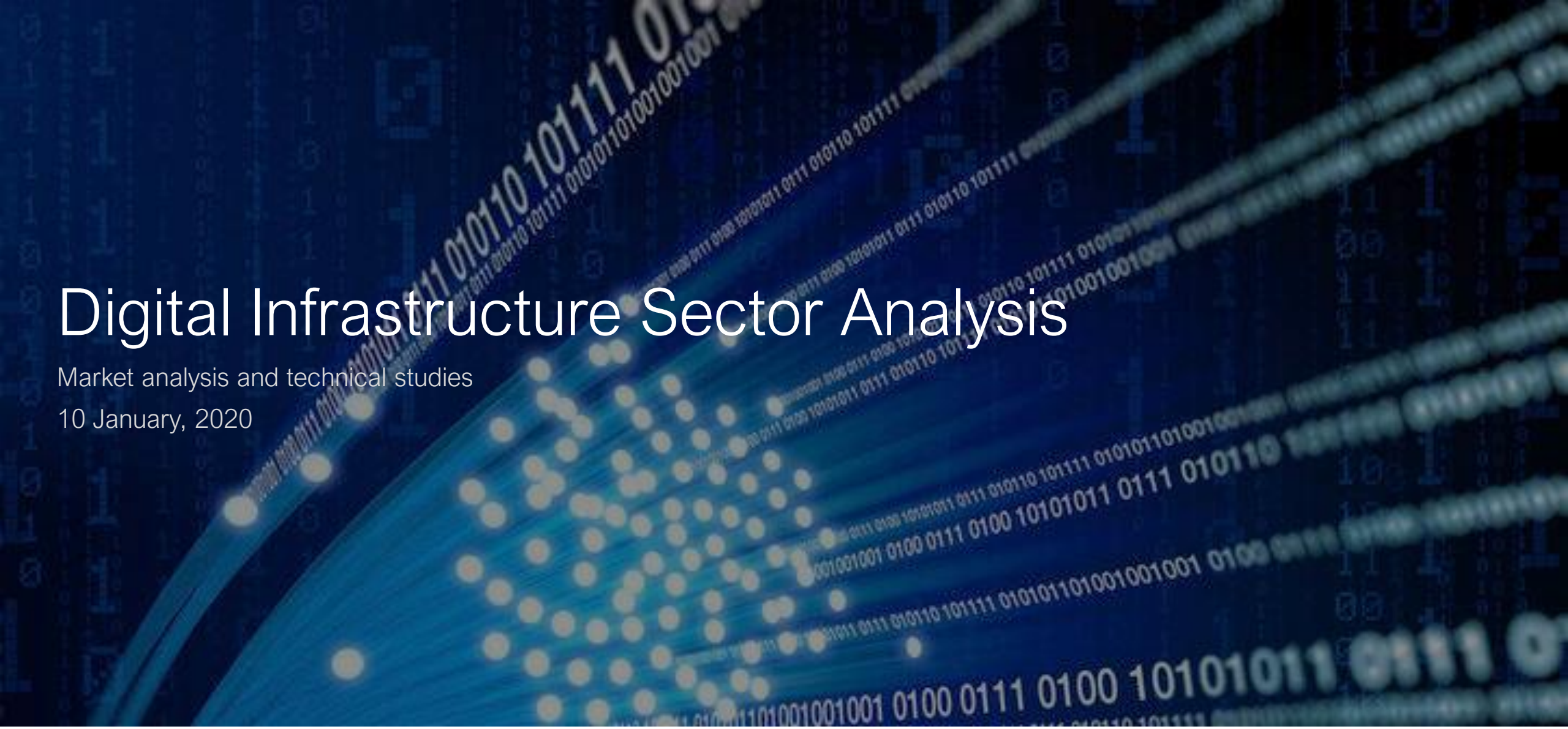


Digital Infrastructure Sector Analysis

Market analysis and technical studies

10 January, 2020

This study has been prepared by the staff of the Asian Infrastructure Investment Bank (AIIB), advised by Ovum led by Dr. CW Cheung as the technical consultant to the Bank.
The study team is also grateful for the views and support provided by various partners. The study does not necessarily represent the views of AIIB, its Board of Directors or Shareholders.

Content

Focus of analysis

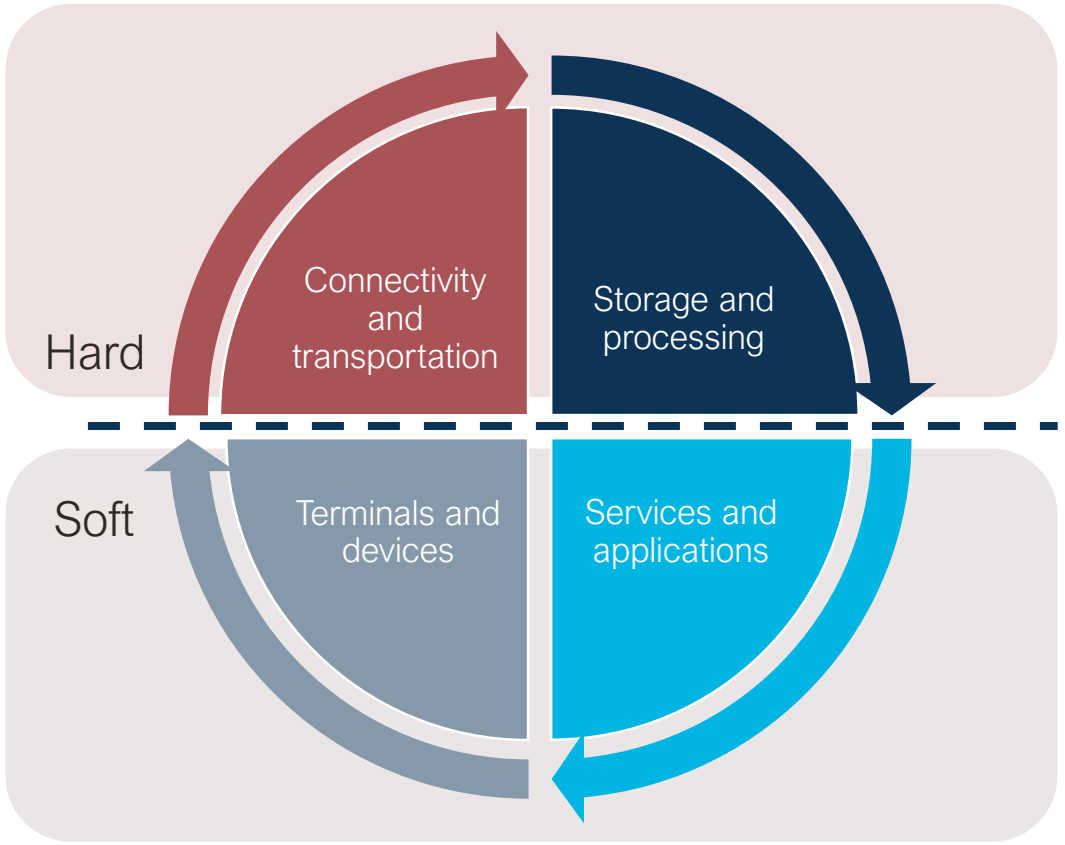
1. Overview of the Digital Infrastructure ecosystem
2. Dive into the Digital Infrastructure ecosystem
3. Infrastructure enhancing digital technologies and applications

1. Overview of the Digital Infrastructure ecosystem

The new “bridges and roads” that support the economy, in particular the digital economy

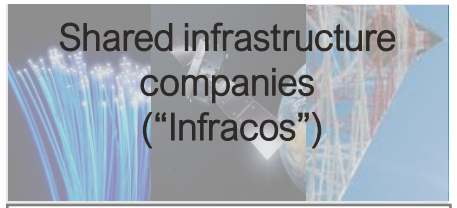
The Digital Infrastructure ecosystem

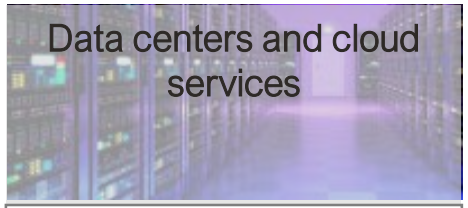
- Digital Infrastructure is **1 integrated system**
- Digital Infrastructure includes **2 categories**: (hard) *physical and (soft) non-physical*
- Digital Infrastructure contains **4 components** that work interactively
- Digital Infrastructure is the **key foundation** and **enabler** for the 21st century economy

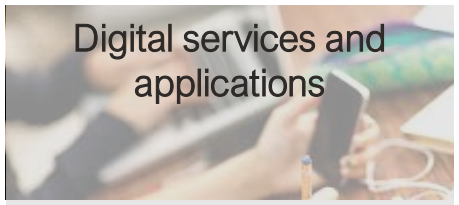


The digital landscape – key investible sectors

Connectivity and transportation	Storage and processing	Services and applications	Terminals and devices
The physical infrastructure that carries digital data between devices, data infrastructure and services.	The computing power to run services and storage of data of users.	The functions / applications that create economic value-add to business sectors and customers.	The interfaces between users (human or machines) and the digital services and applications.





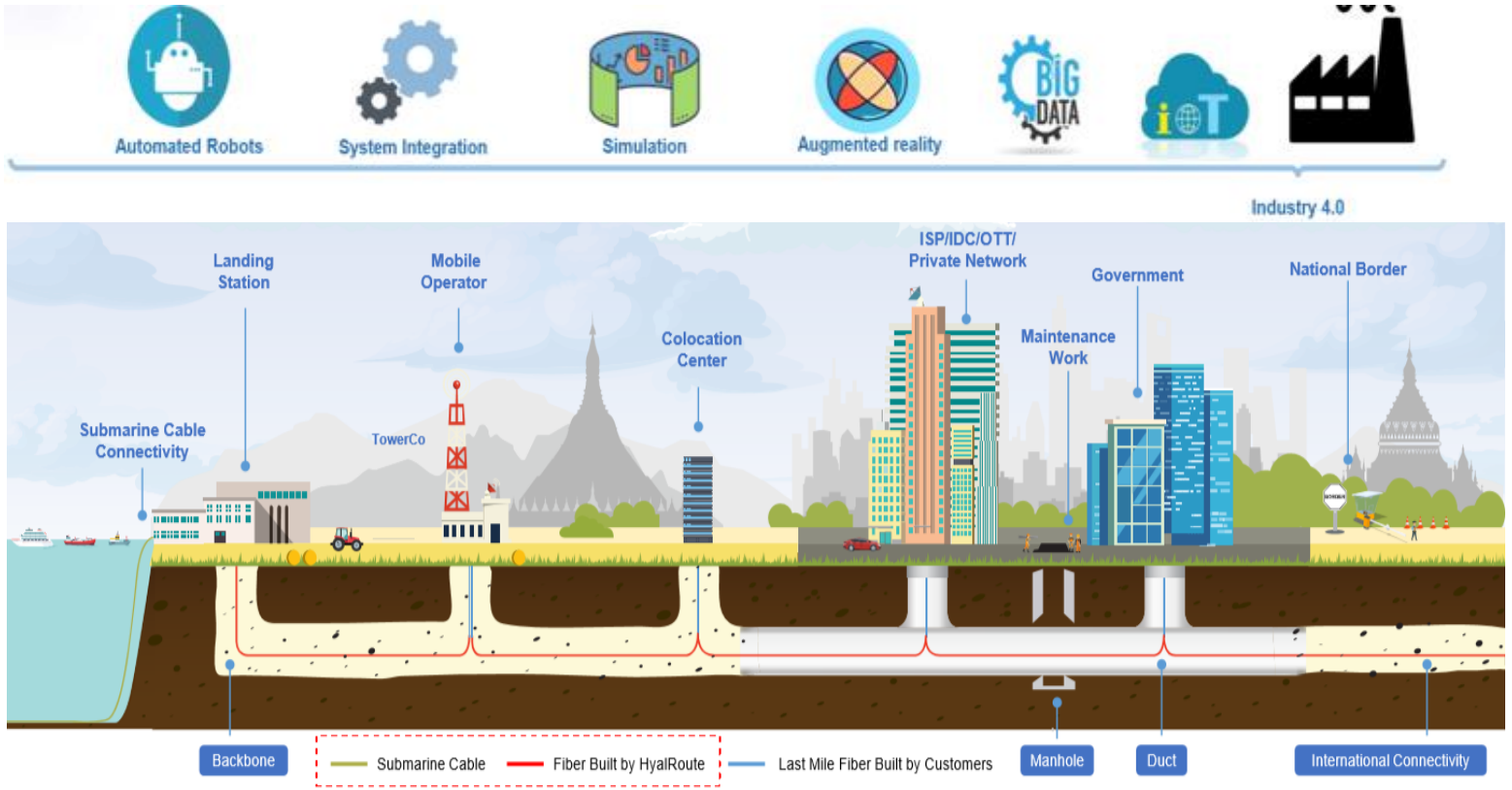


Sources: AIIB analysis, Ovum

Digital Infrastructure supports nations full digital development

Just like roads and rails, Digital Infrastructure is the foundation of digital economic activities and technological applications

- **Digital Infrastructure** serves as the basis for “Industry 4.0” innovations, value-adding digital activities and significant productivity improvement.
- Nations require international, regional and national **backbone transport infrastructure** to support local activity and international connectedness(e.g. 5G and fiber)
- For emerging markets, **connectivity** is the top priority.
- Once connectivity infrastructure is being established, **local datacenter infrastructure** can be added to support locally-deployed digital services and the growth of a local **digital ecosystem**.



Source: HyalRoute Group, AIIB

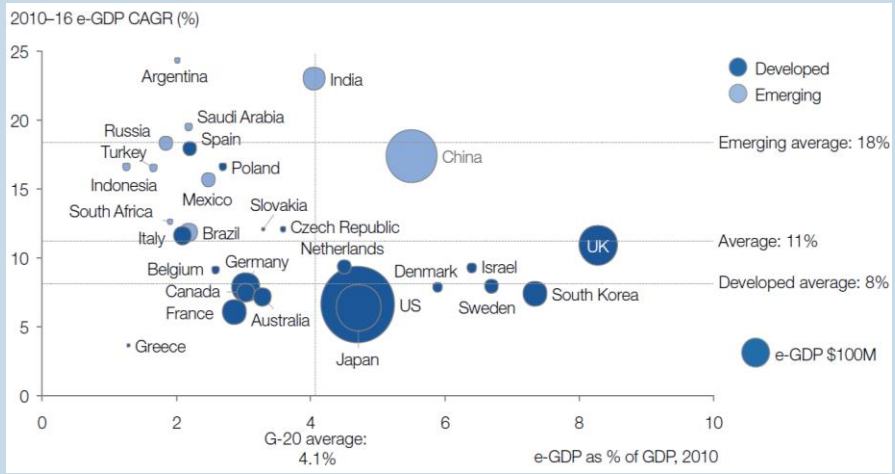
Digital Infrastructure is the building block of a modern economy

Yet Digital Infrastructure financing gap is growing…

1. While digital economy is growing in size and relative economic significance…

- Global digital economy in 2016 was worth $11.5 trillion, or **15.5% of global GDP** and expected to reach 25% in less than a decade.
- Emerging markets see the highest growth of digital economy, due in part to the young population with longest time using the internet.
- Digital economy also encourages **inclusion** by linking people separated by distance or social barriers (e.g. providing schooling and healthcare services digitally)

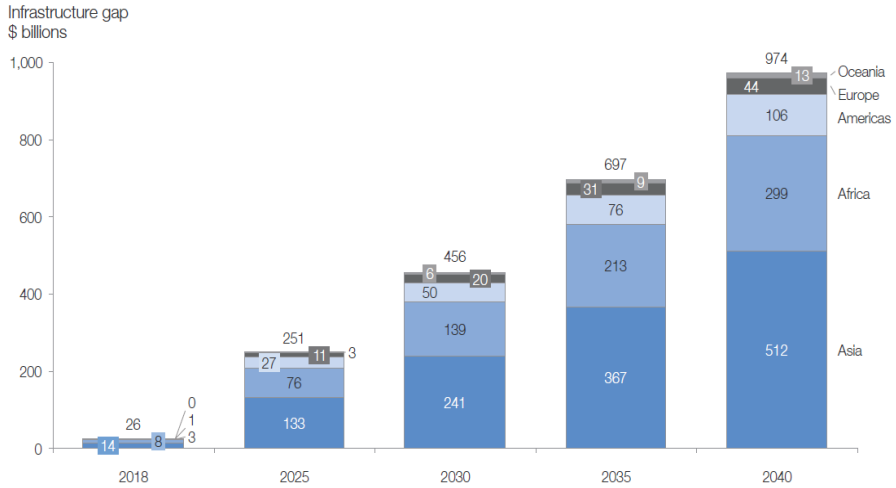
Sources: World Economic Forum, EIU, Ovum, OECD, HooteSuite



2. …Digital Infrastructure financing gap is projected to increase

- Despite the rising importance of digital economy, **Digital Infrastructure financing gap in Asia is growing significantly**, estimated to reach $512 billion by 2040.
- Financing gaps prevalent in middle and low-income countries.
- **More than 50%** of Digital Infrastructure investment gap will be in Asia by 2040, with predicted impact on economic growth.

Sources: World Economic Forum, World Bank; Global Infrastructure Outlook; Oxford Economics.



Mega trends in the Digital Infrastructure ecosystem

	Industry observations	Regional trends and implications
1. Connectivity & transport infrastructure is fundamental, but unevenly distributed	• Connectivity is unevenly distributed across Asian developed, developing and emerging markets. • There is a divide between East and South East Asia where investment is strong, and Central and Southern Asia where lower incomes have delayed investment.	• Fixed connectivity providers enjoy higher barriers to entry, but suffer from affordability issues in Central & Southern Asia, indicating investment opportunities. • Mobile connectivity providers have seen revenue per user fall due to price wars, competition from OTT services like WhatsApp, and price regulation. This is driving consolidation in some Asian markets.
2. Asian data infrastructure is growing fast, but capacity still lags developed regions	• Local data infrastructure is needed to offer digital services without relying on international connectivity. • Data infrastructure in Asia is concentrated geographically in a few locations	• Datacenter co-location (datacenter real estate leasing) is also growing in Asia. • This rising investment means that Asia's installed compute capacity will exceed North America's (and every other region's) by 2021, according to Cisco. • Rising workloads and new data protection rules are making hyperscale datacenter providers invest in Asia. This is placing pressure on smaller independent and telco datacenters.
3. As smartphone growth slows, terminals & devices will be dominated by IoT	• Terminals & devices are either human-operated (smartphones and media devices) or machine operated ("Internet of Things"). The latter is a key foundation for "smart infrastructure". • As smartphone growth slows, the future growth will be driven by machine operated terminals.	• Asia (and particularly China) is already the leading region for IoT connections, and will entrench its dominance in coming years. • Eastern Asia leads this trend globally. Central and Southern Asia is growing fast, but off a much smaller base.
4. Services & applications are driving infrastructure demand	• Services, both B2C and B2B, are growing fast. • Content services and smartphone apps dominate the to-C market, while cloud services dominate the to-B market.	• Cloud services are value-added data storage & processing services that draw on datacenter resources such as compute power, storage and networking. They come in three flavors: Infrastructure-as-a-service, Platform-as-a-Service and Software-as-a-Service

AIIB, Ovum analysis

Key takeaways on the Digital Infrastructure market

1. **Digital economy** is emerging to become one of the most **important growth drivers** and **indispensable part** of modern economy.

2. **Digital Infrastructure development (both soft and hard) is the foundation of digital economy.** It has to be **aligned** with different maturity levels, where digital availability, access, appetite and abilities should be considered holistically.

3. **The financing gap is growing** between the required needs of the digital economy and actual Digital Infrastructure investments; also, the **use of technology in traditional infrastructure sectors are lagging behind**.

4. **AIIB could be a leader in this market**. Digital divide, rising Digital Infrastructure gap, weakening financial capabilities for Digital Infrastructure, and sluggish application of technology into infrastructure sectors, are all contributing to opportunities for AIIB.

2. Dive into the Digital Infrastructure ecosystem

2. Dive into the Digital Infrastructure ecosystem

1. Sector analysis
2. Market insights
3. Social benefits, policy & regulations
4. Financing landscape
5. Challenges, actions and opportunities for AIIB

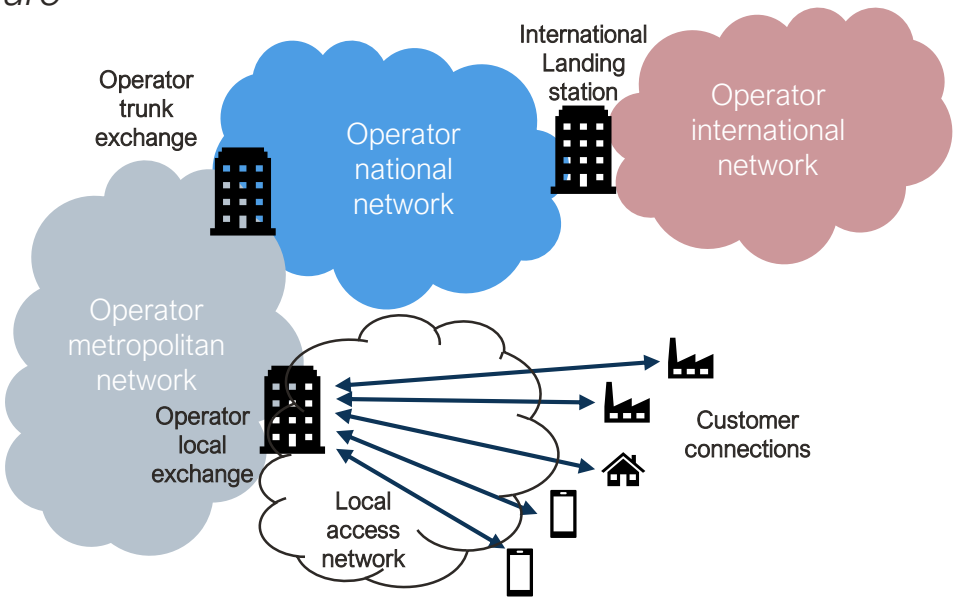
2.1 Sector analysis

Product, revenue model, finance, value drivers, key trends and risks

Connectivity & transport: products, revenue model and finance

Connectivity & transport are the fundamental building blocks of Digital Infrastructure

- **Products:**
  - Local traffic is carried on fixed and wireless access networks.
  - Linked up by metropolitan, national & international backbone networks.
- **Providers:**
  - Traditional fixed and mobile telecom companies ("telcos"), satellite operators and cable operators
  - "Carrier-neutral" wholesale providers and various resellers
- **Revenue model:**
  - Shifted away from fees for usage towards monthly rental in 20 years
  - Mobile revenue has supplanted fixed; data revenue is supplanting voice & text.
- **Finance:**
  - Cashflow management and investment are getting more difficult.
  - **The integrated telco** remains the main **investable unit**.
  - Traditional equity and debt are the main sources of finance, though PPP and public finance are growing.



Sources: AIIB analysis, Ovum

Connectivity & transport: value drivers, trends and risks

Connectivity & transport ROIC is in decline, while capital requirements are rising.

1 Value drivers

- **Scale and capital efficiency** are the key value drivers
- Operators in **growing markets** must **gain scale**
- Operators in **saturated markets** must improve **capital efficiency**.

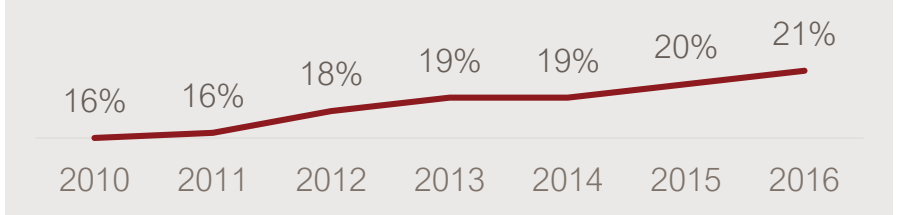
2 Key trends

- Government interest in **accelerating 5G rollout** to support industrial digitalization is growing
- The **growth of IoT** will entrench the dominance of mobile.
- Globally, **telecommunications capital intensity rose** over 2010-16, while **return over invested capital ("ROIC") fell** over the same period.
- The **complexity of compliance** rules is growing as new regulatory domains like data protection expand.

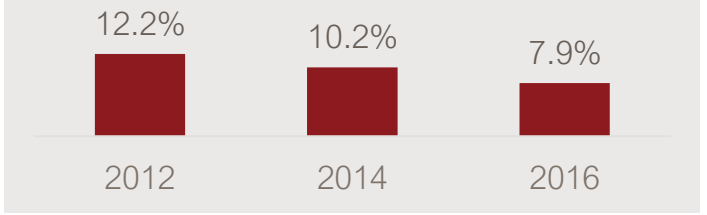
3 Risks

- Price regulation
- Policy acceleration of 5G rollout ahead of demand
- Cybercrime and cyber terrorism
- Persistent low ROIC slowing investment
- Restrictions on Merger and Acquisition ("M&A")
- New regulatory rules like data protection raising costs and disrupting new business models.

Capex intensity - rising



Average ROIC (%) - declining



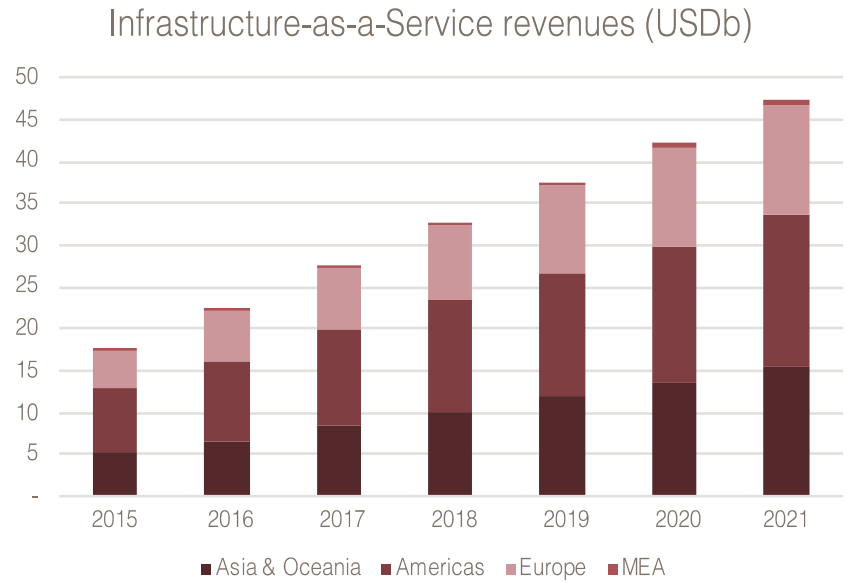
Source: Forbes India, PwC

Sources: AIIB analysis, Ovum

Data storage & processing: products, revenue model and finance

Data storage & processing providers offer facilities to manipulate and store data generated by services and users

- **Products:**
  - Compute, memory, storage, security and network resources
  - Packaged in various configurations.
  - Cloud services are key datacenter value-added offer, and account for around 90% of datacenter revenues. (source: Cisco Global Cloud Index)
- **Providers:**
  - Public cloud providers (AWS, Azure)
  - Private cloud providers (internal to businesses like media and finance)
  - Datacenter Co-location providers (offering datacenter floorspace).
- **Revenue model:**
  - Datacenter services are rented on an hourly to multi-year basis.
  - Cloud prices have fallen fast: "Bezos' Law" - computing power prices have fallen by 50% every 3 years. Global output is growing in double figures (see figure)
- **Finance:**
  - **The investable units:** datacenter/cloud providers and datacenter co-location providers.
  - Traditional equity and debt are the main sources of finance, though PPP and public finance are growing.



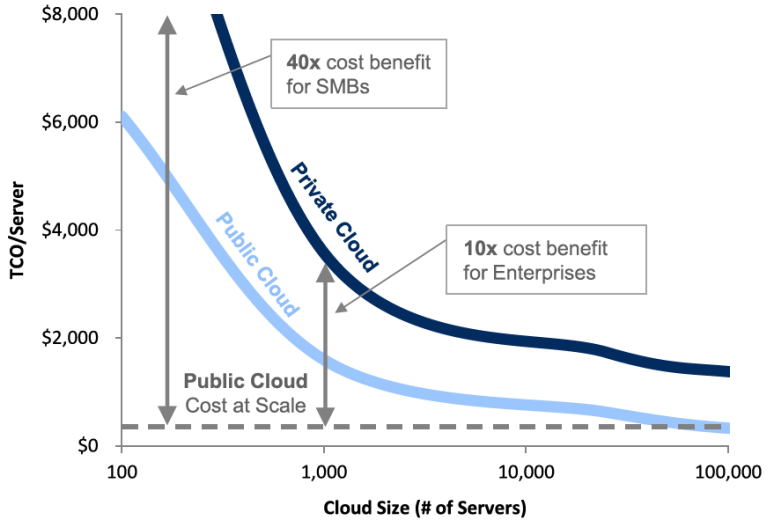
Sources: AIIB analysis, Ovum

Data storage & processing: value drivers, trends and risks

Success will depend on scale, energy efficiency, and meeting new regulatory requirements

1 Value drivers

- **Scale** is **the key driver** of datacenter value.
- Moving from a 1000 to a 100,000 server datacenter **reduces Total Cost of Ownership ("TCO") per server by 80%** (source: Microsoft)



Source: Microsoft

2 Key trends

- The global data center market will reach USD174 billion revenue by 2023, with a **cumulated average growth rate ("CAGR") of 4%** over 2018-23 (Arizton Research).
- **Asia Pacific is the fastest** growing region for hyperscale datacenters, and will be biggest region for datacenter capacity by 2021 (source: Cisco Global Cloud Index).
- **Hyperscale datacenter providers** are expanding their market share (source: Cisco Global Cloud Index).
- **Data protection rules** are forcing operators to increase capex in new markets.

3 Risks

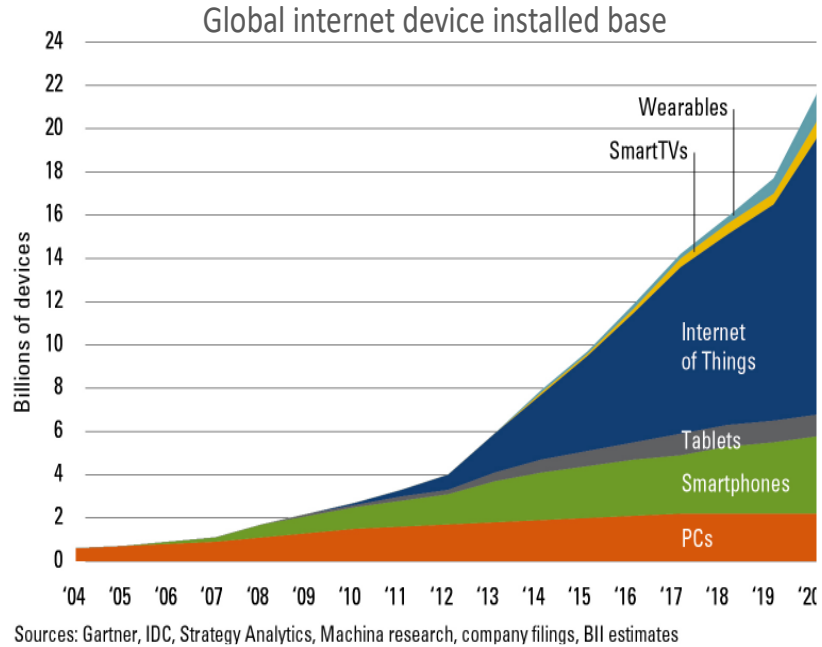
- **High energy use,** exposing datacenters to power price increases driven by climate policies.
- **Tighter national data protection rules,** requiring more local investment.
- **Low scale** of smaller and telco data infrastructure providers to gain scale.
- **Cybercrime** and cyber terrorism.

Sources: AIIB analysis, Ovum

Terminals & devices: products, revenue model and finance

Data storage & processing providers offer facilities to manipulate and store data generated by services and users

- **Products:**
  - **Human operated devices**: Basic and smart phones, tablets, smart media devices and personal computers ("PC"). Penetration is saturating.
  - **Machine operated devices** (the Internet of Things, "IoT"): A wide range of sensors and actuators. The future growth driver.
- **Providers:**
  - **Human operated segment**: Apple, Korean electronics brands, and increasingly Chinese brands including Huawei, ZTE, Oppo and Vivo.
  - **The machine operated segment** is more fragmented and specialized.
- **Revenue model:**
  - Unit sales: Average IoT device prices are falling (from USD1.30 in 2014 to USD0.38 in 2020, source: Atlas Research) while installations are rising fast.
  - IoT devices can be bundled with IoT platforms and applications on a rental model.



Source: BI Intelligence

- **Finance:**
  - **Investable units:** major consumer electronics companies, IoT platform providers and integrators who bundle devices, platforms and services into a single product, and telcos who bundle IoT platforms with mobile connectivity.
  - Main sources of finance: Traditional equity and debt; venture capital investment in new technologies.

Sources: AIIB analysis, Ovum

Terminals & devices: value drivers, trends and risks

Terminals & devices are of two kinds. Human-operated devices include smartphones, tablets and smart media devices. Machine-to-machine (M2M) devices operate automatically, and will be the source of most future device growth.

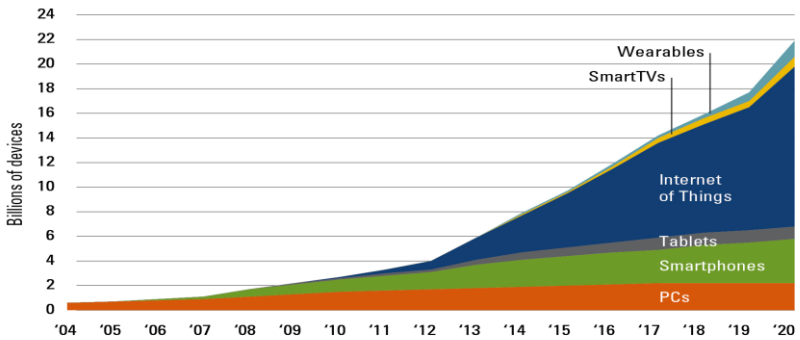
1 Value drivers

- In the **human-operated device segment**, value is driven by branding, marketing, strength of application ecosystem, device quality, and scale of production. Only a few electronics manufacturers account for most device sales.
- In the **Machine-to-machine ("M2M")** terminal segment, value is driven by design, quality and scale. The market is a still fragmented between OEM terminal makers, IoT platform providers, and IT integrators.

2 Key trends

- M2M terminals for IoT systems will drive most terminal growth over the next decade.
- M2M terminal prices are falling fast.
- Human-operated devices will continue to grow, but at declining rates over the next decade.

Global internet device installed base



Sources: Gartner, IDC, Strategy Analytics, Machina research, company filings, BII estimates

3 Risks

- In the human-operated device segment, key risks are low affordability of devices in some unpenetrated markets, and fragmentation of application ecosystems due to geopolitical tensions.
- In the M2M segment, fragmentation of technical standards may limit scale of production and raise costs, and lagging cybersecurity standards may expose IoT systems to accidental or malicious damage.

Sources: AIIB analysis, Ovum

Services & application: products, revenue model and finance

Services & applications are software, using device and data and connectivity infrastructure as inputs.

- **Products:**
  - **B2B services** operating within industry value chains: pre-eminently **cloud services** of various types: infrastructure, and business platforms and applications.
  - **B2C services** that are delivered to consumers and households: traditional websites, ecommerce applications, smart media services and other apps
- **Providers:**
  - **B2B services:** hyperscale operators, telcos and vertical specialist datacenter operators (e.g. media, finance)
  - **B2C services:** Apple, Google, Facebook, Instagram, Twitter and etc.
- **Revenue model:**
  - **B2B services:** usually monthly subscription.
  - **B2C services:** advertising, subscription or transaction fees.
- **Finance:**
  - **Investable units:** the major social media and smartphone platform companies, along with large hyperscale datacenter providers and telcos.
  - Traditional equity and debt are the main sources of finance, with some venture capital investment in new technologies.

B2C Growth

- Social media accounts globally were 3.484 billion in 2019, up 9% year-on-year (Source: Zenith Research)
- There were 194 billion app downloads from Android and Apple devices in 2018, with a USD101 billion spend (Source: App Annie).
- Global e-commerce sales will grow from USD25.0 trillion to USD29.8 trillion by 2022 (Source: eMarketeer.com).

B2B Growth

- Enterprise services include basic compute power, collaboration applications, database/analytics/IoT data processing, and ERP/other business apps. Enterprise workloads in these categories are growing globally around 14-21% per annum (Source: Cisco Global Cloud Index).
- Public cloud service revenues in Asia will be USD41 billion and USD56 billion respectively in 2019 and 2021 (Source: Ovum).

Sources: AIIB analysis, Ovum

Services & application: value drivers, trends and risks

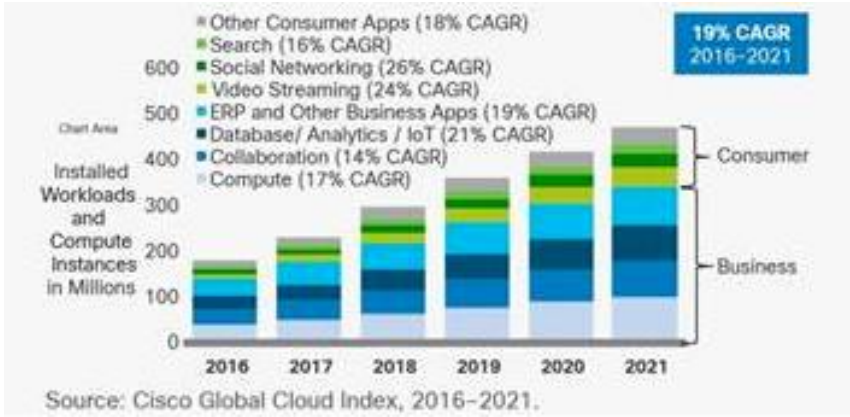
Services fall into two segments. B2C services are targeted to consumers, and include digital media, social media and e-commerce. B2B services are targeted to enterprises, and include cloud-based software-as-a-service (SaaS).

1 Value drivers

- In the B2C segment, value is driven by branding, marketing, strength of the application ecosystem, and scale.
- In the B2B segment, value is driven by marketing, strength of the application ecosystem, quality, and scale.

2 Key trends

- Trend to consolidation in some B2C and B2B service markets due to scale effects (e.g. social media).
- Global e-commerce sales will grow from USD25.0 trillion to USD29.8 trillion by 2022 (eMarketeer.com).
- Steady growth of around 20% CAGR in data workloads for enterprise services.



3 Risks

- Tighter privacy and data protection regulation may disrupt social media and enterprise Customer Relationship Management ("CRM") business models.
- Fragmentation of application ecosystems due to geopolitical tensions.
- Cybersecurity risks of accidental or malicious exposure of personal information, and service disruption.

Sources: AIIB analysis, Ovum

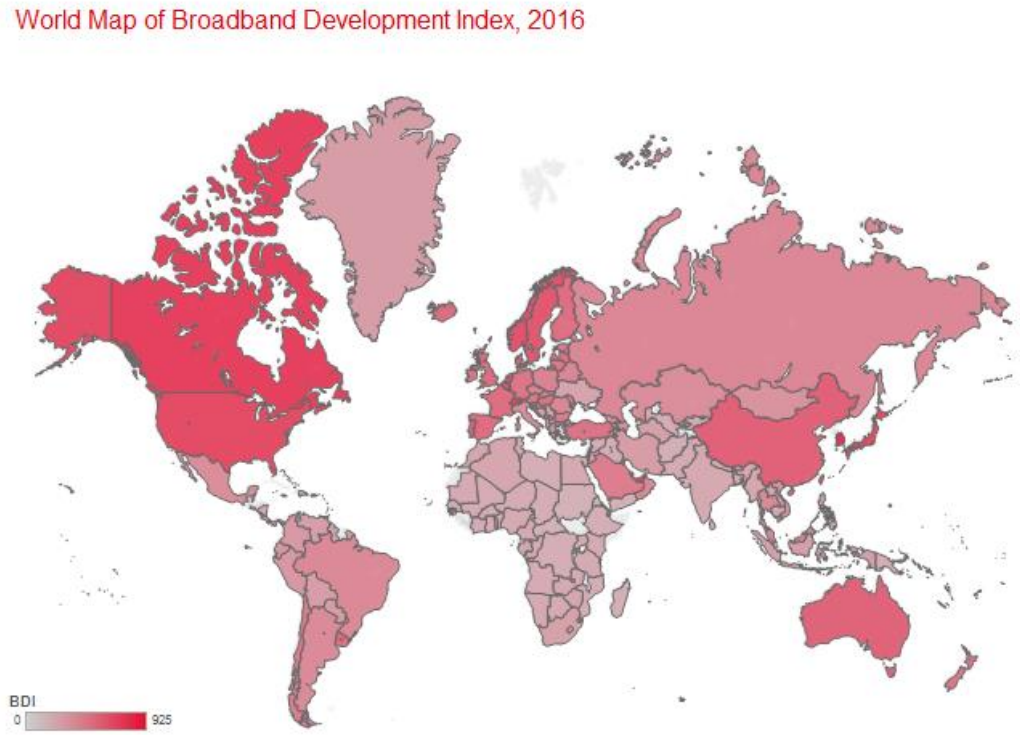
2.2 Market insights

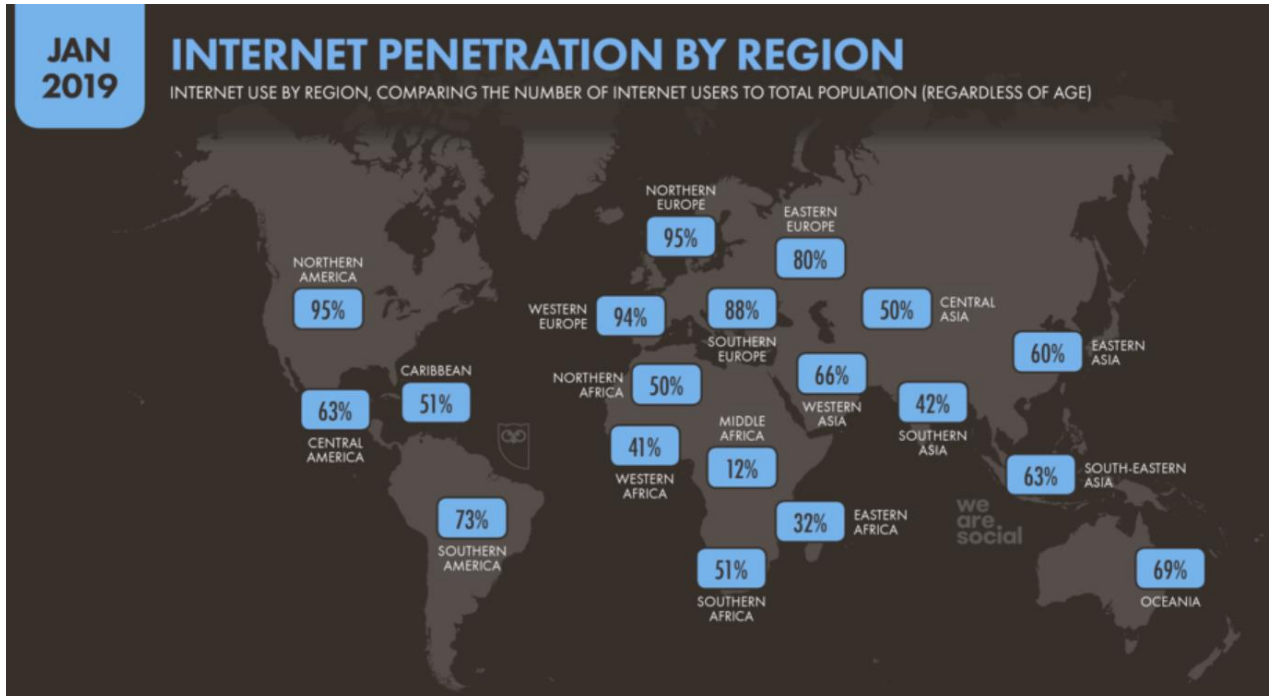
Asian markets are at different stages and have different infrastructure priorities

Key features	Emerging (e.g. India, Myanmar, Afghanistan, Bangladesh)	Developing (e.g. Indonesia, Philippines, Malaysia, Kazakhstan)	Developed (e.g. Singapore, Japan, South Korea)
Policy	National broadband plans are high level only. Mobile technologies are the policy focus.	National broadband plans are clearer, but only Malaysia has seen effective public investment	Government has encouraged mass fixed broadband rollout by private investors
Connectivity	Mobile coverage is expanding but fixed broadband is neglected. International connectivity is limited.	Focus is on universal mobile coverage and urban fixed broadband coverage	Focus on superfast broadband with national coverage targets.
Data center	Not a current policy priority. Limited data infrastructure and inadequate international connectivity.	Efforts to attract data infrastructure investment to support economic growth.	Data infrastructure extensively used to collect and synthesize information for policy making and business.
Investment priorities	Capital for mobile coverage is the priority.	Upgraded mobile network, fixed broadband, and data infrastructure are priorities.	Infrastructure spinoffs and sharing will grow, driven by business needs and regulation.

Digital Divide By Region: Ovum's Broadband Development Index and Internet Penetration

*Nearly **4.0 Billion** people are **not connected** in the **Least Developed, Emerging and Developing Countries***

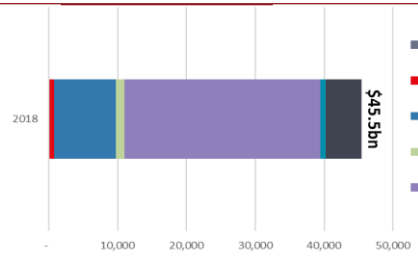
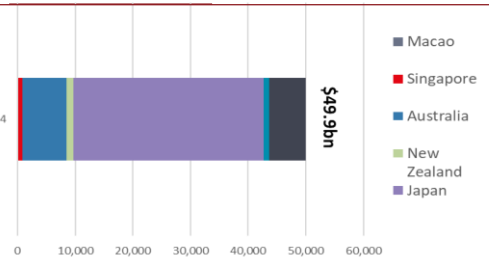
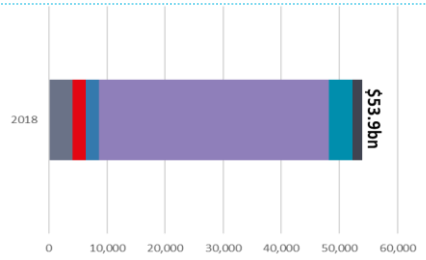
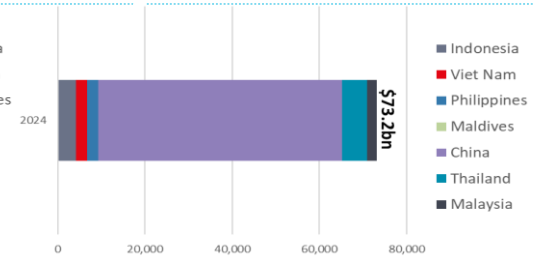
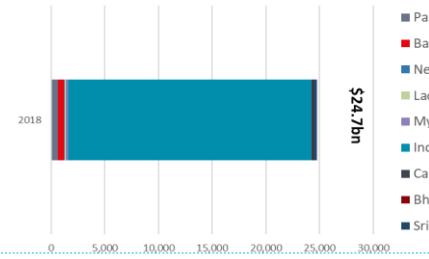
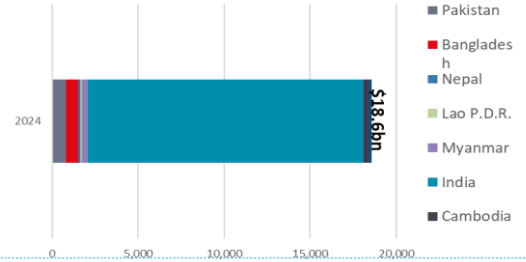




Source: Ovum, INTERNETWORLDSTATS, ITU, World Bank, Hootsuites

There is a growing funding shortfall in emerging Asian markets

Source: ITU; Ovum; local country sources

Market archetypes[1]	Representative Asian markets (rank in descending order of quality score)	2018 annual Investment[2] USD billion, est.	2024 annual Investment[2] USD billion, est.	2018 Population (USDmillion)	2018 Investment per capita, (USD)	CAGR 18-24
Developed; high quality infrastructure	▪ Singapore ▪ South Korea ▪ Japan ▪ Australia ▪ New Zealand			~220	~200	1.6%
Developing; high quality infrastructure	▪ China ▪ Indonesia ▪ Vietnam ▪ Philippines ▪ Thailand ▪ Malaysia ▪ Tonga ▪ Fiji ▪ Mongolia ▪ Maldives			~1,960	~27.5	5.2%
Emerging; low quality infrastructure	▪ Pakistan ▪ Bangladesh ▪ Nepal ▪ Myanmar ▪ India ▪ Cambodia ▪ Sri Lanka ▪ Bhutan ▪ Vanuatu ▪ Lao P.D.R ▪ Samoa ▪ Timor-Leste			~1,850	~13.5	-4.7%

1 Developed / developing / emerging and least developed categorized by ITU classification based on the **ICT Index**; High / low quality defined by WEF Global Competitiveness Report; High / low quality defined by WEF Global Competitiveness Report: pillar 2 (**infrastructure** – 80% weight) and pillar 3 (**ICT adoption** - 20% weight); score above 70 (on a scale of 0-100) is defined as high quality infrastructure

2 Includes data on 24 out of the 55 Asian markets due to limited data availability; countries with missing data include: Pacific Islands; Afghanistan, Mongolia, and few Eurasian markets.

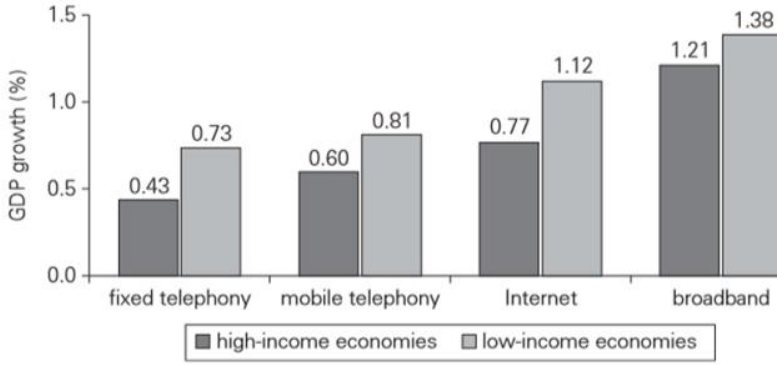
2.3 Social benefits, policy & regulations

Digital Infrastructure delivers significant social-economic benefits

Higher impacts to GDP growth for high broadband penetration (>30%) markets

- Broadband infrastructure investment:
  - strongly correlated with social-economic benefits delivery in developing countries. (see figure on the right side)
- Broadband infrastructure: the strongest economic driver
  - **Every 10% increase** in broadband (3G & above) penetration increases GDP pa in developing countries by **1.38%**
  - **Doubling broadband speed** leads to **0.3%** increase in GDP pc growth
  - 3G to 4G and 5G upgrades will contribute to **1.2% and 2.1%** increase in GDP pc growth respectively (assuming the same penetration)
  - ~30 **jobs creation** per USD1M investment in broadband infrastructure
- Citizen inclusion and digital empowerment
  - Broadband Internet connectivity overcomes digital divide, reduces poverty and enhances gender equity in emerging and developing markets
- Innovations
  - Service and business model innovations have potential to produce dynamic efficiency gains of huge economic benefits

Sources: ITU; Ovum; local country sources



Source: Adapted from Qiang and Rossotto 2009, 45.

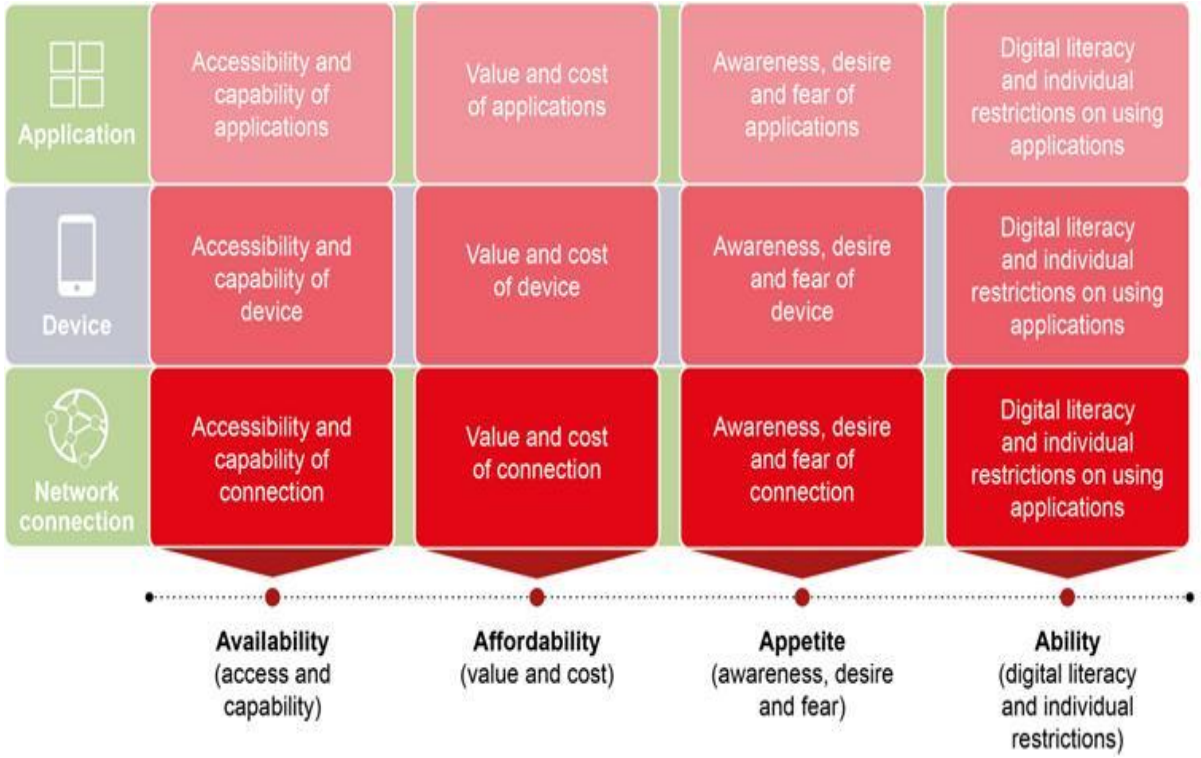
Researcher	Region
Brookings Institute	US
London School of Economics	UK
Czernich et al (2011)	Positive/significant link between broadband penetration and national GDP
World bank: Qiang et al (2009)	Developed and developing markets, 1980-2002
Chalmers University of Technology, Arthur D Little, Ericsson	33 OECD countries
Koutroumpis (2009)	Network effects in various OECD countries
Wavemen (2009)	15 OECD countries 1998-2007

Sources: International economic study on broadband infra

Four “A”s for sustained Digital Infrastructure & economy development:

*It requires **collaborations** of **governments, operators and financiers***

- **Availability**
  - broadband access, connectivity & transport (e.g. ubiquity, capacity, speed, quality)
  - device, terminal, IoT, edge computing eqpt
  - digital services, content, application
- **Affordability**
  - value and cost of broadband infrastructure & services (retail and wholesale)
  - affordable tariff of universal broadband access (e.g. ITU Broadband Commission 2025 Targets 2% of disposable income)
- **Appetite**
  - awareness of broadband & services, recognition of needs and benefits
- **Ability**
  - digital literacy, human capital, knowledge & skills, gender equality, etc.



Policy & regulations for concerted efforts in Digital Infrastructure & economy development:

A signal to prioritized investment/financing opportunity

- The **ITU Broadband Commission** facilitate governments in emerging markets to achieve the **four broadband development advocacy**:
  - Making national broadband policy/plan (NBP) universal
  - Making broadband affordable
  - Connecting broadband to homes and SME
  - Getting people online
  - Achieving gender equality in broadband access
- Governments in developing markets are obliged to fund NBP to achieve the **Broadband Commission 2025 Targets** for "**Connect the Other Half of World**" (3.8 Billion)

- Leading governments in developing markets:
  - promulgate ICT Masterplan (IMP) to implement NBP for development of Digital Infra & connectivity, digital services, ICT capability & skills, etc.
  - See details of "ASEAN ICT Masterplan 2020", and "South Asian Association for Regional Cooperation (SAARC)" in Appendix
  - expand ICT to achieve National Digital Economy Policy
- NBP & IMP pledge government's commitments to Digital Infra & services development
- It serves as a '*green-light* ' to incentivize/reward Digital Infra investment, also a signal to prioritized investment/financing.

ITU Broadband Commission 2025 Targets:
make national broadband policy universal in areas below:
- availability: funded UBS
- affordability: 2% GNI
- internet penetration: 75% world, 65% developing, 35% LDC
- digital skills: 60% youth & adults
- digital financial services: 40% by population
- SME connectivity: 50%
- gender equality

National Broadband Plan (NBP):
- government commitment to broadband development
- targets for speed, penetration, price
- development roadmap (e.g. "mobile first")
- role of government & industry

+

National ICT Masterplan (IMP):
Govn't commitment to digitally smart nation development:
- enhancing infra & connectivity
- enhancing e-services (e-govn't/ finance/ health/ education)
- enhancing ICT capability
- empowering people

Expand ICT

National Digital Economy Policy

2.4 Digital Infrastructure financing landscape

2.4.1 Investment needs and gaps

What are the current and future needs for Digital Infrastructure investments in Asia

Summary of financing landscape: investment needs / gaps by different institutions

Analyses consistently point to an emerging Digital Infrastructure funding gap for Asia

Institutions	Datasets	Definitions	Investment Needs		Investment Gaps		Funding Source	Remarks
			2018 (USDbn)	2030 (USDbn)	2018 (USDbn)	2030 (USDbn)		
1. AIIB and McKinsey in-house analysis	-McKinsey IPAT (2011 onwards), -Expert interviews, IHS Markit ICT (Ovum), IDC, Gartner, etc.	1. Connectivity - Yes 2. Storage - Yes 3. Devices - only related to infra 4. Applications - only related to infra	USD207bn (of which USD127bn is connectivity)	Up to USD500bn (at least USD200bn from connectivity)	N/A	N/A	-Private 72% -PPP 18% -Public 9%	- Private is dominating - PPP is increasing
2. Ovum	Ovum CSP Capex Tracker and other capex datasets	1. Connectivity - Yes 2. Storage - Yes (datacenter only) 3. Devices - No 4. Applications - No	USD193bn	USD369bn	N/A	USD131bn	N/A	- Need forecast based on growing current capex to match projected economic growth. - Gap is the difference between projected need minus projected operator capacity for investment (based on Ovum revenue growth forecast).
3. ADB	ADB's own study	1. Connectivity - Yes 2. Storage - No 3. Devices - No 4. Applications - No	USD112bn	USD218bn	USD46bn	USD85bn (connectivity only)	N/A	- Weak in PPP - Private finance is increasing - Identify investment gap to address climate change related issues
4. World Economic Forum ("WEF")	Word Bank, ADB, Global Infrastructure Outlook, Oxford Economics	1. Connectivity - Yes 2. Storage - Yes 3. Devices - No 4. Applications - No	N/A	N/A	USD14bn	USD241bn	- Private sector dominant	- The gap will rise up to USD512B (in 2040) - Focused at connectivity and Internet-based infra - Prevalent in middle to low income countries - Little investment in advanced digital infra and infra-tech

Source: AIIB, IJGlobal (2001-2019) datasets, WEF, OECD, World Bank, ADB, IFC, ITU, McKinsey IPAT, Ovum CSP Tracker, IHS Markit ICT (now Ovum), IDC, Gartner

Key takeaways on financing landscape in Asia

There exists huge investment gap and opportunity for Digital Infrastructure development in Asia, especially in developing markets

- Ovum analyses the estimation of Digital Infrastructure investment needs in 2018 and 2030 by four different institutions: (i) AIIB/McKinsey (McKinsey's analysis for AIIB and AIIB's inhouse analysis); (ii) Ovum (Ovum's CSP Capex Tracker); (iii) WEF; and (iv) ADB

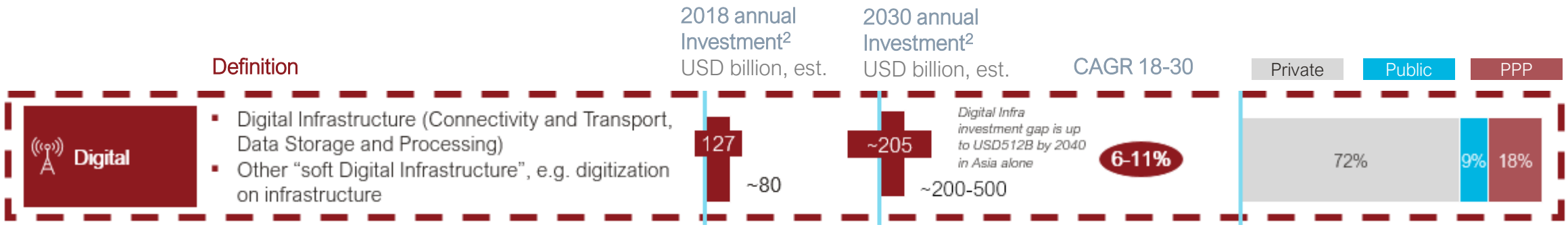
- Different estimations exhibit a **converging range of investment needs** of **(USD112 billion to USD207 billion)** in **2018**, and **(USD218 billion to USD500 billion)** in **2030.** The estimated **investment gaps** is in **range** of **(USD85 billion to 241 billion)** in **2030** (**USD512 billion** in **2040** by WEF's estimation)

- The scope of **Digital Infrastructure sectors** includes **connectivity, storage, devices and applications**, with differences in infrastructure sector coverage being reflected in the size of estimations:
  - AIIB/McKinsey's estimation has the broadest coverage in all four sectors,
  - Ovum's and WEF's estimations cover the connectivity and storage sectors, and
  - ADB's estimation only covers the connectivity sector

- The Digital Infrastructure investment gap is **prevalent in middle to low income countries**, with little investment in advanced Digital Infrastructure (e.g. data center) and infra-technology applications (e.g. smart city/IoT) – a potential development opportunity for AIIB

- The **funding source** is confirmed to be **primarily** from **private sector** in all estimations. For instance, it's **Private 72%**, PPP 18%, and Public 9% (3% from IJGlobal) accordingly to the AIIB/McKinsey' analysis. Public funding and PPP are increasing, but at slow pace and small scale --- a potential development opportunity for AIIB.

Digital infrastructure investment analysis by McKinsey



1 Data center and "soft Digital Infrastructure" are high-level estimation (due to limited data availability)
2 Includes data on 24 AIIB regional members due to limited data availability
3 Project-level data financing documented by McKinsey Infrastructure Project Analytics Tool (IPAT) database; excludes non-project financing; uses expected funding mode

Source: AIIB; McKinsey; WEF; IHS Markit / Global Insight; International Transport Forum (OECD); MEED; Global Water Institute; local country sources

Key observations

- **Digital infrastructure investments will rise** between 6-11% on an annual basis between 2018 to 2030.
- Compared to other Asian infrastructure sectors, Digital Infrastructure investment is dominated by **private capital**.
- **Public and PPP funding** of Digital Infrastructure exists small, and is likely to grow because the external social and economic benefits of Digital Infrastructure are widely recognized

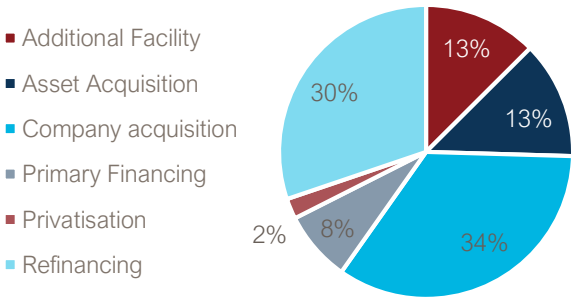
Financing landscape – uses of funding

A preliminary overview of the types of Digital Infrastructure transactions

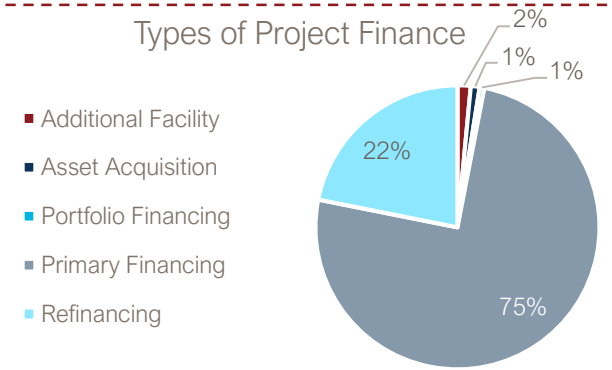
1. The preliminary analysis is done on 242 Digital Infrastructure transactions in Asia and AIIB member countries, from IJGlobal between 2001-2019
2. This is an incomplete dataset reflecting the total financing landscape as many capital expenditure is financed by internal cashflows of the corporates or equity/debt finance raised at the corporate level (hence, no explicit transaction records on each project).
3. According to the latest report, IFC has a Digital Infrastructure portfolio of USD1.5bn over 67 projects globally (~75% in mobile and towers)

Finance Type	No. Transactions	% of Total	Transaction Value (USDm)	% of Total
Corporate Finance	96	40%	69,274	35%
Project Finance	131	54%	122,275	62%
Sovereign/Sovereign Guarantee	15	6%	5,120	3%
Total	**242**	**100%**	**196,669**	**100%**

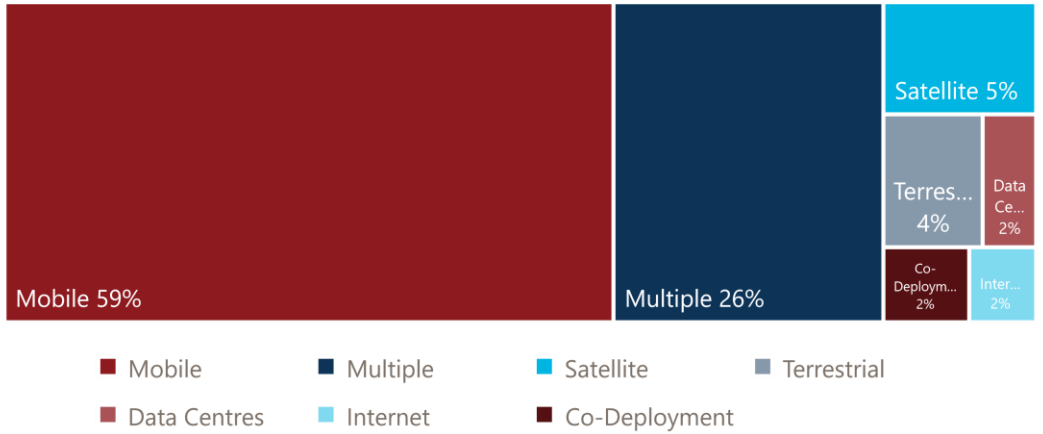
Types of Corporate Finance

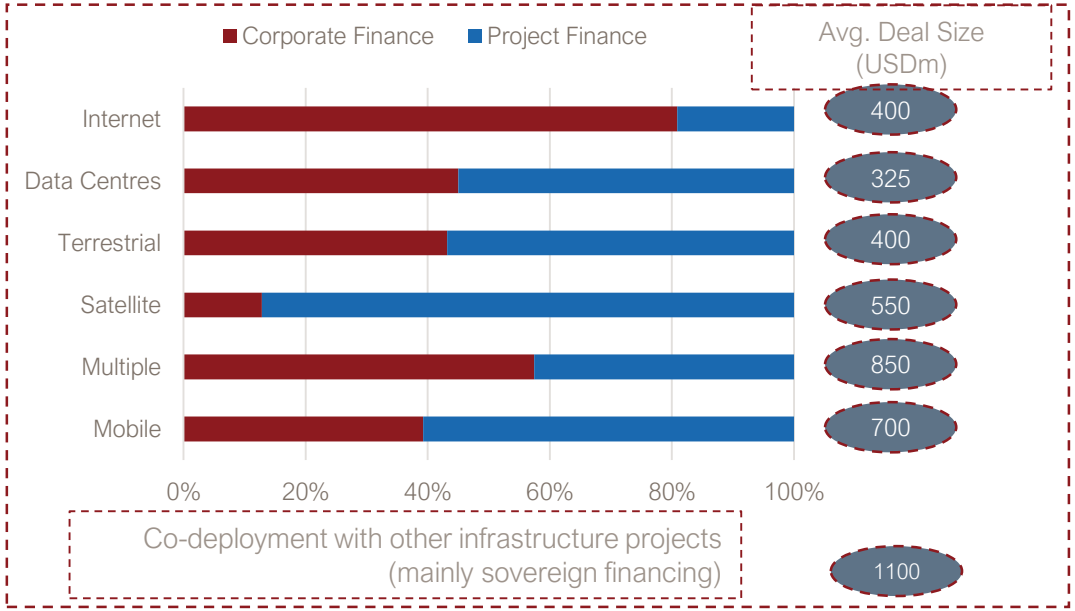


Types of Project Finance



Transaction analysis by subsectors





Source: IJGlobal 2019, AIIB analysis

Top Financiers in Asia

- Besides project financing, providing corporate financing to major operators is an important way to fund Digital Infrastructure development
- Equity sponsors remain to be industry players with little financial sponsors investing in Digital Infrastructure projects directly

Top Debt Financiers in Corporate Finance	Financed Amount (USDm)	% of Total
Infrastructure Development Finance Company	4,343	7%
Credit Agricole Group	2,869	4%
Citigroup	2,804	4%
State Bank of India	2,111	3%
Deutsche Bank	1,972	3%
SBI Capital Markets	1,968	3%
BNP Paribas	1,716	3%
BNP Paribas Fortis	1,578	2%
Canara Bank	1,567	2%
Standard Chartered Bank	1,418	2%
ING Group	1,404	2%
Bank of Baroda	1,319	2%
Housing Development Finance Corp Ltd	1,306	2%
JPMorgan	1,263	2%
ABN AMRO Bank	1,245	2%

Top Debt Financiers in Project Finance	Financed Amount (USDm)	% of Total
Banque Saudi Fransi	1,766	5%
HSBC	1,687	4%
Al Rajhi Bank	1,681	4%
Samba Financial	1,384	4%
ING Group	1,349	4%
BNP Paribas	1,252	3%
National Commercial Bank	1,241	3%
MUFG Bank	1,194	3%
Australia and New Zealand Banking Group	1,103	3%
Standard Chartered Bank	1,036	3%
Citigroup	1,008	3%
Credit Agricole Group	1,000	3%
SABB	981	3%
China Development Bank	946	3%
Sumitomo Mitsui Banking Corporation	891	2%

Top Financial and Industry Sponsors in Equity	No. Deals	Amount (USDm)
Santa Trading Private Limited	1	2,235
Videocon	1	1,561
Maxis Communications	6	1,353
Vodafone	13	1,330
Global Telecom Holding	2	751
Saudi Oger	2	644
CellSAf	2	644
Aditya Birla Group	4	567
Tata Communications	2	466
Tata Group	3	461
Liberty Media Corporation	1	413
Microsoft	1	413
Sumitomo Corporation	1	413
Etisalat UAE	3	371
Sindya Securities & Investments	2	345

Source: IJGlobal 2019, AIIB Analysis

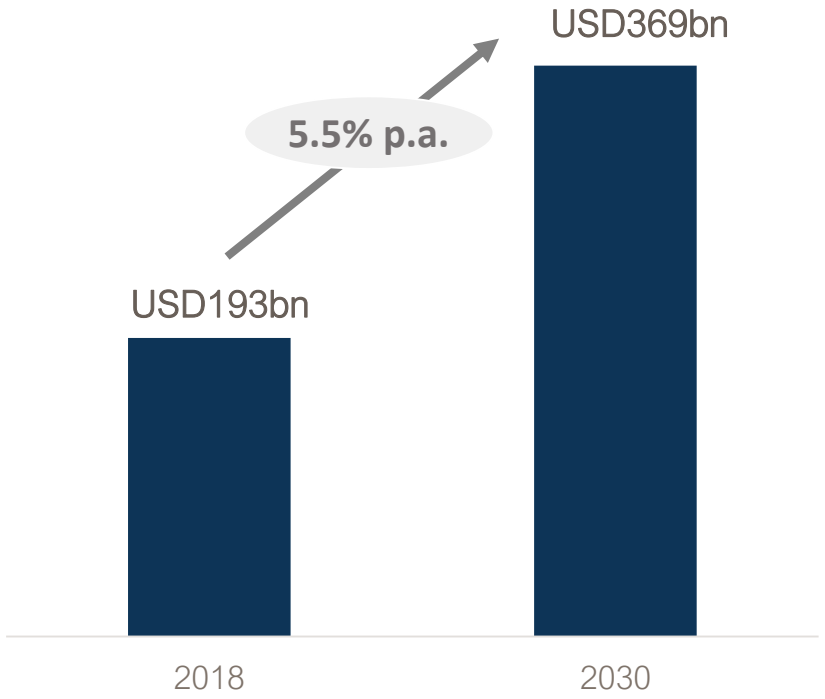
Findings and conclusions

- **Digital Infrastructure investment** is not growing fast enough to meet projected needs based on growing population and usage, leaving an investment gap.
- Compared to other Asian infrastructure sectors, Digital Infrastructure investment is dominated by **private capital**.
- Most of this investment is funded internally by the Digital Infrastructure industries. Of the remainder, **project finance dominates**, followed by corporate finance.
- However, **public and PPP funding** of Digital Infrastructure exists small, and is likely to grow because the external social and economic benefits of Digital Infrastructure are widely recognized.
- This will **open up new opportunities for private capital** to participate in the expansion of digital access, as governments seek to mobilize private capital to achieve these external benefits. The size of the digital investment gap suggests that a serious government push to address the gap would open up large financial opportunities.

Ovum projects ICT capex needs in Asia will reach ~USD369bn in 2030

Ovum foresees a Digital Infrastructure investment gap of around USD131bn by 2030

- Based on projected average economic growth of 5.5% p.a., Ovum has projected total ICT capex needs in Asia for the following types of operator in the period of 2018 to 2030:
  - Communications Service Provider (CSP) for fixed and mobile connectivity related capex.
  - Carrier Neutral Service Provider (CNP) for tower and related capex.
  - Datacenter Internet Content Service Provider (ICP) for datacenter and related capex.
- Ovum estimates that the total projected ICT capex needs in Asia will grow from **USD193bn p.a. in 2018** to reach **USD369bn p.a. in 2030**.
- However, Ovum expects that growing pressures on operator revenue and margin will see connectivity operator capex grow more slowly than the economy over the coming decade. Data centers providers are also facing revenue pressures as prices for datacenter services fall rapidly.
- Continued growth in capex in line with forecast revenue growth rates (around 1.7% p.a.) would see **the investment gap reach USD131bn by 2030**.



Source: Ovum CSP Tracker, Ovum analysis

Other findings by country / regions / digital players

Asia digital revenue growth is healthier than other regions, helping to support operator capex out of cashflow.

- Asia's telco and data center operator capex is forecast to hold up better than other regions, as industry revenue growth rates are higher. This will allow them to fund more capex out of cashflow, but not enough to avoid a substantial investment gap.
- The **investment gap** arises principally in emerging markets, particularly those in **Central and Southern Asia and in South-East Asia**.
- In contrast, developed markets such as Australia, Singapore, South Korea and Japan are well-served. Some developing markets like China are also well-served.
- About **54%** of the investment gap is accounted for by **connectivity** (including towers and other passive assets), the **balance** is for **datacenter infrastructure**.

Source: Ovum CSP Tracker, Ovum analysis

2.4.2 Drivers of the digital investment gap

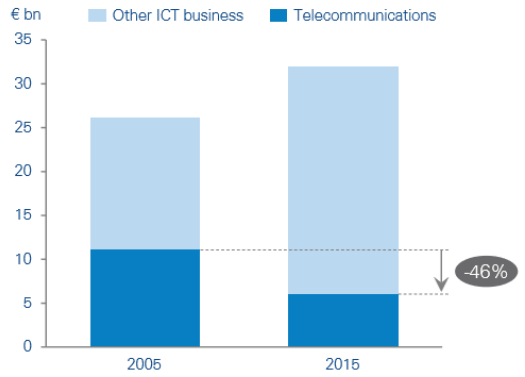
Digital Infrastructure investment needs are rising, but the main current funders are facing declining revenues and investment capacity

- In recent years, telecommunications has been under pressure from significant declines in sales, coupled with new investment requirements in 5G and fiber.
  - Between 2005 and 2015, telecommunications providers' revenues almost halved (a 46% drop, for example, in Austria).
  - Gross capital formation fell by 13% over this period, lifting capital intensity.
- The telecommunications industry – which is the main funder of 5G, fiber expansion, and other Digital Infrastructure developments – cannot independently raise the financial resources needed for network expansion over the next decade.

As a result, the funding needed to achieve development goals will not be met solely by digital operator investment. There is a Digital Infrastructure investment gap.

1. Share of annual income by Telecommunications players vs. other ICT businesses (downstream digital services) in selected countries in Europe

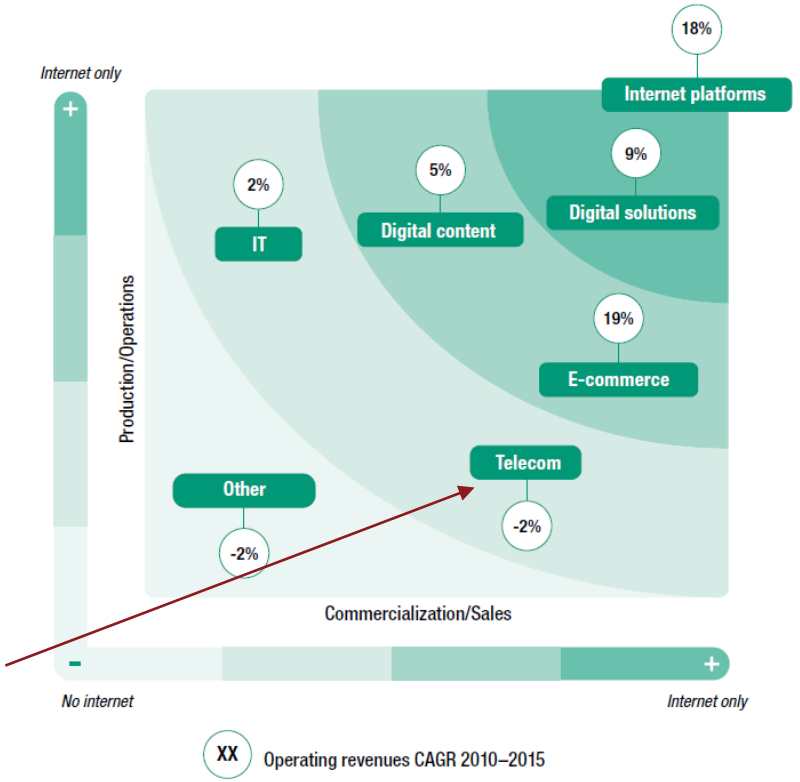
Source: ADL



2. Ever-increasing usage but decreasing revenue is limiting financial capacity to fund future CAPEX by the industry (currently the main funder).

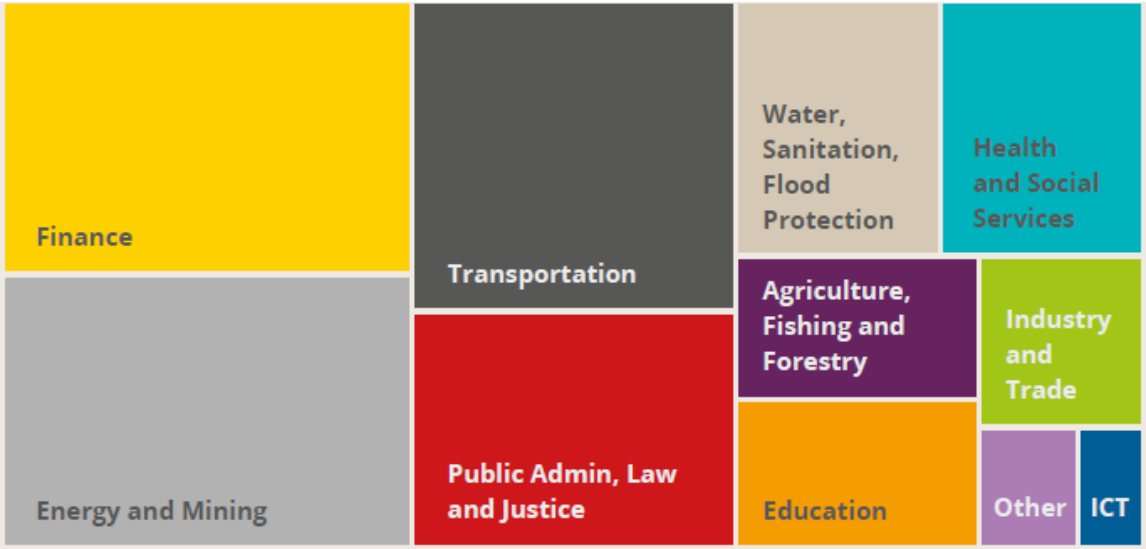
Although Digital solutions, ecommerce, and digital content achieved 9-19% CAGR in revenue over 2010-15, telcos actually experienced a drop in revenue of around 2% globally due to competition, commoditization and consequent lower tariffs

Source: UNTCAD



Source: ©UNCTAD, based on UNCTAD's FDI/MNE database, company reports and data from Orbis BvD and Thomson ONE.
Note: Positioning in the internet intensity matrix is indicative and based on a qualitative assessment. The categories "Internet platforms", "Digital solutions", "E-commerce" and "Digital content" include 92 companies (of which 10 internet platforms, 14 e-commerce, 23 digital solutions and 45 digital content) from UNCTAD's ranking of the top 100 digital MNEs. The categories "IT" and "Telecom" include 92 companies (of which 66 IT and 26 telecom) from UNCTAD's ranking of top 100 ICT MNEs. The category "Other" includes 80 companies operating in non-ICT industries from UNCTAD's overall list of the top 100 MNEs.

Challenges for public sectors: MDBs have low commitments in Digital Infrastructure, despite recognizing its importance



Based on data from 9 MDBs (IBRD, IDA, IFC, AFDB, ADB, IaDB, EIB, AIIB and NDB);
Sources: MDBs, Xalam Analytics Research

1. **Most institutions believe the proportion of investments into Digital Infrastructure will increase** and think that **digital integration in traditional infrastructure projects is a key** step to increase digital investment share of MDB and impacts of commitment.
2. **Despite the increasing importance, MDB's commitment to the digital sector is very low**. Just **1%** of MDB commitments are in digital projects. The last ICT strategy by ADB, for example, was done in November 2003.
3. **Investment in the digital sector is perceived as a private sector activity** — this is fostering a "middle class-centric" view of digital markets, whereby capital investments are primarily focused on the needs of the growing urban middle class, leading to a deepening of the digital divide, between rich and poor countries and between urban and rural areas.

Key recommendations from the World Wide Web Foundation and Alliance for affordable internet:

- Change the investment narrative within and outside of MDBs to re-establish the ICT sector as a priority.
- Develop innovative financing solutions for rural area projects.
- Increase investments in the development of enabling policy frameworks.

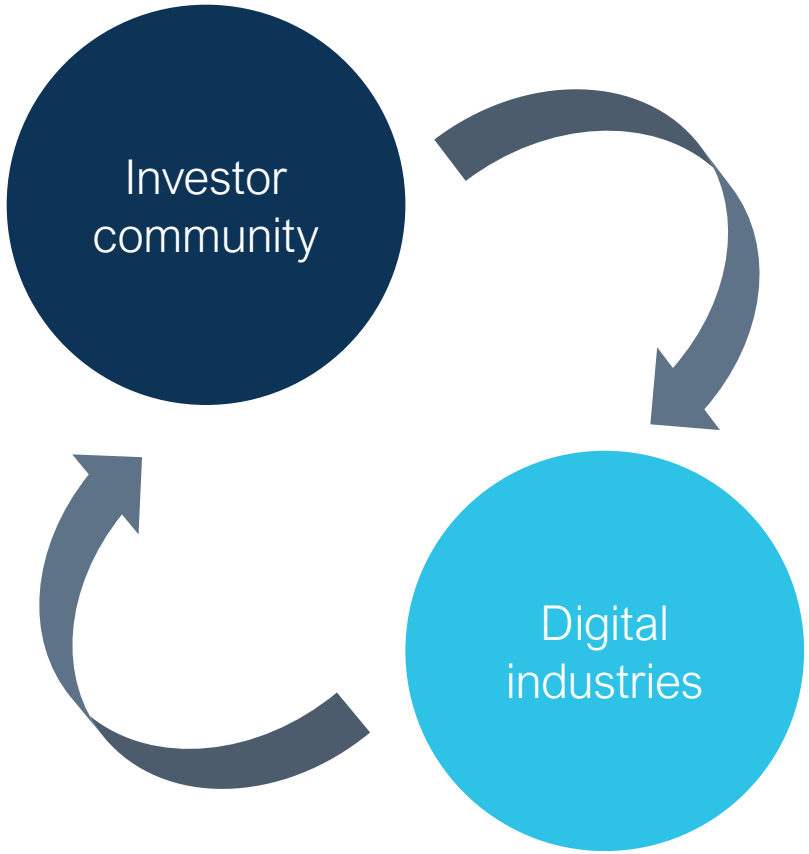
Source: World Wide Web Foundation, Alliance for affordable internet

Drivers of the Digital Infrastructure investment gap

Digital Infrastructure investment markets face inhibitors on both supply and demand sides of finance markets

Supply-side

- Traditional criteria support individual projects in more wealthy, urban areas with **good short-term return**, rather than projects in middle to low income markets, and sub-urban and remote territories, with long-term returns.
- MDBs and public sectors have **low commitments and limited capability** (funding, human resource, skills, etc.) for Digital Infrastructure investment.
- Lack of **investment/financing innovations**, instruments and tools to manage new risk profiles.
- Financing perceived to be role of private sectors, with **limited public sector commitment**.
- Socio-economic and externality benefits of digital connectivity are recognized, but **not sufficiently supported by policy intervention**.



Demand-side

- **Diminishing ROIC and rising capex demands** limiting operator investment capacity (e.g. 5G and FTTx).
- Innovations call for more capex needs. The ***innovation cycle*** creates a time and financing capacity gap, and further widen the gap between developed and developing markets
- Lack of collaborations between governments, operators and financiers to **promoting awareness and affordability of access** to Digital Infrastructure and services (especially in emerging markets).
- Higher risk due to **lack of project management processes**, systems and practices in traditional operators for construction and operation of new Digital Infrastructures.
- Lack of **skilled technical personnel** for the **construction and operation** of new digital technologies and infrastructures.

Sources: AIIB, Ovum analysis

Supply side gap drivers – impact varies with infrastructure class

Importance of supply side inhibitors varies with infrastructure class

- Different infrastructure classes are affected differently by **different inhibitors**.
- **Tower spinoffs** are now well-understood and serviced.
- At the other extreme, **rural investment** is impacted by many inhibitors.
- **Datacenter** is also underinvested, and the economic and social externalities of better data infrastructure are still unrecognized.

Important Moderate Less important

	Limited Public Investment	Limited investor capability (funding, human resource, skills)	Short term investment timeframes	External benefits unsupported / uncoordinated	Lack of financial innovation
Domestic fiber	Important	Moderate	Moderate	Moderate	Moderate
International fiber	Important	Moderate	Moderate	Moderate	Moderate
Towers	Less important	Less important	Less important	Less important	Less important
Satellite	Less important	Moderate	Moderate	Less important	Moderate
Datacenter	Important	Moderate	Less important	Important	Moderate
Rural connectivity	Important	Important	Important	Important	Important

Sources: AIIB, Ovum analysis

Demand side gap drivers

Operator pressures and affordability issues in emerging markets reduce infrastructure investment incentives.

1. **Revenue pressure** on operators has reduced capacity for investment, particularly in markets where average revenue per users (ARPUs) are very low e.g. Indonesia.
2. **The affordability issue** is concentrated in markets in Central and Southern Asia, where smartphone penetration is still below 50% and fixed broadband penetration is even lower. The issue may ease in coming years, as 4G smartphone prices fall with the release of 5G models, and competition drives mobile connectivity prices lower, resulting in many households relying on mobile broadband. There are also affordability issues in some South-East Asian markets.
3. **Many incumbent telcos lack expertise and scale in datacenters**, and struggle to attract investment. Some have abandoned datacenters to specialists.
4. **Rapid growth in new technologies** such as 5G, IoT, cybersecurity and data analytics is causing **skills shortages** that constrain digital service growth and the associated infrastructure investment.

Sources: AIIB, Ovum analysis

Regulatory gap drivers

Governments are positioned to address many inhibitors, but efforts are still unevenly distributed.

National digital strategies in Asia are strongly associated with developed or developing markets, including: Australia, China, Japan, Malaysia, Singapore, South Korea, Thailand, and New Zealand. In the remaining markets, regulatory gaps are often unaddressed and inhibit investment.

Supply side regulatory gaps

- Poorly structured **communications regulation and spectrum licensing** that limits market entry.
- **Foreign ownership** restrictions.
- Lack of attention to **infrastructure bottlenecks** such as Internet Exchange Points (IXPs)
- Weak **universal service** targets.
- Limited **public funding** of Digital Infrastructure, or poorly structured public funding which fails to leverage private investment.
- Lack of investment in **government datacenters** to build scale and depth in the digital ecosystem.

Demand side regulatory gaps

- **Over-taxation** of digital services and devices.
- Lack of investment in general **digital awareness**.
- Lack of investment in **digital technical skills**.
- Weak **cybersecurity, data protection and privacy regulation**.
- **Over-regulation** of content.

Risk profiles in different components of the Digital Infrastructure ecosystem

The level and nature of risk in each sector depends on the regulatory, competitive and technological trends

	Regulatory	Commercial (existing competition)	Technological (new competition)
Data consumption and generation	Medium: Device platform access can be subject to sanction (e.g. US/Huawei)	Low: Handset demand driven by 5G rollout; IoT demand rising	Medium: rise of wearables and IoT will generate fast innovation
Data connectivity and transport	Low: M&A refusals and new entrant privileges can disrupt profitability	Medium: market disruptors (e.g. RJIO, OTTs) will lift competition	Low: Vendors bear much of the risk of technology development
Data storage and processing	Medium: national data protection rules will disrupt global, regional markets	High: Hyperscale providers are investing in and disrupting national markets	Medium: Cybersecurity and big data innovation will drive differentiation
Digital service and applications	Medium: Efforts to create level-playing field for TV and OTT may disrupt OTT	High: Lower barriers to entry enhance applications competition	High: There will be ongoing service innovation and emergence of new platforms

Summary of Risks

Risk Category	Risk Description
1. Demographics, Economic, Social & Environmental	• **Low literacy levels and GDP per capita** will take time to overcome for growth of Internet and broadband services • **Social unrest** arising from labor rights protection during economic transitions • **Ineffective market competition** render investment/financing business case invalid • **Environmental & sustainability development** risks, e.g. pollution and disastrous environmental damages
2. Political, Legal & Regulatory	• **Political risk** arising from government transitions and power delegation • **Inconsistent government policies** in course of economic reforms and transformation • Uncertainty of **changing telecoms policies & regulations** during market liberalization and competition • Threats **of technology substitution/obsolescence** lead to shortened assets life-cycle
3. Financing & Project Execution	• **Investment/financing risks** arising from financing markets, instruments/tools, portfolio design & management, etc. • Risks of participating partners, stakeholders and investees in **leadership, management, execution and fulfilment** • **Project risk** exposure including natural disasters, labor strike/riot, unanticipated project slippages, escalated cost, etc.
4. Institutional and Corporate Governance	• **Institutional and corporate governance** risks among investors/financiers, investees, partners, stakeholders • **Fraudulent and corruption** threats during infrastructure project cycle

2.5 Challenges, solutions and opportunities for AIIB

Challenges to financers and investors

1. Decreasing income and squeezing margin of operators curtail corporate finance capability (private investment) to sustain investment in Digital Infrastructure (e.g. 5G) through corporate financing.

2. The challenging financial return (but high economic benefit) of sub-urban and rural connectivity (e.g. fixed and mobile broadband) discourages private investments, and widens digital divide and inclusion gaps especially in mid and low incomes markets.

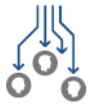
3. The social-economic and externality benefits (e.g. synergic benefits to adjunct infrastructure industries and other sectors) of Digital Infrastructure are not well understood and recognized by financing / investment community, as well as well coordinated and supported by the national policy & regulations in related adjunct industries and sectors.

4. Lack of investment policy incentives and investor-friendly regulations to support financing and rollout of capital intensive infrastructure (e.g. satellite) build in sub-urban, rural or terrain difficult areas.

Key challenges and suggested actions for financiers

A preliminary overview of key recommendations and observations today

6 key challenges and risks faced by Digital Infrastructure investors



Market factors

Elements of **competition from operators and infrastructure providers**, as well as concerns over **consumer adoption and willingness to pay**

Risk mitigation factors

Concerns that existing means of **mitigation are inadequate and complex**, and are often derived from a lack of available market and investment research

Partnership factors

Perception that partnership models of infrastructure finance are **overly complex and of limited financial benefit**

Project factors

Inadequate project preparation, small project size and lack of comfort with alternative technologies

Regulatory factors

Areas of **spectrum policies, pricing barriers and regulatory uncertainty**

Sourcing factors

Project obscurity and the lack of a conventional pipeline for surfacing ICT infrastructure projects

Indicative actions proposed by World Economic Forum

Public-sector tools to improve overall investment environment

- **Implementing "dig once" policies** to reduce overall costs per connection and allow funders to bundle investments across different types of infrastructure
- **Reworking tax policies** to incentivize investment and reduce financial burdens for those willing to invest
- **Providing anchor tenancies** to infrastructure expansion to help incentivize infrastructure investment and improve the business case for private investors
- **Releasing new spectrum in a timely and affordable manner** to significantly reduce costs and barriers to entry for mobile network operators
- **Incentivizing small cell deployment** by providing access to site locations to speed bureaucratic approvals and allow sharing agreements
- **Promoting the establishment of IXPs** to reduce latency and costs

Collaboration via blended finance arrangements

Private, multilateral and multi-sectoral tools to unlock additional funding options

- **Bundling mechanisms or infrastructure funds** to combine ICT infrastructure projects across geographies, technologies and populations
- **Securitization mechanisms** to have a similar effect on risk mitigation to bundling mechanisms, and to benefit from special tax treatment
- **Multistakeholder funds** to attract capital from multiple sectors to address development needs
- **Co-investment vehicles** to allow MNOs to solicit additional funds from other players when expanding and upgrading infrastructure
- **Risk guarantees** to isolate individual risk elements in projects and improve business cases for investors
- **Increased effectiveness of project preparation facilities** to address many risks associated with smaller projects that have limited resources to support investor due diligence
- **Development of infrastructure marketplaces** to bring together infrastructure project owners, investors, public-sector actors and other stakeholders to share information, discuss potential investments and arrive at blended financing arrangements

Source: World Economic Forum

Sample Solutions: Market-led infrastructure sharing: HyalRoute

Privately funded infrastructure sharing in Cambodia and Myanmar (financed by AIIB)

HyalRoute has created a **privately-funded network of shared dark fiber** in Myanmar and Cambodia

- HyalRoute Communication Group, a Singaporean-based independent telecom infrastructure provider, was granted dedicated licenses by the Cambodia and Myanmar governments respectively to provide **national fibre optics network infrastructure sharing services** via its local subsidiaries – Cambodia Fibre Optic Communication Network (CFOCN) and Myanmar Fibre Optic Communication Network (MFOCN).
- Within the last decade, the firm has constructed extensive terrestrial fibre optics cable (over 18,000 km) that covers the entire Cambodia and Myanmar.
- HyalRoute provides its products through sale/lease and services to target clients include telecom operators, internet service providers ("ISP"), TV and media operators, governments as well as corporate clients.
- HyalRoute also offers access to duct systems in major cities, maintenance services and international connectivity.

Source: AIIB, Ovum

Sample Solutions: PPP model - Red Compartida, Mexico

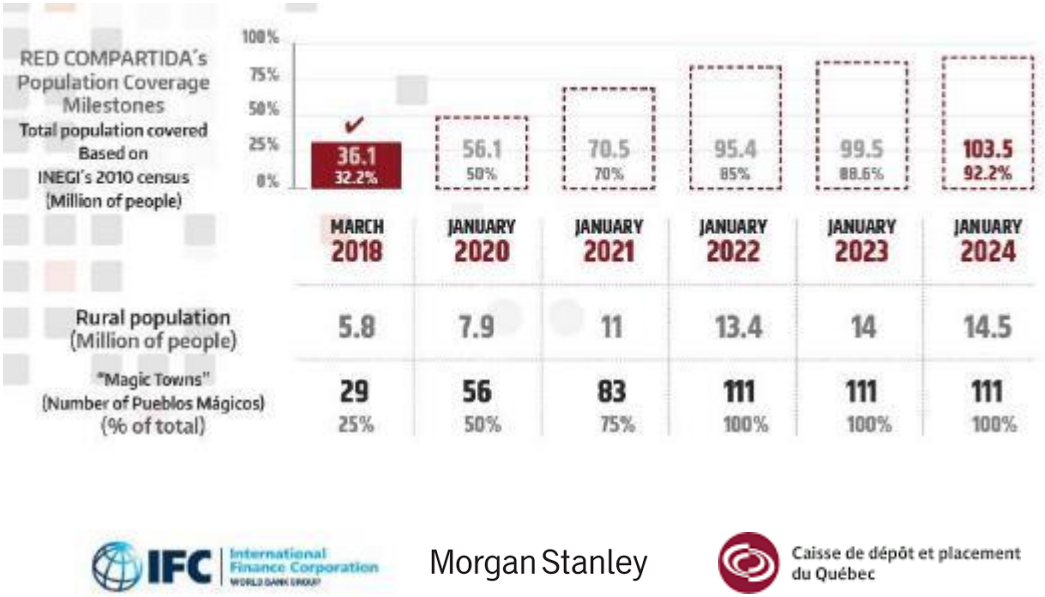
Private capital's interest in the sector is not always organic, but a result of proper structuring in Emerging Markets

Background and Results

- Red Compartida is an ambitious telecom project aiming to roll out **4G-LTE** to more than **90%** of **Mexico's population** by **2023**, with a special focus on **rural areas**. It is expected to require more than **USD7 billion** in **investment** over its life cycle.
- Mexico's telecom market was traditionally dominated by one player. It controlled access to large parts of the telecommunications infrastructure and was at times accused of anti-competitive behavior.
- Thus, the Red Compartida initiative was created. Private telecom operators will rent **network capacity at a wholesale price** and in turn be able to provide quality and cost-efficient telecom services across Mexico.

Innovative Financing and Partnership

- Altan Redes was awarded the Red Compartida project with a network concession for a term of 20 years (and an option to extend it another 20 years). The public-private partnership agreement was signed in January 2017. Existing telecom operators in Mexico were barred from participating in the bidding for the project.
- The project has **financing from both the private and public sector** and will see the Mexican government put the spectrum and fibre-optic links in place.
- The company is backed by a **wide range of investors**, with a Morgan Stanley-managed infrastructure fund **and** the **IFC** (largely through its China-Mexico Fund) holding approximately **33% and 27%**, respectively, and the remainder split between industrial and private stakeholders as well as a Canadian pension fund.
- In addition to paying an annual fee for spectrum, Altan Redes will contribute 1% of its income from network rentals to the Mexican government's Secretariat of Finance and Public Credit.



IFC International Finance Corporation WORLD BANK GROUP

Morgan Stanley

Caisse de dépôt et placement du Québec

Source: World Economic Forum, IFC

Financing Implications to AIIB

	Industry trends and implications to actors	Implications to AIIB specifically
1. Digital Infrastructure Financing gap is rising	• Annual Asian Digital Infrastructure spending will grow based on multiple in-house analyses and Ovum's proprietary study. • Despite the growth in investment spending, WEF expects the Asian Digital Infrastructure gap to also grow significantly, estimated to reach USD512 billion by 2040.	• Investments in Digital Infrastructure is essential to driving economic growth and achieving AIIB's mandate. • Investments in Digital Infrastructure can help diversify AIIB's portfolio (which is highly concentrated not only in infrastructure but also energy/transportation) and improve risk-weighted return on both individual assets and overall portfolio.
2. MDB's commitment is very low	• MDBs' annual Capital Commitments in digital are low (~1% between 2010-2016) but MDBs agree that this is an emerging sector with great economic impacts that deserves attention. • To bridge financing gaps and digital divide, it requires new ways of thinking about return (economic return to society).	• AIIB has a significant comparative advantage because of lack of legacy and sole mandate in infrastructure (Other MDBs have limited capital allocation to infrastructure, not to mention Digital Infrastructure). • AIIB may lead the dialogue by setting up a dedicated strategy and be the lead financier to crowd in other MDBs.
3. Private capital alone is not solving the problem of the digital divide	• Private investors focus on developed markets, urban or well-populated areas and companies with natural monopoly status; • Emerging markets, rural connectivity and next-generation Digital Infrastructure remain challenging. • According to GSMA, better investor education and more in-depth project planning can help attract financing.	• AIIB can help develop the framework and knowledge base to help mobilize more private capital into emerging markets, rural connectivity and next-generation Digital Infrastructure opportunities. • AIIB should work with both public and private sectors to encourage more innovative and PPP financing arrangements (see in the case study of Red Compartida). • Blended finance could be essential to finance the least developed economies and rural connectivity.
4. New financing sources required for opportunities	• Digital Infrastructure is mainly financed by communication services providers / companies who face increasing financial challenges. • Carrier neutral infrastructure providers / companies ("Infracos") and asset spin-offs are gaining popularity as it reduces repetitive capex in duplicated infrastructure construction and unlocks values.	• AIIB might provide growth capex financing (both project and corporate) to telecom players or technology companies to support infrastructure roll-out or upgrade. • AIIB could encourage independent / shared Infracos which will attract more infrastructure or real asset investors. • AIIB could support the setup of these Infracos / trusts by funding the spin-offs of these assets from telecom players to release values.

Sources: World Bank, McKinsey, WEF, Delta Partners, Bloomberg, data from 9 MDBs (IBRD, IDA, IFC, AFDB, ADB, IDB, EIB, AIIB and NDB)

Key takeaways on Digital Infrastructure financing

1. **AIIB could be a leader in this market**. Digital divide, rising Digital Infrastructure gap, weakening financial capabilities for Digital Infrastructure of the industry, are all contributing to opportunities for AIIB's involvement.

2. The **industry and corporates are the main funding sources** for Digital Infrastructure development, despite their increasing pressures of financial performances. Digital Infrastructure is still not yet mainstream for financial investors

3. **While it is core to Digital Infrastructure, private capital alone does not solve every problem** of the digital divide and financing gap. However, **MDB commitment in this sector is very low** despite the rise of digital divide and acknowledgement among the MDBs themselves that this is an increasingly impactful sector.

4. The **increasing Digital Infrastructure financing gap in Asia** calls for new sources of financing: from institutional / financial investors, or creating and spin-off of Digital Infrastructure assets into shared "Infraco" or investment trust to reduce repetitive capex

3. Infrastructure enhancing digital technologies and applications

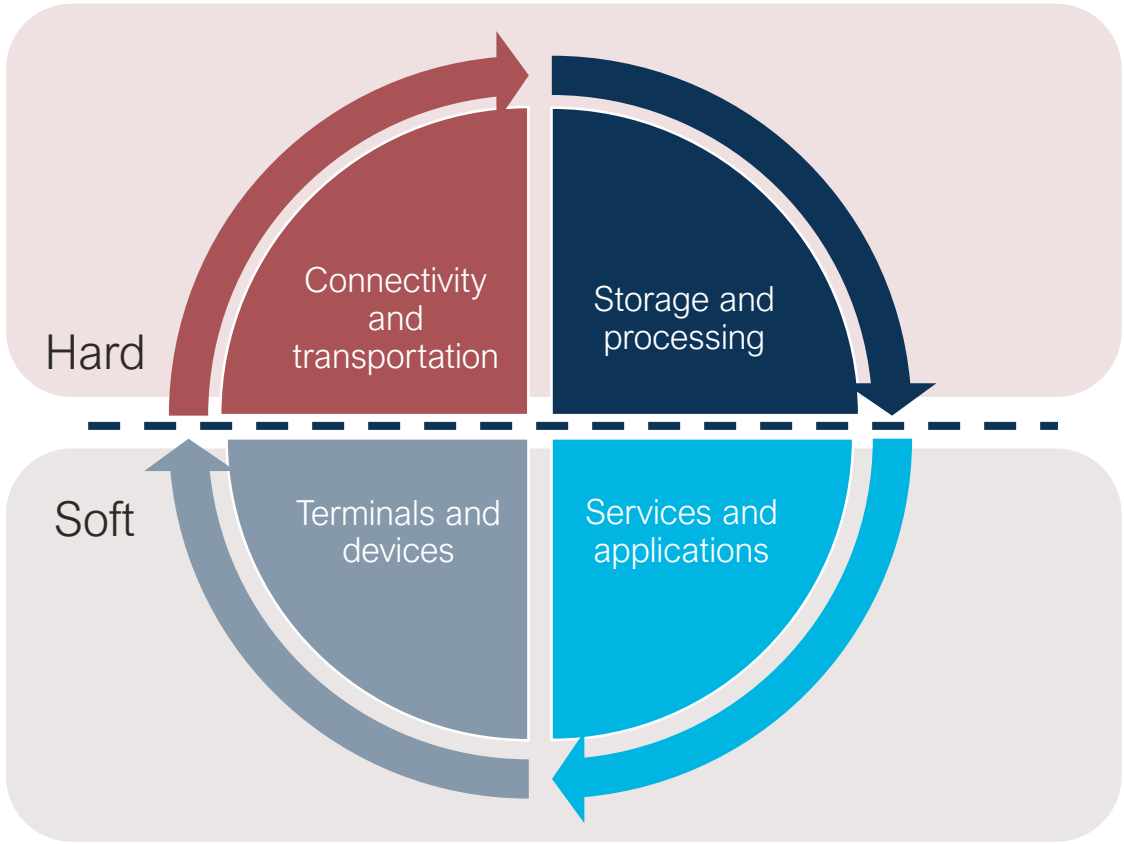
To improve efficiency, reduce costs and lead to sustainability – utilization of technology and soft Digital Infrastructure can be a ‘supply-side’ solution to infrastructure financing gap in Asia and improve their quality.

3.1 Challenges and opportunities for digital applications in the infrastructure industries

The role of the Digital Infrastructure ecosystem in all other infrastructure industries

Infrastructure industries focus on digital terminals and applications to improve company and industry productivity

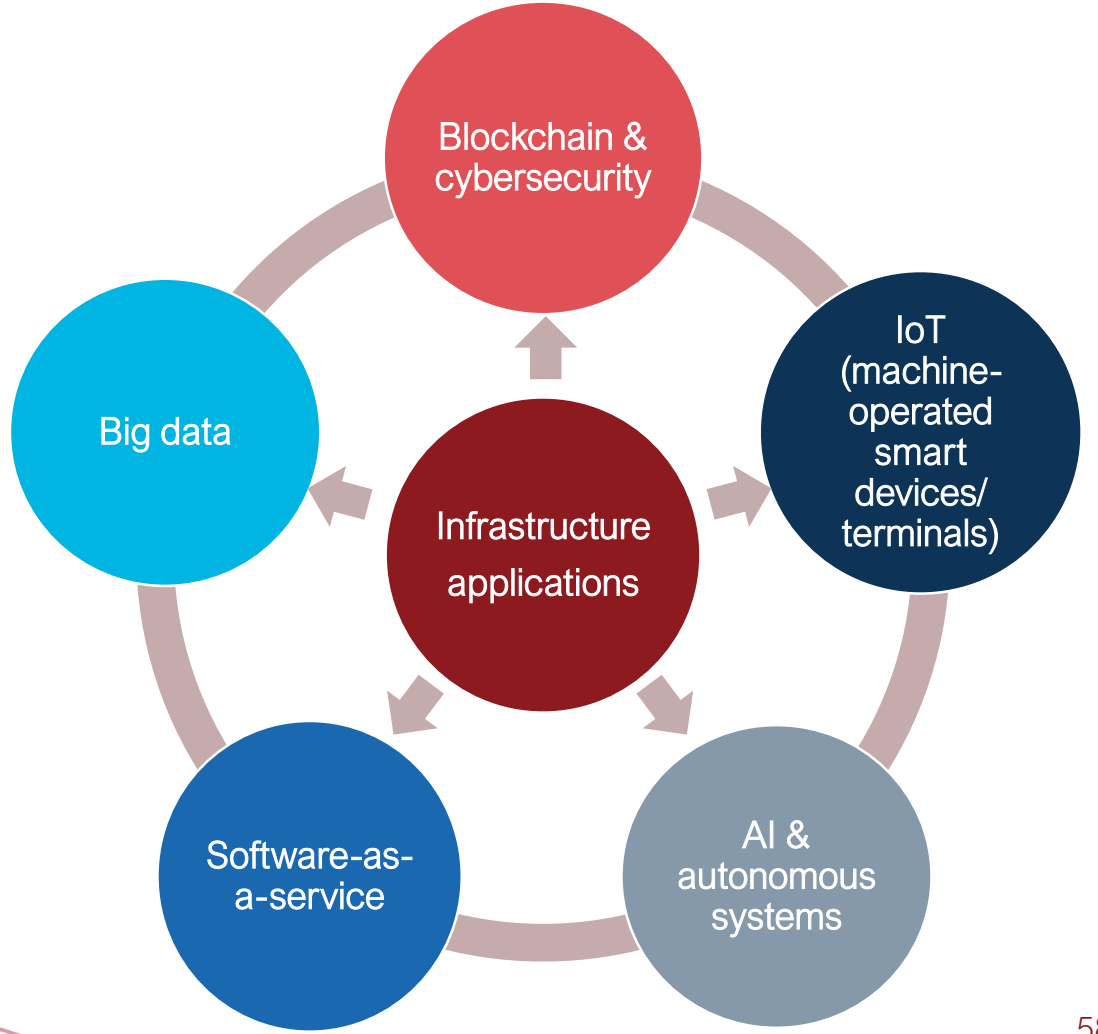
- Building on the 'hard' connectivity and storage/processing resources, the soft Digital Infrastructure can enable all other sectors and customers.
- Given this opportunity, the infrastructure industries can **innovate and integrate** in the 'soft' components of the digital ecosystem, i.e. terminals/devices and services/applications – to make their **infrastructure design, financing, construction, and operations smarter**.
- These soft components allow them to collect, analyze and use data to drive **productivity growth** and new, **transformative ways of working** in all parts of the **project cycle**.



Technology building blocks of Digital Infrastructure applications

A new cluster of inter-related software technologies has emerged to enable productivity–enhancing digital applications in the infrastructure industries

- **IoT (machine-operated devices/terminals).** Networked sensors & actuators that can collect and act on information in real time, and new kinds of networked devices like drones. 5G will dramatically increase the capacity of IoT systems to generate and store data.
- **AI & autonomous systems.** ICT systems that learn from, adapt to, and respond to new information.
- **Software-as-a-service.** Software applications that can be delivered from centralized datacenters cheaply and easily.
- **Big data and analytics.** Technology to analyze and add value to the "data lakes" emerging from customer interactions and IoT.
- **Blockchain & cybersecurity.** Authentication and security technologies to protect all of these ICT systems from malicious or accidental damage.



New digital applications are emerging in all infrastructure sectors

And digitalization is creating new targets for investment that cross traditional infrastructure sector boundaries

	Power & Energy	Transport	Water	Smart cities
Productivity opportunities	• Smart meters • Smart grids and smart load management • Gas leak detection • Fuel efficiency • Predictive maintenance • Grid outage response automation	• Intelligent traffic lights • Real-time road navigation • Public transit information and management • Digital public transit payment • Dynamic speed limits • AV remote control centers • Driverless trains & trucks • Predictive maintenance	• Water quality monitoring • Water storage monitoring • Leakage detection and control • Predictive maintenance	• Real-time air quality information • Smart streetlights • Smart bins • Waste collection route optimization
Transformation opportunities	• Dynamic wholesale and retail pricing • Energy storage management • Industry structural reform & markets for local generation • "Digital twin" simulation for generation and grid • New structural arrangements to promote competition • Digital construction practices	• Dynamic smart parking • Dynamic congestion pricing • Shared and autonomous riding • Mobility as a service (multimodal public transit) • "Digital twin" for transport simulation and management • Digital construction practices	• Behavior-based water consumption tracking and pricing • Long and short term water market trading • Smart drainage & stormwater management for grey water recycling • "Digital twin" simulation for extreme events prediction • Digital construction practices	• Digital tracking and payment for waste disposal • Building energy management systems and dynamic pricing • Home energy consumption tracking and environmental services • "Digital twin" city simulation • New structural arrangements to promote third-party access to city data for applications development • Digital construction practices
New investment targets	**Datacenters and cloud services** providers, **Big data platform** providers, **AI-based analytics** providers, **IoT and sensor platform** providers, **Blockchain and cybersecurity platform** providers			

These digital technologies can generate new efficiency and sustainability opportunities

- MGI has estimated that USD13 trillion could be added to global GDP by 2030 through digitization, automation and AI.
- For infrastructure-based companies, McKinsey estimates that transforming operations and systems can **reduce operating expenses up to 25%**, with performance gains of 20% to 40% in areas including **safety, reliability, customer satisfaction, and regulatory compliance**.

- Infrastructure sectors can also achieve **transformative benefits** by creating new markets, new kinds of service, and new engagements with customers and the labor force.
- Examples include new **digital ride-sharing apps**, **dynamic pricing** for energy generation and use, **new products** such as recycled water supply.

- A key **sustainability benefit** from digitalization is energy efficiency. These arise both from reduced energy consumption and from higher efficiency in the generation and distribution of energy.

Source: McKinsey Global Institute, AIIB/Ovum analysis

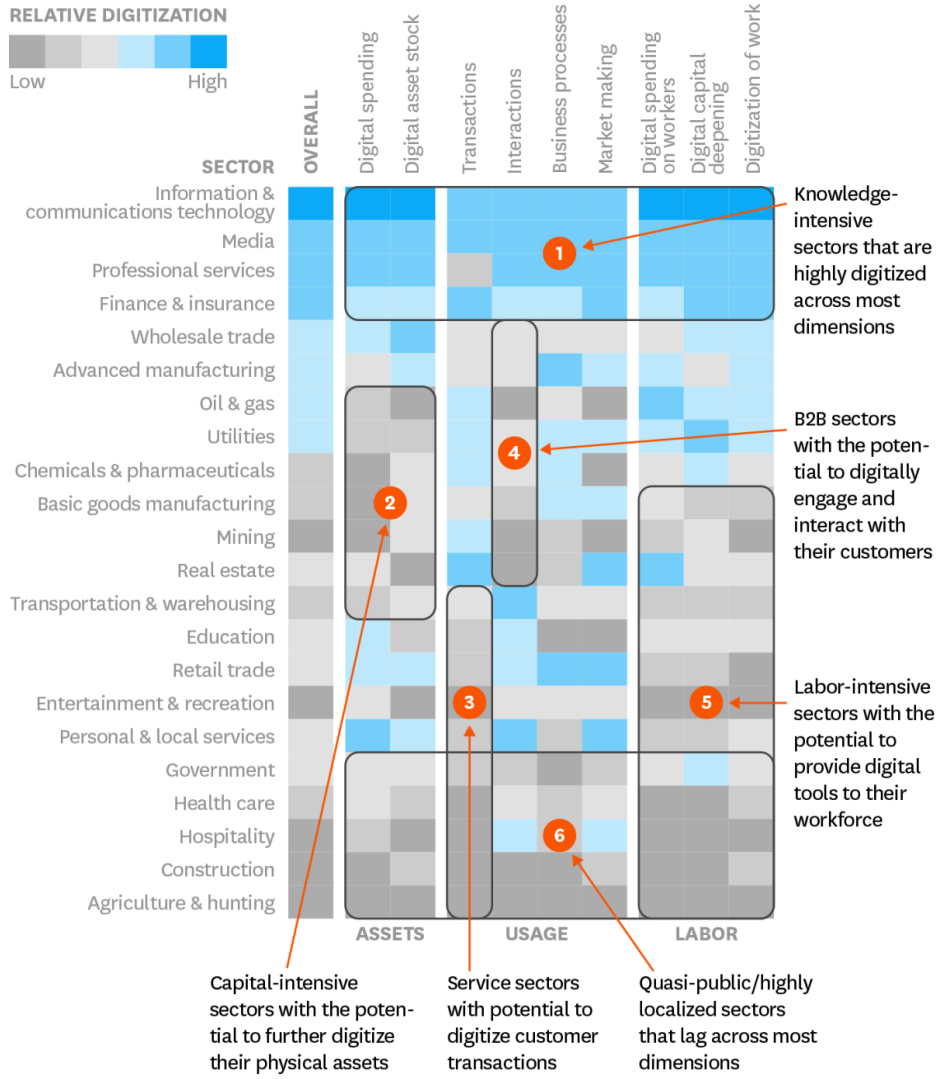
Source of activities for GHG emission reduction	Estimated global incremental potential for GHG emissions reduction by 2030
Smart Buildings – ICT in legacy buildings	545
Smart buildings – ICT in planning and operating new buildings	439
Transport mode switching enabled by smart urban planning	190
Telecommunications and virtual meetings (smart work)	159
In-vehicle ICT and intelligent transport infrastructures (smart vehicles and intelligent transport)	1,486
E-commerce and dematerialization	927
ICT for energy efficiency in industry (improving day-to-day operations; smart industry plant and process design; e-optimization	815
ICT in energy supply systems (removal of network constraints)	59
Total	**4,620**

Source: WWF

But infrastructure sectors lag others in capturing value and sustainability benefits

Infrastructure sector digitalization performance is mixed – at best

- **Knowledge-intensive sectors** like ICT, media and professional services have **adopted digital technology** at high levels.
- In comparison, **infrastructure sectors** (e.g. utilities, real estate, transportation & warehousing, construction) **lag** the leading performers despite the potential for large gains:
  - **Digitization of physical assets** to improve incremental efficiency.
  - **Digitalization of interactions** with wholesale and retail partners to create new services, introduce dynamic pricing and consumption regimes, and transform the sector with new structural arrangements.
  - **Construction**, including the construction phase of the infrastructure project cycle, is **amongst the worst performers on digitalization**. There are large potential gains from digitalizing assets, processes and labor management.



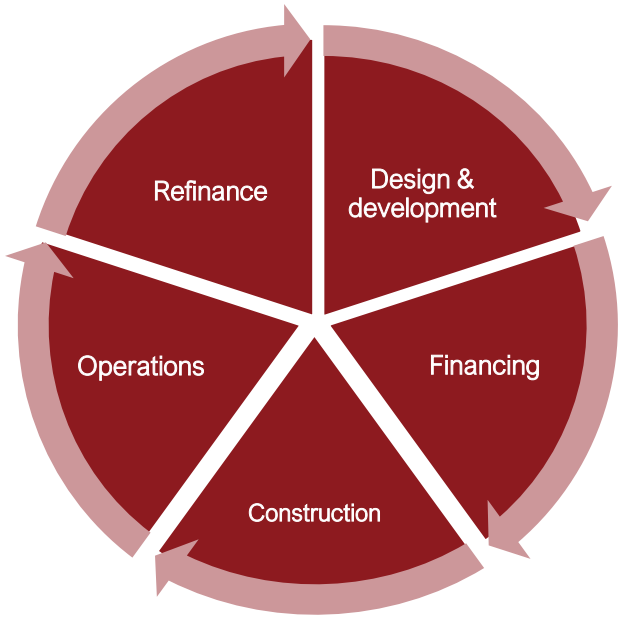
Source: McKinsey, HBR

Obstacles to infrastructure digitalization

*Different **obstacles to digitalization** arise at different parts of the **infrastructure project cycle***

Refinance

- Lack of skills for data-enabled financial analysis
- Poorly designed or documented legacy contracting and financing processes
- Lack of skills to develop digitalization business cases
- Lack of interoperability between proprietary digital financial applications



Planning, design, development

- Lack of digital design skills and analytics tools
- Poorly structured or non-existent historic databases
- Poor user interfaces to data and design tools
- Legacy procurement systems

Operations

- Weak change management processes and culture
- Company silos and fragmented datasets
- Poorly designed or tacit legacy operating processes
- Lack of digital skills and tools
- Lack of real-time data
- Lack of interoperability between proprietary digital solutions

Financing

- Lack of skills for data-enabled financial analysis
- Poorly designed or documented legacy contracting and financing processes
- Lack of skills to develop digitalization business cases
- Lack of interoperability between proprietary digital financial applications

Construction

- Industry fragmentation and company decentralization
- High variance between different projects
- Weak change management processes and culture
- Lack of digital skills
- Lack of interoperability between proprietary digital solutions

Sources: Ovum analysis, adapted from PwC, McKinsey

What do other MDBs do in applying soft Digital Infrastructure in development work?

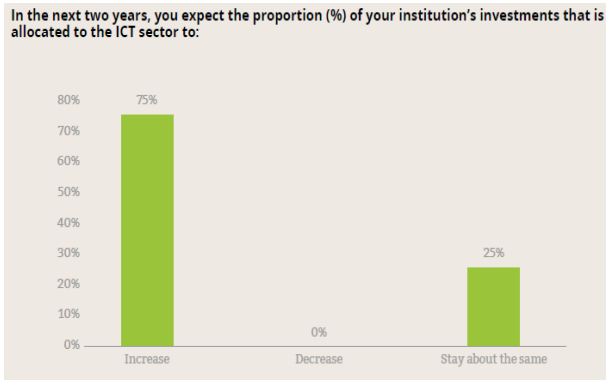
Most MDBs agree and realize the importance of digital technology to infrastructure

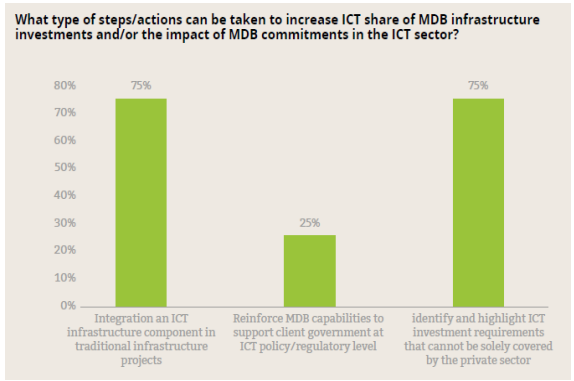
All MDBs have expressed the importance of digital technologies and set up dedicated units, funds, facilities, initiatives, events or publications to raise the awareness and facilitate adaptations of technologies and innovations for development and infrastructure.

- World Bank have set up **Digital Development Program (DDP) and InfoDev.**
- ADB has set up the **Digital Technology for Development Unit** in March 2018, held ADB Digital Development Forum and set up **ADB Venture Facilities.**
- IFC has a dedicated **Venture Capital team** focusing on cleantech, fintech and etc. (with 20+ investment professionals, portfolio of ~USD500m)
- IFC AMC published an article and recommended investors should actively cultivate an innovation network to stay abreast of new developments.

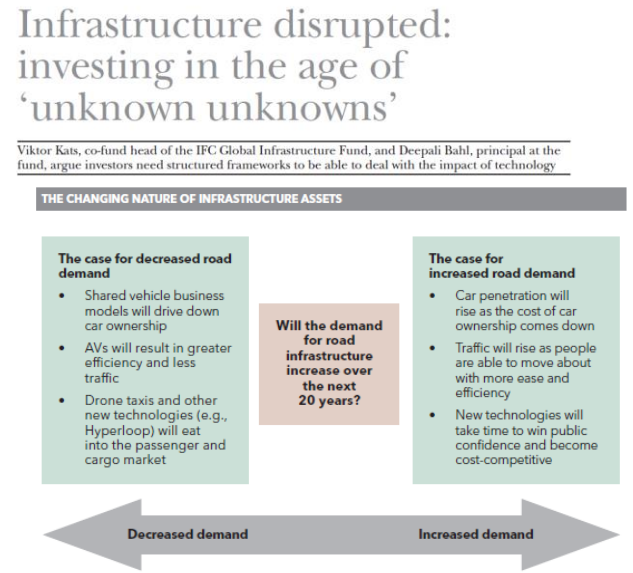
What do other MDBs think about technology?

- 75% of MDB expects the proportion of **investments in ICT will increase.**
- 75% of MDBs believe that **integration of ICT component in traditional infrastructure projects is the key to increase impact of MDB's commitments.**





Sources: World Wide Web Foundation, Alliance for Affordable Internet



Sources: IFC

Digitalization investment imperatives

*Investors must look for expertise in **cultural change**, **talent**, and **technology** in management selection*

- Successful implementation of infrastructure digitalization offers opportunities for productivity improvement on a scale not seen for decades.
- However, it will require **new ways of working**, and a management capable of delivering **new modes of operation**.
- AIIB's main **channel of influence**, apart from initial investment choice, is **choice of management through the board**. AIIB should influence management selection to overcome known obstacles to infrastructure digitalization.
- **AIIB's focus** in limited sectors (infrastructure particularly) will be a **key comparative advantage** to execute this change as it can concentrate and avoid diffusion of resources (other MDBs spread their focuses too thin).

	Adopting digital ways of working	Attracting and retaining digital talent	Modernizing the IT architecture and environment
	● Gain the support of senior leaders so a digital transformation has high priority ● Build a digital factory to produce new applications and insights using digital-native methods	● Highlight the intellectual challenge and social value of the utility's work ● Tap into a broad pool of digital specialists who value the balance and stability that a utility offers	● Simplify the utility's product portfolio and business processes ● Shift from all-in-one, monolithic IT systems to modular IT architectures
AIIB board imperatives	Seek out C-level management with a track record of digital innovation success	Insist on strategies for short and medium term digital talent attraction and development	Develop and promote and model IT architectures for investment classes, and benchmark.

Source: Adapted from McKinsey

Why and how does this affect AIIB?

1. Infrastructure investors need to be **aware of transformative changes** brought by technology innovation to promote and seize emerging opportunities (investment thesis) and avoid investing in stranded assets (risk management).

2. There are **progressive and incremental value-adds** and opportunities from technologies that could be readily incorporated in existing infrastructure sectors if the right incentives are put into place. This will improve efficiency (portfolio value creation) and E&S performances (sustainability).

3. **Other MDBs are also aware of the importance** of technology and digital components for development and are developing different facilities / initiatives to support.

4. AIIB needs to **be agile and innovative** to become a 21st century development bank for infrastructure – technology and innovation is an important cross-cutting priority for clients/projects, as well as drivers for internal efficiency.

5. Technology has impact in many ways, so **finding the right strategic focus** within technologies is essential to maximize financial and strategic benefits for the Bank in all infrastructure sectors. Focus on **integration of soft Digital Infrastructure and technologies in AIIB infrastructure sector** (city, energy, transportation, water and utilities) is key to success.

3.2 Benefits and potential applications in the infrastructure industries

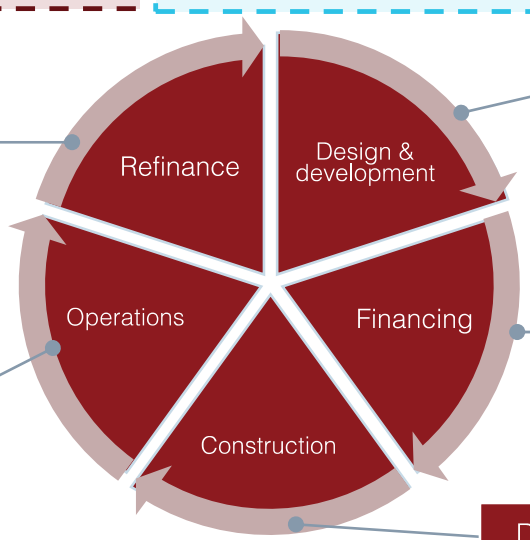
Digitalization enables efficiency and transformation across the investment cycle

Benefits are similar across infrastructure sectors, both incremental and transformational. There are new risks as well.

Incremental benefits:
- Higher operational efficiency and lower opex costs.
- Higher capital efficiency with improved maintenance and longer asset lifetimes.
- More sustainability with lower power and materials costs
- Improved infrastructure planning & design through better demand modelling and optimized construction.

Transformational benefits:
- Better customer service with service customization.
- Higher dynamic efficiency with new marketplaces and dynamic pricing.

New risks:
- Disruption of companies and markets.
- Cybersecurity attacks.
- Regulation of privacy and data protection.



How can ICT help value capture (e.g. new revenue source) and capital market development for infrastructure?
- Data & Analytics
- Smart contracts (other distributed ledger technologies)
- Digital payment systems (pay-as-you-use)
- Capital market technologies

Better planning, design and development
- Digital design management, digital twins
- High definition surveying and geolocation
- Data-driven demand analysis
- VR/AR for design and collaborations
- E-procurement system

How can technology help infrastructure financing
- Predictive forecasting / Data-enabled credit analysis
- Smart financial contracts
- Streamlined digital financing processes

How can technology improve the operational efficiency, maintenance and longevity?
- Remote monitoring of building systems
- Predictive analytics to assist maintenance
- Satellite imagery / Drones technology for inspections (e.g. offshore wind turbines)

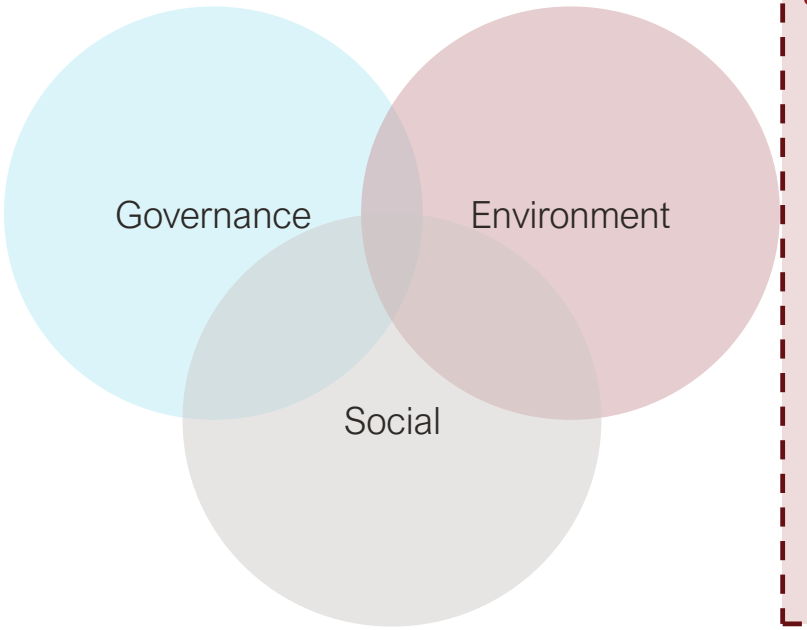
Digital technologies to help the construction industry to be more efficient?
- 5D Building Information Modeling
- 3D printing, preassembly, robot-assembled construction
- IoT and advanced analytics
- Digital equipment management, safety monitoring, big-data ESG trackers

Sources: AIIB and Ovum analysis, Bloomberg, Global Infrastructure Partner, PwC Digital, McKinsey

Digitalization also generates social, environmental and governance benefits

Digitalization can generate systemic and external benefits in several domains

- Poor governance flourishes with lack of transparency and the proliferation of middlemen. Technologies such as **process automation and blockchain** can increase the **auditability and transparency of interactions** within and outside organizations.
- Numerous studies have shown that digitalization corresponds to **decreases in corruption**, **improving trust** between citizens, customers and organizations.



- Environmental goals, particularly **reductions in carbon dioxide emissions**, can be assisted by digitalization:
  - Digital optimization of city transport and waste collection can minimize energy consumption and time wasted.
  - Digitalization of energy grids can reduce wasted energy and facilitate the inclusion of renewables.
  - Digitalization of national transport systems can optimize travel and delivery times while reducing energy consumption.

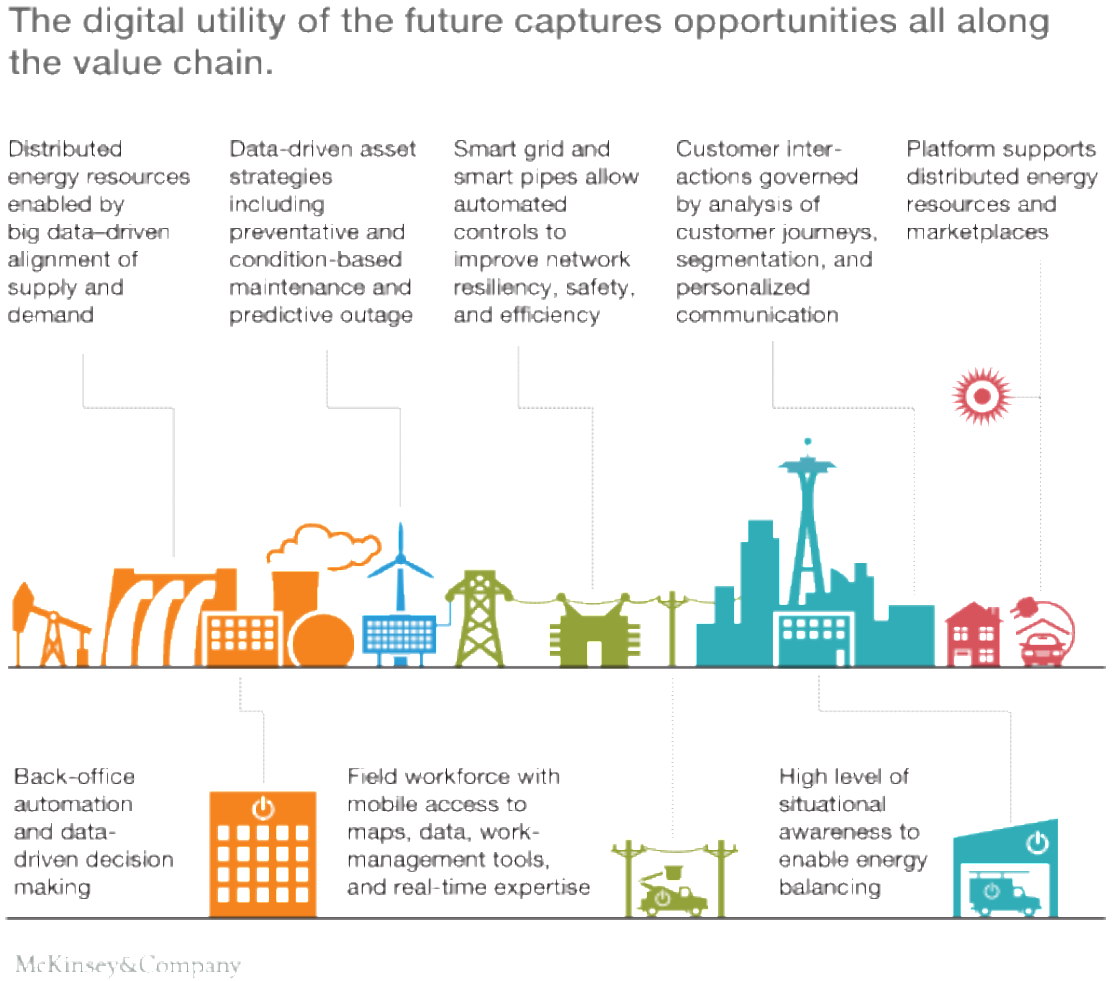
- Digitalization is being used by governments and the private sector to **extend services to underserved populations**:
  - Digital banking and e-wallets to the unbanked.
  - Educational services and E-health
  - Improved infrastructure services for the delivery of energy and transport services

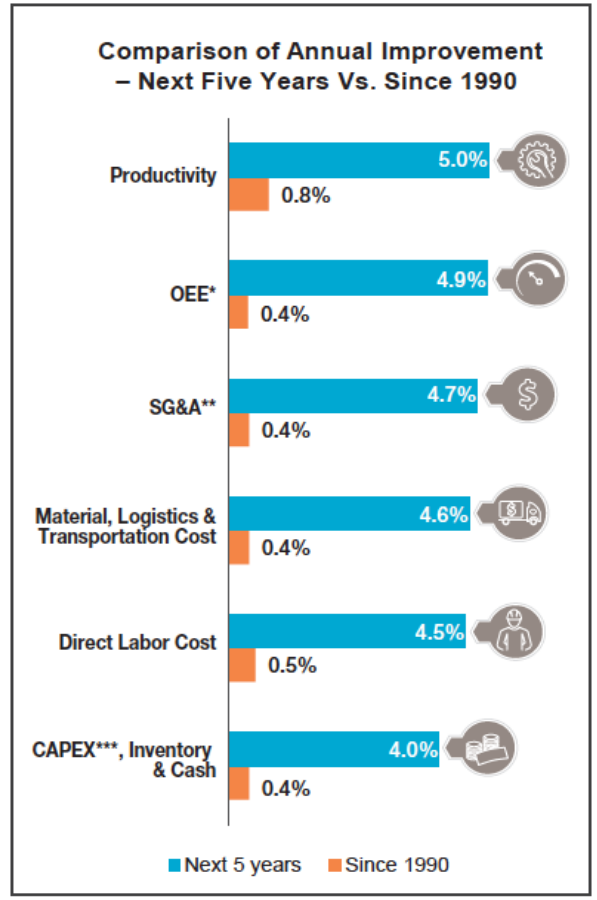
Power & energy: scope of infrastructure digitalization benefits

Grid-based electricity has significant digitalization potential

Digital technologies have improved energy systems for decades, but the **pace of adoption is accelerating**. For example, global investment in digital electricity infrastructure and software has been increasing by 20% p.a. in recent years (IEA).

Industry surveys show that energy utility operators expect to capture far more **productivity growth from technology innovation** in the next five years than in the previous twenty-five years (CapGemini).





Source: CapGemini

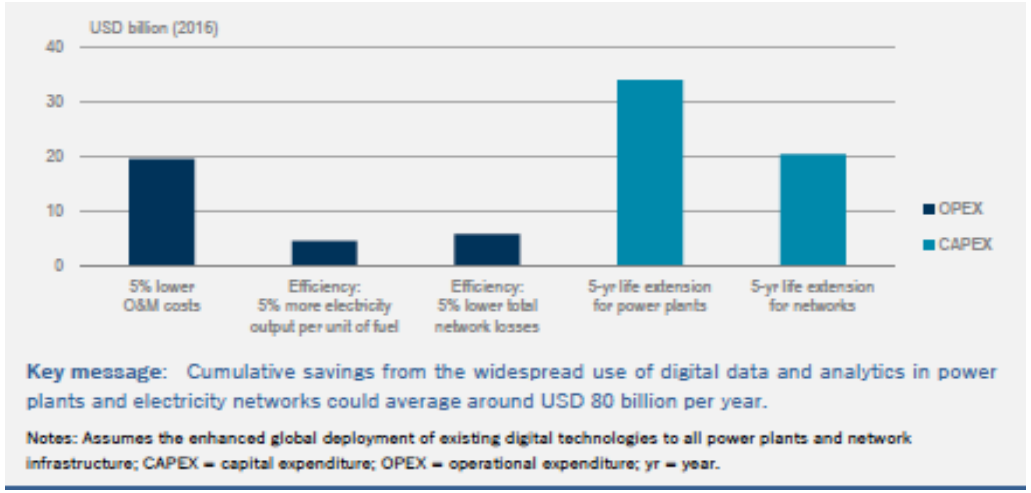
Power & energy: optimization through digitalization

Digital applications can drive efficiency and sustainability in production, distribution, consumption and trade

Digitalization within the power sector has the potential to **save** around **USD 80 billion per year globally**, or about **5%** of total **annual power generation costs**:

Key impact areas are:

- Reduced O&M costs.
- Improved power plant, network and appliance efficiency.
- Reduced unplanned outages, greater resilience
- Extended operational lifetime of assets.



Key message: Cumulative savings from the widespread use of digital data and analytics in power plants and electricity networks could average around USD 80 billion per year.

Notes: Assumes the enhanced global deployment of existing digital technologies to all power plants and network infrastructure; CAPEX = capital expenditure; OPEX = operational expenditure; yr = year.

Source: IEA

Digital technologies are combined into applications that create **multiple benefits**

	AI	Big data analytics	IoT	Software-as-a-service	Blockchain & cyber-security
Generation & distribution efficiency	Predictive maintenance				
	Improved generation efficiency				
	Dynamic wholesale pricing				
Consumption efficiency	Smart grid management				
			Smart meters		
	Dynamic retail pricing				
Grid resilience	Predictive maintenance				
	Grid outage response automation				
Asset lifetime improvement	Predictive field-force management				
	Smart load management				

Source: AIIB, Ovum analysis

Power & energy: industry transformation through digitalization

The creation of new markets for consumption of power (gas & electricity) will drive efficiency of use.

Digitalization allows for inflexible utility silos to shift to a **responsive digitally interconnected system**.

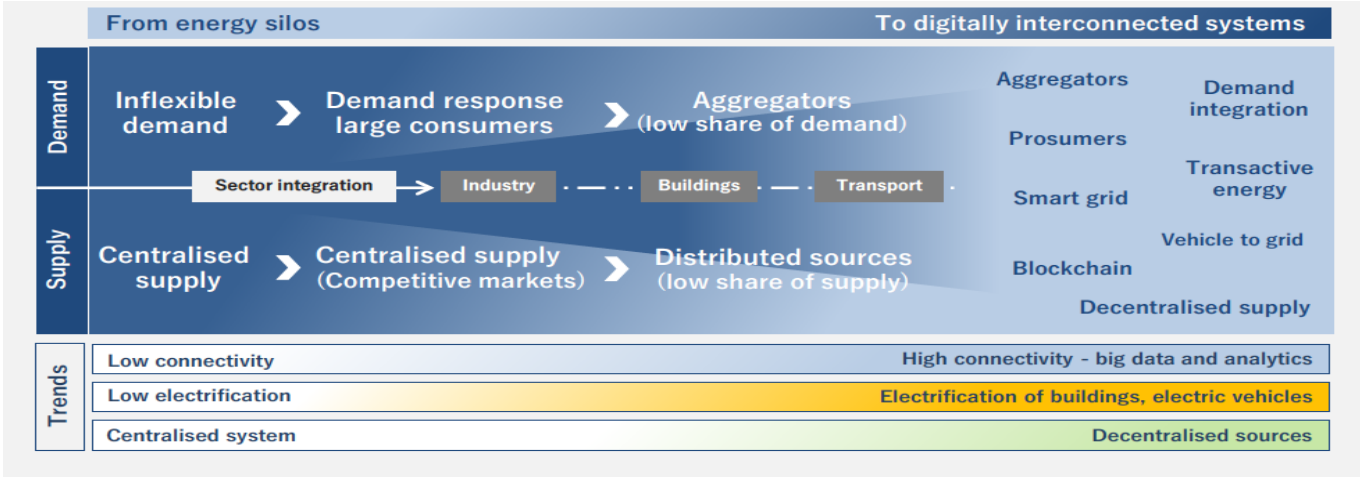
Digitalization allows consumers to automatically respond to price and environmental signals from the system – a mechanism known as **demand response**.

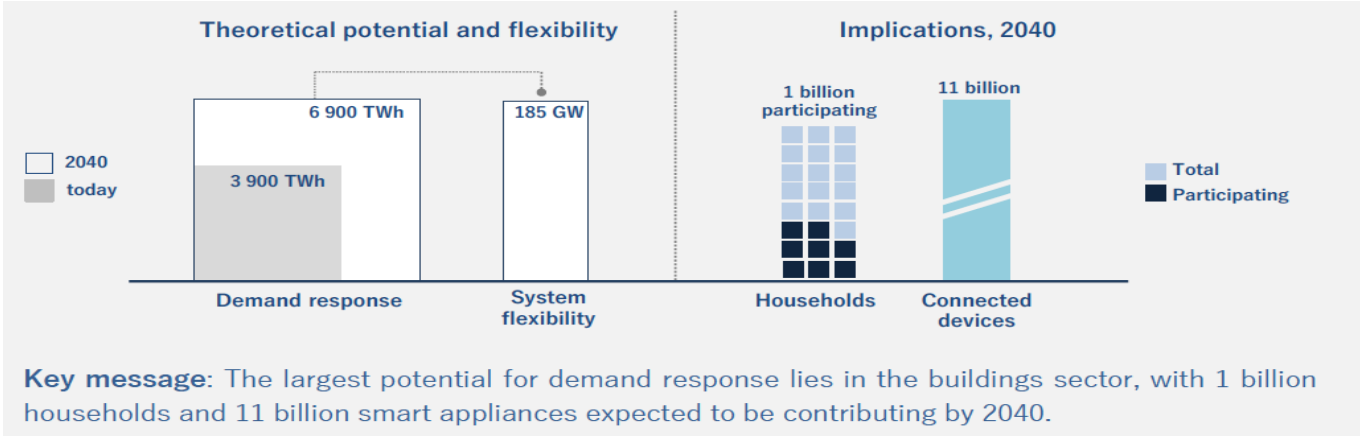
Several technologies will drive demand response:

- Automation and AI control of purchasing decisions.
- Internet of things (IoT) devices in the residential and commercial sector (e.g. smart thermostats directly connected to the power market and to weather forecast providers)
- EVs and smart charging systems will allow further integration across demand and supply.

Potential efficiency improvements are equivalent to an **extra 185GW of generation capacity in 2040**.

This will require technical, market and institutional changes. The process is at an early stage in most countries, but is set to accelerate as digital technology improves.





Key message: The largest potential for demand response lies in the buildings sector, with 1 billion households and 11 billion smart appliances expected to be contributing by 2040.

Source: IEA

Transport: scope of infrastructure digitalization benefits

More connected transport infrastructure and vehicles can yield more efficient and sustainable travel.

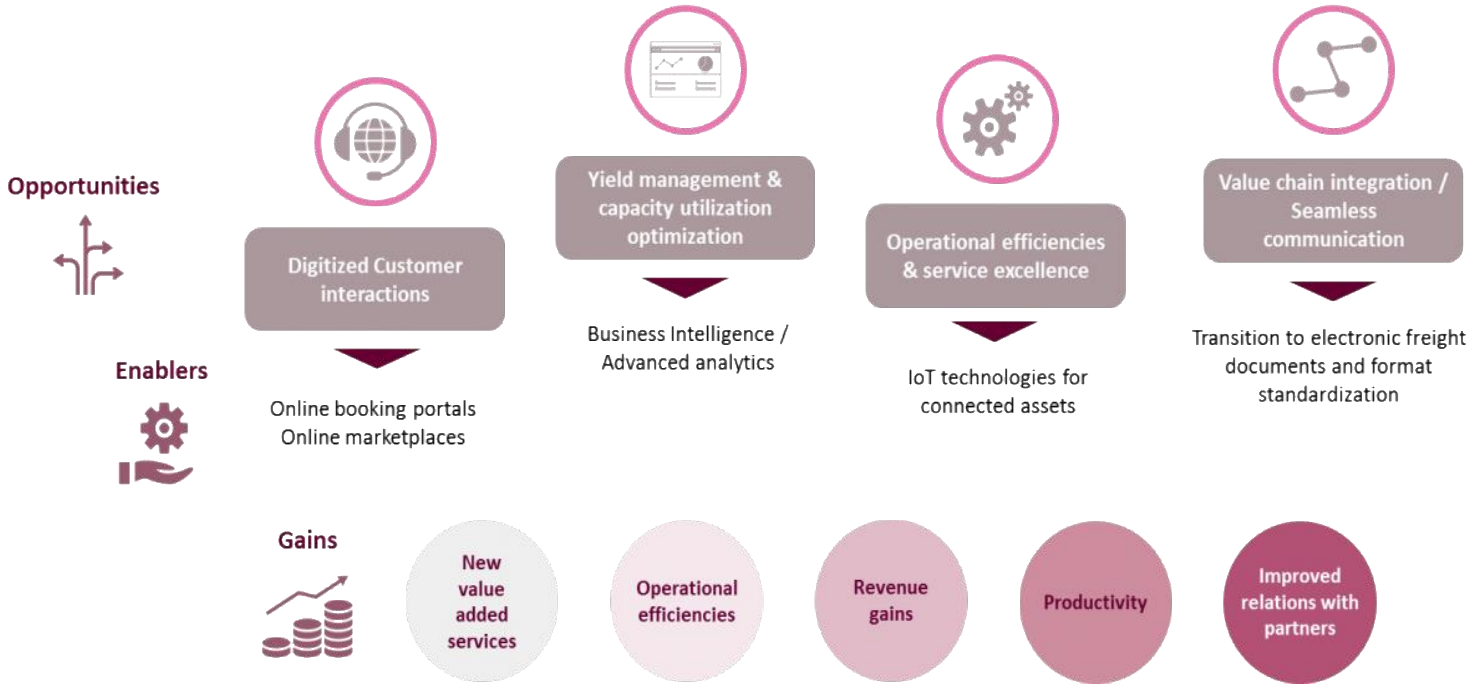
The big digitalization opportunities in transport infrastructure arise from **smarter and more connected vehicles and infrastructure**.

The benefits include:

- Improved construction efficiency.
- Optimized usage for energy and economic efficiency.
- Reduced maintenance costs.
- Increased asset lifetimes.

The potential economic benefits are enormous. For example, ADB has estimated that the **London congestion charge** alone generates an **economic surplus of USD 110-150 million per annum**.

Globally, the **opportunity** across road, rail, sea and air transport is in the **trillions of dollars**. Increased **efficiency** also translates into **sustainability benefits** from reduced energy use.

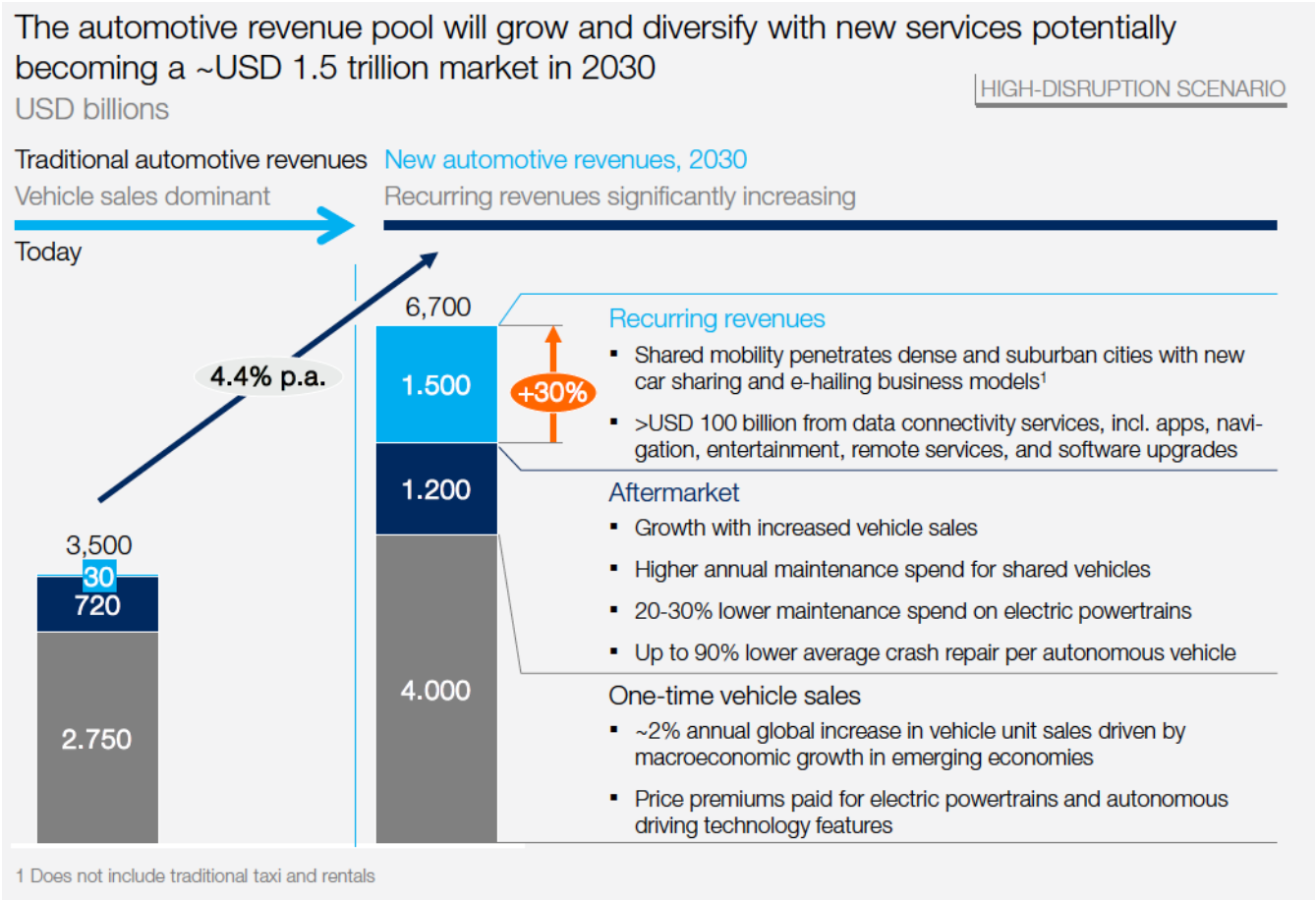


Sources: SIAPartners

Transport: industry transformation through digitalization

*Transport-as-a-service is changing patterns of **transport consumption**.*

- Ride sharing apps are driving new kinds of **vehicle sharing**. McKinsey forecasts that a disruptive push could see significant automotive revenues shift from ownership to pay per use or subscription.
- **Dynamic pricing regimes** based on digital technologies are creating new markets for transport infrastructure use, designed to improve efficiency and to internalize sustainability costs.
- In the public transport segment, digitalization can support **demand-driven routing** and greater customer choice. Dynamic pricing has significant scope to drive higher public transport infrastructure utilization and ROI.



Source: McKinsey

Transport: optimization through digitalization

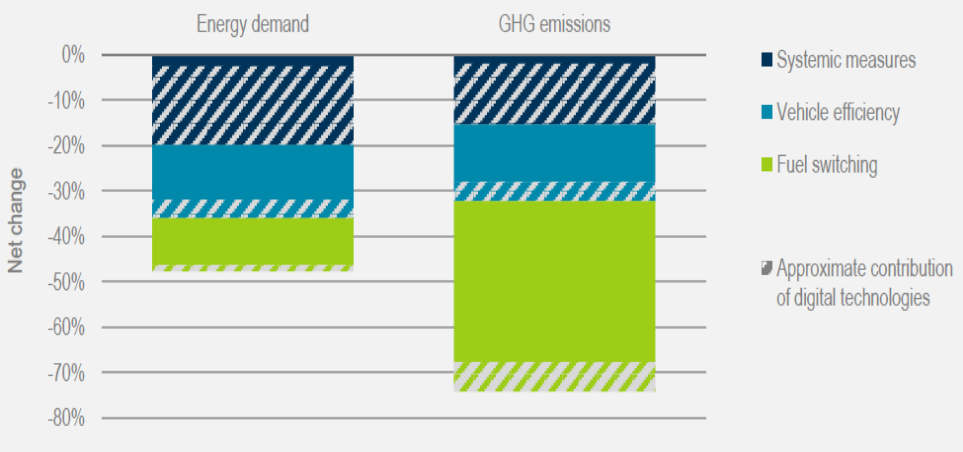
Digital applications can drive efficiency and sustainability in construction, operation and maintenance.

Digitalization within the transport sector has the potential to save around USD 80 billion per year globally, or about 5% of total annual power generation costs:

Key impact areas are:

- Improved **construction** efficiency.
- Optimized **usage**.
- Reduced **maintenance** costs.
- Optimized **utilization** through dynamic pricing.

Digitalization contribution to energy and emissions reduction in road freight



Source: IEA

	AI	Big data analytics	IoT	Software-as-a-service	Blockchain & cyber-security
Construction efficiency	Demand measurement & digitally optimized design				
	Project performance diagnostics				
	Remote construction site monitoring				
Usage optimization	Supply chain optimization				
	Predictive analytics				
	Dynamic congestion charging				
Reduced maintenance	Predictive maintenance				
	Performance monitoring				
Asset lifetime improvement	Asset lifecycle management				
	Predictive maintenance				

Source: AIIB, Ovum analysis

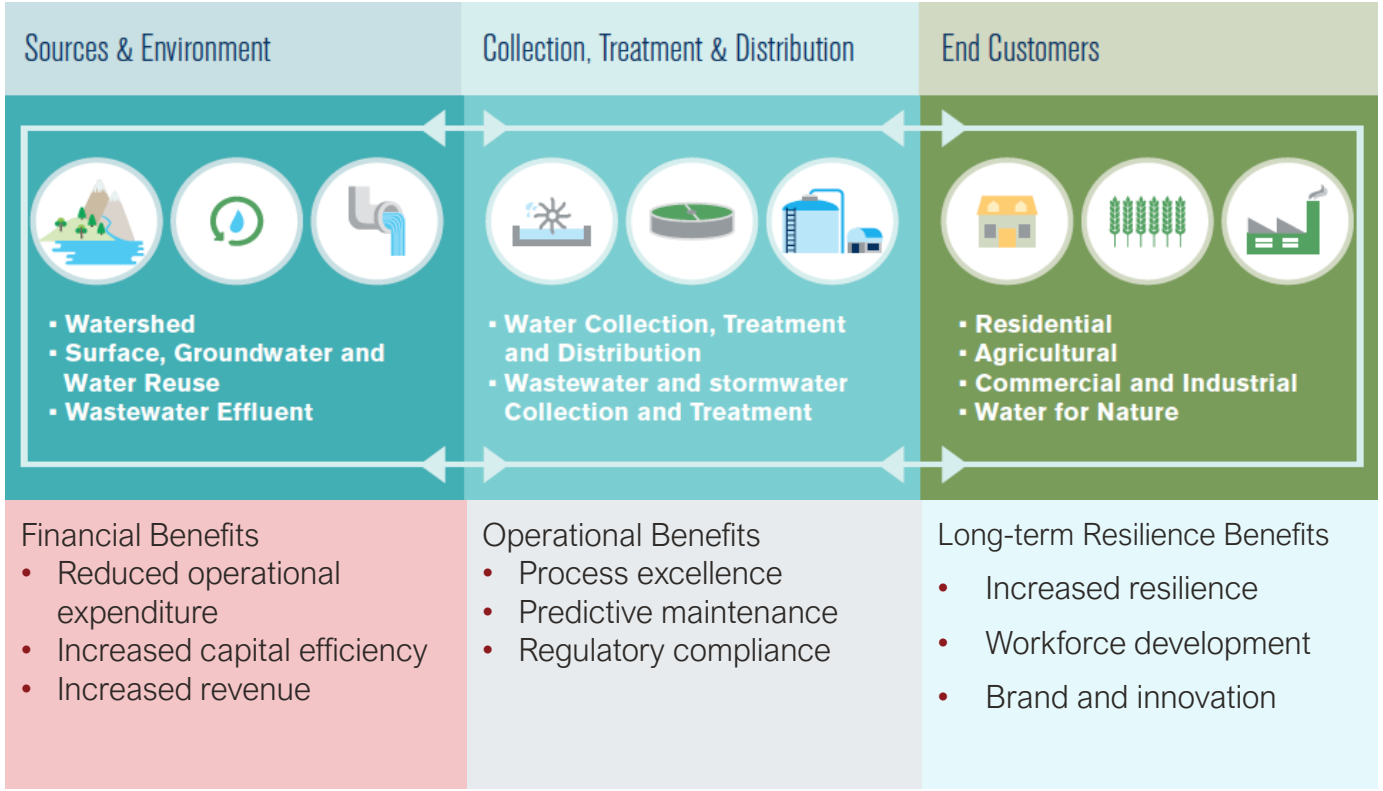
Water: scope of infrastructure digitalization benefits

As pressure on global water resources grows, digitalization can improve operational and capital efficiency.

The global water industry is turning to **digitalization** to **improve efficiency**, reduce waste, and **protect water resources** from contamination and/or overuse.

The benefits include:

- **Integrated management** of water resources through remote monitoring and management.
- Better **monitoring and control** of treatment processes and water infrastructure.
- More responsive and efficient engagement with customers through **demand management** and **dynamic pricing** markets.



Source: Adapted from International Water Association

Water: optimization through digitalization

Potential digital savings in the water sector are significant, and can be redeployed to other water-related goals.

Global Water Intelligence (GWI) has estimated that the potential global digitalization savings over the five years to 2020 were USD173 billion for drinking water treatment, distribution, and customer services, metering and billing.

The potential global savings over the same period for wastewater management were another USD143 billion.

These savings could be applied to significantly accelerate the **SDG goal** of **providing water**, **sanitation and hygiene** (WASH) services globally.

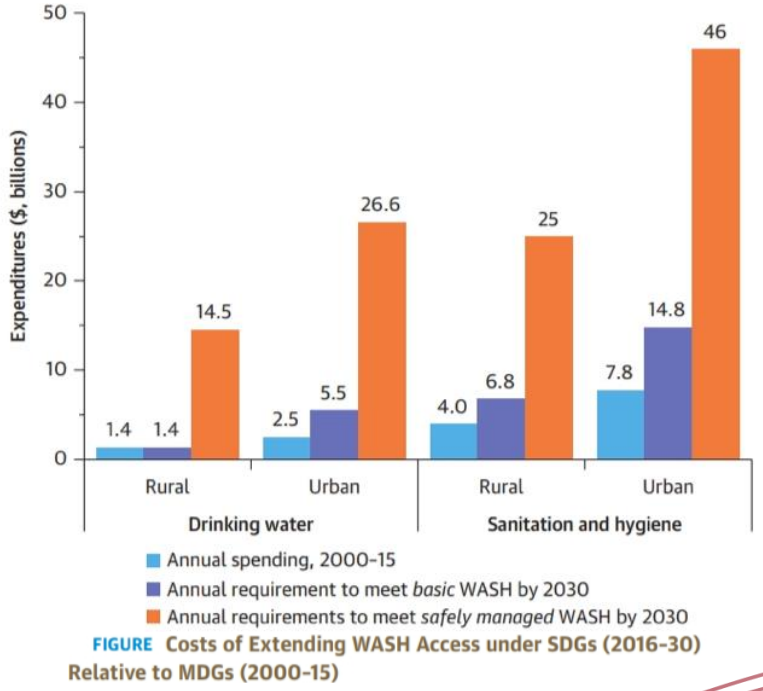


FIGURE Costs of Extending WASH Access under SDGs (2016-30) Relative to MDGs (2000-15)

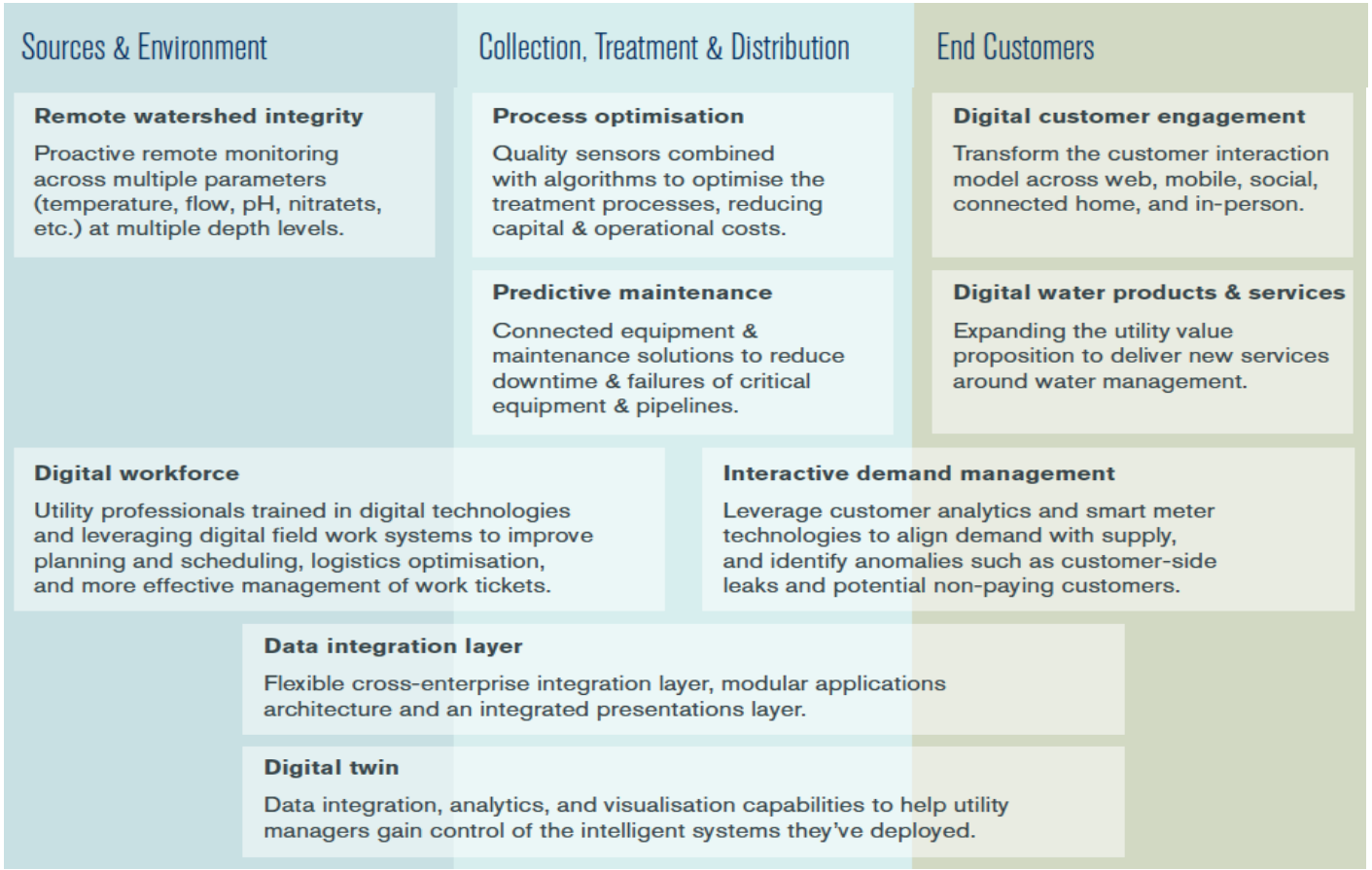
	AI	Big data analytics	IoT	Software-as-a-service	Blockchain & cyber-security
Construction efficiency	Demand measurement & digitally optimized design				
	Project diagnostics				
	Remote site monitoring				
Resource & usage optimization	Predictive usage analytics & supply forecasting				
	Smart metering				
	Blockchain-based water trading				
Reduced maintenance	Predictive maintenance				
	Automated leak detection				
Asset lifetime improvement	Asset lifecycle management				
	Predictive maintenance				

Water: industry transformation through digitalization

Digitalization can shift the water industry from a transactional model to a dynamic and responsive ecosystem.

Digital technologies have the potential to **transform** the **economics** of the **water and wastewater sector** through:

- Process optimization.
- Interactive demand management to align with supply.
- Increased sustainability, resiliency and watershed connectivity.
- Workforce transformation.
- Ensuring public health, transparency, and proper governance.
- Aiding regulatory compliance.

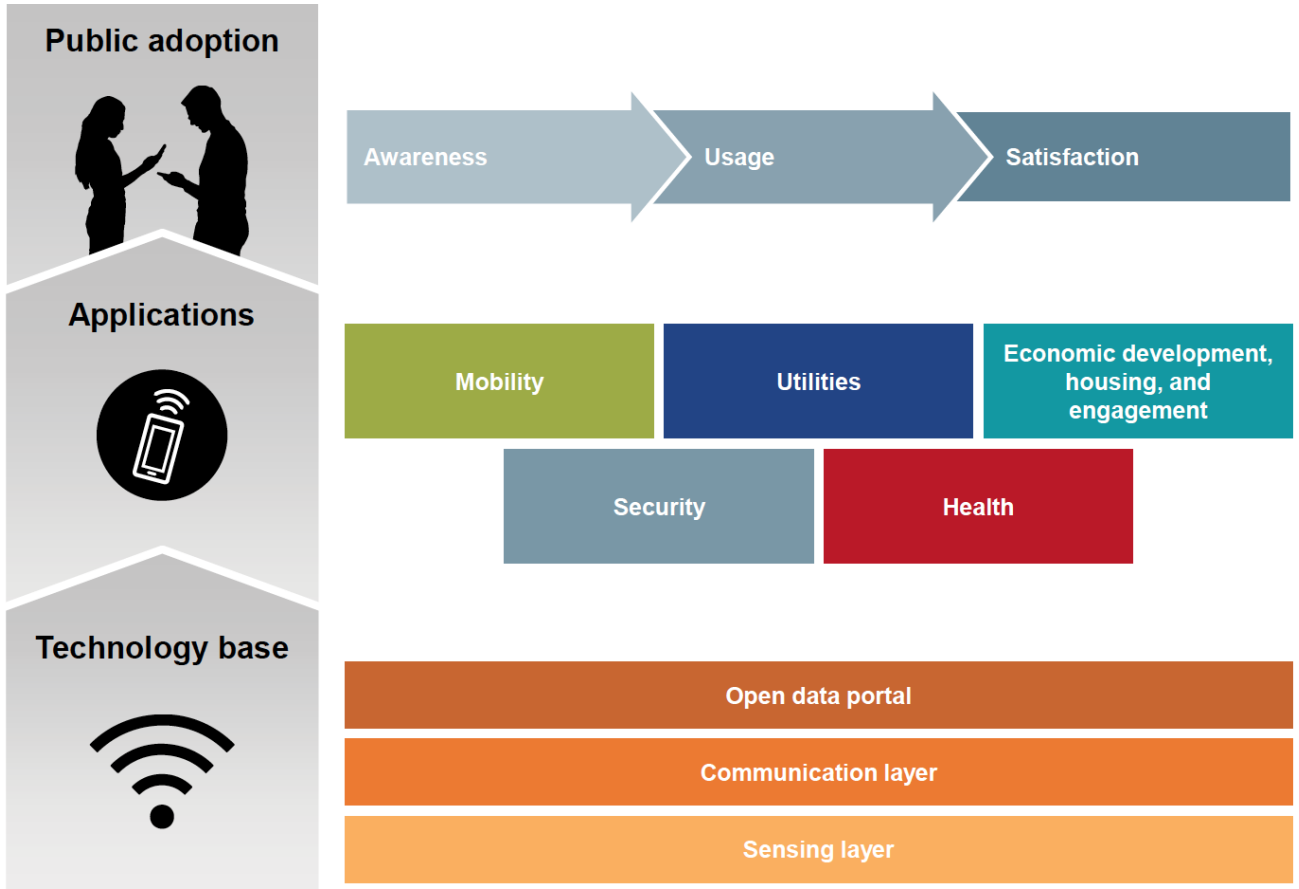


Source: International Water Association

Smart cities: scope of infrastructure digitalization benefits

Cities are the most complex environment to deploy digitalized services.

- Smart city implementation involves multiple service and infrastructure verticals, linked together by a **shared sensing, communications and data management platform**.
- Smart city is where **digitalized infrastructure sectors** meet and are integrated.
- Smart city applications are **attracting PPP investment** as city administrations seek to optimize city environments and operations.



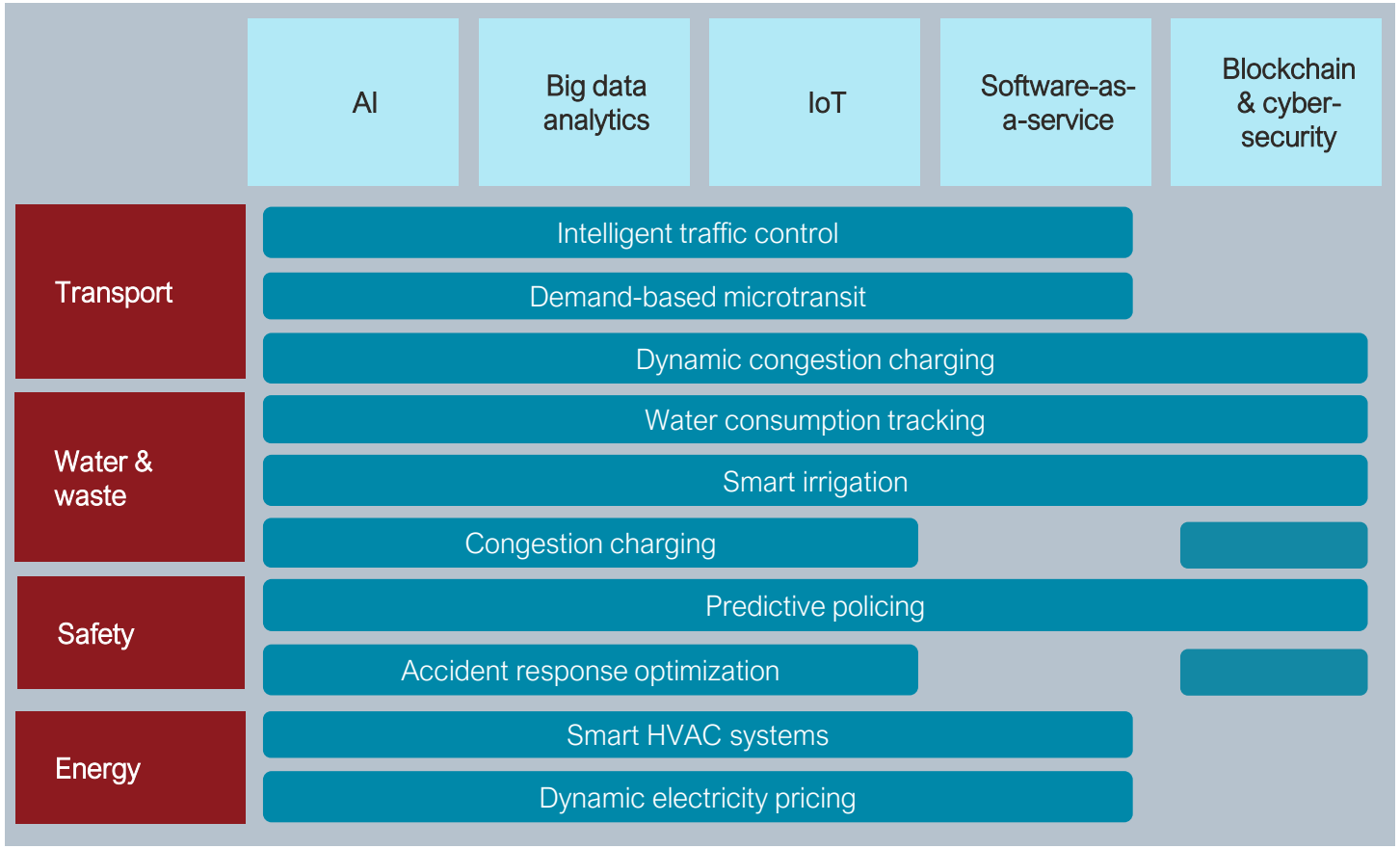
Source: McKinsey Global Institute

Smart cities: optimization through digitalization

Digitalization of city operations has demonstrated benefits.

MGI found that various **digital applications** for **smart cities** could:

- Reduce **traffic fatalities** by 8-10%.
- Accelerate **emergency response times** by 20-35%.
- Reduce the average **commute times** by 15-20%.
- Reduce **crime incidents** by 30-40%.
- Cut **greenhouse gas emissions** by 10-15%.
- Reduce **water consumption** by 20-30%.

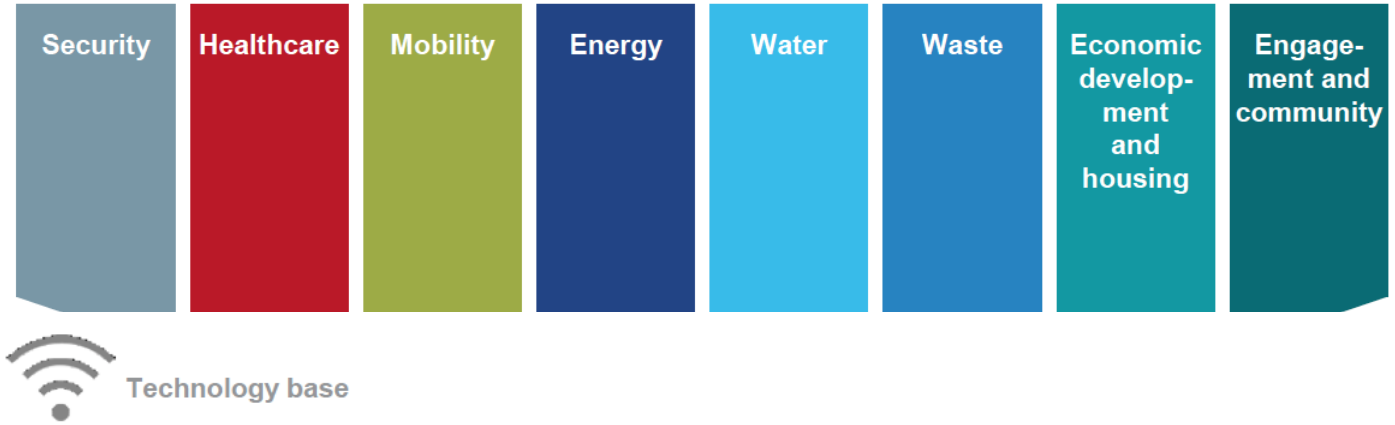


Source: AIIB/Ovum analysis

Smart cities: city transformation through digitalization

Digitalization of cities is based on a pervasive Digital Infrastructure, available to multiple digital developers.

- **Smart systems** speed up city government, allowing agencies to watch events as they unfold, understand how demand is changing, and respond with faster and often lower-cost solutions.
- Adding sensing, connectivity and data infrastructure enables cities to **expand** the **capacity and lifespan** of existing **physical assets**.
- Opening up access to sensor grid data – with appropriate privacy safeguards - drives **innovation by private digital service developers**.
- MGI estimates that the majority of this digital investment is profitable, which opens the door to **partnerships between city governments and private investors**.



Sensing layer	Communication layer	Open data portal
▪ Penetration of smart water and energy meters ▪ Density of water and air quality sensors ▪ Density of publicly accessible surveillance cameras ▪ Number of waste capacity sensors ▪ Smartphone and PC penetration	▪ Availability and extent of LPWAN infrastructure (unlicensed and licensed technologies) ▪ Availability and extent of public Wi-Fi ▪ Broadband and mobile up- and download speeds ▪ Latencies	▪ Extent of data available ▪ Ease of access ▪ Frequency of updates ▪ Support for developers

Source: Adapted from McKinsey Global Institute

The End

Additional studies on financing gap

WEF, ADB and the others

World Economic Forum ("WEF") - Who are the main funders of Digital Infrastructure development

Industry remains the major funding source for Digital Infrastructure, but it may require diversifications

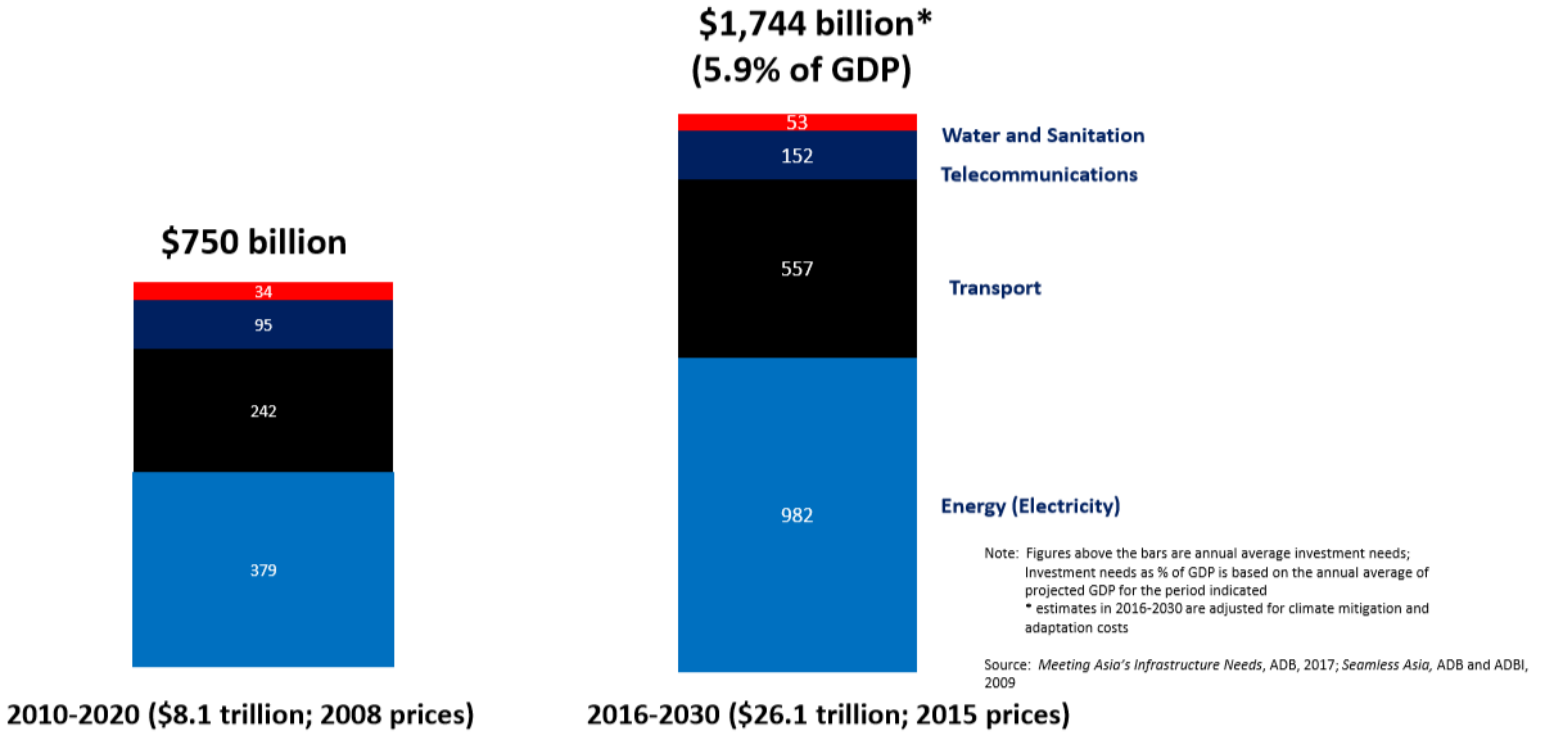
- The **current financial models rely primarily on investment by network operators (through corporate finance)**.
- However, Digital Infrastructure may no longer be an attractive standalone investment for traditional investors and operators as most profits are made in the end-user services but not in infrastructures.
- There is a need for more proactive financing arrangements and mobilizing other financial sponsors (e.g. sharing infrastructure)

	Actors	Examples	Notes	Objectives	Risk appetite	Investment Volume / Trends[1]	
						Digital Infrastructure	Digital Technology
Private sector	Industry	MNOs/ISPs/Tower companies	• **Vast majority of funding** & "front line" of profitable investment	• Provide connectivity for profit	Low	Highest / ↑	Low / ↑
Private sector	Financial sector	Investment & commercial banks	• **Willingness to invest is often complicated** by concerns over competing infrastructure networks, uncertainty around technological developments, and the belief that investment is the responsibility of MNOs and ISPs	• Provide financing and capital for profit	Low	Low / →	Low / →
Private sector	Financial sector	Private investment firms (pensions, VC, PE, etc.)		• Grow capital for profitability • Diversify portfolio	Low	Medium / →	High / ↑
Private sector	Other private sector	Technology firms Other sectorial firms		• Expand customer base • Invest for business sustainability	Low-Medium	Medium / ↑	Highest / ↑
Private sector	Non-profit	Foundation/NGOs	• **Longer-term investment horizons**, enabling investment in lower-IRR projects that do not meet objectives of other investors	• Develop philanthropy by addressing inequalities	Medium-High	Low / ↑ (High in rural)	Medium / ↑
Public sector	Multilateral	Multilateral development bank/Fund	• Investment usually **motivated by national interest**, with social and development outcomes prioritized alongside (or above) economic profitability • Funds can be **combined with private-sector** money to mitigate some kinds of investment risk and improve investment climate	• Provide financing to foster long-term economic development	High	Low / →	Low / →
Public sector	Public sector	Sovereign wealth fund		• Create long-term value for investors by driving sustained economic development	Medium	Medium / ↑	Medium / ↑
Public sector	Public sector	USFs		• Expand connectivity in underserved areas through subsidies and fees	High		
Public sector	Public sector	National development bank/Fund		• Provide financing to foster national long-term economic development	High		

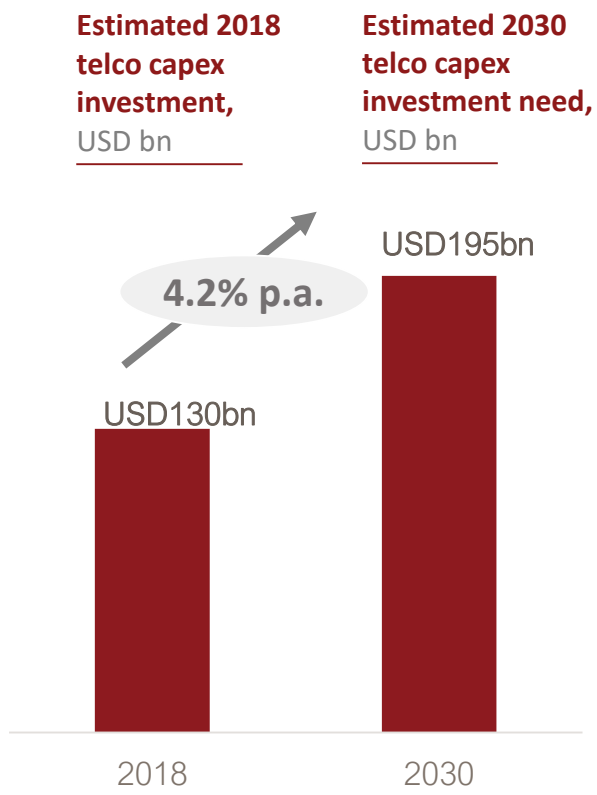
1. qualitative and indicative only Source: WEF

ADB - Key challenge in huge need for infrastructure investment in Asia

- Developing Asia will need to invest USD26.1 trillion from 2016 to 2030, or USD1.7 trillion per year including climate mitigation & adaptation cost.
- Telecommunications infrastructure investment needs (mainly in traditional basic connectivity infrastructure such as mobile and fixed telephony and broadband) will grow from USD130 Billion in 2018 to USD195 Billion in 2030 at CAGR 4.2%.



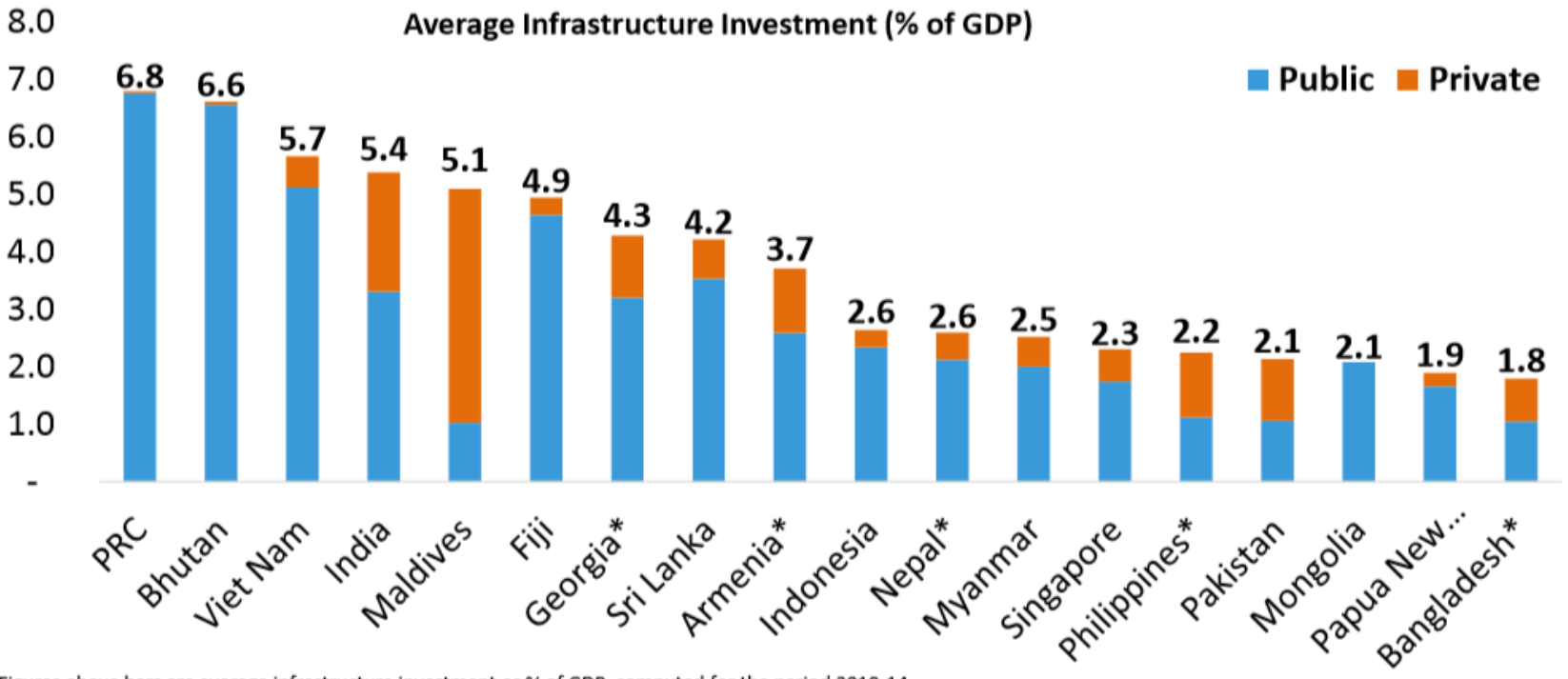
Source: Infrastructure Financing Challenges in Southeast Asia, Alfredo Perdiguero,
Director, Regional Cooperation and Coordination Division Southeast Asia Department Asian Development Bank
Policy Dialogue on Infrastructure Financing Strategies for Southeast Asia, Manila, 29 August 2017



Source: ADB, Ovum analysis

ADB - Investment in infrastructure: considerable variations by country

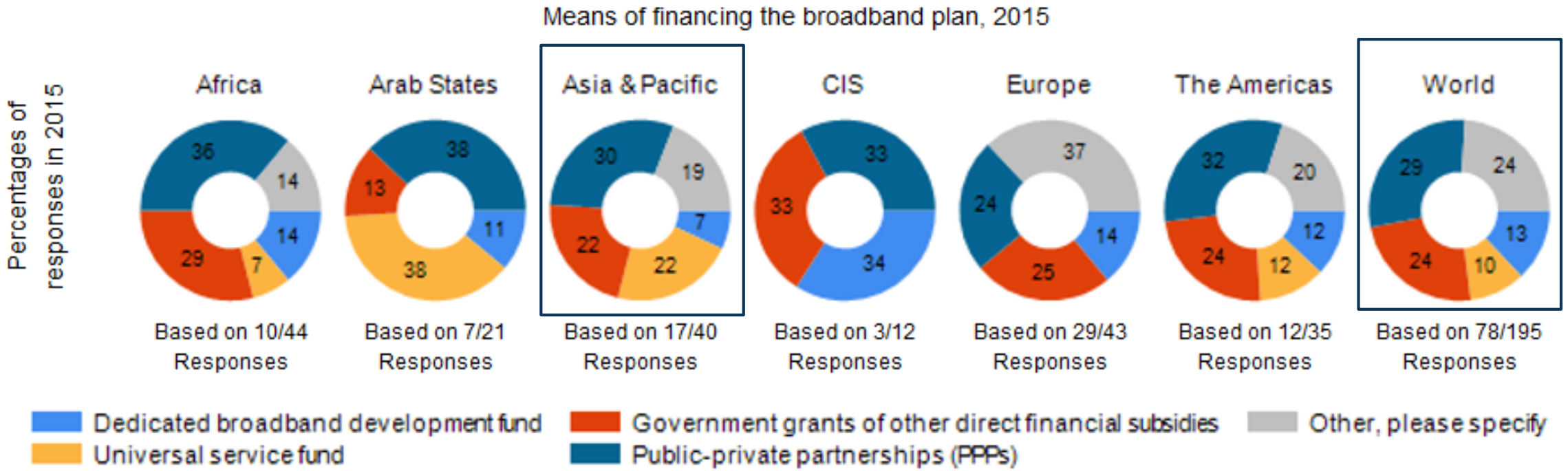
- Telecoms infrastructure investment (as % of GDP) varies among developing Asia countries, with varying social-economic benefits
- MDBs have financed an estimated 2.5% of infrastructure investments in developing Asia. Excluding the PRC and India, MDB contributions rise above 10%. A growing proportion of ADB finance is now going to private sector infrastructure project.



Note: Figures above bars are average infrastructure investment as % of GDP, computed for the period 2010-14
Public sector includes central government budget only. Actual budget investments except Armenia, Bhutan, Georgia, Maldives, Myanmar and Thailand, which are planned or estimated budget investments
Source: *Meeting Asia's Infrastructure Needs*, ADB, 2017

ITU - Infrastructure investment has different funding mode in bridging the digital divide

Funding mode in APAC is similar to World average: PPP, Government Grants and Universal Service Fund are key, a potential opportunity for MDBs and AIIB in sub-urban and rural connectivity infrastructure



Source: ITU Global Survey on Broadband Funding (2015)

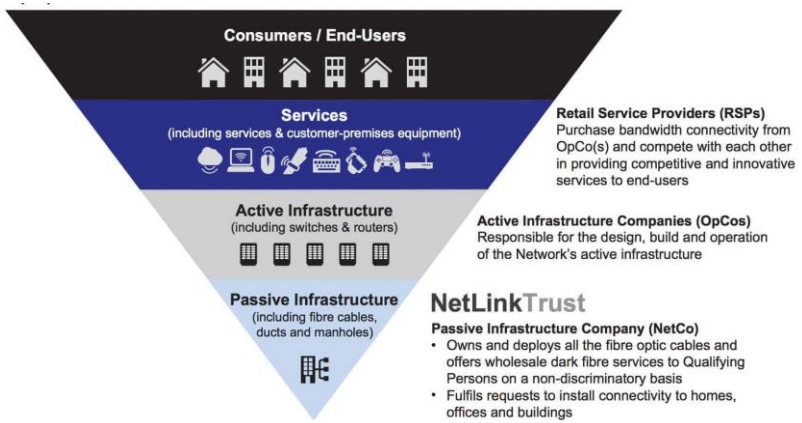
More case studies on financing solutions

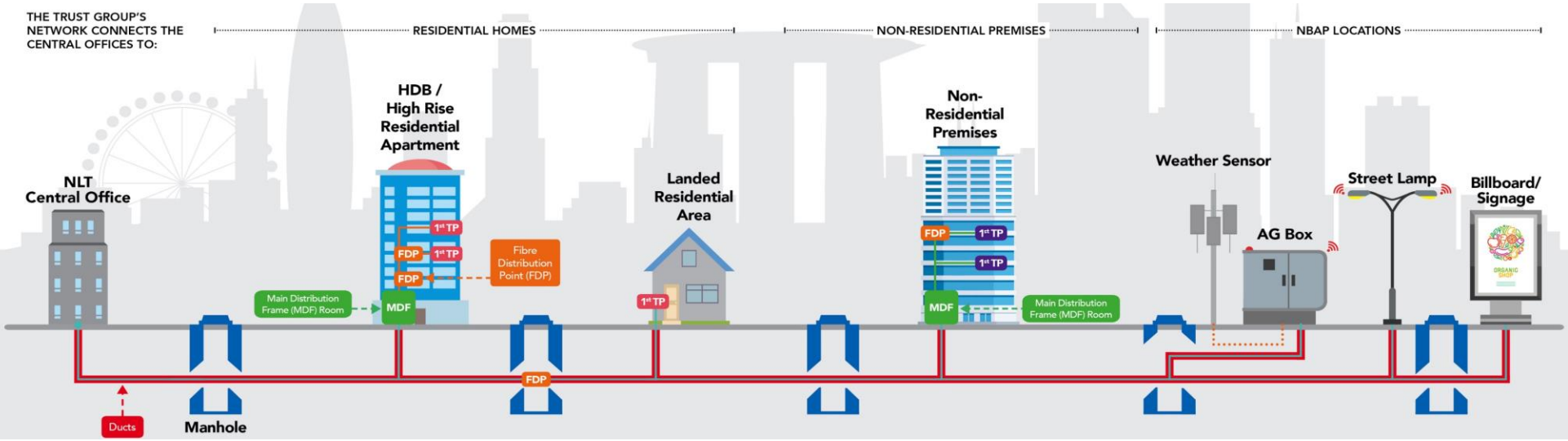
Learning and practices sharing on financing mode

Case study 1: SingtelI-NBN Trust

Singapore Government successfully leveraged major carrier investment in fixed networks by tendering government grants.

- In 2009 the Singapore Government tendered the allocation of a total of SGD1 billion to a structurally separated FiberCo (dark fiber) and Opco (network electronics).
- The structural separation of the FiberCo (NetLink Trust) from the telecom players (including Singtel, which retained a shareholding) opened the market to new entrants,
- This, along with better fixed technology, has benefited end users with better coverage and prices.
- The government of Singapore has played an active role in achieving this – the set up of the regulatory asset base model is critical to the success.
- In other markets, when the governmental regulations are absent, the wholesale independent fiber companies can be created with commercial contractual arrangements.
- The structure enable the shared infrastructure companies to be set up – which bring efficiencies of a shared network while promoting connectivity service level competition (analogous to the regime in some national energy sectors).





Source: NetLink NBN Trust

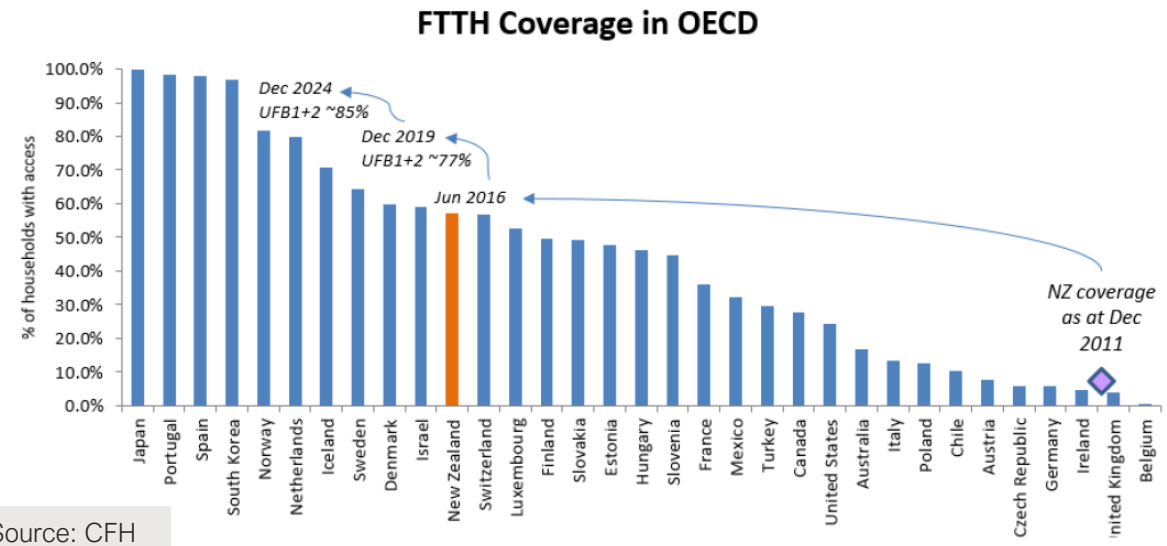
Case study 2: New Zealand Ultrafast Fiber Program

New Zealand Government leveraged grant funding for a fiber rollout to mobilise private investment and promote structural reform.

- In 2011 the New Zealand Government tendered a Government-funded program of investment in a new, open-access FTTH network - the Ultrafast Broadband initiative, or UFB. The Government committed NZDUSD1.345 billion to the Phase 1 tender process to cover 75% of the population.
- Telecom New Zealand (Telecom) voluntarily demerged is fixed access network (now called Chorus), which was a condition of participation in the UFB Initiative.
- Crown Fibre Holdings Limited (CFH) is a Government-owned company set up to manage the project. The country was divided into regions , and the CFH has selected four companies at tender and set up contracts ('deeds') with them to deploy fiber. The main partner is Chorus, which won 69% of the coverage area, with the remainder covered by three other companies.
- The Government announced extensions to the Phase 1 rollout in January and September 2017 to reach another 12% of population.
- The initiative has significantly improved New Zealand's fiber coverage ranking, and

UFB phase	Crown investment	Premises covered	End-users (such as households and businesses) covered	Population covered (%)
UFB phase one	$1.345 billion	~1,174,000	~1,526,000	~75.4%
UFB phase two (January 2017 expansion)	$307 million	~200,000	~216,000	~8.6%
UFB phase two (August 2017 expansion)	$130 million	~60,000	~60,000	~1.9%
Total	**$1.782 billion**	**~1,434,000**	**~1,801,000**	**~86% (87% with privately funded fibre)**

Source: NZ Commerce Commission

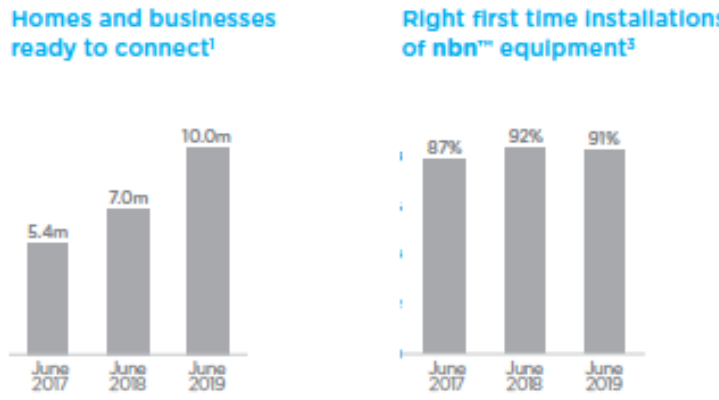


Source: CFH

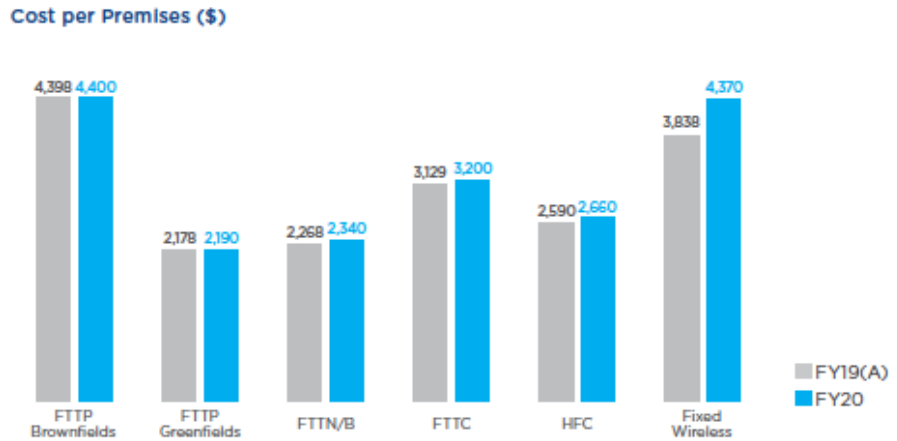
Case study 3: Australian National Broadband Network

Australian Government created a fully-funded government owned company to roll out fiber to 93% of population

- In 2009 the Australian Government announced that it would create a wholly-Government owned and funded company to roll out fiber to 93% of the population, and fixed wireless and satellite to the remainder. The project cost was estimated at AUD45 billion. The new National Broadband Network Company (NBN Co) entered into negotiations for access to the incumbent Telstra's duct system.
- The Government estimated to the capital expenditure of the project initially to be AUD43 billion. NBN Co later revised down the cost in its business plan to AUD37.4 billion, with a return on investment of 7.1%.
- After several years of delays, a new Government in 2013 shifted the technology mix to include FTTN and hybrid fiber-coax (HFC) in urban areas to speed up rollout and rein in rising costs.
- The network in in track to complete in 2020 at final cost of AUD51 billion. However, estimated final ROI on the project is expected to be a fraction of the initial 7.1% target.
- However, many commentators argue that the program would have been more successful if it has 1) leveraged private sector construction expertise in the early stages, and 2) leveraged private capital and exploited private sector disciplines on management and operations in the government-owned company.



Source: NBN Co



Source: NBN Co (AUD)

More case studies on integrating soft Digital Infrastructure

Improving efficiency, reducing costs and leading to sustainability

Power & Energy: Enel (Italy) case study

Electricity grid digitalization supports integration of distributed renewable energy sources

The problem:

- Renewable energy is more distributed and more dependent on the environment.
- Enel could not identify the sources of network problems, could not determine best locations for connecting alternative resources, and had no clear information on how to maximize the operation and value of renewable resources like solar and wind.

In response, Enel implemented a digital grid to provide more visibility :

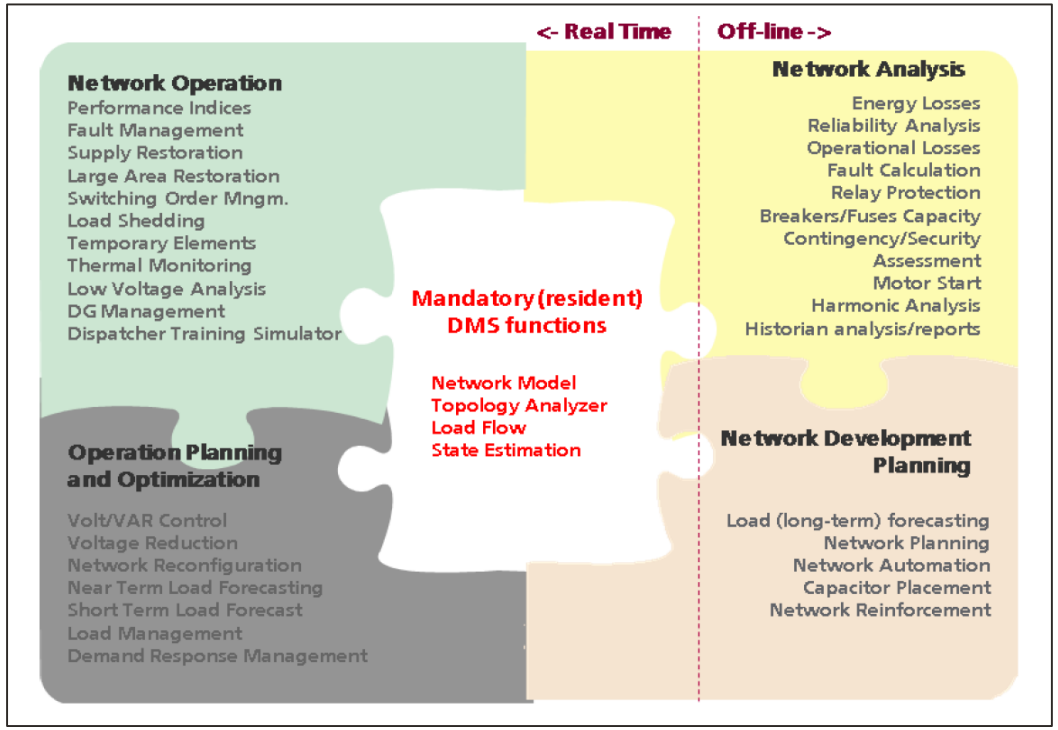
- Integrated legacy DMS, SCADA, OMS, EMS and demand management systems (along with their sensor networks) into a common platform with a unified interface.
- Visualization of grid status and dynamics to minimize energy wastage.
- Data analytics for demand and supply forecasting and management.
- "Digital twin" for off-line "what if" analysis for stress testing and capacity planning.

The benefits applied principally to **design & development** and **operations**:

- Optimization of existing networks with no further investments.
- More than 40% of Italy's energy is now renewable.
- Estimated energy savings of about 144 GWh per year.
- CO2 emissions reduction of 75,000t CO2 per year.
- Renewables can be implemented at a much lower social and operational cost.

Improved ROI due to digitalization is cited by Enel as a basis for improved asset value and improved dividend performance.

- **Enel has funded** its digital innovation from cashflow, which is supplemented mainly by ongoing bond issues and bank loans. Hybrid forms of finance and emerging market finance also play a role.



Source: Schneider Electric

Transport: Network Rail (UK) case study

Predictive maintenance reduces transport maintenance costs.

The problem:

- Network Rail in the UK was looking for a way to reduce rail downtime and maintenance costs in its network.

In response,

- Network Rail installed sensors around 64,000 assets on its rail and switching infrastructure with an AI-driven bid data platform to analyze incoming data to predict failures of physical assets in advance.
- This is the first step in a 15-year program of infrastructure upgrades(the Digital rail Strategy) including implementation of the European Train Control System, of an AI-driven traffic rail management to improve flow of rolling stock, and of driver decision support systems.

The benefits currently apply to **operations**:

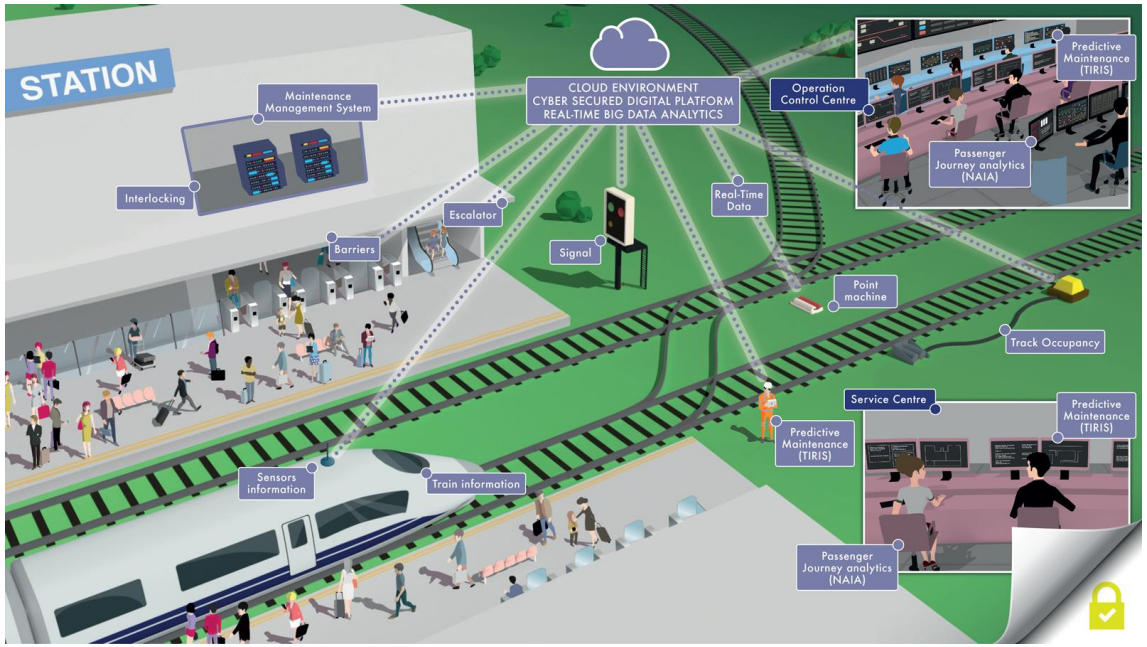
- Accurately schedule and budget for 'just-in time' maintenance.
- Reduce in-service failures and unplanned maintenance, with higher availability of services.
- Reduce unplanned maintenance and site visits by half, and cut costs by 30%.
- Achieved 500% ROI on digital investment.

Subsequent phases of the Digital Rail Strategy will improve both **operations** and **design & development** of future rail services.

Source: Thales, Network Rail

Funding:

- Network Rail is a public sector company funded by grants from UK and Scottish Governments, charges on train operators, and commercial property income.
- Network Rail's Digital Rail Strategy is directly funded by grants from the UK Government.



Source: Thales

Water: San Antonio Water System (SAWS) case study

Reduction of sewage overflow incidents with transformational savings.

The problem:

- *Clean Water Act 1972* seeks to eliminate sewer overflows, usually caused by blockages or excess stormwater. SAWS work crews have used a pipe cleaning schedule based on historical information at over 800 sites, costing USD1.2m annually.
- But had no real-time information about actual flow restrictions. Overflows still occur.

In response:

SAWS piloted a digital system to obtain real-time network information at 10 high frequency cleaning sites:

- Iridium satellite-connected sensor network embedded in manhole covers.
- Digital applications to process, analyze water level data, and display and alert management.
- Crews directed to clean based on measured water levels.

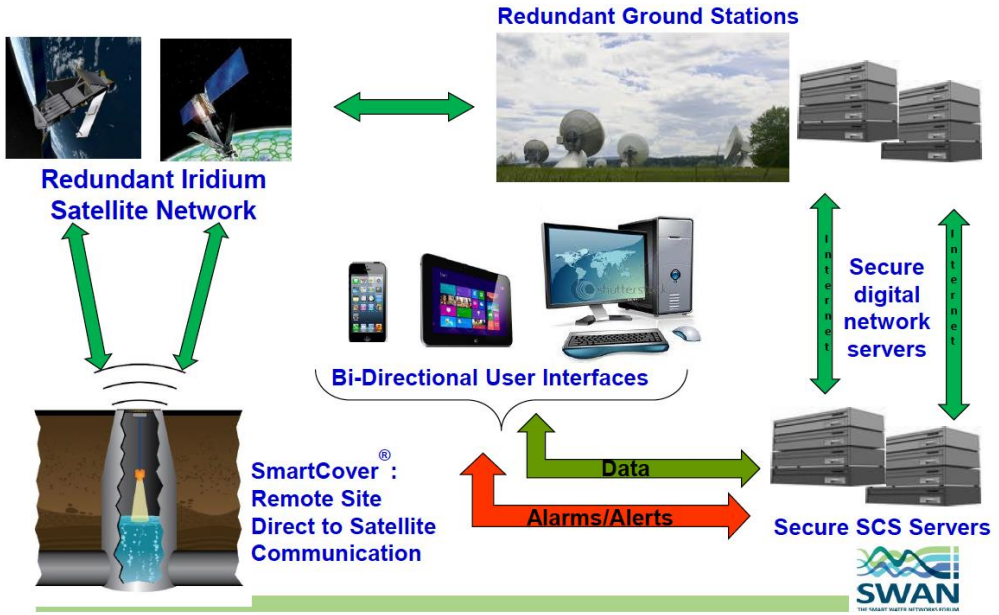
The benefits were principally on **operations** and **environmental outcomes**:

- Daily level readings and continuous overflow protection.
- Site visits projected to be down 85%, 5 year costs down by USD2.2m with full installation.
- Reduced accidents and GHG emissions with fewer truck rolls.
- Extended asset life as less cleaning reduces wear on infrastructure by up to 20%.
- Similar system in Hawthorne, CA reduced overflows by 99% long term.

Based on the pilot project's results, SAWS now has about 300 smart covers in operation and plans to install 200 more. The utility and the company estimate that 750 overflows have been averted.

Funding:

- SAWS is a public utility owned by the City of San Antonio. The utility has funded the project out of cashflow, including cleanup costs saved.



Source: The Smart Water Network Forum

References

References

Source (Sections 1, 2.1 & 2.2: DI Sector & Market Analysis)	Statement or Subject	Link or Document
Oxford Economics	The digital economy is worth $11.5 trillion globally, equivalent to 15.5 percent of global GDP and has grown two and a half times faster than global GDP over the past 15 years.	Huawei & Oxford Economics. (2017). Digital Spillover. Measuring the true impact of the Digital Economy. Retrieved from https://www.huawei.com/minisite/gci/en/digital-spillover/files/gci_digital_spillover.pdf
World Economic Forum (WEF)	Digital Infrastructure financing gap in Asia is growing significantly, estimated to reach USD512 billion by 2040	See Figure 3 of WEF White Paper "Financing a Forward-Looking Internet for All", 2018 http://www3.weforum.org/docs/WP_Financing_Forward-Looking_Internet_for_All_report_2018.pdf
Ovum Research	High proportion of young (digital) population using internet boosts digital economy development in emerging markets	Digital Economy 2025: series of research reports https://www.ovumkc.com/
Ovum Research	Broadband Development Index (BDI) for fixed and mobile broadband development	World BDI Map, world and country BDI index and data https://www.ovumkc.com/
Ovum Research	Current market overview and forecasts for digital infrastructure, services, products and applications	Current and forecast data for world, regions and countries https://www.ovumkc.com/
World Development Report	10 percentage point increase in fixed broadband penetration would increase GDP growth by 1.21% in developed economies and 1.38% in developing ones	http://pubdocs.worldbank.org/en/391452529895999/WDR16-BP-Exploring-the-Relationship-between-Broadband-and-Economic-Growth-Minges.pdf

References

Source (Section 2.3: Social Benefits, Policy & Regulation	Statement or Subject	Link or Document
ITU and Broadband Commission	Broadband Commission 2025 Targets for "Connect the Other Half of World: 3.8 billion people (half the world's population) remain unconnected to the internet.	International Telecommunication Union (ITU). UN Broadband Commission sets global broadband targets to bring online the world's 3.8 billion not connected to the Internet [Press release], 23 January 2018, https://www.itu.int/en/mediacentre/Pages/2018-PR01.aspx
Ovum Research	Global research on ICT Policy & Regulations	Policy & regulations for development of digital economy, digital infrastructure, ICT services & applications, with country regulation profiles and case studies, etc. https://www.ovumkc.com/
International Research and ITU	-Every 10% increase in broadband (3G & above) penetration increases GDP pa in developing countries by 1.38% -Doubling broadband speed leads to 0.3% increase in GDP pc growth -3G to 4G and 5G upgrades will contribute to 1.2% and 2.1% increase in GDP pc growth respectively (assuming the same penetration)	Varies research institutions: Brookings Institute, US; London School of Economics, UK; Czernich et al 2011; World bank, Qiang et al 2009 (developed & developing countries, 1980-2002); Chalmers University of Technology, Arthur D Little, Ericsson (33 OECD countries); Koutroumpis 2009 (network effects in OECD countries); Wavemen 2009 (16 OECD countries 1998-2007) Also see Section 2 of ITU Report "Impact of Broadband on Technology", April 2012, pp https://www.itu.int/ITU-D/treg/broadband/ITU-BB-Reports_Impact-of-Broadband-on-the-Economy.pdf

References

Source (Sections 2.3: Social Benefits, Policy & Regulation)	Statement or Subject	Link or Document
Research paper	Faster download speeds which, when doubled, results in an increase of 0.3% in per capita GDP growth.	See, for example, Kongaut, Chatchai and Erik Bohlin. “Impact of broadband speed on economic outputs: An empirical study of OECD countries”, Paper for the 25th European Regional Conference of the International Telecommunications Society, Brussels, Belgium, 22-25 June 2014: https://www.econstor.eu/bitstream/10419/101415/1/795234465.pdf
Deloitte for GSMA	-A 10 percent increase in mobile penetration increases Total Factor Productivity in the long run by 4.2% -A doubling of mobile data use leads to an increase of 0.5% in per capita GDP growth	"What is the impact of mobile telephony on economic growth?” https://www.gsma.com/publicpolicy/wp-content/uploads/2012/11/gsma-deloitte-impact-mobile-telephony-economic-growth.pdf
Pew Research Center	Figure: Impact of Internet Access to Social Outcomes	Internet seen as positive influence on education but negative on morality in emerging and developing nations: https://www.pewresearch.org/global/2015/03/19/internet-seen-as-positive-influence-on-education-but-negative-influence-on-morality-in-emerging-and-developing-nations/
UN	SDG Target 9c: Significantly increase access to information and communications technology and strive to provide universal and affordable access to the Internet in least developed countries by 2020	Sustainable development goal 9: https://sustainabledevelopment.un.org/sdg9

References

Source (Section 2.4: DI Financing Landscape)	Statement or Subject	Link or Document
McKinsey and AIIB analysis	Infrastructure investment by funding mode	McKinsey Infrastructure Project Analytics Tool (IPAT) database IJGlobal 2001-19 datasets AIIB infrastructure investment project database
Ovum Research	Forecast of digital infrastructure investment in Asia	Telecoms investment trackers and capex forecast data for digital infrastructure, digital services and applications in Asian region and markets https://www.ovumkc.com/
World Economic Forum (WEF)	Future investment and challenges in digital infrastructure	WEF White Paper "Financing a Forward-Looking Internet for All", 2018 http://www3.weforum.org/docs/WP_Financing_Forward-Looking_Internet_for_All_report_2018.pdf
ADB	Huge need for infrastructure investment in Asia Total Telecommunications Infra financing to reach $2,280 billion by 2030	Infrastructure Financing Challenges in Southeast Asia, Alfredo Perdiguero, ADB: Policy Dialogue on Infrastructure Financing Strategies for Southeast Asia, Manila, 29 August 2017 https://www.unescap.org/sites/default/files/SEA_01_Day 1 PM_Mr Alfredo Perdiguero_Infrastructure Financing Challenges in Southeast Asia (Aperdiguero 29 Aug 2017).pdf
OECD	Adequate infrastructure is necessary for sustainable economic and social development. However investment in infrastructure in most developing and emerging economies needs to be substantially increased to support more rapid economic growth	Fostering Investment in Infrastructure: Lessons learned from OECD Investment Policy Reviews, January 2015 http://www.oecd.org/daf/inv/investment-policy/Fostering-Investment-in-Infrastructure.pdf

References

Source (Section 2.4: DI Financing Landscape)	Statement or Subject	Link or Document
Ovum Research	Telecoms investment trackers and capex forecasts for digital infrastructure, digital services and applications	Investment trackers and capex forecast data for Asian region and markets https://www.ovumkc.com/
ADB	Investment need of Asia's infrastructure (defined as transport, power, telecommunications, water supply, and sanitation) 2030	Meeting Asia's Infrastructure Needs, 2017 https://www.adb.org/sites/default/files/publication/227496/special-report-infrastructure.pdf
OECD	Describes the methodology and data sources used for the estimate of infrastructure investment needs in the OECD Report 2017 for investment in climate and growth. It also provides a comparison with other existing estimates of infrastructure investment needs, and highlights related uncertainties and potential areas for further work.	Technical note on estimates of infrastructure investment needs https://www.ovumkc.com/
World Wide Web Foundation, Alliance for Affordable Internet (A4AI)	MDBs have low commitments in digital infrastructure, despite recognizing its importance	CLOSING THE INVESTMENT GAP: How Multilateral Development Banks Can Contribute to Digital Inclusion http://a4ai.org/wp-content/uploads/2018/04/MDB-Investments-in-the-ICT-Sector.pdf
ADL	Digital infrastructure investment needs are rising, but the main current funders are facing declining revenues and investment capacity	Digital infrastructure as a driver of competitiveness: Future of connected infrastructure https://www.adlittle.com/en/digital-infrastructure-driver-competitiveness

References

Source (Section 2.4: DI Financing Landscape)	Statement or Subject	Link or Document
United Nations Conference on Trade and Development (UNCTAD)	Ever-increasing usage but decreasing revenue is limiting financial capacity to fund future CAPEX by the industry	World Investment Report (wir2017) - Figure IV.6 of Chapter IV "Investment and Digital Technology" https://unctad.org/en/PublicationsLibrary/wir2017_en.pdf

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Source (Sections 3: Digital Technologies)	Statement or Subject	Link or Document
MGI	Digitalization of infrastructure sectors	Imaging construction's digital future, June 2016 https://www.mckinsey.com/industries/capital-projects-and-infrastructure/our-insights/imagining-constructions-digital-future Full Report - Bridging global infrastructure gap, June 2016 https://www.un.org/pga/71/wp-content/uploads/sites/40/2017/06/Bridging-Global-Infrastructure-Gaps-Full-report-June-2016.pdf
International Energy Agency (IEA)	Digitization of Power & Energy Sector	The Digitalization of Energy: A $500B Opportunity in EVs and Demand Response https://www.greentechmedia.com/articles/read/the-digitalization-of-energy-a-500b-opportunity-in-evs-and-demand-response Digitization and Energy: Technology Report, Nov 2017 https://www.iea.org/reports/digitalisation-and-energy
McKinsey	Transport-as-a-service: autonomous vehicles (AVs), connected cars, electric vehicles (EVs), and shared-mobility services	Disruption of electric and autonomous vehicles https://www.mckinsey.com/industries/automotive-and-assembly/our-insights/how-sharing-the-road-is-likely-to-transform-american-mobility#
International Water Association (IWA)	Digitization of Water Industry	Adapted from Figure 1 of Digital Water Report https://iwa-network.org/wp-content/uploads/2019/06/IWA_2019_Digital_Water_Report.pdf

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Source (Sections 3: Digital Technologies)	Statement or Subject	Link or Document
GWI	The potential global digitalization savings over the five years to 2020 would reach USD173 billion for drinking water treatment, distribution, and customer services, metering and billing.	The Future of Water: "Digital Water is already here" https://www.fisiait-the-future-of-water.com/en/facts-data/digital-water-is-already-here.html
Ovum Research	Digitization of Enterprises and Applications Innovations in enterprises, governments and utilities (e.g. electricity, transport, smart city, etc.)	ICT in Enterprises – global, region and country: industry trackers, enterprise profiles, case studies, etc. https://www.ovumkc.com