line monthly broadband to the consumer as a percentage of monthly income. Generally, the lower the broadband cost, the higher the adoption rates.
There is a cap on fixed-line monthly broadband cost as per cent of monthly GNI per capita at 350. All countries that exceed this value receive a score of 0.

Sources: International Telecommunication Union and World Bank

1.1.8 Handset prices affordability (per cent of monthly GDP per capita)

This indicator is based on the Affordability pillar of the Mobile Connectivity Index published by the GSMA. It relates to the cheapest smartphone or feature phone that allows users access to the Internet. The main source for the data is Tarifica (https://tarifica.com/).

Source: GSMA Mobile Connectivity Index 2019

1.2 Adoption Stage

1.2.1 Smartphone penetration (per 100 inhabitants)

The number of mobile-broadband subscriptions per 100 inhabitants. Mobile-broadband subscriptions refer to subscriptions to mobile cellular networks with access to data communications (e.g., the Internet) at broadband speeds, irrespective of the device used to access the Internet.

Source: International Telecommunication Union

1.2.2 Average revenue per user (USD)

The annual average revenue per user (ARPU) calculated over the given period (12 months for annual data). ARPU is used to measure consumer spending on mobile services. This measure of ARPU is "blended", which means that both pre-paid and post-paid subscribers are being counted in the metric. The metric includes data and voice.

Source: Telegeography

1.2.3 Average fixed-broadband download speed (Mbps)

Fixed-broadband download speed averages for all years are based on Ookla’s analysis of Speedtest data collected between 1 October and 30 September of each calendar year. A faster speed is a positive indicator for better performance.

Source: Ookla

1.2.4 Average mobile download speed (Mbps)

Mobile download speed averages are based on Ookla’s analysis of Speedtest data. A faster speed is a positive indicator for better performance.

Source: Ookla

1.2.5 Average mobile download latency (Ms)

This measures average mobile latency (or how long it takes for data to travel between its source and destination). Averages are based on Ookla’s analysis of Speedtest data.

Source: Ookla

1.2.6 Tablet possession (per cent of household)

The percentage of households having at least one item of portable, usually battery-powered, and very thin personal computer with a touchscreen panel.

Source: Euromonitor International 2021

1.2.7 4G coverage (per cent of population)
Percentage of the population covered by at least an LTE / WiMAX mobile network refers to the percentage of inhabitants that live within range of LTE / LTE-Advanced, mobile WiMAX / WirelessMAN or other more advanced mobile-cellular networks, irrespective of whether or not they are subscribers.

Source: International Telecommunication Union

1.2.8 Servers per population (per 1 million people)

The number of distinct, publicly trusted TLS / SSL certificates found in the Netcraft Secure Server Survey.

Source: World Bank

1.3 Acceleration Stage

1.3.1 5G coverage (per cent of population)

The percentage of population covered by 5G networks.

Source: GSMA Intelligence

1.3.2 5G deployment

This indicator assesses whether operators have implemented 5G New Radio technology in the country, including as part of a trial or a fuller commercial deployment. Limited availability refers to a 5G network that is present but where devices are limited to select users, usually in a testing environment. Commercial availability refers to a 5G network where any consumer can purchase a device for use on this network.

Source: Ookla

1.3.3 Public cloud services spending (per cent of worldwide)

Information technology spending on public cloud services as a percentage of the worldwide total.

Source: Gartner

1.3.4 Gender equality in mobile phone access (per cent of difference)

The Economist Intelligence Unit calculated the gender gap ratio according to the following formula: (male access – female access) / male access. In the second and third editions of the index, the Economist Intelligence Unit calculated the gender gap ratio with female access as the denominator: (male access – female access) / female access. Scores for these editions have been updated to reflect this change. To calculate the equality index, an absolute value was taken from the raw data, and the lower the number, the higher the equality index was assigned.

Source: International Telecommunication Union

1.3.5 Gender equality in Internet use (per cent of difference)

The Economist Intelligence Unit calculated the gender gap ratio according to the following formula: (male access – female access) / male access. In the second and third editions of the index, the Economist Intelligence Unit calculated the gender gap ratio with female access as the denominator: (male access – female access) / female access. Scores for these editions have been updated to reflect this change. To calculate the equality index, an absolute value was taken from the raw data, and the lower the number, the higher the equality index was assigned.

Source: International Telecommunication Union
1.3.6 Government effort to promote 5G (survey)

This indicator assesses whether the country has developed a strategy or initiatives to promote 5G. Countries receive a higher score if the policy or strategy recognizes multiple use cases of 5G. Multiple use cases may include the following: fixed wireless access, enhanced mobile broadband, massive machine-type communications, Internet of Things or ultra-reliable low-latency communications. Other use cases or applications may also apply if specifically mentioned (e.g., 5G for precision agriculture, smart city/home applications, autonomous vehicle applications). Note that policies, strategies or initiatives may be embodied across a number of documents (e.g., policy or strategy documents, government committee notes).

Source: Economist Intelligence Unit country research

1.3.7 Government initiatives to make Wi-Fi available

This indicator assesses whether the Wi-Fi network is free to join or not. “Public” means that the Wi-Fi network and associated hotspot(s) must be accessible in a public park, library, public building, airport, train or ferry terminal. “Largest city” means largest city in the country by population.

Source: Economist Intelligence Unit country research

1.3.8 Private sector initiatives to make Wi-Fi available

This indicator assesses whether the Wi-Fi network is free to join or not and whether the public Wi-Fi is available to anyone (general population, tourists, etc.) or just to customers of the largest Internet service provider (ISP) in the country. The largest ISP means the largest private-sector run ISP, not state-owned. “Public” means that the Wi-Fi network and associated hotspot(s) must be accessible in a public park, library, public building, airport, train or ferry terminal. “Largest city” means largest city in the country by population.

Source: Economist Intelligence Unit country research

2. Government Pillar

2.1 Foundation Stage

2.1.1 Ease of doing business

The Ease of Doing Business Index aggregates a country’s percentile rankings on 10 topics covered in the World Bank’s Doing Business report series. The topics are: starting a business, dealing with construction permits, getting electricity, registering property, getting credit, protecting minority investors, paying taxes, trading across borders, enforcing contracts and resolving insolvency. A high ranking indicates that the regulatory environment is more conducive to setting up a business.

Source: World Bank

2.1.2 Intellectual property protection

The World Economic Forum Executive Opinion Survey is conducted on an annual basis to gather information from business leaders on topics for which hard data sources are scarce or non-existent. It is part of the effort to supplement the Global Competitiveness Report in
assessing issues that drive national competitiveness. This indicator measures response to the survey question: In your country, to what extent is intellectual property protected? (the answer ranges from 1 = not at all to 7 = to a great extent). It is based on 2018-2019 weighted average or most recent period available.

Source: World Economic Forum Executive Opinion Survey

2.1.3 ICT regulatory environment

This indicator is based on a composite index – the Information and Communications Technology (ICT) Regulatory Tracker – that provides a measure of the existence and features of ICT legal and regulatory frameworks. The index covers 50 indicators that are distributed across four pillars: Regulatory Authority, Regulatory Mandate, Regulatory Regime and Competition Framework. Scores are standardized to a scale of 0 to 2.

Source: International Telecommunication Union

2.1.4 Privacy regulation

The lack of clear privacy regulations can limit adoption if users feel their data and personal information are not secure online. Therefore, it is important that the country has privacy laws, which enable users to know what is legally acceptable within the country.

Source: Economist Intelligence Unit country research

2.1.5 Burden of government regulation

This indicator measures response to the survey question: In your country, how burdensome is it for companies to comply with public administration’s requirements (e.g., permits, regulations, reporting)? (the answer ranges from 1 = extremely burdensome to 7 = not burdensome at all). It is based on 2018-2019 weighted average or most recent period available.

Source: World Economic Forum Executive Opinion Survey

2.1.6 Business and government investment

Building digital infrastructure and capabilities requires significant investments from both governments and businesses. To measure these investments, the indicator assesses different sources of private and public investment, including foreign direct investment, research and development (R&D) spending, and investment freedom.

Source: Cisco

2.1.7 R&D expenditure by government and higher education (per cent of GDP)

This indicator refers to the combined expenditure by governments and higher education institutions on R&D as a percentage of GDP. The government sector comprises all units of central, regional and municipal government, but excludes public enterprises (which fall under the business enterprise category). Higher education institutions are those that primarily focus on providing formal tertiary education (i.e., levels 5-8 of the International Standard Classification of Education). R&D expenditure is defined as all current expenditure plus gross fixed capital expenditure for R&D performed by governments and higher education institutions, whatever the source of funds.

Source: United Nations Educational,
Scientific and Cultural Organization

2.1.8 Government promotion of investment in emerging technologies

The data refers to the simple mean of the average answers to a similarly worded question regarding five different emerging technologies: In your country, to what extent does the government foster investment (public and private) in artificial intelligence and machine learning, robotics, app- and web-enabled markets, big data analytics, and cloud computing? (the answers range from 1 = not at all to 7 = to a great extent).

Source: World Economic Forum Executive Opinion Survey

2.2 Adoption Stage

2.2.1 e-Government Development Index

The e-Government Development Index presents the state of e-government development of the United Nations member States. Along with an assessment of the website development patterns in a country, the index incorporates the access characteristics, such as the infrastructure and educational levels, to reflect how a country is using information technologies to promote access and inclusion of its people. The index is a composite measure of three important dimensions of e-government, namely, provision of online services, telecommunications connectivity and human capacity.

Source: United Nations Department of Economic and Social Affairs

2.2.2 e-Participation Index

The e-Participation Index assesses, on a 0-to-1 (best) scale, the quality, relevance and usefulness of government websites in providing online information and participatory tools and services to their citizens.

Source: United Nations Department of Economic and Social Affairs

2.2.3 Online Service Index

The Online Service Index assesses the quality of government's delivery of online services on a 0-to-1 (best) scale. It measures the evolution of e-government services (smart services) in terms of availability, quality, connectivity and diversity of channels, and the use by the public of these services. The index is based on data collected from an independent Online Service Questionnaire conducted by the United Nations Department of Economic and Social Affairs, which assesses the national online presence of all 193 United Nations member States, complemented by a Member State Questionnaire.

Source: United Nations Department of Economic and Social Affairs

2.2.4 Legal framework’s adaptability to digital business

This indicator measures response to the survey question: How fast is the legal framework of your country adapting to digital business models (e.g., e-commerce, sharing economy, fintech, etc.)? (the answer ranges from 1 = not fast at all to 7 = very fast). It is based on 2018-2019 weighted average or most recent period available.

Source: World Economic Forum Executive Opinion Survey

2.2.5 National digital identification system

This indicator assesses whether the country has a national digital identification system. It measures response to the survey question: Does the country have a national
digital identification system to be used online to access government services?

Source: World Bank

2.2.6 Effectiveness of government

This indicator assesses the quality of the civil service and the degree of its independence from political pressures, the quality of policy formulation and implementation, and the credibility of the government's commitment to such policies.

Source: World Bank

2.2.7 Government's responsiveness to change

This indicator measures response to the survey question: In your country, to what extent does the government respond effectively to change (e.g., technological changes, societal and demographic trends, security and economic challenges)? (the answer ranges from 1 = not at all to 7 = to a great extent). It is based on 2018-2019 weighted average or most recent period available.

Source: World Economic Forum Executive Opinion Survey (various editions)

2.2.8 e-Commerce legislation

This indicator refers to countries’ adoption of e-commerce legislation. The Global Cyberlaw Tracker provides information on whether a country has adopted legislation (or has a draft law pending adoption) in four areas: electronic transactions, consumer protection, privacy and data protection, and cybercrime. Scores range from 0 (no legislation) to 4 (adopted legislation in all four areas).

Source: United Nations Conference on Trade and Development

2.3 Acceleration Stage

2.3.1 Cloud regulation

The cloud regulation segment comprises three parameters: Privacy, Government Regulatory Environment and Intellectual Property Protection. The data for each of the three parameters was normalized to a 10-point scale and then aggregated to provide scores out of 30.

Source: ACCA

2.3.2 Publication and use of open data

This indicator refers to the fourth edition of the Open Data Barometer, an index that provides a measure of how governments publish and use open data based on the following three dimensions (weights given in parentheses): Readiness (35 per cent), Implementation (35 per cent) and Impact (30 per cent).

Source: World Wide Web Foundation

2.3.3 Government Artificial Intelligence Readiness Index

The index measures governments' readiness to implement artificial intelligence in the delivery of public services to their citizens. It looks at the capabilities and enabling factors required for a government to be ready for artificial intelligence implementation, but it does not measure the implementation itself.

Source: Oxford Insights

2.3.4 Open data policies

This indicator assesses whether the government has a formal open data policy that applies to the public sector (i.e., the government makes public sector data – both public and
publicly-funded data – publicly available to the general population), and whether the government has an open data website or platform that centralizes this data.

Source: Economist Intelligence Unit country research

2.3.5 Trust in online privacy

This indicator measures response to the survey question: How confident are you that your activity online is private? It is ranked by responses indicating “somewhat confident” and “very confident”.

Source: Economist Intelligence Unit Survey

2.3.6 Trust in government website and apps

This indicator measures response to the survey question: To what extent do you trust the information you receive from the following sources online? – Government websites / apps. It is ranked by responses indicating “mostly” and “completely”.

Source: Economist Intelligence Unit Survey

2.3.7 Online security or cybersecurity

The Global Cybersecurity Index provides a measure of the level of cybersecurity commitment of countries. It is a composite index made up of 25 indicators that are distributed across five main pillars: Legal Measures, Technical Measures, Organizational Measures, Capacity Building Measures and Cooperation measures. Scores are standardized to a scale of 0 to 1.

Source: International Telecommunication Union

2.3.8 Future orientation of government

This indicator is based on the average score of the following four Executive Opinion Survey questions: How fast is the legal framework of your country in adapting to digital business models (e.g., e-commerce, sharing economy, fintech, etc.)? (the answer ranges from 1 = not fast all to 7 = very fast); in your country, to what extent does the government ensure a stable policy environment for doing business?; in your country, to what extent does the government respond effectively to change (e.g., technological changes, societal and demographic trends, security and economic challenges)?; in your country, to what extent does the government have a long-term vision in place? For the last three questions, the answers range from 1 = not at all to 7 = to a great extent.

Source: World Economic Forum Global Competitiveness Index

3. Business Pillar

3.1 Foundation Stage

3.1.1 Foreign direct investment net flow

This indicator is based on data from the International Monetary Fund Balance of Payments Database, supplemented by data from the United Nations Conference on Trade and Development and official national sources.

Source: International Monetary Fund

3.1.2 R&D expenditures by businesses

The expenditures on R&D, expressed as a percentage of GDP (2016 or most recent year available). This indicator covers current and capital expenditures (both public and private) on creative work undertaken systematically to increase knowledge.
– including knowledge of humanity, culture and society – and the use of knowledge for new applications. R&D covers basic research, applied research and experimental development.

Source: World Bank World Development Indicators Database

3.1.3 Business environment

The Economist Intelligence Unit business environment rankings quantify the attractiveness of the business environment. The business rankings model examines 10 separate criteria or categories, covering the political environment, macroeconomic environment, market opportunities, policy towards free enterprise and competition, policy towards foreign investment, foreign trade and exchange controls, taxes, financing, the labour market, and infrastructure.

Source: Economist Intelligence Unit Business Environment Rankings

3.1.4 High-tech exports (USD)

High-technology exports are products with high R&D intensity, such as in aerospace, computers, pharmaceuticals, scientific instruments and electrical machinery. Data is in current US dollars. Since industrial sectors specializing in a few high-technology products may also produce low-technology products, the product approach is more appropriate for international trade.

Source: United Nations Comtrade

3.1.5 Medium- and high-tech industry

This indicator refers to the percentage of the value added of medium- and high-tech industry out of the total value added of manufacturing. The manufacturing sector relates to sector D in the International Standard Industrial Classification of all Economic Activities (ISIC) revision 3 (1990) or sector C in ISIC revision 4 (2008). The definition of “medium- and high-tech industry” is based on the R&D intensity of economic activities. See United Nations (2019) or Galindo-Rueda & Verger (2016) for details on the classification.

Source: United Nations Industrial Development Organization

3.1.6 Labour productivity per employee

The Conference Board provides two calculations of its estimates on output, labour and labour productivity: an original version based on official GDP data and an adjusted version based on GDP growth and levels that consider rapidly falling ICT prices. This indicator is based on the estimates of the adjusted version.

Source: The Conference Board Total Economy Database

3.1.7 Scientific publications

The index measures the number of published papers cited in other papers at least h times. The h-index reflects both the number of publications and the number of citations per publication. Only articles, reviews and conference papers are considered. The document universe is defined by those tracked by Scopus, an abstract and citation database of peer-reviewed literature: scientific journals, books and conference proceedings. A log transformation is applied to the raw score before it is normalized to a 0 to 100 scale.

Source: SCImago Journal & Country
3.2 Adoption Stage

3.2.1 Computer software spending

This indicator includes the total value of purchased or leased packaged software such as operating systems, database systems, programming tools, utilities and applications. It excludes expenditures for internal software development and outsourced custom software development. The data is a combination of actual figures and estimates, and is reported as a percentage of GDP.

Source: World Economic Forum

3.2.2 Venture capital availability

This indicator measures response to the survey question in the new edition of the Executive Opinion Survey, which includes the distribution of venture capital by region: In your country, how easy is it for startup entrepreneurs with innovative but risky projects to obtain equity funding? (the answer ranges from 1 = extremely difficult to 7 = extremely easy).

Source: World Economic Forum

3.2.3 Mobile apps development

This indicator is included in the Mobile Connectivity Index published by GSMA. It is one of four indicators that make up the Local Relevance Subindex, which, in turn, is part of the Content & Services Pillar. The original data is sourced from AppFigures (https://appfigures.com/).

Source: GSMA

3.2.4 Digital content (news) in local languages

This indicator assesses whether there is local news for the largest metropolitan area in local languages, including both official and non-official languages. For countries with more than one official language, the justification covers each of the official languages. Non-official languages may include native, indigenous or minority languages (e.g., immigrant populations) commonly spoken but not recognized as official languages. The availability of online news in non-official languages can help to empower native and minority communities to produce their own culturally and locally relevant online content. Audio or video content may attract different user groups and may be preferred by speakers of non-written languages or users with lower levels of comprehension or literacy. The frequency with which content is updated will also draw users online.

Source: Economist Intelligence Unit country research

3.2.5 e-Government services in local languages

This indicator assesses whether there is a local government website available for the largest city in the country and whether the site offers transactional services that can include: applying for any type of license or permit, registering for programmes / services and paying bills and fees. If the city website provides downloadable applications, but the process is not entirely online, the country scores a 1. In order to score a 2, the entire process must be online.

Source: Economist Intelligence Unit country research

3.2.6 Business use of digital tools

This indicator measures response to
the survey question: In your country, to what extent do businesses make good use of the latest digital tools to sell their goods and services (e.g., e-commerce, digital payment, mobile web stores, social media stores)? (the answer ranges from 1 = not at all to 7 = to a great extent).

Source: World Economic Forum

3.2.7 ICT-enabled organizational model creation

This indicator measures the average answer to the question: In your country, to what extent do ICTs enable new organizational models (e.g., virtual teams, remote working, telecommuting) within companies? (the answer ranges from 1 = not at all to 7 = to a great extent).

Source: World Intellectual Property Organization

3.3 Acceleration Stage

3.3.1 Startup environment

This indicator assesses a country’s startup environment, such as its venture capital availability and investment, new business density, and patent and trademark registrations.

Source: Cisco

3.3.2 Robot density

This indicator refers to the estimated number of multipurpose industrial robots per 10,000 persons employed in the manufacturing industry (ISIC revision 4: C). The International Federation of Robotics collects country-level data on operational stock of industrial robots and, for some countries, computes robot densities. The computed robot densities are published in the annual World Robotics Report.

Source: International Federation of Robotics

3.3.3 Use of big data analytics

This indicator assesses the extent to which companies are using big data and analytics to support decision-making.

Source: Institute for Management Development

3.3.4 Innovation capability

This indicator measures response to the survey question: In your country, how widespread are well-developed and deep clusters (geographic concentrations of firms, suppliers, producers of related products and services, and specialized institutions in a particular field)? (the answer ranges from 1 = non-existent to 7 = widespread in many fields). It is based on 2018-2019 weighted average or most recent period available.

Source: World Economic Forum Executive Opinion Survey

3.3.5 Adoption of emerging technologies

The data refers to the simple mean of the average answers to a similarly worded question regarding five different emerging technologies: In your country, to what extent are companies adopting artificial intelligence, robotics, app- and web-enabled markets, big data analytics, and cloud computing? (the answers range from 1 = not at all to 7 = to a great extent – on par with the most technologically advanced economies).

Source: World Economic Forum Executive Opinion Survey

3.3.6 Number of tech unicorns

A unicorn company is a privately-
owned startup that has a current valuation of USD1 billion or over.

Source: CB Insights

3.3.7 Growth of innovative companies

This indicator measures response to the survey question: In your country, to what extent do new companies with innovative ideas grow rapidly? (the answer ranges from 1 = not at all to 7 = to a great extent). It is based on 2018-2019 weighted average or most recent period available.

Source: World Economic Forum Executive Opinion Survey

4. People Pillar

4.1 Foundation Stage

4.1.1 Labour force participation (per cent of total population ages 15-64)

Labour force participation rate is the proportion of the population ages 15-64 that is economically active: all people who supply labour for the production of goods and services during a specified period. The labour force is the supply of labour available for producing goods and services in an economy. It includes people who are currently employed and people who are unemployed but seeking work as well as first-time jobseekers. Not everyone who works is included, however. Unpaid workers, family workers and students are often omitted, and some countries do not count members of the armed forces. Labour force size tends to vary during the year as seasonal workers enter and leave.

Source: International Labour Organization

4.1.2 Adult literacy (per cent of people)

Adult literacy rate is the percentage of people ages 15 and above who can both read and write, and has the ability to understanding a short simple statement about their everyday life.

Source: United Nations Educational, Scientific and Cultural Organization

4.1.3 Harmonized test score

Harmonized test scores from major international student achievement testing programmes. They are measured in equivalent units from the Trends in International Maths and Science Study, where 300 is minimal attainment and 625 is advanced attainment. Most recent estimates are used, and the year of most recent estimate is shown in data notes.

Source: World Bank

4.1.4 Public expenditure on education (per cent of GDP)

The total general (local, regional and central) government expenditure in educational institutions (current and capital). It excludes transfers to private entities such as subsidies to households and students, but includes expenditure funded by transfers from international sources to government. It includes pre-primary, primary, secondary and tertiary public institutions.

Source: Eurostat

4.1.5 Basic skills

This indicator measures adult literacy (25 per cent) + school life expectancy (25 per cent) + mean years of schooling (25 per cent) + tertiary enrolment (25 per cent).

Sources: United Nations Development Programme and United Nations Educational,
Scientific and Cultural Organization

4.1.6 Mean years of schooling

The average number of completed years of education of a country’s population aged 25 years and older, excluding years spent repeating individual grades.

Source: United Nations Educational, Scientific and Cultural Organization

4.2 Adoption Stage

4.2.1 Digital skills among active population

This indicator measures response to the survey question: In your country, to what extent does the active population possess sufficient digital skills (e.g., computer skills, basic coding, digital reading)? (the answer ranges from 1 = not at all to 7 = to a great extent). It is based on 2018-2019 weighted average or most recent period available.

Source: World Economic Forum Executive Opinion Survey

4.2.2 Quality of vocational training

This indicator measures response to the survey question: In your country, how do you assess the quality of vocational training? (the answer ranges from 1 = extremely poor among the worst in the world to 7 = excellent among the best in the world). It is based on 2018-2019 weighted average or most recent period available.

Source: World Economic Forum Executive Opinion Survey

4.2.3 Ease of finding skilled employees

This indicator measures response to the survey question: In your country, to what extent can companies find people with the skills required to fill their vacancies? (the answer ranges from 1 = not at all to 7 = to a great extent). It is based on 2018-2019 weighted average or most recent period available.

Source: World Economic Forum Executive Opinion Survey

4.2.4 Support for digital literacy

This indicator assesses the existence of a strategy that supports digital literacy whereby the government plan or strategy should include courses in ICT skills, computer science, programming or other classes where computers are mandatory in the curriculum. The plan or strategy must also include training teachers on ICT skills.

Source: Economist Intelligence Unit country research

4.2.5 Schools with Internet access

The percentage of secondary educational institutions with any type of Internet connection, whereby the Internet is defined as: “Worldwide interconnected networks that enable users to share information in an interactive format – referred to as hypertext – through multiple wired or wireless devices (e.g., personal computers, laptops, personal digital assistants, smartphones, etc.) via broadband and narrowband connections”. Where data gaps existed, data on primary educational institutions was collected.

Source: United Nations Educational, Scientific and Cultural Organization

4.2.6 Skills of current workforce

This indicator is based on a composite index that measures the extent of staff training, quality of vocational training, skillset of graduates, digital skills among active population and ease of finding skilled
employees.
Source: World Economic Forum

4.3 Acceleration Stage

4.3.1 Critical thinking in teaching
This indicator measures response to the survey question: In your country, how do you assess the style of teaching? (the answer ranges from 1 = frontal, teacher-based and focused on memorizing to 7 = encourages creative and critical individual thinking). It is based on 2018-2019 weighted average or most recent period available.
Source: World Economic Forum Executive Opinion Survey

4.3.2 Pupil to teacher ratio in primary education
The average number of pupils per teacher, based on headcounts of both pupils and teachers. It is based on 2017 data or most recent period available.
Source: World Economic Forum

4.3.3 School computers per student
The Programme for International Student Assessment measures the availability and quality of material resources in schools by asking school principals if their school’s capacity to provide instruction is hindered by: a lack of educational materials (i.e., textbooks, ICT equipment, library or laboratory material); inadequate or poor-quality educational materials; a lack of physical infrastructure (i.e., building, grounds, heating / cooling systems, lighting and acoustic systems); or inadequate or poor quality physical infrastructure.
Source: Organisation for Economic Co-operation and Development’s Programme for International Student Assessment

4.3.4 Female digital skills training
This indicator assesses whether strategies and plans addressing e-inclusion of females and digital skills training for women exist that help reduce the gender digital divides.
Source: Economist Intelligence Unit country research

4.3.5 Female Science, Technology, Engineering and Mathematics (STEM) education
This indicator assesses whether policies or government initiatives exist that encourage women and girls to study STEM.
Source: Economist Intelligence Unit country research

4.3.6 Skills of future workforce
This indicator is based on a composite index that measures critical thinking in teaching and pupil-to-teacher ratio in primary education
Source: World Economic Forum

5. Ecosystem Pillar

5.1 Foundation Stage

5.1.1 Nominal GDP
This indicator measures the total economic value of a country. Countries with higher GDP typically have higher purchasing power for ICT.
Source: Economist Intelligence Unit

5.1.2 GNI per capita
Higher income increases the chances for affordability of access.
Source: World Bank
5.1.3 Democracy Index
This index measures the quality of democracy and the biggest threats to sustaining democracy.
Source: Economist Intelligence Unit

5.1.4 Corruption Perceptions Index
This index measures the perceived levels of public sector corruption worldwide.
Source: Transparency International

5.1.5 Price stability
Inflation is normalized in a U-shaped function to capture the detrimental effects of high inflation and deflation. Countries with inflation rates between 0.5 per cent and 4 per cent receive the highest possible score of 100. Outside this range, scores decrease linearly as the distance between the optimal value and the actual value increases. Due to the special conversion applied to this indicator, the ranking for this indicator is based on progress scores rather than raw values.
Source: International Monetary Fund

5.1.6 Debt dynamics
This indicator is a category-based min-max normalization of the debt change. The debt change is the difference between the 2017 and 2018 expected values of the debt-to-GDP ratio. To transform the debt change value into a 0 to 100 score, each country was assigned to a specific category that determined the value boundaries.
Source: World Economic Forum

5.2 Adoption Stage
5.2.1 Flexibility in labour market
This indicator is based on a composite index that measures redundancy costs, hiring and firing practices, cooperation in labour-employer relations, flexibility of wage determination, active labour market policies, workers’ rights, ease of hiring foreign labour, and internal labour mobility.
Source: World Economic Forum

5.2.2 Diversity of workforce
This indicator measures response to the survey question: In your country, to what extent do companies have a diverse workforce (e.g., in terms of ethnicity, religion, sexual orientation, gender)? (the answer ranges from 1 = not at all to 7 = to a great extent). It is based on 2018-2019 weighted average or most recent period available.
Source: World Economic Forum Executive Opinion Survey

5.2.3 International co-inventions
This indicator computes the sum of the patent family applications with at least one co-inventor located abroad, filed in at least two of the major five intellectual property offices in the world: the European Patent Office, the Japan Patent Office, the Korean Intellectual Property Office, the State Intellectual Property Office of the People’s Republic of China, and the United States Patent and Trademark Office. Data was extracted from the PATSTAT database by earliest filing date and inventor country, using fractional counts, and expressed in applications per million population. A log transformation was applied to the raw score before it was normalized to a 0 to 100 scale.
Source: Organisation for Economic Co-operation and Development
5.2.4 Multi-stakeholder collaboration

This indicator is based on the average score of the following three Executive Opinion Survey questions: In your country, to what extent do people collaborate and share ideas within a company? (the answer ranges from 1 = not at all to 7 = to a great extent); in your country, to what extent do companies collaborate in sharing ideas and innovating? (the answer ranges from 1 = not at all to 7 = to a great extent); in your country, to what extent do businesses and universities collaborate on R&D? (the answer ranges from 1 = do not collaborate at all to 7 = collaborate extensively).

Source: World Economic Forum Executive Opinion Survey

5.2.5 Cluster development and depth

This indicator is based on the average answer to the survey question: In your country, how widespread are well-developed and deep clusters (geographic concentrations of firms, suppliers, producers of related products and services, and specialized institutions in a particular field)? (the answer ranges from 1 = non-existent to 7 = widespread in many fields).

Source: World Economic Forum Executive Opinion Survey

5.2.6 Joint venture / strategic alliance deals

Refinitiv's data on joint venture / strategic alliance deals provides details on the country of origin of partner firms, among others. The data extraction corresponded to a query on joint venture / strategic alliance deals between 1 January 2018 and 31 December 2020. The country of each company participating in a deal (n companies per deal) was allocated, per deal, a score equivalent to 1/n (with the effect that all country scores added up to the total number of deals). The data was reported as GDP based on purchasing power parity.

Source: International Monetary Fund

5.3 Acceleration Stage

5.3.1 Energy efficiency regulation

The score is based on a country’s performance in 12 indicators: national energy efficiency planning; energy efficiency entities; information provided to consumers about electricity usage; incentives and mandates for industrial and commercial end users; incentives and mandates for the public sector; incentives and mandates for utilities; financing mechanisms for energy efficiency; minimum energy efficiency performance standards; energy labelling systems; building energy codes; transport; and carbon pricing and monitoring. For more information, see https://rise.worldbank.org/indicators#pillarenergy-efficiency.

Source: World Bank Energy Sector Management Assistance Program

5.3.2 Renewable energy regulation

The score is based on a country’s performance in seven indicators: legal framework for renewable energy; planning for renewable energy expansion; incentives and regulatory support for renewable energy; attributes of financial and regulatory incentives; network connection and use; counterparty risk; and carbon pricing and monitoring. For more information, see https://rise.worldbank.org/indicators#pillar-
renewable-energy.

Source: World Bank Energy Sector Management Assistance Program

5.3.3 Environmental treaties in force

This indicator measures the total number of international treaties from a set of 29 for which a state is a participant. A state is acknowledged as a participant whenever the status for each treaty appears as ratified, accession or in force.

Source: International Union for Conservation of Nature

5.3.4 Sustainable Development Goal (SDG) 11: Sustainable Cities and Communities

The safety and sustainability of cities is captured by two indicators: urban pollution and road safety. Urban pollution is an official indicator related to SDG 11: Make cities and human settlements inclusive, safe, resilient and sustainable (indicator 11.6.2), and is measured by annual mean concentrations of fine particulate matter in urban areas that are less than 2.5 microns in diameter. Road safety refers to death rate due to road traffic injuries per 100,000 people. It is an official indicator related to SDG 3: Ensure healthy lives and promote well-being for all at all ages (indicator 3.6.1), but it is also associated with SDG Target 11.2: By 2030, provide access to safe, affordable, accessible and sustainable transport systems for all, improving road safety, notably by expanding public transport, with special attention to the needs of those in vulnerable situations, women, children, persons with disabilities and older persons. The data refers to the simple mean of the reversed normalized scores of the two indicators.

Source: World Health Organization

5.3.5 GDP per unit of energy use

This indicator is reported as GDP based on purchasing power parity (2015) per total energy supply (TES). TES is made up of the cost of production + imports − exports − international marine bunkers − international aviation bunkers +/- stock changes. GDP / TES is an indicator of energy productivity.

Source: International Energy Agency

5.3.6 Environmental performance

The 2020 Environmental Performance Index ranks 180 countries on different categories covering environmental health and ecosystem vitality. These indicators provide a gauge of how close countries are to achieving established environmental policy targets. The index offers a scorecard that highlights leaders and laggards in environmental performance and provides practical guidance for countries that aspire to move towards a sustainable future. The index ranges from 0 to 100, with 100 indicating best performance.

Sources: Yale University and Columbia University, 2020 Environmental Performance Index; and Bourguignon, F., and Morrison, C. (2002).