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ECONOMIC IMPACT OF GOOGLE'S APAC NETWORK INFRASTRUCTURE

David Abecassis, Dion Teo, Goh Wei Jian, Dr. Michael Kende, Prof. Neil Gandal

SEPTEMBER 2020

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Contents

Analysys Mason Pte Limited
39 Robinson Road
#17-03 Robinson Point
Singapore 068911
Tel: +65 6493 6038
singapore@analysysmason.com
www.analysysmason.com

Registered in Singapore No. 200506242R
Subsidiary of Analysys Mason Ltd
North West Wing, Bush House, Aldwych
London WC2B 4PJ, UK
Reg. No. 5177472

This report was commissioned by Google and prepared independently by Analysys Mason, a global consultancy specialising in telecoms, media and technology.

The analysis contained in this document is the sole responsibility of Analysys Mason and does not necessarily reflect the views of Google or other contributors to the research.

We would like to thank the many industry experts whom we interviewed for the purposes of writing this report.

Acronyms	Meaning
ACMA	Australian Communications and Media Authority
APAC	Asia Pacific
ASEAN	Association of South-East Asian Nations
BCG	Boston Consulting Group
CASP	Content, Application and Service Provider
CDN	Content Delivery Network
CLS	Cable Landing Station
EEZ	Exclusive Economic Zone
EMEA	Europe, the Middle East and Africa
FTTH	Fibre-to-the-Home
GCP	Google Cloud Platform
GDP	Gross Domestic Product
GGC	Google Global Cache
GSMA	Global System for Mobile communications Association
GVA	Gross Value Added
HD	High-definition
ICPC	International Cable Protection Committee
IMDA	Infocomm Media Development Authority (Singapore)
IPTX	IP Transit
IRU	Indefeasible Rights of Use
ISP	Internet Service Provider
IXP	Internet Exchange Point
MNC	Multinational Companies
NASA	North America and South America
NBN Co	National Broadband Network Company (Australia)
OADM	Optical Add/Drop Multiplexer
OECD	Organisation for Economic Co-operation and Development
OFCA	Office of the Communications Authority (Hong Kong)
OSNR	Optical Signal-to-Noise Ratio
PoP	Points of Presence
PwC	PricewaterhouseCoopers
QAM	Quadrature Amplitude Modulation
RFS	Ready For Service
SaaS	Software-as-a-Service
SDM	Space Division Multiplexing
SLTE	Submarine Line Terminating Equipment
SMB	Small and Medium Businesses
UFB	Ultra-Fast Broadband (New Zealand)
UNCLOS	United Nations Convention of the Law of the Sea

1 Executive summary

Network infrastructure is a critical link in the delivery of the internet to consumers and businesses around the world, supporting digital transformation

The internet is now essential to how consumers, businesses and governments around the world live and work. As more and more people and businesses access the internet, use more services and consume more content, investments are required to improve network infrastructure. This infrastructure provides the critical link from content and services in content, application and service providers' (CASP) data centres, to customers and end users on internet service providers' (ISP) networks.

Network infrastructure underpins the reliable and secure cloud services that are essential for digital transformation. Enterprises outside the digital space are moving their IT to the cloud, saving costs and improving operational efficiency in the process. Enterprises in the digital space are now increasingly 'cloud-native', gaining access to a highly scalable infrastructure with networking capabilities that enable global reach with optimal quality. These cloud customers have access to capabilities that most of them would otherwise not be able to build by themselves.

Google has invested over USD2 billion in network infrastructure in APAC since 2010, contributing to improved connectivity outcomes, which support 1.1 million additional jobs and USD430 billion in additional GDP for the region

In response to increasing demand for online content and services, Google has made significant investments in network infrastructure globally, and in particular in Asia Pacific (APAC). It is an investor in six already-deployed submarine cable systems, and in parallel it purchases two-third of its international bandwidth in the region from APAC carriers. Within individual countries, Google has deployed Points of Presence in 15 cities across 8 economies and Google Global Cache (GGC) nodes across 278 cities, and leases capacity on domestic fibre networks between these points of presence, data centers and submarine cable landing stations (CLS).

These investments create positive impacts on the connectivity ecosystem across APAC: increased supply of international bandwidth helps reduce the price of that bandwidth for CASPs and ISPs alike, enabling them to offer end users ever greater speeds and lower prices. New routes, on new submarine cables, improve the resilience and reliability of networks, and in some cases help reduce latency and improve performance. Better networks, in turn, result in a better experience for users of important applications such as video conferencing, cloud services and payments.

These connectivity improvements have a remarkable economic impact, both directly in the telecoms sector and as a 'spill-over' in other sectors of the economy. Simply put, they help create more jobs, and increase GDP and economic growth. The econometric models we developed for this study suggest that Google's network investment led to 1.1 million additional jobs as of 2019 and an extra USD430 billion in aggregate GDP for the region from 2010 to 2019 (in real 2019 USD). [1]

In addition to the impact of connectivity improvements on internet use, promoting further network infrastructure investment is important to support future cloud demand. Enterprise demand for cloud services is growing rapidly and will support the next phase of digital transformation for companies throughout APAC. This is a fundamental building block to the future economic success of every country, in the region and globally, through the stimulation of new business models and innovation.

Further investment in submarine capacity in APAC promises large additional benefits through connectivity and cloud adoption, contingent on supportive regulatory and investment environments

In anticipation of future growth in data traffic, Google will continue to make investments in new submarine cables, such as the PLCN, Indigo, and JGA-S systems, and further densify the edge network infrastructure across APAC cities. Such continued networking investments from Google are expected to support 1.8 million additional jobs and drive additional economic benefits of approximately USD415 billion in GDP term (real 2019 USD) over the next five years (2020-2024).

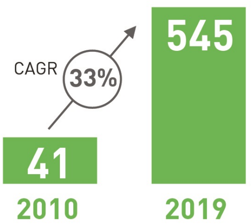
While there has been increasing investment in this area, more can be done to make the environment more conducive to further investment. Economies with strong submarine cable supply typically have conducive regulatory and investment policies, supported by transparent and well-enforced laws: they provide best practices on how other economies, in the region and elsewhere in the world, can attract more investment in internet infrastructure.

1 Economic impact estimates include the effect of Google's edge network and submarine cable investments for APAC, excluding India and China

Economic impact of Google’s network infrastructure in APAC

DATA TRAFFIC IN APAC IS GROWING STRONGLY, DRIVEN IN PART BY THE POPULARITY OF GOOGLE'S SERVICES

APAC data traffic growth 2010–2019 (EB)



12% Google services' share of APAC internet traffic

GOOGLE INVESTED OVER USD2 BILLION IN NETWORK INFRASTRUCTURE ACROSS APAC, WHICH SUPPORTS THE GROWTH OF THE INTERNET

>$2bn Google's APAC network infrastructure investment

- **6** submarine cables invested into and deployed
- **15** cities across **8** countries with Google PoPs
- **~2/3** of bandwidth purchased from telcos
- **278** cities where GGC caches are deployed

GOOGLE'S INFRASTRUCTURE INVESTMENT HELPS APAC ECONOMIES REALISE STRONG ECONOMIC BENEFITS FROM INCREASED INTERNET USAGE

Last 10 years (2010-2019)	Next 5 years (2020-2024)
1.1m Jobs	**1.8m** Jobs
$430bn in GDP	**$415bn** in GDP

THESE INVESTMENTS IMPROVE THE CONNECTIVITY ECOSYSTEM WHICH BENEFITS CONSUMERS AND BUSINESSES

2024

4.6 million internet users

246 Exabytes internet traffic

367Tbit/s in additional capacity

4.1x faster download speeds in countries with strong submarine cable supply vs. rest of APAC

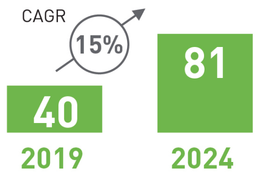
12-49% reduction in end-user latency

74% lower IP transit prices in countries with strong submarine cable supply vs. rest of APAC

3 new use cases supported
- Video Conference
- Commerce and Transactions
- Cloud Services

APAC CLOUD SPEND IS EXPECTED TO GROW STRONGLY DRIVING ADDITIONAL ECONOMIC BENEFITS

APAC cloud spend (USD bn)
2019–2024

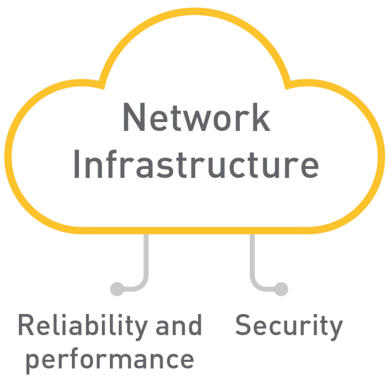


Benefits of cloud adoption

- supports digital transformation agenda

- generates additional jobs and GDP

NETWORK INFRASTRUCTURE IS IMPORTANT FOR CLOUD – IT IMPROVES:



"[GCP] provides low end-to-end latency, fully managed infrastructure with 99.9% system availability, along with auto-scaling of storage and compute"
traveloka
Country: Indonesia

"[GCP] processes data in the scale of hundreds of gigabytes to speed up analytics… Delivers network performance 10 times faster between data centres."
ninjavan
Country: Singapore

"[We] migrated [our] infrastructure to GCP for its reliable subsea cable network and load balancing."
17 Media
Country: Taiwan

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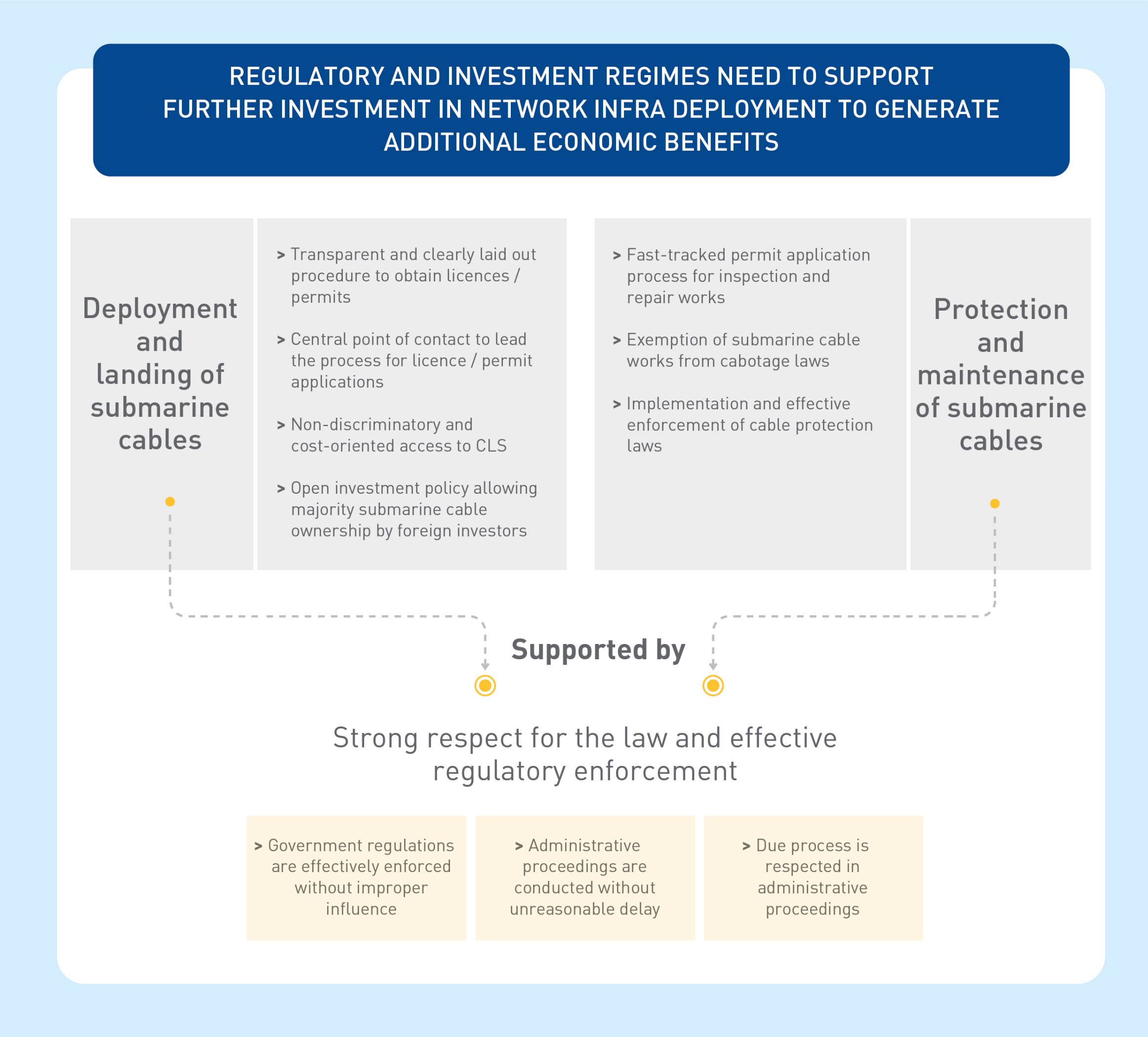
REGULATORY AND INVESTMENT REGIMES NEED TO SUPPORT FURTHER INVESTMENT IN NETWORK INFRA DEPLOYMENT TO GENERATE ADDITIONAL ECONOMIC BENEFITS
Deployment and landing of submarine cables
> Transparent and clearly laid out procedure to obtain licences / permits
> Central point of contact to lead the process for licence / permit applications
> Non-discriminatory and cost-oriented access to CLS
> Open investment policy allowing majority submarine cable ownership by foreign investors
> Fast-tracked permit application process for inspection and repair works
> Exemption of submarine cable works from cabotage laws
> Implementation and effective enforcement of cable protection laws
Protection and maintenance of submarine cables
Supported by
Strong respect for the law and effective regulatory enforcement
> Government regulations are effectively enforced without improper influence
> Administrative proceedings are conducted without unreasonable delay
> Due process is respected in administrative proceedings

2 Introduction

This report discusses the impact of Google's network infrastructure investments in APAC, excluding China and India, and was commissioned by Google. The analysis contained in this report, including all future projections, is the sole responsibility of Analysys Mason and does not necessarily constitute an endorsement on the part of Google. The research that underpins this report was conducted between November 2019 and March 2020. We acknowledge the dynamic situation surrounding the world economy and have used the most up to date information and database available as of 30 March 2020. We are also mindful of global events that are currently unfolding which creates a dynamic situation around submarine cable deployment and landing in APAC.

> "Handling traffic on Google's infrastructure and bringing it close to people helps limit the burden on operators—whose networks have different levels of reserve capacity—to allow them to focus on delivering that last mile"
>
> **Urs Hölzle, Senior Vice President,**
> Technical Infrastructure, Google

In this introductory section, we explain how a large and complex interconnected network infrastructure underpins the internet as we know it. In APAC,[2] where the majority of people live in coastal and island nations, the internet is heavily reliant on submarine cables. CASPs, who provide content, services and applications on the internet, are increasingly relying on their own network infrastructure to collect and deliver data to thousands of ISPs, as close as possible to their customers (consumers and businesses). Google has been very active in this space, in APAC and globally,[3] investing in network infrastructure that delivers its services close to end users. This frees up investment capacity within telecom operators and ISPs to improve other parts of their networks on which users rely to access the internet (see quote).

In the remainder of this report, we introduce the network infrastructure investments made by Google across APAC and explore the economic impact of these investments (Section 3). We then compare regulatory and investment regimes across APAC and highlight some best practices in enabling and attracting network investments, with a focus on submarine cable infrastructure (Section 4). Finally, we provide a perspective on the importance of network infrastructure for cloud services, which are a critical part of the region's digitalisation plans (Section 5). The annex provide further detail on the economic impact assessment used to estimate the job and GDP impact of Google's network infrastructure investments (Annex A).

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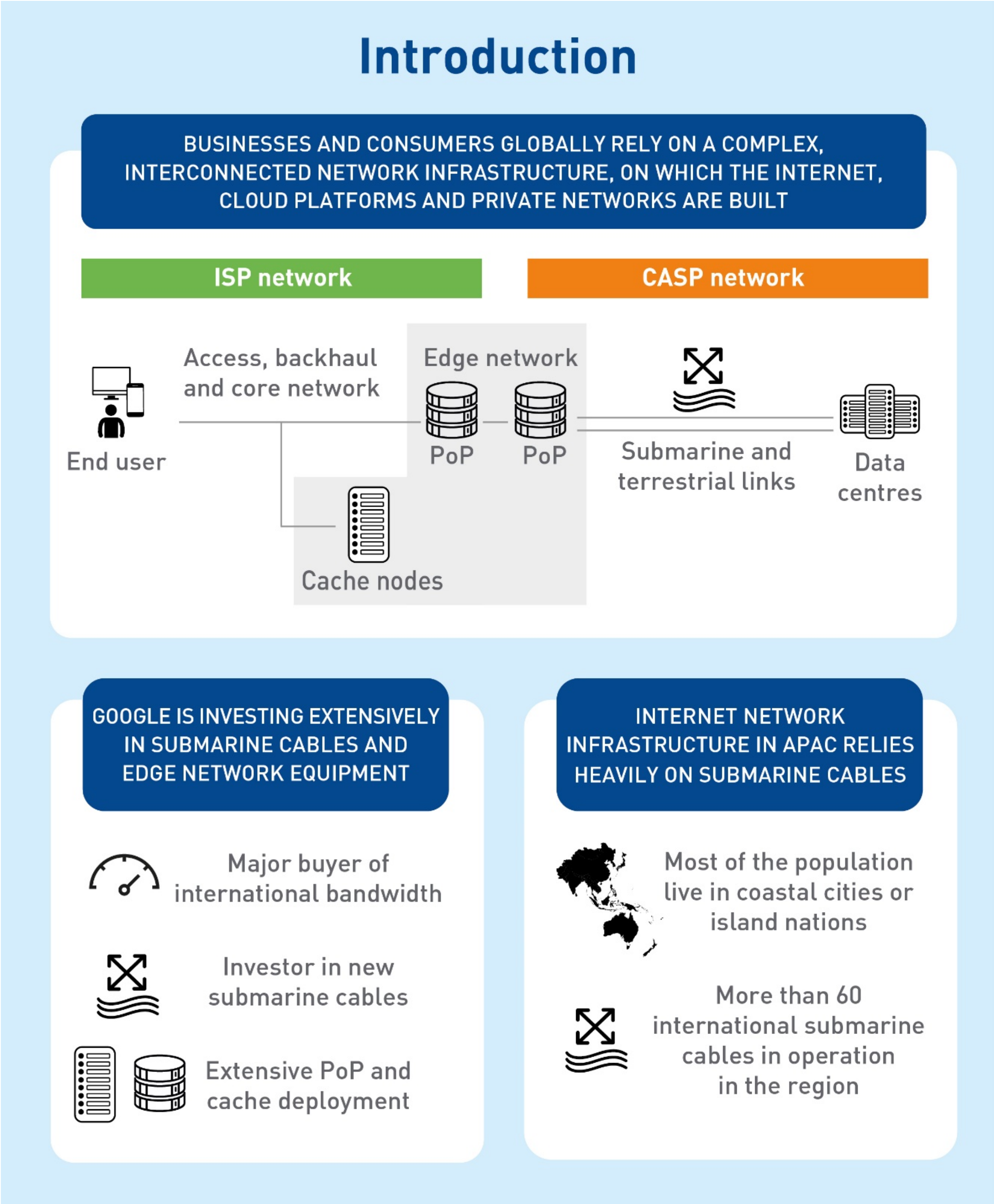
2 This includes ASEAN, East Asia, South Asia and Advanced Asia aligned with IMF definitions; see https://www.imf.org/~/media/Files/Publications/REO/APD/2019/Oct/English/text.ashx

3 See for example Analysys Mason, Infrastructure investment by online service providers (2018), available at https://www.analysysmason.com/consulting-redirect/reports/Online-service-providers-Internet-infrastructure-Dec2018/; Copenhagen Economics, Google's Hyperscale Data Centres And Infrastructure Ecosystem In Europe (2019), available at https://www.copenhageneconomics.com/dyn/resources/Publication/publicationPDF/0/500/1569061077/copenhagen-economics-google-european-dcs-infrastructures-impact-study_september2019.pdf


Introduction
BUSINESSES AND CONSUMERS GLOBALLY RELY ON A COMPLEX, INTERCONNECTED NETWORK INFRASTRUCTURE, ON WHICH THE INTERNET, CLOUD PLATFORMS AND PRIVATE NETWORKS ARE BUILT
ISP network
CASP network
End user
Access, backhaul and core network
Edge network
PoP
PoP
Cache nodes
Submarine and terrestrial links
Data centres
GOOGLE IS INVESTING EXTENSIVELY IN SUBMARINE CABLES AND EDGE NETWORK EQUIPMENT
Major buyer of international bandwidth
Investor in new submarine cables
Extensive PoP and cache deployment
INTERNET NETWORK INFRASTRUCTURE IN APAC RELIES HEAVILY ON SUBMARINE CABLES
Most of the population live in coastal cities or island nations
More than 60 international submarine cables in operation in the region

2.1 Businesses and consumers globally rely on a complex, interconnected network infrastructure, on which the internet, cloud platforms and private networks are built

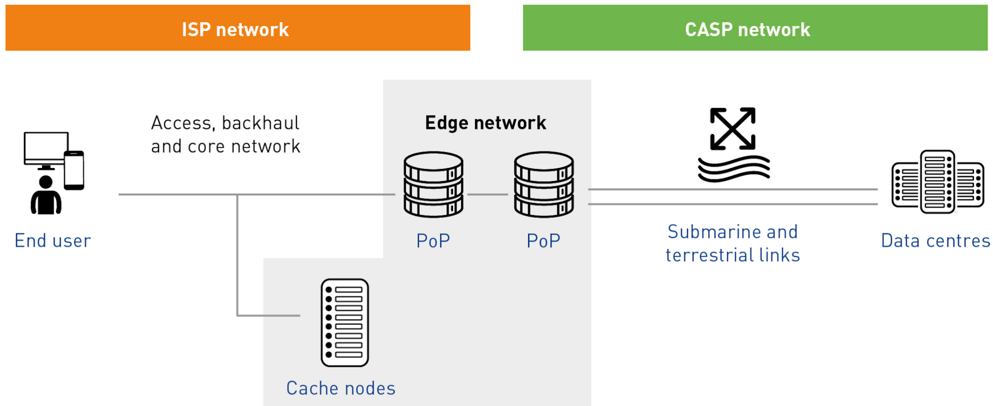
Access to the internet has become increasingly important in enabling consumers and developing businesses globally to communicate, learn, work, socialise, and participate fully in everyday life. Over the last decade, the internet has continued to evolve rapidly, spurred by improvements in access networks (4G, fibre optics) and innovative services and applications: high-definition video streaming services and digital services including commerce and transportation. The cloud services that make much of these services and applications possible[4] have become more mature, complementing already-established social media, search engines, online marketplaces and other platforms.[5]

In order for these services to be delivered across the internet, many stakeholders are investing in a complex chain of infrastructure assets, deployed on a massive scale globally and across the value chain, as shown in Figure 2.1.

4 Services such as Netflix and GoJek make extensive use of commercial cloud computing platforms; see https://cloud.google.com/customers/go-jek

5 Deloitte – "Value of connectivity: Economic and social benefits of expanding internet access", Feb 2014; see https://www2.deloitte.com/content/dam/Deloitte/uk/Documents/technology-media-telecommunications/deloitte-uk-tmt-value-of-connectivity-tmt.pdf

Figure 2.1: Infrastructure assets that enable content, services and applications on the internet in 2020 [Source: Analysys Mason, 2020]



Value chain element	End user	Access networks	Edge network	Submarine and terrestrial links	Data centres
Description	**End users** access the internet using applications on devices and initiate data requests across the connectivity value chain	**Access**, backhaul and core networks provide internet connectivity to end users via mobile or fixed-line networks	**Edge network** elements serve to bring content closer to end users by serving as efficient points of inter-connection (points of presence, or PoPs) and storage of static content (cache nodes)	**Submarine and terrestrial** fibre cables facilitate the transmission of data between data centres and PoPs, which are typically across different geographies	**Data centres** are facilities that store content and process data at large scale

Online content and applications are primarily hosted in a small number of data centres around the world. When end users want to access content or use services online, the relevant information has to travel from one or more data centres, all the way to the end users' network and device, often through multiple interconnected networks. Data goes from data centres at the 'core' of CASPs' networks towards end users, through transport links including submarine and terrestrial fibre cables that connect multiple locations across the globe.

Data from CASPs is delivered through these international links to PoPs across the globe. These PoPs are located in a variety of facilities where multiple CASPs and ISPs can exchange traffic (or 'peer') via public internet exchanges or direct connections. The ISP takes the traffic and delivers it through its own network, including its access network, to the end user who initiated the request. In many cases, the content is already located in the ISP's network, or at the very edge of the CASP's network, in caching infrastructure. Caches store popular static content in anticipation of end-user demand and reduce the need to carry traffic from core data centres.[6] Caching reduces costs for both ISPs and

6 Caching is typically suitable for content which is static in nature, though technological advances are increasingly enabling the caching of dynamic content; see https://www.cloudflare.com/learning/cdn/caching-static-and-dynamic-content/

CASPs, significantly increasing ISPs' capacity to serve large volumes of traffic to end users efficiently, and reduces latency.

2.2 Internet network infrastructure in APAC relies heavily on submarine cables

Most of the population of the APAC region lives in coastal or island nations, with cities positioned relatively close to the sea. As a result, international networks are primarily (but not exclusively) reliant on submarine cables rather than terrestrial fibre.

There are currently 61 international submarine cable systems in operation in the APAC region, totalling 550 000km in length and more than 1500Tbit/s in design capacity. These submarine cables provide international connectivity through three main corridors:

- Intra-APAC (such as Asia Pacific Gateway and Southeast Asia Japan Cable)
- APAC–NASA (such as Asia-America Gateway, UNITY and FASTER)
- APAC–EMEA (such as Asia Africa Europe-1 and SEA-ME-WE-5).

The level of international connectedness of countries and territories in APAC differs by the extent (number of cables) and quality (diversity of routes) of supply of submarine cables, as shown in Figure 2.2 below.

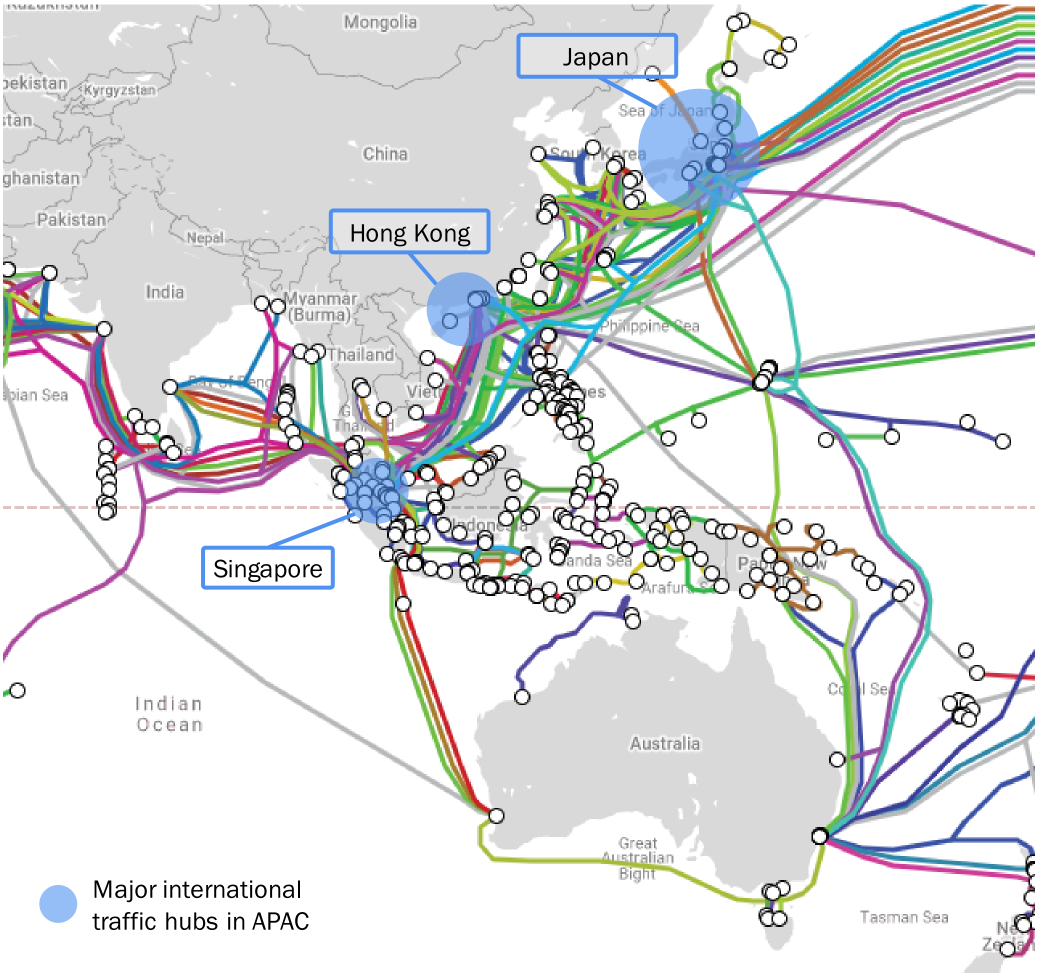
Figure 2.2: Classification of APAC economies by level of international connectivity [Source: Analysys Mason, TeleGeography, 2020]

Level of international connectivity	APAC countries / territories (number of cables)	Classification description
Strong	Singapore (23) Japan (21) Hong Kong (10)	▪ Typically connected to ten or more international submarine cables and serve as regional connectivity hubs linking to a diverse set of destinations ▪ Diverse set of suppliers available in these economies
Average	Malaysia (19) Indonesia (18) Australia (12) Taiwan (10) South Korea (9) Philippines (8) Thailand (8)	▪ Typically less connected than hubs in the region ▪ Malaysia is connected to 19 international cables but most of them are connected to neighbouring countries (e.g. Singapore, Indonesia) and close to half are provided by the incumbent, Telekom Malaysia ▪ Indonesia is connected to 18 international cables, but is heavily reliant on the route to Singapore ▪ Australia is connected to 12 international cables, but supply is predominantly provided by the incumbent, Telstra, which has stakes in 7 cables ▪ Taiwan's cables mainly serve intra-APAC routes and lacks diversity to destinations outside Asia
Weak	Pakistan (6) Vietnam (5) Sri Lanka (4) Brunei (4) Myanmar (3)	▪ Typically connected to less than five submarine cables ▪ Access to international connectivity is typically through participation in extensive networks such as AAE-1 and SEA-ME-WE-5

Level of international connectivity	APAC countries / territories (number of cables)	Classification description
	New Zealand (3) Bangladesh (2) Cambodia (2)	

Strongly connected nations include key regional traffic hubs, such as Japan (trans-Pacific and intra-Asia), Hong Kong (East Asia and South-East Asia) and Singapore (Europe, East Asia, South-East Asia), which are highlighted in Figure 2.3.

Figure 2.3: Submarine cable routes in APAC [Source: Analysys Mason, TeleGeography, 2020]



Other APAC economies typically connect to these hubs as a gateway for their broader international connectivity; for example, Indonesia is very well connected to Singapore, through which it can connect globally. This could represent a concentration risk as cable cuts do occur both from natural disasters (i.e. earthquakes) as well as human activities (e.g. fishing and maritime activities). It is therefore beneficial for the region to improve route diversity and redundancy to ensure resilience of the underlying infrastructure supporting the internet.

Case study: Vietnam's vulnerability to submarine cable disruptions

Vietnam is connected to five international submarine cables (see Figure 2.4). It has historically experienced frequent submarine cable breakage incidents due to weather, seismic activity and marine activities.[7] Of the five cables, the AAG cable has been prone to cuts, causing intermittent issues since its debut in 2009, yet it is heavily relied upon and carries more than 60% of Vietnam's international internet traffic.[8] In December 2019, Vietnam suffered severe disruptions to its internet connectivity when three major cables encountered concurrent disruptions – up to 30% of Vietnam's international internet transmission capacity was lost[9] during the period when cable repair processes occurred.

Vietnam's resilience to these disruptions could be improved with a more diverse set of international submarine cable routes. In particular, Vietnam is expected to benefit from the upcoming high-capacity SJC2 cable both in terms of its connectivity via a third alternative landing point and reduced reliance on existing cables.

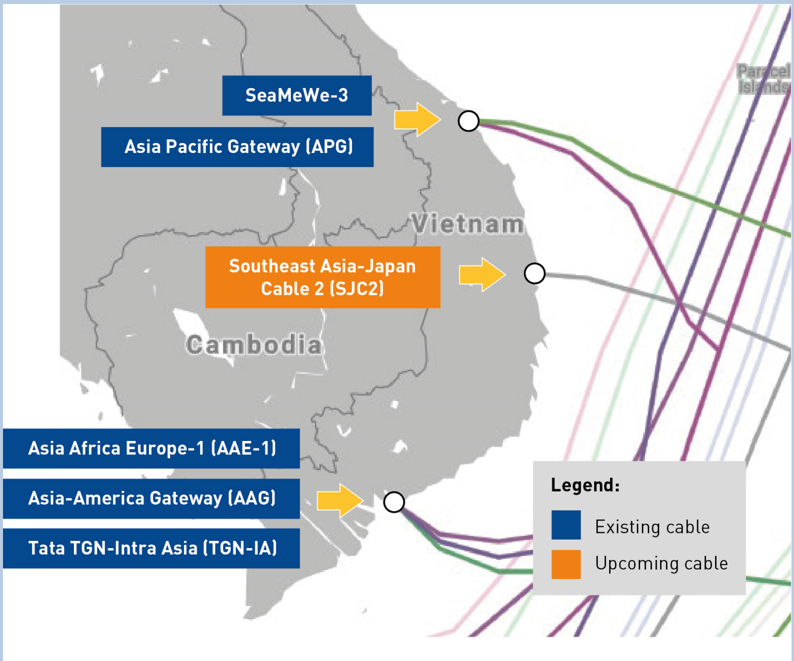


Figure 2.4: Overview of submarine cables connecting to Vietnam [Source: TeleGeography, Analysys Mason, 2020]

Traditionally, investments in submarine cable networks were either driven by telecoms operators or private owners. Telecoms operators participate in the construction of globe-spanning infrastructure

7 Saigoneer – "Sharks, Anchors & Red Tape: Why It Takes Forever to Fix Vietnam's Broken internet Cables", Nov 2017; see https://saigoneer.com/saigon-technology/11885-sharks,-anchors-red-tape-why-it-takes-forever-to-fix-vietnam-s-broken-internet-cables

8 VNEspress – "Vietnam to enjoy faster internet as undersea cable repairs conclude", Jan 2020; see https://subtelforum.com/vietnam-cables-to-be-repaired-by-next-month/

9 Vietnam News – "internet connections to slow due to problems with undersea cables", Dec 2019; see https://vietnamnews.vn/society/570288/internet-connections-to-slow-due-to-problems-with-undersea-cables.html

for their own traffic and typically form consortia to diversify investment risk – key consortia members in APAC include regional operators such as Telstra, Singtel, China Unicom and China Telecom. On the other hand, private owners (such as Hawaiki and SEAX) typically deploy systems with lower capacity and fewer branches, to address intra-regional needs.

In recent years, the fast growth in demand for internet content and applications has led to CASPs taking on a growing role in the supply of submarine cables, rather than simply being on the demand side for submarine capacity. This is driven by CASPs' scale, as together they are now the biggest users of capacity: in 2018, CASPs made up over half of used international bandwidth demand in APAC, which they satisfied through a mix of owned and leased capacity.[10] In addition, CASPs have increasingly complex infrastructure requirements, as they seek to manage the quality of the services they offer, in particular availability, resilience and latency. In response to these trends, and whilst they continue to purchase bandwidth on a large scale, they are increasingly investing directly in new cables. As shown in Figure 2.5, between 2010–2019, large CASPs co-invested in six new submarine cables, representing 34% of the potential incremental capacity in APAC. Google has invested in four of these cables (with 2 more cables, PLCN and JGA-S, operational in 2020).

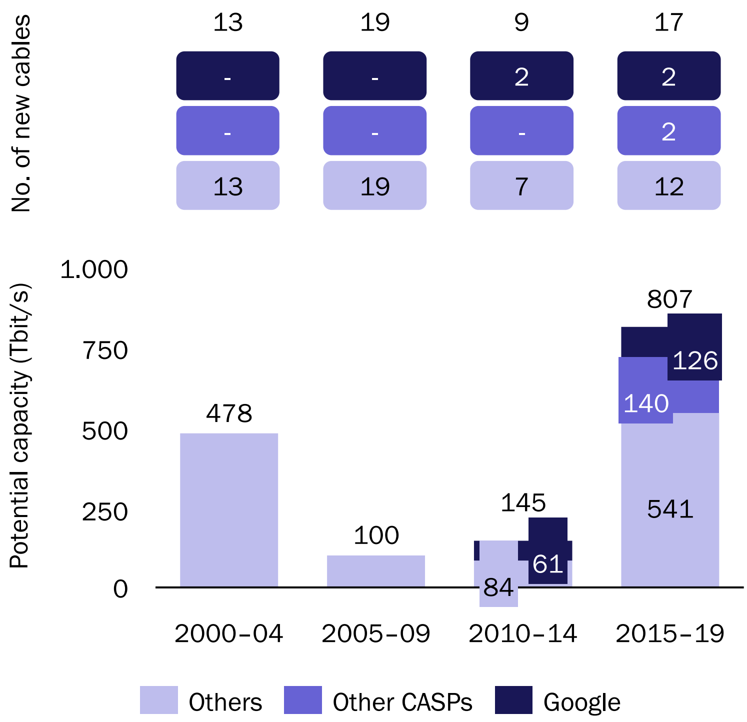


Figure 2.5: Number of new international submarine cables launched between 2010–2019 and the corresponding potential capacity, by type of cable ownership [Source: Analysys Mason, 2020]

10 TeleGeography Global Bandwidth Research Service; APAC refers to Asia and Oceania regions

2.3 Google is investing extensively in submarine cables and edge network equipment

Google services account for a significant proportion of APAC internet traffic, as shown in Figure 2.6, and demand for its services continues to grow. Historically, traffic has been driven by video, in particular on YouTube. Google's investment decisions have aimed to ensure that the quality and availability of these services remained consistently high, whilst mitigating the resulting bandwidth requirements and helping ISPs manage their bandwidth costs. More recently, demand from cloud customers has picked up pace and has started to shape Google's network infrastructure investments and planning. A key goal of Google's investments is to ensure well-provisioned, high-bandwidth, low-latency, highly secure cloud connections between cloud regions.[11]

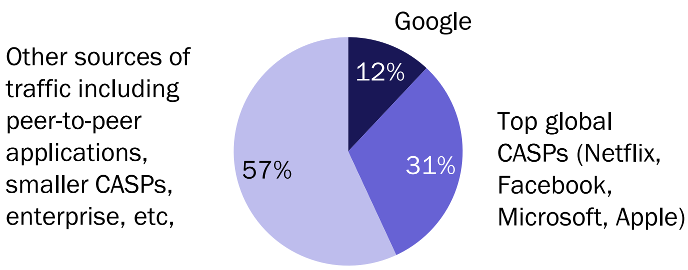


Figure 2.6: internet traffic (total uplink and downlink) in APAC by source[12] [Source: Sandvine,[13] 2019]

Google is a major buyer of international bandwidth and is investing directly in new cables

For many years, internet content delivery over long distances has traditionally been served through the purchase of IRUs[14] and shorter-term leases from global carriers who own and sell capacity on both submarine and terrestrial cables. Google remains a major buyer of international bandwidth,[15] but it has also been investing directly in the supply of submarine cables, mostly as a member of consortium cables and, in a few instances, has deployed private cables (e.g. Curie, Dunant, Equiano and Junior). As of 2019, Google had investments in ten 'live' submarine cables around the world. A further four cables have been announced but have not yet been launched, as is shown in Figure 2.7 below.

These submarine cable investments help increase the amount of capacity available to Google, but also bring other benefits: they lower the unit cost of carrying traffic, increase the diversity of routes available between locations globally, and improve the availability, reliability and quality of Google's

11 See: https://www.blog.google/products/google-cloud/delivering-increased-connectivity-with-our-first-private-trans-atlantic-subsea-cable/

12 Google refers to services including YouTube, Google Cloud, Google Play, Google Search, Google Docs, Google Drive, DoubleClick, Gmail, and Crashlytics; internet traffic data is based on the subscriber traffic downloaded from and uploaded to the internet and extracted from 160 fixed, mobile and WIFI operators worldwide

13 Sandvine – "The Global internet Phenomena Report", Sep 2019; see https://www.sandvine.com/global-internet-phenomena-report-2019

14 Indefeasible rights of use, see: https://en.wikipedia.org/wiki/Indefeasible_rights_of_use

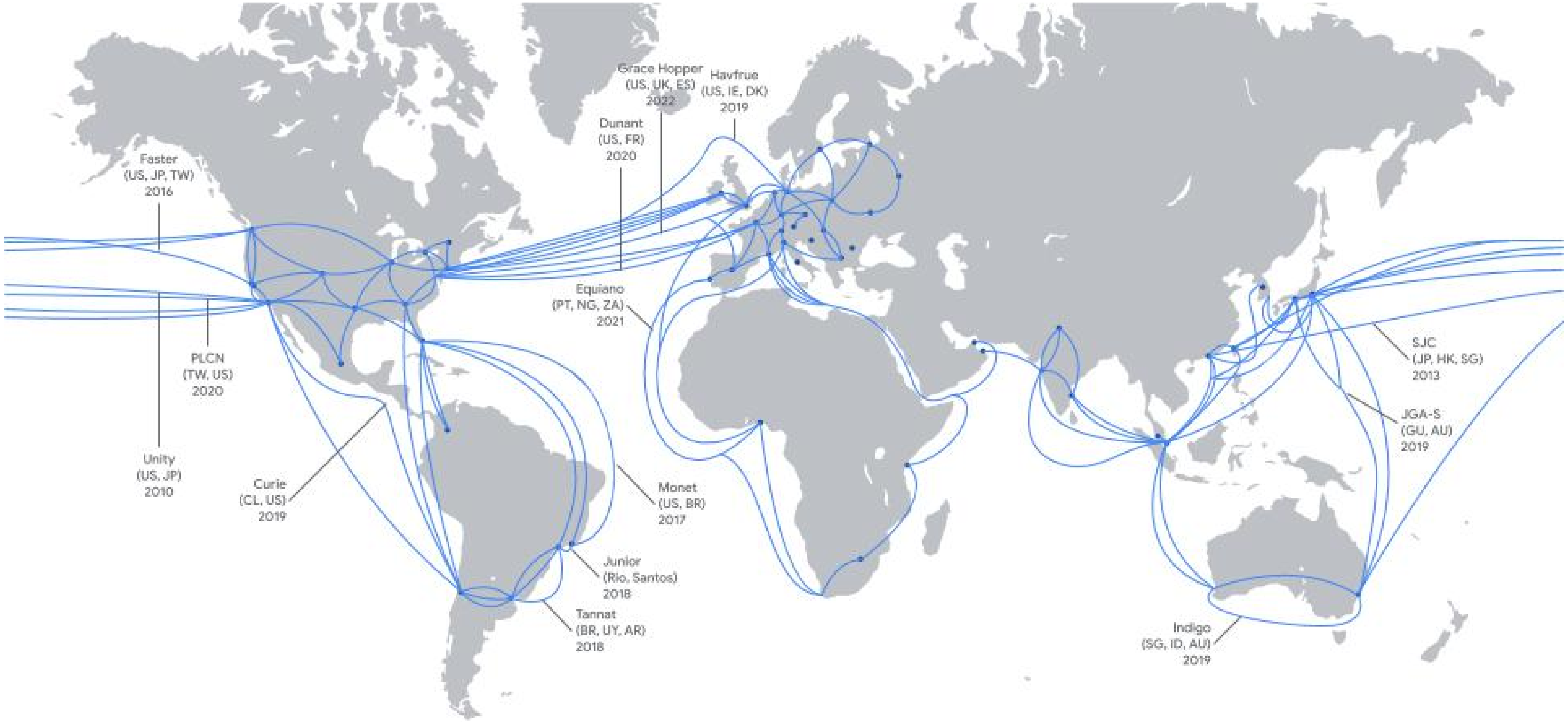
15 See TeleGeography Global Bandwidth Research Service; APAC refers to Asia and Oceania regions, cited above

services. They also provide guarantee on future supply of international capacity, especially in economies where this supply is constrained.

Taking on ownership interests in submarine cables means that Google can potentially swap capacity with other bandwidth suppliers and users, including APAC regional telcos, on other submarine cable routes. This offers better utility of available capacity for both parties: Google has access to more bandwidth on new routes, while the swap partners also benefit from securing capacity on more diverse routes which improves the resilience of their respective networks.

Furthermore, Google's direct investments complement its continued purchase of international capacity from global and regional carriers. Google's demand for bandwidth on these carriers' cables helps support further investment in new cables beyond Google's direct investments.

Figure 2.7: Google's global submarine cable investments with Google landing points and RFS year [Source: Google, 2020]



Google's major involvement in new submarine cables helps to accelerate the launch of cables, stimulates technological advancements and introduces new deployment best practices

Google's partners in submarine cable consortia see its involvement as a source of financial stability (see quote). This helps reduce the financial risks inherent to any new cables and improve fund-raising (which are notable obstacles in the consortium model).[16]

> "really happy to have Google in the partnership as it is difficult for the [local] private sector to invest by themselves."
>
> "In the case of [cable], there were disagreements between telcos and they couldn't get it launched… Google came in to provide leadership and project management as a neutral party."
>
> **Submarine cable consortium partners**

As a major partner in new cable builds, Google can support the cable deployment process from the design stage through to deployment and ongoing operations and maintenance. This allows Google, in collaboration with its partners, to be truly innovative, enabling the deployment of cutting-edge submarine cable technology. These innovations bring greater capacity and lower unit cost compared to what traditional cables can deliver. An example is Google's Dunant cable which is expected to deliver a record-breaking capacity of 250Tbit/s across the Atlantic as the first ever in-service undersea cable featuring a 12 fibre-pair space division multiplexing (SDM) design,[17] compared to 6 or 8 fibre-pairs in traditional submarine cables.[18] Google also introduced operational best practices which enabled greater flexibility. More examples of technology innovations and operational best practices, specifically those involving Google's APAC cables, are highlighted in Section 3.1 of this report.

Google also invests in edge network infrastructure to deliver traffic to ISPs and end users

Google carries its traffic through international links, including its own submarine cables, to over 43 countries or territories[19] across the world, where it has deployed edge PoPs. These PoPs facilitate the content delivery process by connecting Google's data centres with the broader global internet ecosystem, enabling peering at locations closer to the ISPs. Google has set up PoPs at over 100 interconnection facilities around the world, which are opened for interconnection to networks under Google's open peering policy.[20] These PoPs also require connectivity and Google either purchases

16 SubOptic – "What Future For the Consortium Model?", 2016; see https://suboptic.org/wp-content/uploads/fromkevin/program/TU1B.3%20What%20Future%20For%20the%20Consortium%20Model.pdf

17 Space Division Multiplexing (SDM) is a multiplexing technique which multiplexes spectrum resources in both frequency and core dimensions to improve bandwidth efficiency and transmission capacity; see: https://ui.adsabs.harvard.edu/abs/2018OptFT..42...63Z/abstract

18 See: https://cloud.google.com/blog/products/infrastructure/a-quick-hop-across-the-pond-supercharging-the-dunant-subsea-cable-with-sdm-technology

19 PeeringDB, see https://www.peeringdb.com/net/433

20 Google, see https://peering.google.com/#/options/peering

domestic connectivity from domestic telecom operators in the form of leased lines and dark fibre, or deploys its own terrestrial infrastructure to connect these PoPs to other Google facilities, including to submarine CLSs.

In addition, Google has also invested in cache nodes as part of its GGC programme, which brings content closer to end users and reduces interconnection requirements.[21] Google has deployed caches in approximately 4000 ISP networks across the world, of which 25% are in APAC. In doing so, it has reduced latency and enabled vastly greater amounts of content to be served to end users, at minimal costs to ISPs.

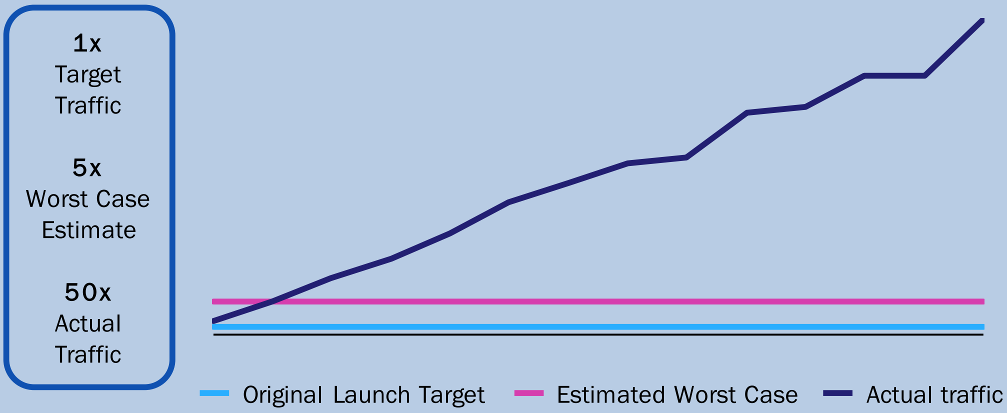
These investments in network infrastructure create large connectivity and economic benefits, as discussed in the next section.

21 Google, see https://peering.google.com/#/infrastructure

Case study: Google's edge network infrastructure investments pay off when handling surge in Pokémon GO traffic

Pokémon GO is an augmented reality mobile application that was launched on iOS and Android devices in July 2016 by Niantic. By September 2016, Pokémon GO was available in over 90 countries and had been downloaded more than 500 million times. The teams involved targeted 1x player traffic and had a worst-case estimate of roughly 5x the original traffic target. However, the launch was a huge success and was more popular than initially expected - player traffic surged well past Niantic's expectations within 15 minutes of launching in Australia and New Zealand.

Figure 2.8: Illustrative example of Cloud Datastore transactions per second during launch of Pokémon Go [Source: Google,[22] Analysys Mason, 2020]



Although the traffic load generated was much higher than expected, Google's cloud network infrastructure allowed for scalability and was able to handle the unexpected surge. Google's global network of fibre infrastructure (both submarine and terrestrial) handled much of the game traffic, and minimised the latency for users worldwide. Google's extensive cache infrastructure (GGC) also enabled the Google Play Store to cater to the huge surge in application downloads, mitigating the potential cost implications for ISPs and mobile network operators.

> "More than a dozen teams across Cloud Platform and other core Google products rallied to support us as we pushed live improvements to the game for our players. In parallel, Google's infrastructure teams worked to tune systems, ensuring sufficient capacity for us to keep up with the game's skyrocketing popularity."
>
> **Phil Keslin**
> Niantic (CTO)

22 Google Cloud Blog, see: https://cloud.google.com/blog/products/gcp/bringing-pokemon-go-to-life-on-google-cloud

3 The economic impact of Google's network infrastructure investments in APAC

Google's investments in network infrastructure support the delivery of its services to end users, by improving service performance and reliability. More broadly, Google's investments improve the overall performance and cost-effectiveness of internet infrastructure. This translates into better connectivity outcomes, including more internet users and usage of new internet applications by both consumers and businesses.

Across APAC, Google has invested over USD2 billion in its network since 2010. This investment has actively supported a large increase in internet usage across the region and enables further economic growth. We estimate that this investment supported 1.1 million jobs by the end of 2019 and generated USD430 billion in additional GDP (in real terms) over the last ten years, of which USD65 billion was in 2019 alone.[23]

Google is continuing to invest heavily in network infrastructure in APAC, in particular through a range of new submarine cables currently in deployment or announced. Between 2020 and 2024, we estimate Google's network investments will support up to a further 1.8 million jobs throughout the region and generate up to USD415 billion in additional GDP (USD94 billion in 2024 alone).

This section explains how Google's investments positively impact the connectivity ecosystem in APAC, which translates into economic benefits in the form of jobs, GDP and economic growth. The following subsections:

- introduce Google's investments across the network infrastructure value chain in APAC (Section 3.1)
- discuss how these investments benefit consumers and business who use Google's services (Section 3.2)
- explain how these benefits extend to other stakeholders and to the broader connectivity ecosystem in APAC (Section 3.3)
- quantify the economic impact of Google's investments, focusing on submarine cables and edge network infrastructure (Section 3.4).

23 GDP figures are in constant USD using 2019 as the base year and using a fixed exchange rate to USD in 2019; GDP statistics in USD are sourced from Euromonitor

Economic impact of Google's network infrastructure in APAC

GOOGLE INVESTED OVER USD2 BILLION IN NETWORK INFRASTRUCTURE ACROSS APAC, WHICH SUPPORTS THE GROWTH OF THE INTERNET

>$2bn

Google's APAC network infrastructure investment

- **6** submarine cables invested into and deployed
- **15** cities across **8** countries with Google PoPs
- **~2/3** of bandwidth purchased from telcos
- **278** cities where GGC caches are deployed

Google services benefit from the acceleration of supply on international capacity and the increasing diversity of routes

THESE INVESTMENTS IMPROVE THE CONNECTIVITY ECOSYSTEM WHICH BENEFITS CONSUMERS AND BUSINESSES

2024

4.6 million internet users

246 Exabytes internet traffic

367Tbit/s in additional capacity

4.1x faster download speeds in countries with strong submarine cable supply vs. rest of APAC

12-49% reduction in end-user latency

74% lower IP transit prices in countries with strong submarine cable supply vs. rest of APAC

3 new use cases supported

- Video Conference
- Commerce and Transactions
- Cloud Services

GOOGLE'S INFRASTRUCTURE INVESTMENT HELPS APAC ECONOMIES REALISE STRONG ECONOMIC BENEFITS FROM INCREASED INTERNET USAGE

Last **10** years **(2010-2019)**

1.1m Jobs

$430bn in GDP

Next **5** years **(2020-2024)**

1.8m Jobs

$415bn in GDP

3.1 Since 2010, Google has spent over USD2 billion in deploying and operating its network infrastructure in APAC

From 2010 to 2019, Google invested in excess of USD2 billion in its network in APAC. This includes payments to telecoms operators for international bandwidth on routes that originate or terminate in an APAC country,[24] and increasing capital expenditures directed at the construction, deployment and operation of submarine cables landing in APAC as part of consortiums. These investments also include the costs of deploying and operating PoPs in peering facilities, supplying caching equipment to ISPs that participate in the GGC programme, and provisioning and operating terrestrial capacity where relevant (e.g. in metropolitan areas where Google is present in multiple locations).

Google has made direct investments in four submarine cable systems landing in APAC, and delivered numerous innovations in the submarine cable landscape

As of 2019, Google has invested directly in four operational submarine cables in the APAC region, covering intra-APAC and APAC–NASA routes, and capable of delivering 187Tbit/s in total system capacity which has the potential to support more than 50 million video calls in HD.[25] In addition, Google has invested in two more cables – PLCN and JGA-S. These cables are currently being deployed and are expected to be Ready For Service (RFS) in 2020 (see Figure 3.1).

Figure 3.1: Google's submarine cable investments in APAC [Source: Google, TeleGeography, 2020]

Submarine cable system	Cable landing points	RFS year (*: expected)
Unity	Japan, USA	2010
SJC	Singapore, Hong Kong, Japan, China, the Philippines, Brunei, Thailand	2013
Faster	Japan, Taiwan, USA	2016
Indigo	Singapore, Indonesia, Australia	2019 2020*[26]
PLCN[27]	Taiwan, USA, the Philippines	2020*
JGA-S	Australia, Guam	2020*

24 Through IRUs, typically paid upfront for the life of a cable, or through annual leases

25 Assumes 3.2Mbit/s required per participant for HD video meetings, see: https://support.google.com/a/answer/1279090?hl=en

26 Singapore and Australia landings are already 'live', and the Indonesia landing is expected to launch in 2020

27 The USA-Taiwan route for PLCN is active whereas USA-Hong Kong route is proposed but not active

Google has indicated its intention to continue investing in more infrastructure assets globally, including submarine cables,[28] to increase capacity between existing routes and to explore new routes (see quote).

Further investment in submarine cables over the next few years will support the growth in cloud traffic that is expected across APAC. Google's commitment to further investment is clear: in 2020, new cloud regions[29] have been launched in Seoul and Jakarta, with Melbourne and Delhi to come in 2021.

> “At Google, we've spent $30 billion improving our infrastructure over three years, and we're not done yet …. Google is committed to connecting the world and serving our Cloud customers.”
>
> **Ben Treynor Sloss**
> Google (Vice President, Engineering)
> Jan 16, 2018

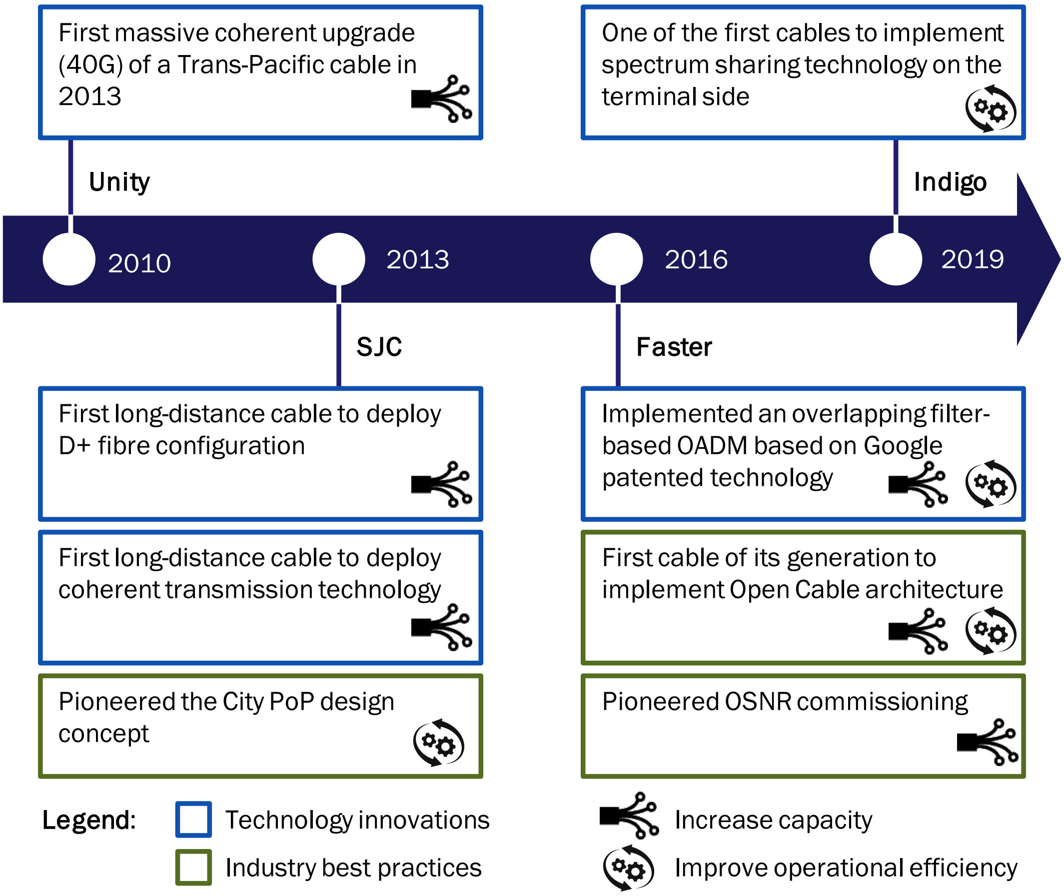
The APAC cables shown above are underpinned by Google investment and supported by Google's engineering expertise, and have driven numerous innovations in the submarine cable industry (Figure 3.2) that have been acknowledged by industry players (see quote).

> “Google has acquired the best talents (engineers) in the Industry.”
>
> “Google cables were able to push the capacity limit… our own technical team thought it would not be possible.”
>
> **Interviews with Submarine cable consortium partners**

28 See https://www.blog.google/products/google-cloud/expanding-our-global-infrastructure-new-regions-and-subsea-cables/

29 Cloud region is a specific geographical location where cloud computing resources such as virtual machine instances or zonal persistent disks are hosted; see https://cloud.google.com/compute/docs/regions-zones

Figure 3.2: Innovations enabled by cables invested by Google in APAC [Source: Google, 2020]



Google's submarine cable investment in APAC started with the Unity submarine cable system. This system launched in 2010 and was also the first Trans-Pacific cable that successfully underwent an upgrade with coherent transmission technology[30] at 40G in 2013. This 'world-first' upgrade increased the spectral efficiency of the optical fibres in the cable, enhancing the bandwidth capacity of the submarine cable system. Additional innovations in other APAC cables enabled higher capacity and higher operational efficiency:

- Deployment of D+ fibre in 2013 ahead of technology maturity allowed the SJC cable to be ***upgraded by up to three times the capacity*** that was originally planned two years after the cable launched.
- Adopting a City PoP design enables a more centralised interconnection model at a PoP location, driving a ***more cost-effective backhaul*** as transponders for the backhaul terrestrial system are no longer needed, and ***simplifying traffic handoff*** at convenient locations nearer to customers. Separation of the submarine line terminating equipment (SLTE) from the power feeding

30 Coherent transmission technology uses digital signal processing techniques to compensate for signal degradation incurred inside the fibre medium and is one of the most important technological advancements in optical transmission in the last decade

equipment located at the cable landing station also ***improves resilience and cost efficiency*** as the SLTE can be placed in the City PoP.[31]

- Implementing an overlapping filter-based Optical Add/Drop Multiplexer (OADM)[32] based on Google patented technology[33] that improves the efficiency of cables ***leading to higher capacity*** and ***enables greater flexibility*** in reconfiguring cable branching units for traffic routeing.

- Deploying an open cable architecture demonstrates the viability of a multi-vendor SLTE solution, and enables third-party suppliers to provide equipment to cable owners. This compares to traditional practice where there is vendor lock-in[34] as one submarine cable supplier provides all equipment including the fibre optic cable, the OADM and transponders. The stimulation of competition further encourages the development and use of ***more efficient and cost-effective*** equipment.

- Introducing Optical Signal-to-Noise Ratio (OSNR)[35] as a contractual standard in an open cable resulted in ***simpler design*** for transponder providers. This is because transponder providers can design the active system based on OSNR which defines the ***highest modulation scheme*** (and therefore the maximum data rate) that can be used to transmit a signal. This means that the transponder provider does not have to consider any other technical parameters in the submarine cable to configure the system. As an example, the FASTER cable delivered an 8 Quadrature Amplitude Modulation (QAM)[36] signal (resulting in a 4bit/s/Hz spectral efficiency) to ***set the record for transmission speed*** over the Trans-Pacific route covering over 10 000km.

- Implementing spectrum sharing technology on the terminal side adds ***flexibility in the spectrum assignment and control management*** for cable parties sharing a fibre pair. This allows cable owners to be able to offer virtual fibre pair products to customers.

Google continues to buy capacity from telecoms operators for much of its requirements, both internationally and in metropolitan areas where it has its own fibre network

In addition to direct investments in submarine cables, Google continues to lease bandwidth and buy IRUs from telecoms operators operating in APAC to fulfil most of its international capacity

31 This separation of the SLTE is not allowed everywhere as some jurisdictions do not allow the SLTE to be deployed outside the cable landing station

32 Optical Add/Drop Multiplexer is a device used in wavelength-division multiplexing systems for multiplexing two or more wavelengths into the same fibre via 'adding' and 'dropping' optical channels, see:

33 See https://patents.google.com/patent/US9225457B2/en

34 Vendor lock-in is commonly defined as "Proprietary lock-in or customer lock-in, which makes a customer dependent on a vendor for products and services, unable to use another vendor without substantial switching costs"; see https://www.techrepublic.com/article/5-ways-to-avoid-vendor-lock-in/

35 Optical signal-to-noise ratio is a measure of the quality of optical signals based on ratio of signal power to noise power in an optical channel, see: https://optiwave.com/wp-content/uploads/2015/10/TC-Optical-Signal-to-Noise-Ratio-OSNR.pdf

36 8QAM means that 3 bits can be transmitted in a single symbol (with 3 different levels). QAM is a form of modulation that uses two carriers and varying symbol rates to increase throughput in data transmission, see: https://www.cablefree.net/wirelesstechnology/qam-modulation/

requirements in the region. The capacity from these purchases accounts for around two-thirds[37] of the total international capacity used by Google in APAC. As Google continues to expand the reach of its edge network to new locations beyond its own submarine cable network and demand continues to grow for Google services, we expect to see an increase in Google's absolute spend on bandwidth purchased from the telecoms operators operating in APAC, in parallel with continued spending on its own infrastructure. We also expect to see more co-investment between Google and telecoms operators in new cables.

Besides international links from submarine cables and purchased international connectivity, Google also requires terrestrial fibre capacity within APAC countries to connect its infrastructure in metropolitan areas to international capacity paths.

Google operates edge PoPs in 15 cities across 8 APAC economies, and has deployed GGC nodes in more than 278 cities in almost every APAC economy

In APAC, Google's network is directly accessible in 15 cities, across 8 economies (see Figure 3.3). Most of the PoPs were deployed before 2010 and have been bringing Google content to interconnection locations that are geographically closer to ISPs for over a decade. These PoPs enable traffic to be exchanged between Google and ISPs in the region, rather than in Europe or the USA, improving end users' experience and reducing costs for ISPs. New PoPs are being deployed primarily to support Google Cloud services (most recently in Korea in early 2020). We expect PoPs to be deployed in more locations in tandem with the opening of new cloud regions to support the digital transformation ambitions of enterprises in APAC.

Figure 3.3: Number of Google PoPs in APAC [Source: Google, PeeringDB,[38] 2020]

APAC country	APAC cities	Public peering 'fabrics[39]'	Private peering facilities
Japan	Tokyo, Osaka	11	5
Australia	Sydney	5	3
Singapore	Singapore	5	2
Hong Kong	Hong Kong	4	2
South Korea	Seoul, Anyang-si	2	4
Taiwan	Taipei, New Taipei City	2	3
Malaysia	Kuala Lumpur, Johor Bahru, Cyberjaya	3	3

37 Google data received in Feb 2020; covers key APAC economies including Hong Kong, Taiwan, Australia, Singapore, Japan, South Korea, Malaysia and Indonesia

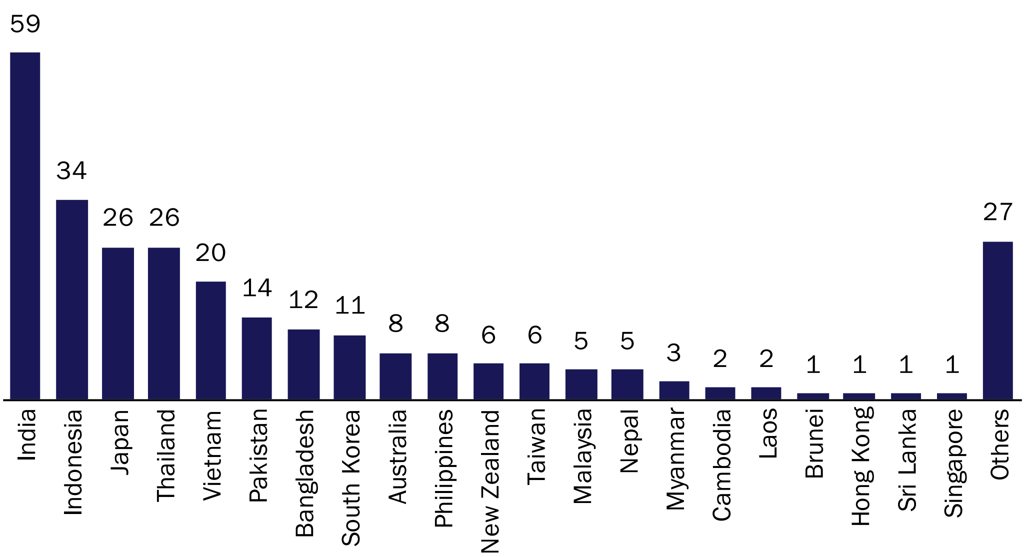
38 The number of Google PoPs refers to the unique number of public and private peering facilities in which Google participates. Google also deploys on-net cache nodes within Google's network (e.g. in internet exchange points (IXPs))

39 Public peering is accomplished across layer 2 access technology, generally called a shared fabric, See https://en.wikipedia.org/wiki/Peering

APAC country	APAC cities	Public peering 'fabrics[39]'	Private peering facilities
Indonesia	Jakarta, Jakarta Selatan, Kabupaten Bekasi	4	3

Google's GGC nodes sit within partner ISPs' networks, and primarily store static content popular with end users. This includes Google services like YouTube and Google Play. The first GGC edge nodes were rolled out in Australia in 2008 and more nodes were then progressively rolled out across APAC. Although initial deployments took place in developed APAC economies, over the past six years roll-outs have focused on emerging economies. GGC nodes are now present in 278 cities[40] across most APAC economies (see Figure 3.4 below). Between 65 to 80%[41] of Google's egress traffic towards a partner ISPs' users can be served from GGC.

Figure 3.4: Number of cities with at least one GGC node in APAC [Source: Google,[42] 2020]



3.2 Google's services benefit from the acceleration of supply on international capacity and the increasing diversity of routes

Google's initiative to invest directly in new submarine cables is driven by several factors. First, it allows Google to have more control over certain aspects of the new submarine cable system, including where it lands and the route it takes to reach these landing points. Second, Google's

40 Cities as defined by Google based on GGC location database received in March 2020

41 Based on information from Google; 65–70% of content served to end users in English-speaking and/or multi-language-speaking economies is cached, compared to 75–80% for other economies

42 The 'Others' category comprises 21 other APAC countries where Google has deployed GGC nodes , including Samoa and the Cook Islands

financial strength ensures that projects in which it is involved can be financed more rapidly and more securely than might otherwise be the case. Finally, Google's engineering innovations ensure that these new cables are state-of-the-art and 'push the envelope' from a technical perspective.

All these factors contribute to lower latency and improved reliability for Google's services. In addition, Google's submarine cable investments support the expansion of its edge network, which further improves service performance and reduces costs for ISPs.

The addition of new submarine cable routes in APAC improves the performance and resilience of Google's services, which also benefits the broader connectivity ecosystem

Google's investments in new cables create new routes within a region (such as the Singapore-Perth–Sydney route for a portion of the Indigo cable)[43], and improve the number and diversity of paths used to carry traffic between regions (such as the Piti–Sydney route for JGA-S cable), as shown below in Figure 3.5. This reduces the latency of links to newly connected locations compared to existing routes. As an example, the recent landing of the submarine cable Indigo connecting Sydney to Singapore resulted in a 77ms reduction in latency between these two cloud regions, from 168ms to 91ms on average (a reduction of 46%).[44] This matters for a whole sway of applications: the user experience for two-way voice and video communications degrades rapidly above 100ms latency (one way) and in modern video games, graphics are updated approximately every 15ms, so very low latency improves the online gaming experience.

43 While the Indigo cable lands in Perth, Google currently does not route traffic to or from Perth over this facility

44 Google Cloud Platform – "The High-Performance Network", Cloud Next'19; the two cloud regions refer to asia-southeast1 and australia-southeast1; the latency reduction refers to the latency difference between early 2018 and late 2018

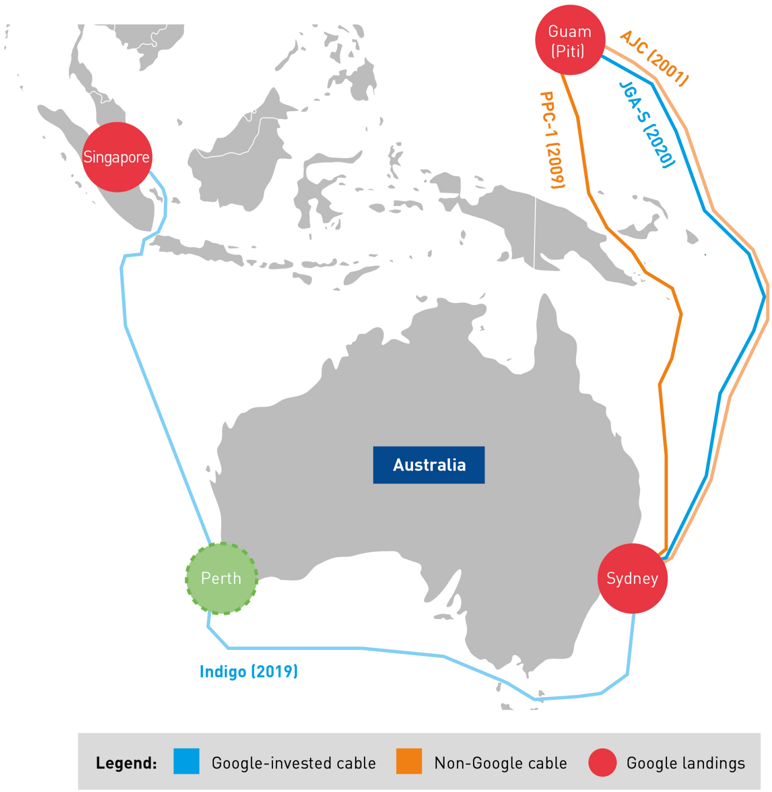


Figure 3.5: Overview of selected submarine cable routes in Australia [Source: TeleGeography, Analysys Mason, 2020]

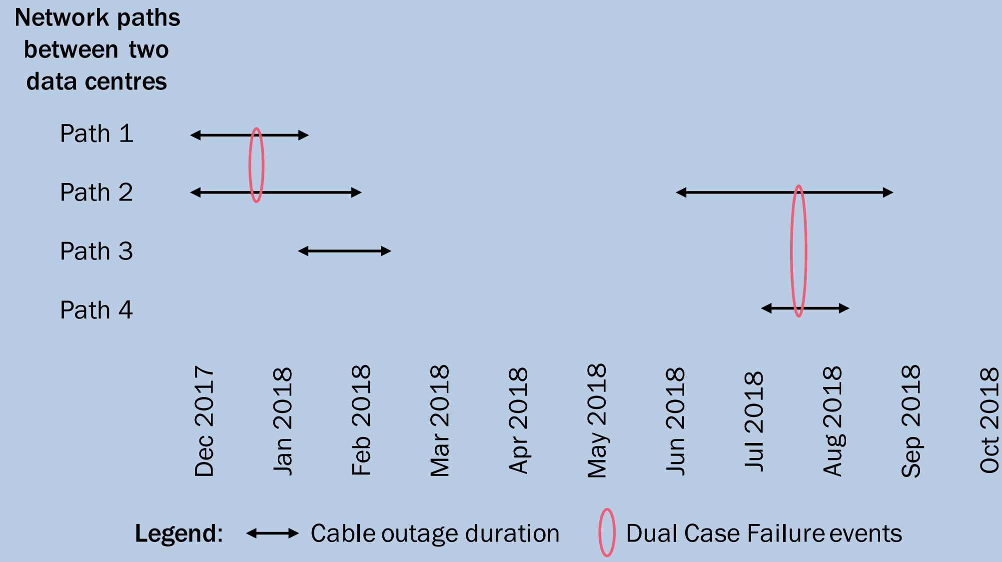
The addition of new routes also enhances service reliability; when existing routes experience faults,[45] Google services can continue working well due to the availability of redundancy mechanisms to reroute through alternative cables.

45 Masi, Smith and Fisher – "Understanding and mitigating catastrophic disruption and attack. *Sigma: Rare Events*", 2010

Case study: Google's ability to maintain service availability in 'Dual Case Failure' events

In 2018, Google experienced two Dual Case Failure events, losing connectivity on two network paths between its data centres in APAC within the same period of time. One of these events was a worst-case failure scenario, where Google lost one of its largest critical paths.

Figure 3.6: Redacted illustration of Google's Dual Case Failure events in APAC in 2018 [Source: Google,[46] Analysys Mason, 2020]



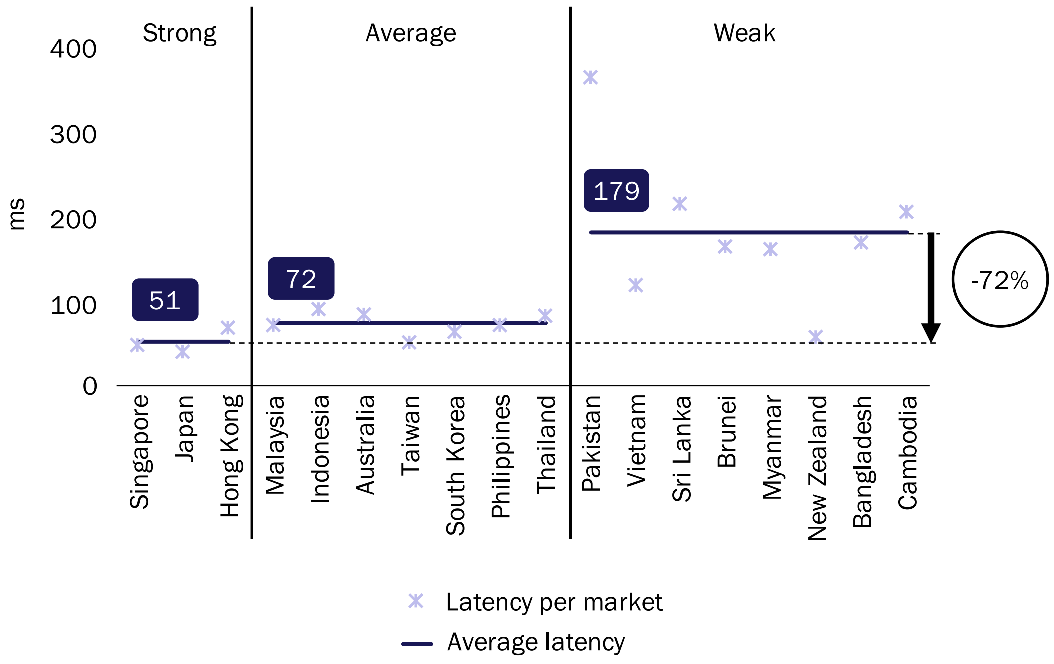
The actual identification and rectification of the failure points on submarine cables can often take months, requiring permits from relevant authorities, and relying on the availability of specialised submarine cable repair ships and favourable weather conditions. This could have severely impacted Google's ability to deliver content to APAC economies. However, because of Google's network infrastructure planning and investments in APAC over the past 10 years, Google services, including Google Cloud, were not disrupted by these Dual Case Failure events.

> "We try very much to not leave anything to chance when we are building out this network."
>
> **Donald Clark**
> Google (Global Network Infrastructure)

46 Google Cloud Next '19; see https://youtu.be/pIZXvVI8vIM?t=400

The improvement in latency and resilience is not only advantageous to Google's services, it also benefits the broader connectivity ecosystem in APAC. As shown in Figure 3.7, APAC economies that have a stronger level of international connectivity through submarine cables (as defined in Figure 2.2) achieve lower end-user latencies compared to other economies:[47] in 2019 well-connected economies experienced 72% lower end-user latencies on average compared to economies with weaker cable supply. New Zealand is an exception in this regard – its ISPs have well-developed domestic networks and proximity to Sydney in Australia has enabled them to offer consistently-low latency to their users.

Figure 3.7: End-user latency compared against the extent of international connectivity in APAC [Source: M-lab,[48] 2019]



This finding on latency have been further supported our econometric analysis we conducted for this study also shows a strong correlation between low latency and the total number of submarine cables landing in a given economy. Furthermore, Google-invested cables have been shown to have greater effect on the reduction of end-user latency compared to other cables. Based on the output of the modelling, we estimate that Google's investments in submarine cables contributed to a 12–49% reduction in end-user latency[49] in 2019 across APAC economies they land in.

47 End-user latency measured by the average round trip time, based on the "rtt_avg" metric from M-lab data (https://www.measurementlab.net/visualizations/)

48 Based on data points from May 2018 to Apr 2019 for each APAC for better comparability across economies due to data availability; Data points refer to the average of monthly median data points; Latency for Taiwan excludes Aug 2018, Sep 2018, Feb 2019 and Apr 2019 to remove anomalies from data on Hinet

49 Analysys Mason modelling estimates that end-user latency would have been between 6 and 158ms higher across Japan, Hong Kong, Singapore, Taiwan, the Philippines and Brunei if Google had not been an investor in these cables

The investments in submarine cables also support the expansion of Google's edge infrastructure, which improves the performance of Google's services and reduces costs for ISPs in APAC

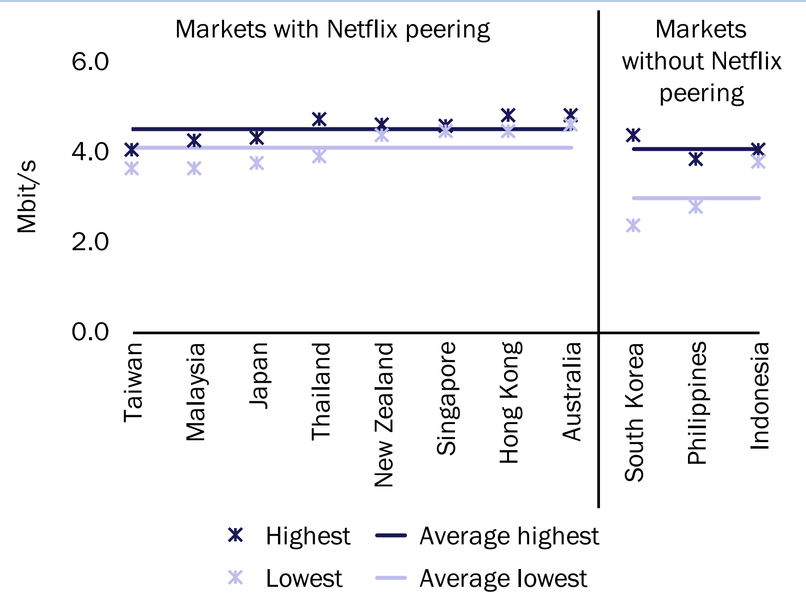
Google's submarine cables connect its data centres to each other and to its edge PoPs in APAC and around the world. This brings Google products and services closer to ISPs in APAC and allows ISPs to interconnect with Google to exchange traffic within APAC instead of having to connect to another region further away (e.g. the USA or Europe). The availability of PoPs in APAC also allows GGC cache nodes, which are deployed across APAC within ISPs' networks, to be more efficient in filling -up content. Bringing services closer to end users, through this delivery network, enables Google to ensure a more consistent user experience in the APAC region. Other large CASPs have adopted similar strategies: Netflix, for example, has implemented its own content delivery network (CDN) initiative, called Open Connect (see case study below).

Case study: Impact of Netflix Open Connect on viewing performance in APAC

Netflix, one of the top media-streaming service providers, accounts for a significant share of internet traffic globally.[50] To sustain its ability to improve Netflix viewing experience for end users, Netflix launched its own CDN initiative, Open Connect, in 2011. Through Open Connect, Netflix actively peers with ISP networks globally and upholds an open peering policy – 95% of Netflix global traffic is delivered via direct connections between Open Connect and partner ISPs.

Figure 3.8 illustrates the impact of Netflix CDN–ISP peering arrangements on end users' prime-time viewing experience, measured by ISP speeds. The Netflix ISP Speed Index tracks 11 APAC economies, and Netflix has established peering arrangements in eight of these. It has done this via participation in an internet exchange in the country and/or private peering facilities. Overall, there is strong evidence indicating that Netflix has performed more consistently where it has peering arrangements. This can be seen in the narrow spread between the highest and lowest speeds delivered (see Figure 3.8). Indonesia is an exception – Netflix managed to achieve a steady performance in the country even without a direct peering point. This can be attributed to the strong submarine cable connectivity to Singapore.

Figure 3.8: Netflix ISP Speed Index by APAC countries in Dec 2019 [Source: Netflix,[51] 2020]



50 Sandvine – "The Global Internet Phenomenon Report", Oct 2018; see https://www.sandvine.com/hubfs/downloads/phenomena/2018-phenomena-report.pdf

51 Netflix ISP Speed Index is a measure of prime-time Netflix performance on ISPs and is not a measure of overall performance of other services/data that may travel across the specific ISP network; data points are based on the values of the top four ISPs by speed in each APAC economy

We estimate that, in 2019, Google's edge infrastructure in APAC served nearly all of the demand for Google's services in the region, with around 71% served by GGC and another 27% served by PoPs located in APAC. The small residual share of traffic was collected by ISPs from PoPs located outside APAC (usually North America), typically where ISPs preferred to receive it or because of specific routeing conditions. The interviews we conducted with APAC ISPs also highlighted the effectiveness of Google's edge network in enabling vast amounts of traffic to be delivered to end users at minimal cost to ISPs. These caches represent a key piece in ISPs' traffic management strategy – they serve a significant portion of ISP traffic and help ISPs constrain their spending on international bandwidth and IP transit (see quote).

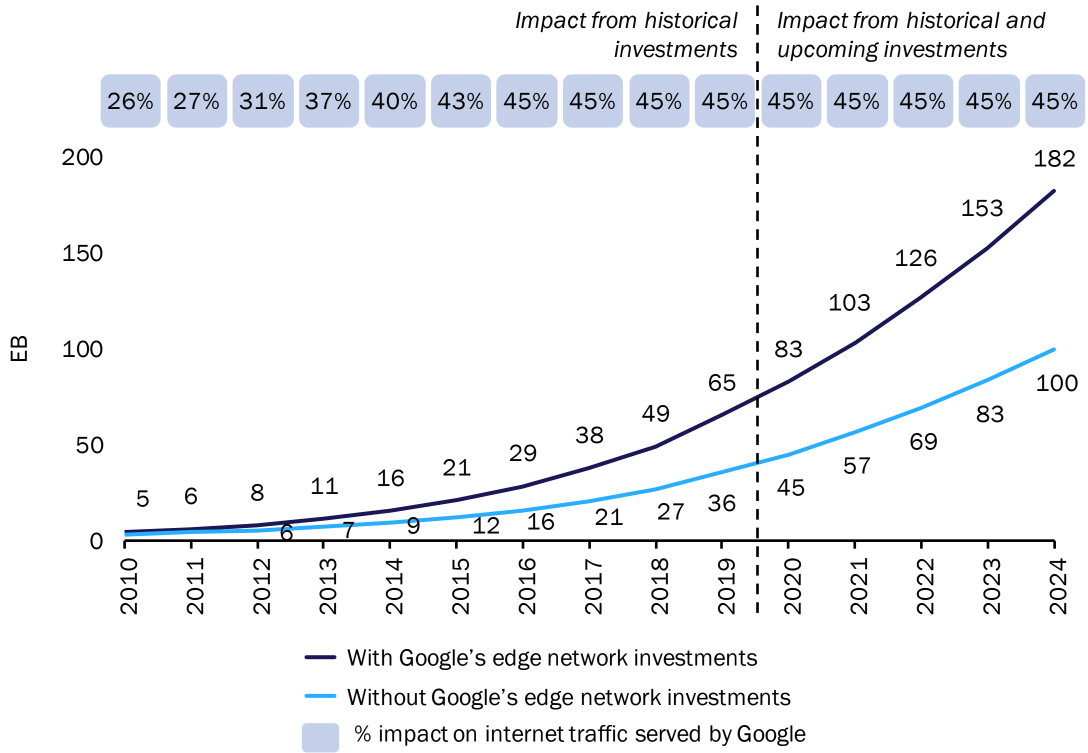
> “Our current distribution of (total) traffic served is 64% via CDNs, 25% via peering and the remaining 11% via IP transit. This has an implication on our traffic cost – CDNs incur minimal cost, peering traffic averages at USD0.3 per Mbit/s, while IP transit averages at USD1.4 per Mbit/s.”
>
> **Senior Principal Engineer,** ISP in Malaysia

In the absence of Google's edge network infrastructure investments in APAC, ISPs would have to either interconnect with Google in another PoP location outside of APAC or rely on IP transit from global carriers. This would mean a significant increase in international bandwidth usage, with associated costs incurred by ISPs. We expect that, in such a situation, ISPs will be constrained in international bandwidth, which will lead to lower speeds and longer loading time for end users, resulting in a loss of data traffic (see quote).

> “We had an incident when the cache of a CASP was down for four hours when we had a 'bill shock' in our IP transit cost for that month. There are limitations in the caching capabilities done by ISPs – without caches from CASPs, we will likely face some traffic loss.”
>
> **Head of Networks and Engineering,** Telco Group with APAC presence

52 Google's edge investment serves traffic from Google's services, including Google Cloud, which is traffic internal to Google's cloud customers. This differs from traffic served by Google's submarine cable investments, which support traffic from a multitude of CASPs, ISPs, consumers and businesses.

Figure 3.9: Impact of Google's investments in edge network infrastructure on internet traffic served by Google's services in APAC [Source: Analysys Mason, 2020]



3.3 Google's submarine cable investments have resulted in improved connectivity across APAC, enabling up to 10% of total internet traffic in 2019

Google's investments in new submarine cables increase supply of international bandwidth to the region. This increased supply leads to reduced prices for buyers of international bandwidth, benefiting many stakeholders in the internet ecosystem including ISPs and CASPs. This leads to improvements in the quality of users' experience of the internet and stimulates use cases such as cloud services, video conference and transaction services that rely on low latency and/or high internet speeds.

These benefits in turn generate positive connectivity outcomes in the form of more users and data traffic, supported by our econometric modelling which shows a statistically strong correlation between the introduction of submarine cables and an increase in both internet penetration and data traffic in the countries where they make landfall. Further details on the methodology and econometrics equations behind the modelling on submarine cable and edge network investment impact can be found in Annex A.

The increase in submarine cable supply results in prices 74% lower on average in strongly connected compared to less connected APAC economies

New submarine cables bring additional international bandwidth capacity to economies they land in as well as open new routes to other destinations. This also allows submarine cable owners to swap capacity on other routes, usually at better rates compared to the open market. These effects drive down the cost of international bandwidth and allow ISPs to achieve cost savings from lower usage of international bandwidth and through lower-cost routes. ISP comments during interviews conducted for this project reflect these findings (see below).

“ New submarine cables in the region is one of the reasons for the unprecedented decline [in prices of international bandwidth] over the past five years. ”

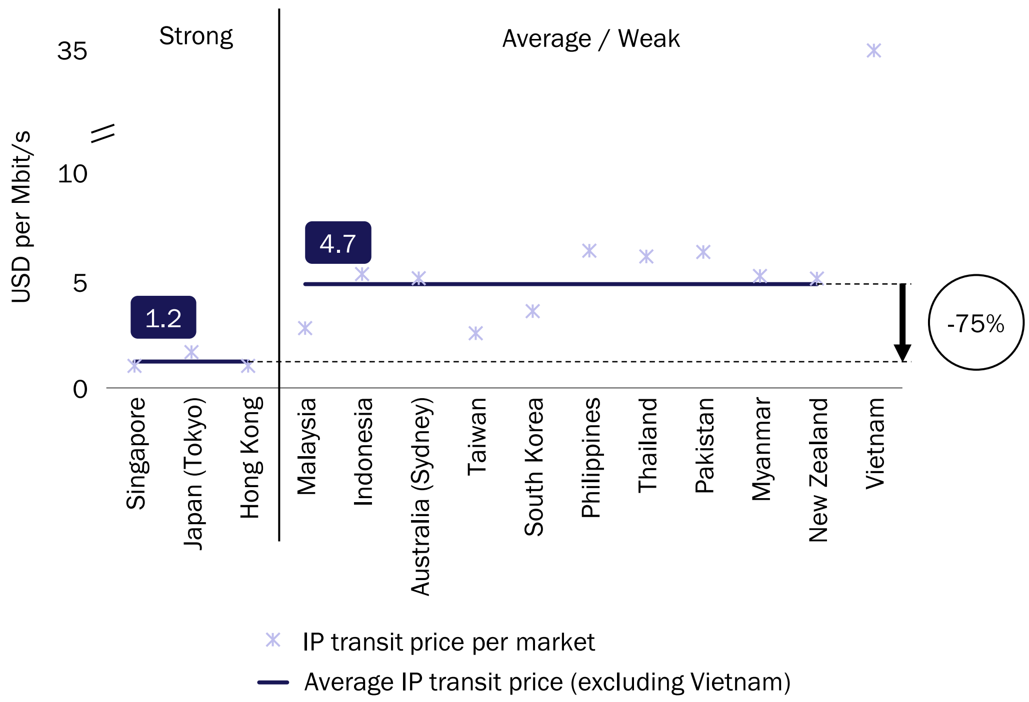
Head of Networks and Engineering, Telco Group with APAC presence

“ We have witnessed IPTX prices (cost per Mbit/s) erode over the last five years… The new submarine cables by the internet companies, Google and Facebook, does impact the overall IPTX price.”“We have witnessed IPTX prices (cost per Mbit/s) erode over the last five years… The new submarine cables by the internet companies, Google and Facebook, does impact the overall IPTX price. ”

Senior Principal Engineer, ISP in Malaysia

The extent of submarine cable supply has a discernible impact on international bandwidth prices (see Figure 3.10).

Figure 3.10: IP transit prices[53] compared against the extent of international connectivity in APAC [Source: TeleGeography, Analysys Mason, 2019]



IP transit prices are much lower in economies with strong submarine cable supply; in 2019, IP transit prices in well-connected economies were 74% lower on average. In some cases, and as expected, operators of existing submarine cables have responded to competition from new supply by lowering prices. This effect can be seen in Australia – detailed in the case study below.

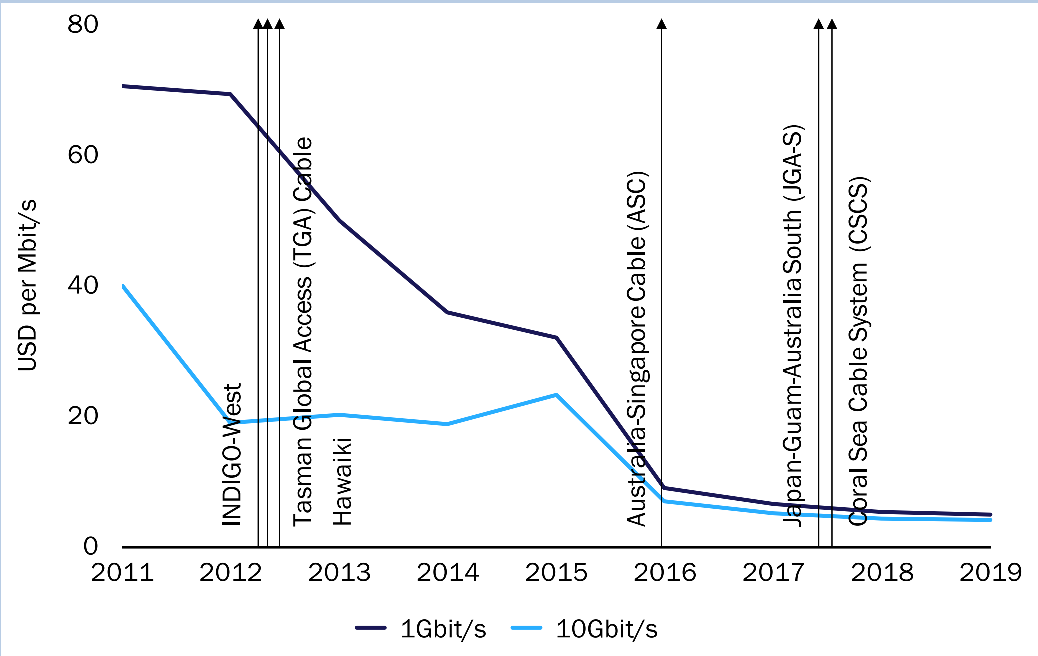
Case study: Impact of new submarine cables on IP transit prices in Australia

Over the past decade, six international submarine cables with a landing point in Australia were announced. Five were operational at the end of 2019, and the last one, JGA-S, entered into service in 2020. These six cables connect Australia to other global economies and effectively tripled the total usable submarine capacity in Australia. Google is an investor in both the JGA-S and INDIGO cables.

53 Refers to USD per Mbit/s of IP transit prices in 2019 based on the committed data rate of 10Gbit/s from TeleGeography; calculation is based on averaging the weighted median prices by quarters (up to Q3 2019) to derive 2019 prices; IP transit price data for 10Gbit/s is referenced, as it provides the highest number of available data points (14 APAC economies with submarine cables)

The launch of new cables boosts the supply of international capacity, especially as technological advances allow for greater design capacities at lower unit costs than were possible on older cables, potentially impacting prices. As illustrated in *Figure 3.11*, following the 2013 announcement that three new submarine cables would be landing in Australia, IP transit prices declined drastically between 2013 and 2016, from USD71 per Mbit/s to USD11 per Mbit/s for a 1Gbit/s capacity, a 31% reduction on average each year. Between 2016 and 2019, IP transit prices continued to decline in tandem with new cable announcements to reach USD6 per Mbit/s, a further reduction of 18% on average each year.

Figure 3.11: Historical IP transit prices[54] in Sydney, Australia and mapped against announcements of new international submarine cables between 2010 and 2019 [Source: TeleGeography, 2019]



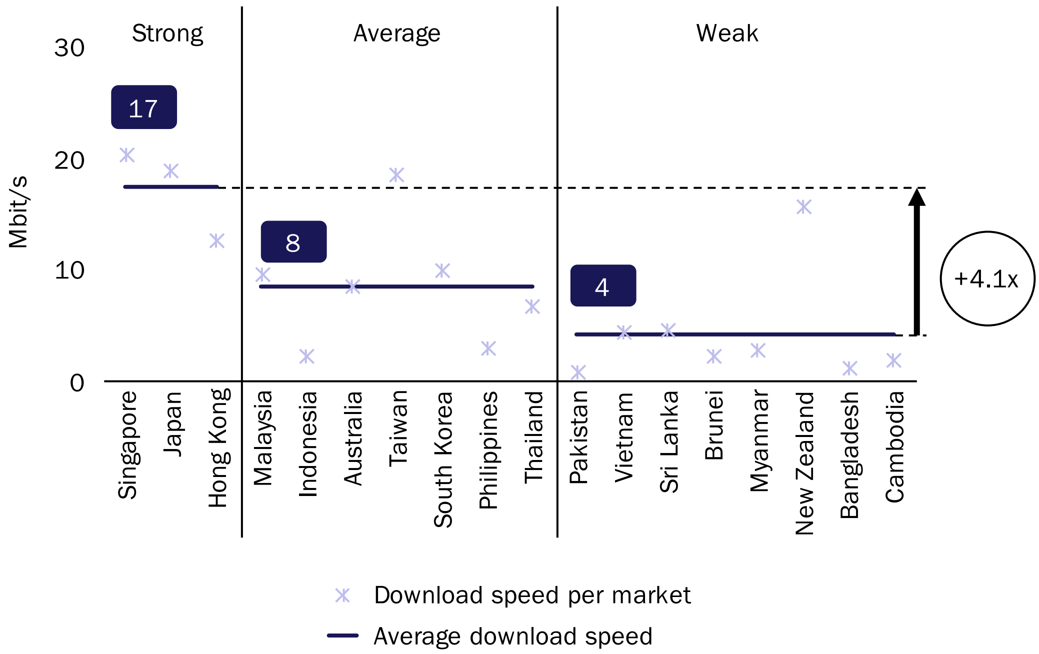
ISPs typically have a relatively fixed budget to fulfil their international bandwidth requirements, which they use to purchase IP transit and route-specific bandwidth leases. The decrease in the unit cost of international bandwidth means that ISPs can provision higher capacity to carry more traffic with the same budget, and use a wider variety of routes to improve resilience and reliability.

54 Refers to USD per Mbit/s of IP transit prices in Sydney based on the committed data rate of 1Gbit/s and 10Gbit/s from TeleGeography

> "IP transit prices declined rapidly over the past few years [……] allowed us to maintain the total spend for international bandwidth while serving a much greater volume of traffic."
>
> **Manager,** ISP in Taiwan

The ability to carry more traffic through a greater variety of routes translates to faster download speeds, and a better quality of experience of the internet for end users. Figure 3.12 provides evidence that APAC economies with a stronger supply of international submarine cables achieve faster download speeds, up to four times that of other economies in 2019. The relatively high download speed in New Zealand is due in part to a high fibre penetration[55] as a result of the country's Ultra-Fast Broadband (UFB) government initiative which results in New Zealand outperforming peers despite relatively low submarine cable supply to the country. The same can be said for Taiwan, where strong domestic policies supported the extensive deployment of high-speed broadband infrastructure.

Figure 3.12: Download speed compared against the extent of international connectivity in APAC [Source: M-lab,[56] 2019]



55 New Zealand ranks fifth in fibre-to-the-home (FTTH) penetration in APAC (excluding China) as of Dec 2018; see https://www.ftthcouncilap.org/ftth-council-asia-pacific-releases-apac-market-panorama-report-2019/

56 Based on data points from May 2018 to Apr 2019 for each APAC country for better comparability across economies due to data availability; 'data points' refer to the average of monthly median data points; download speed for Taiwan excludes Aug 2018, Sep 2018, Feb 2019 and Apr 2019 to remove data anomalies from data on Hinet

The positive impacts of submarine cable investments on the connectivity ecosystem stimulate the adoption of new services, and drive increase in internet users and traffic

Improvements in latency and internet speed increase ISPs' ability to deliver innovative services such as cloud services, video conferencing and gaming.[57] Low latency is also critical for transactional services, including e-commerce. A 2017 Akamai study shows that a 100-millisecond delay in website load time can lower online retail conversion rates by 7%,[58] and operators in APAC have told us that they see submarine cable capacity as essential to support growth in cloud and e-commerce usage (see quote).

> “These investments in submarine cables are important to support cloud services and transactions over the internet.”
>
> **Manager, International Strategy,** APAC Telco

Research has also shown that use of the Internet by enterprise players has had a positive impact on the performance of businesses,[59] and the adoption of cloud services can provide further benefits to business and the overall economy. This is explored further in Section 4.

End users (individuals and businesses alike) are deriving greater value from their internet usage when international connectivity is less constrained and cheaper. Existing services can provide a better quality of experience, and new use cases requiring lower latency or greater international bandwidth emerge. This leads to further and increased investments from ISPs looking to improve both broadband coverage and capacity, creating a virtuous cycle that supports an ***increase in internet penetration*** and in ***internet traffic***.

► *Impact on internet penetration*

The increase in internet penetration as a result of better connectivity from submarine cables is substantiated by academic studies.[60] This correlation is supported by econometric modelling that we conducted specifically for this report, which demonstrates a positive correlation between low latency

57 In particular cloud and online multiplayer gaming

58 Akamai Online Retail Performance Report: Milliseconds Are Critical, 2017; see https://www.akamai.com/uk/en/about/news/press/2017-press/akamai-releases-spring-2017-state-of-online-retail-performance-report.jsp

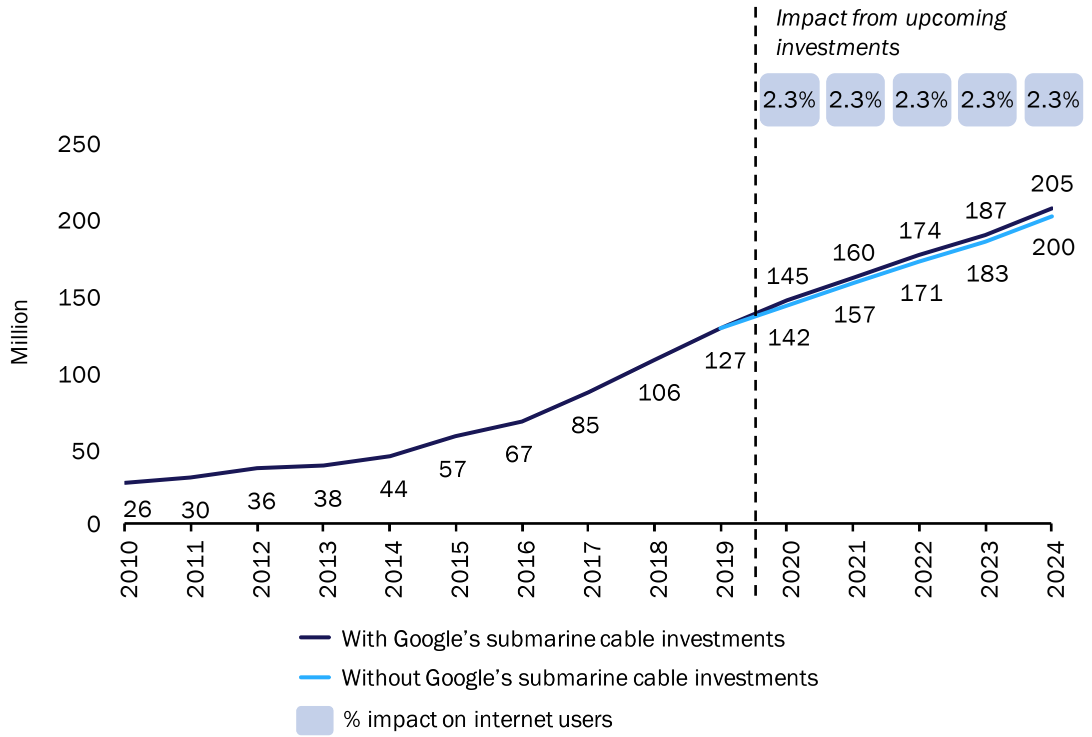
59 E.g. by FERDI for sub-Saharan Africa – "Digital vulnerability and local performance of firms in developing and transition countries", Jun 2019; see https://papers.ssrn.com/sol3/papers.cfm?abstract_id=3032902

60 See Fondation Pour Les Etudes Et Recherches Sur Le Developement International (FERDI) – "Telecommunication Submarine-Cable Deployment and the Digital Divide in Sub-Saharan Africa", May 2019 available at https://papers.ssrn.com/sol3/papers.cfm?abstract_id=3202941; also see Myongji University – "The effect of the internet on economic growth: Evidence from cross-country panel data", May 2019 available at https://www.sciencedirect.com/science/article/abs/pii/S0165176509001773

and high availability of bandwidth on the one hand, and an increase in internet penetration on the other hand.

The Indigo cable, in which Google has invested, will land in Indonesia in 2020. Even though Google does not have capacity landing in Indonesia, the addition of a new cable, deployed with the latest technology innovations, will improve connectivity outcomes in the country. Depending on estimates, between half and two-third of Indonesians were internet users in 2019,[61] a proportion that could grow as submarine cable supply increases. Based on the studies and modelling mentioned above, we estimate that the Indigo cable could lead to 4.6 million additional internet users by 2024 in Indonesia (Figure 3.13).

Figure 3.13: Impact of Google's investment in submarine cables on internet users in Indonesia [Source: Analysys Mason, ITU, Euromonitor, 2020]



► *Impact on internet usage*

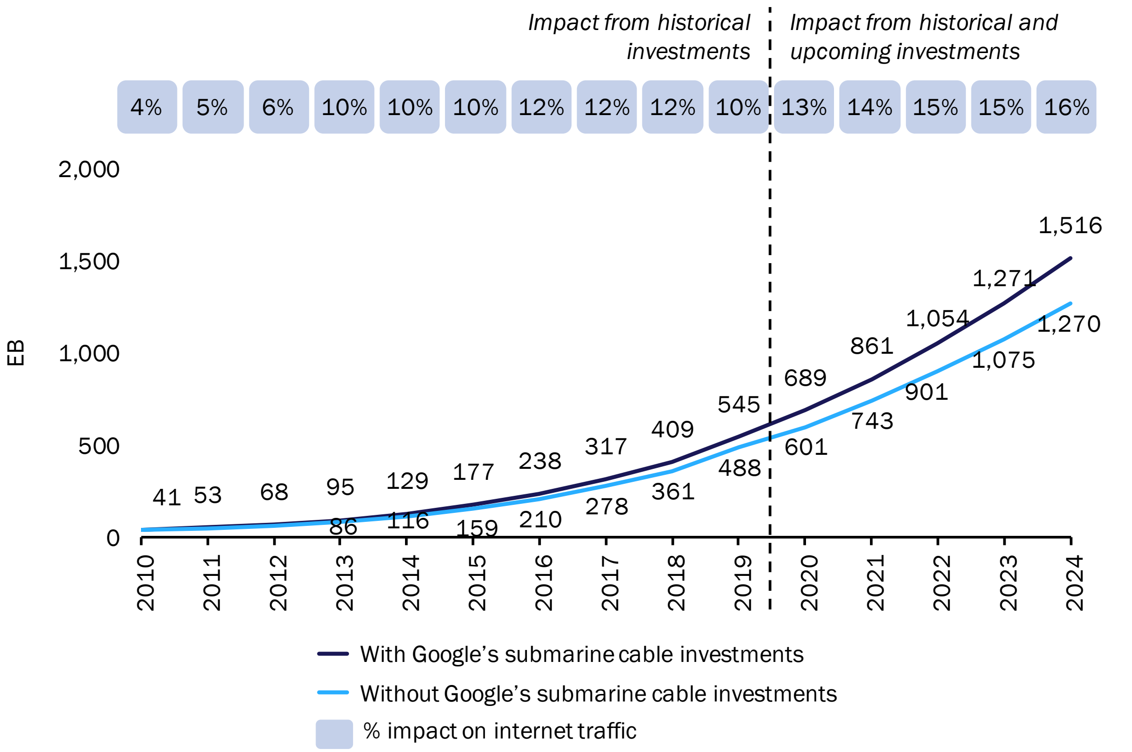
Similarly, the analysis and econometric modelling we conducted for this report shows a strong correlation between low latency, high availability of bandwidth and low cost of bandwidth on the one hand, and internet traffic on the other: this is consistent with what we would expect, as greater supply improves performance and reduces unit costs, enabling and incentivising greater demand.[62]

61 The ITU estimated that 40% of Indonesians had used the internet within a three-months period in 2018, whereas the Indonesia Internet Service Providers' Association estimated internet penetration at about 65% in the same year

62 The 'within value' of R-squared from the regression is 0.84, with 1.00 being the perfect fit

We estimate that internet traffic in APAC would have been 10% lower in 2019 in the scenario where Google had not made investments in submarine cables, and this impact is expected to increase to 16% by 2024 (Figure 3.14).[63]

Figure 3.14: Impact of Google's investments in submarine cables on internet traffic in APAC economies [Source: Analysys Mason, ITU, GSMA, 2020]



63 Impact on mobile data traffic is attributable to economies in which Google has a submarine cable and which have relatively high internet penetration, namely Japan, Hong Kong, Singapore, Taiwan, Australia, the Philippines and Brunei; we expect the impact of the Indigo cable in Australia to be realised from 2020 onwards as the cable was only RFS in Q4 2019

3.4 Google's network infrastructure investments supported 1.1 million jobs across APAC and unlocked USD65 billion in additional GDP in the region in 2019

Google's investments create benefits from the construction and operation of network assets

The investments in network infrastructure made by Google could benefit APAC economies directly through economic activity and job creation generated from the construction and maintenance of these infrastructure assets. These benefits are likely to be relatively small, as most of these investments relate to the portion of the cables that traverse international waters, which are deployed by a small number of large global suppliers.[64] The ongoing operations and maintenance of network infrastructure are not labour intensive, with the monitoring work handled both at the network operations centre as well as remotely by Google engineers. The bulk of in-country investment by Google relates to PoPs, metro fibre networks, GGC nodes, as well as submarine landing stations. These represent up to a third of Google's total investment in the region since 2010.

Even though these direct benefits are relatively small, they generate indirect and induced benefits. Copenhagen Economics conducted an economic impact study of Google's infrastructure investments in Europe,[65] and found that direct investments into building, laying out and maintaining the submarine cables, landing stations, PoPs and in-country access network led to the generation of economic activity and creation of jobs. This study also describes further positive economic outcomes through indirect and induced effects from Google's investments (i.e. effects in the broader supply chain and the knock-on impact on the broader economy of the jobs created and income generated).

New cables impact connectivity, creating greater internet penetration and data usage, and generating much more significant economic impacts from additional GDP growth

As discussed in Section 3.2 and Section 3.3, Google's direct and indirect investment in network assets is enabling rapid and sustained growth in internet traffic, and can be expected to support further increases in internet penetration over time.[66]

Taking into account the combined effects of both submarine cable and edge network investments,[67] we estimate that Google's investments in APAC would have enabled 15% of the internet traffic in APAC in 2019.

---

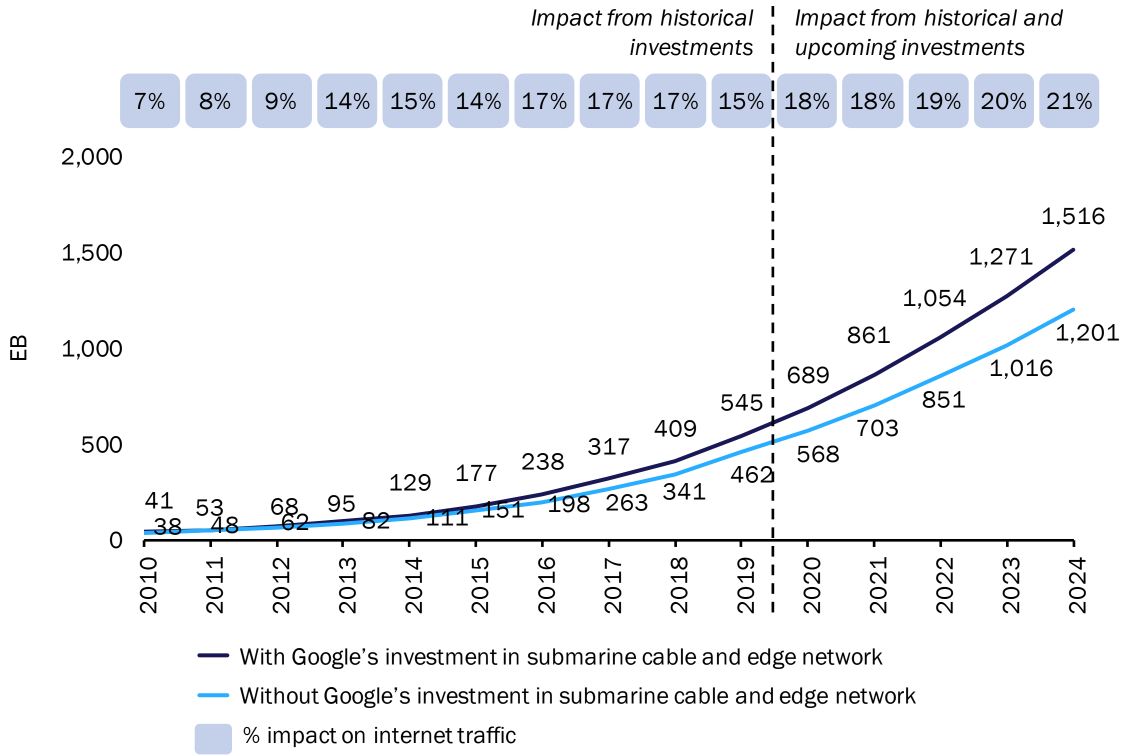
64 These include for example Alcatel Submarine Networks (ASN) and Huawei Marine

65 Copenhagen Economics – "Google's hyperscale data centres and infrastructure ecosystem in Europe"; see https://www.copenhageneconomics.com/dyn/resources/Publication/publicationPDF/0/500/1569061077/copenhagen-economics-google-european-dcs-infrastructures-impact-study_september2019.pdf

66 EXFO – "Testing submarine cables: why it's a big deal", Nov 2018; see https://www.exfo.com/en/resources/blog/testing-submarine-cables/

67 This considers a compounding effect due to the traffic impact from both submarine cable and edge network investments; see Annex A for further discussion

Figure 3.15: Impact of Google's investments in submarine cables and edge network infrastructure on internet traffic in APAC [Source: Analysys Mason, ITU, 2020]



The increased usage of the internet by consumers and businesses across various sectors is correlated with an increase in economic activity, as evidenced in existing studies conducted by the OECD[68] and the GSMA, Deloitte and Cisco.[69]

In order to reflect the specificities of the APAC region and the rapid developments since these studies were published, we conducted our own econometric modelling, in partnership with Professor Neil Gandal at Tel Aviv University. Using an endogenous growth model, we found a strong correlation between an increase in mobile data usage and higher GDP per capita: a doubling of mobile data usage could result in a 0.5% increase in real GDP per capita (see Annex A).

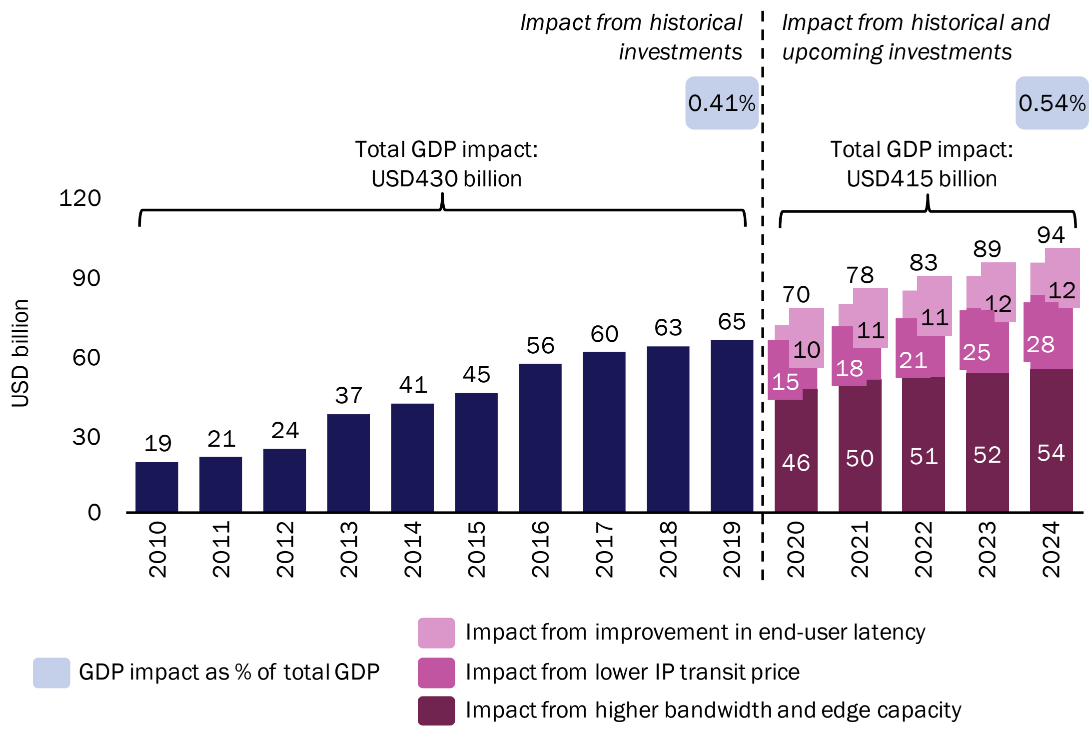
On this basis, we estimate that the increase in internet usage linked to Google's network infrastructure investments in APAC contributed USD430 billion to the region's GDP from 2010 to 2019 (in real 2019 USD, see Figure 3.16); in 2019 alone, we estimate that GDP was USD65 billion higher than it would have been without Google's infrastructure investments. This represents 0.41% of the combined GDP in APAC in 2019, a small but significant portion.

68 Organisation for Economic Co-operation and Development (OECD) (2012-06-05), "The Impact of Internet in OECD Countries", OECD Digital Economy Papers, No. 200, OECD Publishing, Paris, see http://dx.doi.org/10.1787/5k962hhgpb5d-en

69 GSMA, Deloitte, Cisco – "What is the impact of mobile telephony on economic growth?", Nov 2012, see https://www.gsma.com/publicpolicy/wp-content/uploads/2012/11/gsma-deloitte-impact-mobile-telephony-economic-growth.pdf

As discussed earlier, Google's continued network investments from 2020 onwards, including the launch of three new submarine cable systems publicly announced and currently being deployed, are expected to spur higher internet traffic usage and add more internet users, in particular in Indonesia. We estimate that GDP in the APAC region would be USD415 billion lower from 2020 to 2024 (Figure 3.16) in the scenario where Google had not made and would not continue making investments in network infrastructure, of which USD94 billion would be in 2024 alone (in real 2019 USD).

Figure 3.16: Increase in real GDP[70] attributable to Google's network infrastructure investments [Source: Analysys Mason, 2020]



The economic benefits arising from network infrastructure investments translate into jobs: direct jobs in the construction and telecoms sectors[71] and indirect jobs driven by the improvement of broadband connectivity across the broader economy, particularly in services industries such as IT, financial services and manufacturing.[72]

Based on an assessment of the gross value added (GVA) created by an average full-time employee in these industries, in each APAC economy, we estimate that the GDP impact of Google's network

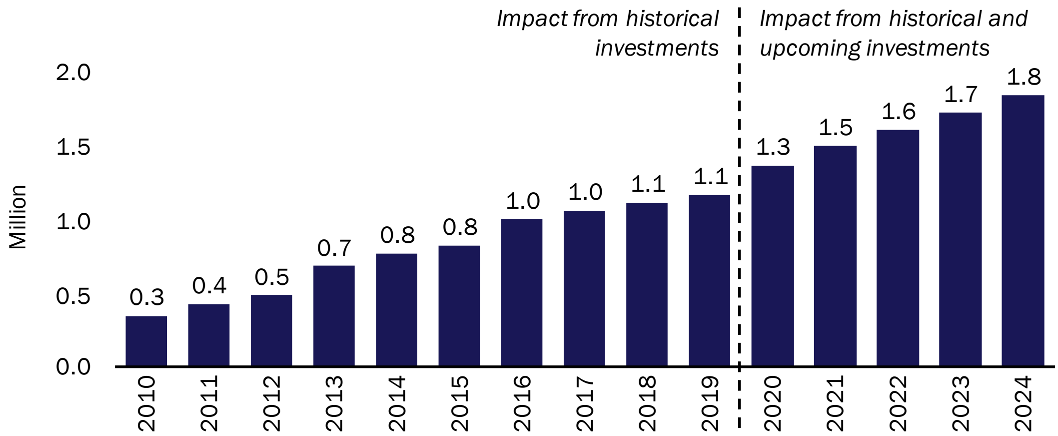
70 GDP figures are in constant USD using 2019 as the base year and using a fixed exchange rate to USD in 2019; GDP statistics in USD are sourced from the World Bank and Euromonitor

71 Report on Consultancy Study on Issues Relating to the Landing of Submarine Cables in Hong Kong, Frost & Sullivan 2010; see https://tel_archives.ofca.gov.hk/en/report-paper-guide/report/rp20100526.pdf

72 Impact of Broadband on the Economy, ITU 2012; see https://www.itu.int/ITU-D/treg/broadband/ITU-BB-Reports_Impact-of-Broadband-on-the-Economy.pdf

investments translated to around 1.1 million jobs[73] at the end of 2019, which will grow to 1.8 million jobs by 2024.

Figure 3.17: Number of additional jobs supported through the increase in GDP attributable to Google's network infrastructure investments [Source: Analysys Mason, 2020]



73 On a full-time equivalent basis

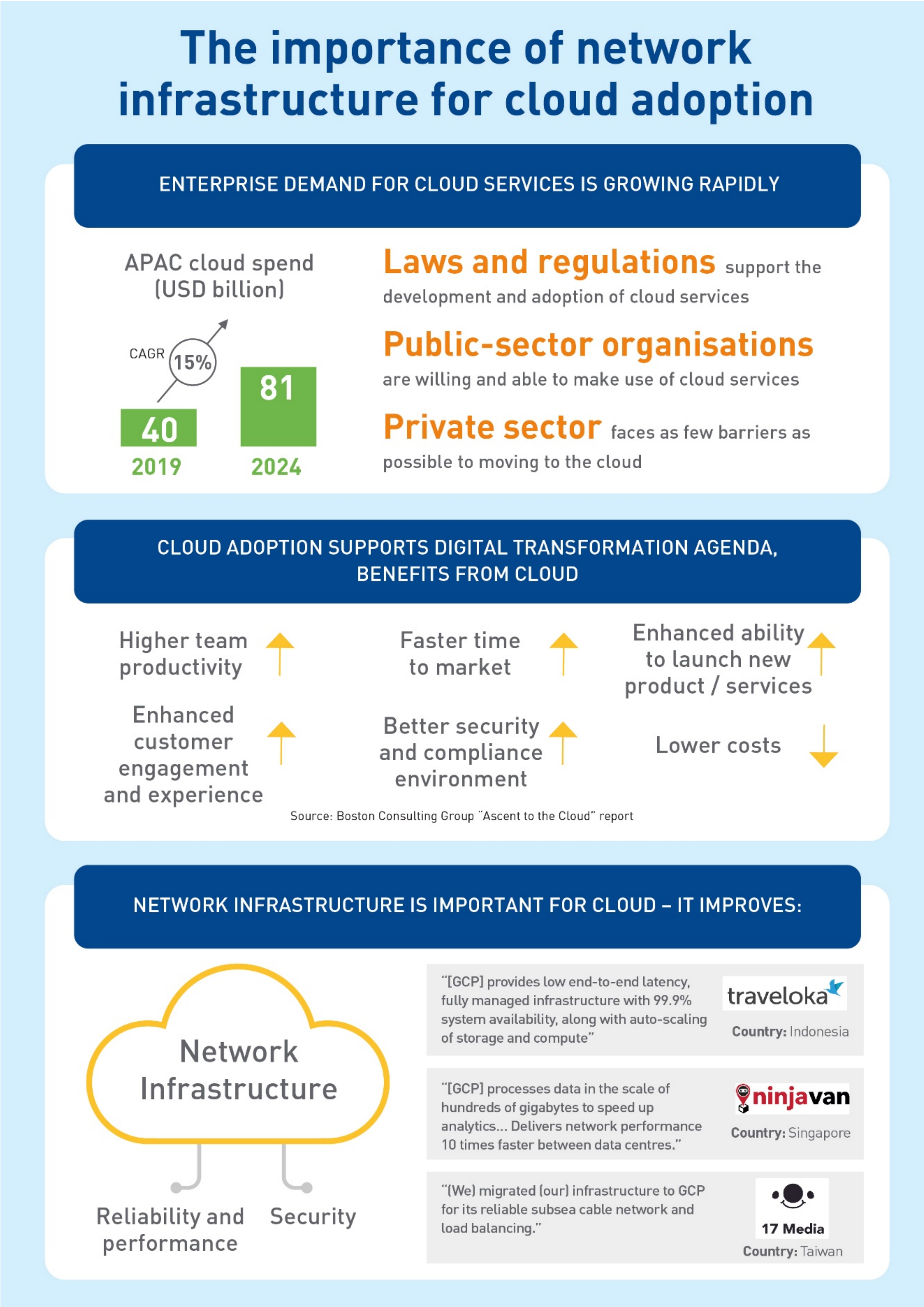
4 The importance of network infrastructure for cloud adoption

Infrastructure investments in APAC, by Google and other firms, expand the scale and improve the performance, resilience and security of their networks. These improvements enable more people and firms to access and use the internet, online services and applications, public cloud services and even private corporate networks. The value derived from the enhanced usage of these services in turn lead to significant economic benefits. To fully realise these benefits, governments in APAC need to ensure that laws and regulations support the development and adoption of such services.

The onset of the COVID-19 crisis has highlighted the importance of cloud platforms and services to enable many sectors of the economy to keep working, despite social distancing and workplace closure measures. Whilst there is considerable uncertainty pertaining to the future economic environment, the outlook for cloud services demand remains positive.

In this section, we:

- Discuss how companies in APAC are progressively integrating cloud services in their IT strategy, and increasingly migrating fully to cloud-based IT. We highlight in particular the factors that drive or inhibit the migration of firms and public-sector organisations to cloud-based information technology. We also illustrate the importance of this explosion of demand for cloud services on the economy of the APAC region specifically, leveraging existing literature to illustrate the potential economic impact of cloud (Section 4.1).
- Explain how Google's network infrastructure investment contributes to the performance, reliability and security of its cloud platform, which is essential to realising the economic potential of cloud in the region (Section 4.2).


The importance of network infrastructure for cloud adoption
ENTERPRISE DEMAND FOR CLOUD SERVICES IS GROWING RAPIDLY
APAC cloud spend (USD billion)
CAGR 15%
40
81
2019
2024
Laws and regulations support the development and adoption of cloud services
Public-sector organisations are willing and able to make use of cloud services
Private sector faces as few barriers as possible to moving to the cloud
CLOUD ADOPTION SUPPORTS DIGITAL TRANSFORMATION AGENDA, BENEFITS FROM CLOUD
Higher team productivity
Faster time to market
Enhanced ability to launch new product / services
Enhanced customer engagement and experience
Better security and compliance environment
Lower costs
Source: Boston Consulting Group "Ascent to the Cloud" report
NETWORK INFRASTRUCTURE IS IMPORTANT FOR CLOUD – IT IMPROVES:
Network Infrastructure
Reliability and performance
Security
"[GCP] provides low end-to-end latency, fully managed infrastructure with 99.9% system availability, along with auto-scaling of storage and compute"
traveloka
Country: Indonesia
"[GCP] processes data in the scale of hundreds of gigabytes to speed up analytics… Delivers network performance 10 times faster between data centres."
ninjavan
Country: Singapore
"[We] migrated [our] infrastructure to GCP for its reliable subsea cable network and load balancing."
17 Media
Country: Taiwan

4.1 Enterprise demand for cloud services is growing rapidly, generating positive economic and environmental impacts

Public cloud adoption by businesses across APAC is increasing rapidly, with spend on public cloud expected to increase from USD40 billion in 2019 to USD81 billion in 2024

As businesses and governments become increasingly adept at integrating digital technology into their day-to-day processes, they collect, store and analyse increasingly large amounts of data. The traditional IT infrastructure deployed by businesses and governments makes use of on-premises servers and systems that rarely provide the scalability and cost efficiency that many organisations now require. As a result, organisations have started to move their data and applications to the cloud. This could be in the form of a private cloud where the organisation operates the cloud infrastructure for its own dedicated use, or as a public cloud where third-party cloud service providers (such as Google Cloud) deploy and operate the infrastructure and deliver services to the customer over the internet. Hybrid cloud environments are also possible; in these, enterprises utilise a mix of on-premises deployments, private cloud and public cloud services.

Based on estimates from Analysys Mason Research, the growth in adoption of cloud services is so far largely driven by large enterprises, which include multinational companies (MNCs), with a take-up rate of almost 50% in 2019 compared to 7% for small, medium and micro businesses (SMBs) (see Figure 4.1).[74]

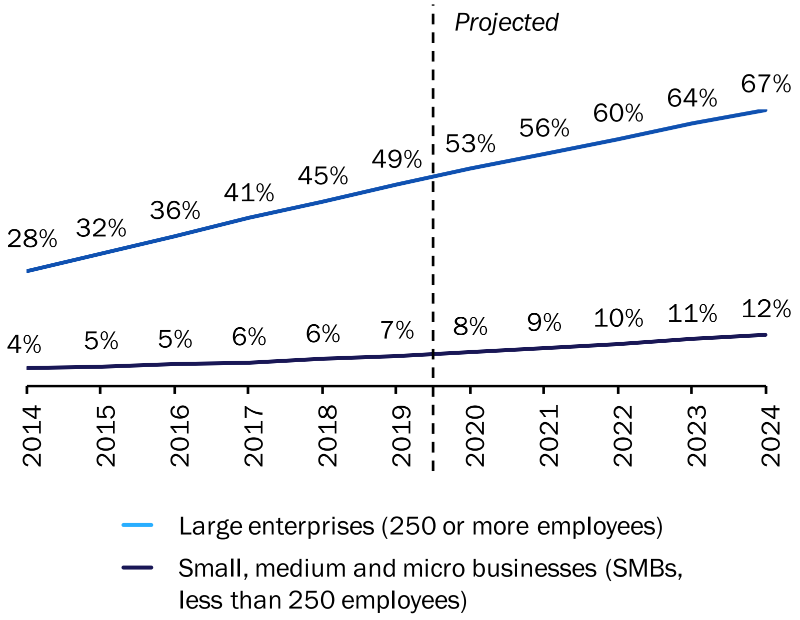


Figure 4.1: Public cloud adoption rate comparison of SMBs and large enterprises in APAC [Source: Analysys Mason Research, 2020]

[74] The studies underlying the cloud market forecasts were conducted before the onset of the COVID-19 pandemic and thus did not include the effects on the economy arising from COVID-19. We have left these forecasts unchanged, although the forecasts used for the main economic impact assessment in this report reflect updated forecasts as of June 2020. The size of the cloud services market may actually increase faster than anticipated as a result of COVID-19

Large enterprises and MNCs have been early adopters of cloud largely because they tend to have more complex IT needs than smaller firms, and have access to in-house expertise that allows them to assess, understand and reap the benefits of cloud adoption before it becomes more mainstream. A VMware study shows that more than 90% of enterprises with over 1000 employees use a multi-cloud environment combining on-premises, private cloud and public cloud deployments, or expect to be using such a multi-cloud environment soon.[75]

On the other hand, SMBs may not have the resources to analyse and realise the benefits of cloud technology, and indeed may be unaware that the software-as-a-service (SaaS) solutions they do use (e.g. Office 365, Google Apps, Xero) are in effect cloud services.[76] As the technology maturity of SMBs increases over time, we expect the cloud adoption rates of SMBs to also steadily improve.

As a result, Analysys Mason Research expects cloud adoption rates in APAC to increase over the next five years to reach 67% of large enterprises and 13% of SMBs in 2024. Public cloud spend in APAC is expected to continue to grow strongly from USD40 billion in 2019 to reach USD81 billion in 2024, representing a growth rate of 15% annually (Figure 4.2).

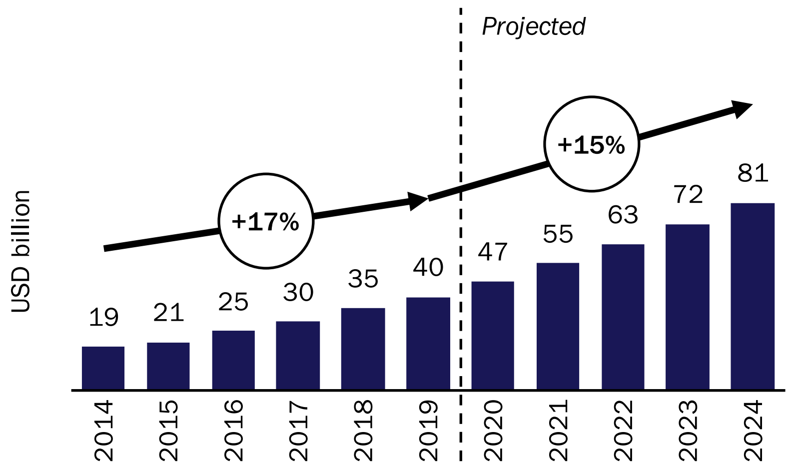


Figure 4.2: Public cloud spend[77] in APAC [Source: Analysys Mason DataHub, 2020]

Improvements in connectivity infrastructure, data security and regulations are required to support the expected growth in cloud adoption across APAC

Countries across APAC differ in their level of cloud readiness. Advanced economies such as Australia, Singapore and Japan have high levels of cloud adoption, ranging between 11% and 27% in 2019. In comparison, developing economies such as the Philippines, Thailand, Malaysia and Indonesia have

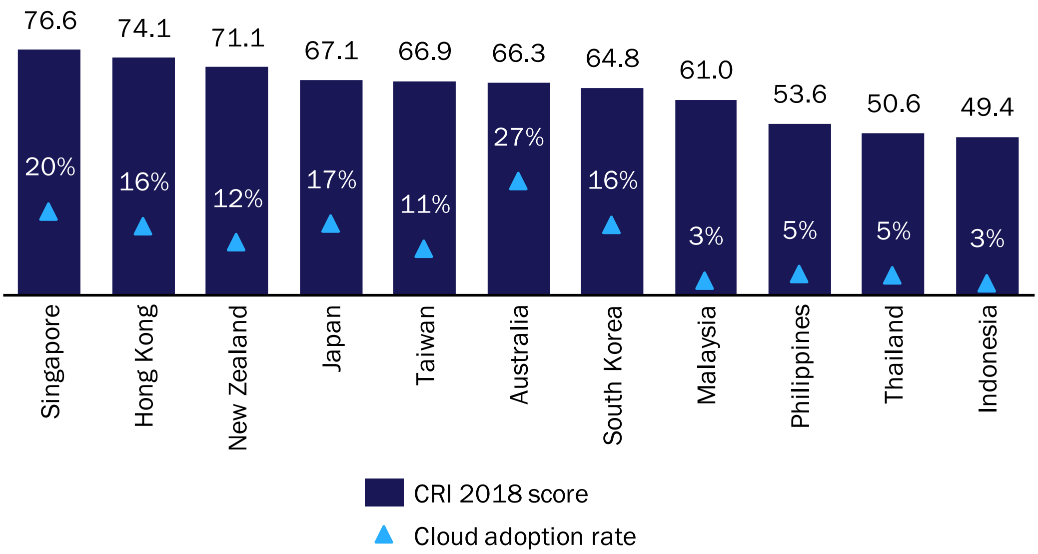
75 451 Research – "Going Hybrid – Demand for Cloud and Managed Services across Asia-Pacific"; see https://cloud.vmware.com/community/wp-content/uploads/9/sites/9/2019/02/10549_Advisory_BW_NTT_VMware.pdf

76 Accenture – "Driving New Growth for APAC SMBs"; see https://www.accenture.com/_acnmedia/pdf-104/accenture-smb-apac-driving-new-growth.pdf

77 'Cloud spend' refers to the sum of SaaS, infrastructure-as-a-service (IaaS) and platform-as-a-service (PaaS) retail revenue accrued to cloud service providers and telecoms operators

lower levels of take-up, at 5% or below for each of these countries. Well-connected countries generally score highly in the Asia Cloud Computing Association's Cloud Readiness Index (see Figure 4.3).

Figure 4.3: Cloud Readiness Index 2018[78] score and cloud adoption rate by APAC economies in 2019 [Source: Asia Cloud Computing Association, Analysys Mason, 2020]



To fully realise the benefits of cloud computing, governments in APAC need to ensure that their economies are 'cloud-ready', by ensuring that laws and regulations support the development and adoption of cloud services, that public-sector organisations are willing and able to make use of these services, and that the private sector faces as few barriers as possible to moving to the cloud.

One of the key contributing factors to cloud readiness is the state of maturity of connectivity infrastructure. A more developed connectivity infrastructure (including submarine cables and edge infrastructure) enables cloud services to be delivered more reliably and effectively and therefore helps to create a more conducive environment for cloud adoption by businesses.

Increased cloud adoption generates a positive economic impact, through increase in GDP and jobs, and drives better environmental outcomes

Across APAC, businesses are embarking on digital transformation and in support of this trend, governments have been introducing initiatives to ensure that the right underlying infrastructure and regulatory environment are available to businesses.[79]

78 The Asia Cloud Computing Association's Cloud Readiness Index measures the readiness of economies to embrace cloud adoption; measurements comprise a mix of quantitative parameters and qualitative assessment; see https://www.slideshare.net/accacloud/the-cloud-readiness-index-cri-2018-by-the-asia-cloud-computing-association-227586361

79 The ASEAN Connectivity 2025 masterplan is a notable initiative within APAC that highlights digital innovation as one of the five key strategic areas that ASEAN member states will need to support; see https://asean.org/storage/2016/09/Master-Plan-on-ASEAN-Connectivity-20251.pdf

Cloud is an important technology that underpins digital transformation (see quote) – more than 90% of organisations surveyed by the Cloud Industry Forum said that cloud is critical or important to their digital transformation strategy.[80] Cloud services, such as those offered on the Google Cloud Platform (GCP), offer companies access to a flexible, reliable and secure infrastructure.[81]

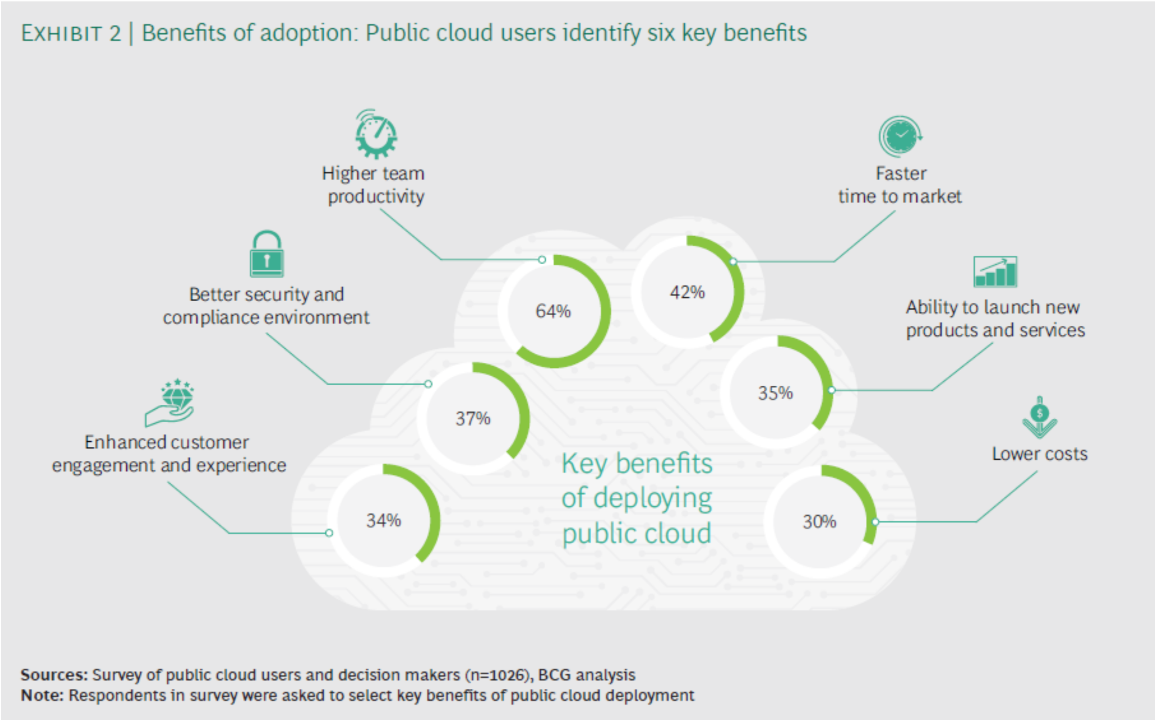
According to a study conducted by BCG, public cloud services deliver six key benefits for both 'traditional' companies and digital businesses (Figure 4.4) which results in tangible financial benefits to APAC economies by driving business profitability.

> "Cloud is very much part of the Digital Transformation agenda… Unbound, at least from a technology point of view, from fixed infrastructure and proprietary IT, businesses using Cloud are free to take more risks and are able to respond quickly to changing market conditions."
>
> **Stephen Ball**
> Aspect Software (Senior Vice President of Europe & Africa)

80 Cloud fundamental to Digital Transformation strategies, Cloud Industry Forum; see https://www.cloudindustryforum.org/content/cloud-fundamental-digital-transformation-strategies

81 See https://www.information-age.com/golden-age-of-startups-technology-lowering-barriers-to-entry-increasing-barriers-to-exit-123483996/

Figure 4.4: Benefits of public cloud adoption [Source: BCG, 2019]



The resultant increase in profit generation from businesses adopting cloud will, in return, generate additional economic activity, such as through increased hiring of labour and increased spend on suppliers, and have a positive economic impact in the markets in which these businesses operate.

A BCG study in 2019 showed that the continued growth in cloud expenditure by organisations could generate between USD375 billion and USD580 billion in cumulative GDP in APAC between 2019 and 2023, resulting in between 950 000 to 2.9 million additional jobs.[82] Other studies beyond APAC also confirm the economic benefits of cloud adoption. A 2019 study by the Internet Association, for example, estimates that cloud adoption added USD214 billion in GDP in the USA in 2017, which supported 2.15 million jobs.[83] A 2017 study by the European Commission estimates that cloud computing could have generated additional revenue of EUR449 billion between 2015 and 2020.[84]

In addition to economic benefits, the increase in the use of cloud computing also reduces companies' carbon footprint, resulting in positive environmental outcomes. Google estimates that a typical company migrating to the cloud would achieve a 68–87% reduction in energy on computing, and also a similar reduction in carbon emissions.[85] A study commissioned by Microsoft also finds that

82 BCG study sponsored by Google, See https://www.bcg.com/publications/2019/economic-impact-public-cloud-apac/default.aspx

83 See https://internetassociation.org/publications/examining-economic-contributions-cloud-united-states-economy/

84 See https://ec.europa.eu/digital-single-market/en/news/measuring-economic-impact-cloud-computing-europe

85 See https://static.googleusercontent.com/media/www.google.com/en//green/pdf/google-apps.pdf

cloud computing is more energy efficient and carbon efficient compared to on-premises IT.[86] This is because cloud services are based on shared infrastructure and computing resources which are utilised across multiple cloud customers, thereby maximising the utility of resources.

4.2 Google's network investments contribute to the reliability and security of its cloud platform, which are critical for enterprises to move to the cloud

The delivery of data to and from cloud customers relies on Google's network infrastructure

In the past few years, Google has focused its efforts on developing its public and hybrid cloud platform, GCP. These efforts are global, and APAC is an important region for GCP. At the end of 2019, GCP had been deployed in seven cloud regions in APAC (excluding India), covering six economies (see Figure 4.5). A new cloud region was opened in Seoul, South Korea, in early 2020 and further expansion reached Indonesia in the middle of 2020,[87] which will bring latency down further for cloud customers in the region.

Figure 4.5: Google's cloud regions[88] in APAC [Source: Google, 2020]

Google's network infrastructure investments[89] enable cloud services to run on the GCP. These networks connect various cloud regions with each other, providing cloud customers with access to resources beyond the cloud region they are based in. As Google Cloud expands to new cloud regions within APAC, network infrastructure investments will need to keep pace with this growth.

86 See https://download.microsoft.com/download/7/3/9/739BC4AD-A855-436E-961D-9C95EB51DAF9/Microsoft_Cloud_Carbon_Study_2018.pdf

87 See https://cloud.google.com/about/locations

88 Each region comprises three zones; see https://cloud.google.com/about/locations#regions

89 In deploying submarine cables, purchasing international capacity, deploying edge network servers and metro networks

Deployment of network infrastructure enhances the performance and reliability of Google Cloud

> "A lot of our customers, especially in Asia, are sensitive to latency, availability and uptime – and that's what our network is offering."
>
> Paul-Henri Ferrand
> (Formerly part of Google's Global Customer Operations)

As discussed in Section 3.2, Google's APAC network infrastructure is planned and deployed in such a way to ensure resilience. Multiple paths are built between cloud regions, which enable cloud services to withstand multiple failure events. Google's network is interconnected with most ISPs in APAC, providing Google the ability to deliver traffic close to the end users. Using Google's network to carry traffic around APAC provides higher availability and better performance for customers than relying solely on the public internet.

A study published by ThousandEyes shows that end-user traffic from Google Cloud enters the internal Google network that is located closest to the customer, irrespective of geographical location – this makes Google Cloud traffic less reliant on the public internet.[90] The same study also provides evidence that Google Cloud achieves lower latency in Asia[91] compared to other cloud service providers (the latter largely rely on the public internet to carry end-user traffic).

Google builds its regional and global network to handle Cloud customer traffic and also its global consumer traffic. The resultant large scale investment brings flexibility advantages to Cloud customers. Google's network can withstand traffic surges during extraordinary events that are important to cloud customers (see quote).

Case study: Google's network infrastructure investments improves flexibility and resilience to end users and customers, as evidenced during the COVID-19 crisis

In 2019–20, the COVID-19 virus spread rapidly and affected many countries around the world. The highly contagious nature of COVID-19 led to many nations implementing measures to encourage social distancing, resulting in people staying at home in what some have called the 'world's biggest work-from-home experiment'.[92] As people globally use more of the internet for both their productivity and entertainment needs, including engaging in bandwidth-intensive video consumption, traffic carried on the networks in the connectivity value chain spiked significantly.

90 See https://marketo-web.thousandeyes.com/rs/thousandeyes/images/ThousandEyes-Cloud-Performance-Benchmark-2019-2020-Edition.pdf

91 As defined by ThousandEyes based on traffic from ISPs located in China, UAE, Vietnam, Turkey, Indonesia, Hong Kong, the Philippines, Japan, India, Saudi Arabia, South Korea, Singapore, Taiwan, Israel

92 Internet Society, see https://www.internetsociety.org/blog/2020/02/is-the-internet-resilient-enough-to-withstand-coronavirus/

Google Meet is Google's premium video conferencing product and by April 2020, its peak daily usage had grown by over 30 times compared to usage in January. In April 2020, it hosted roughly 3 billion minutes of video meetings daily and added about 3 million new users daily, surpassing 100 million daily meeting participants by the end of the month.[93] Google Meet runs on Google's secure, resilient global cloud infrastructure, allowing it to manage the unprecedented surge in users and traffic.

PwC, a global professional services organisation and Google Cloud customer, recently enabled more than 275 000 of its employees to work from home in response to COVID-19. The company's Google Meet video meetings consequently tripled over a short period of time. Due to Google's robust cloud infrastructure, PwC employees were able to seamlessly connect both with internal teams as well as externally with their customers and partners. This illustrates the importance of having access to a flexible, reliable and secure infrastructure to enable business continuity during unforeseen and changing market conditions.

> “As more and more businesses rely on connecting an at-home workforce to maintain productivity, we've seen surges in the use of Google Meet, our video conferencing product, at a rate we've never witnessed before. […] Despite this growth, the demand has been well within the bounds of our network's ability.”
>
> **Thomas Kurian,** Google Cloud (CEO)
>
> “We've designed our network to perform during times of high demand. The same systems we built to handle peaks like the Cyber Monday online shopping surge, or to stream the World Cup finals, support increased traffic [generated] during this pandemic […] peak traffic levels are well within our ability to handle the load.”
>
> **Urs Hölzle,** Google (Senior Vice President, Technical Infrastructure)

Google has since announced that Google Meet would become generally available to internet users worldwide, which should lead to further growth in traffic, and demonstrates how confident it is of the ability of its infrastructure to continue scaling rapidly.

Google Cloud's network capabilities have been recognised and appreciated by many enterprises, including Carousell, Ninja Van and Traveloka in the APAC region and PayPal and Vodafone in the broader global landscape – case studies and testimonials from these players are documented in the Google Cloud blog.[94]

93 Google Cloud Blog, see: https://www.blog.google/products/meet/bringing-google-meet-to-more-people/

94 See https://cloud.google.com/blog/

Case study: Traveloka deployed GCP solutions to support its rapid business expansion

Traveloka is a technology unicorn[95] in the online travel business and is based in Indonesia. Since its inception in 2012, Traveloka has grown its operations to cover seven countries in APAC, supporting more than 40 million active monthly users and an average of 500 000 daily booking transactions.[96]

One of the most strategic parts of Traveloka's business is a streaming data processing pipeline that powers multiple business use cases, including fraud detection, ad optimisation and the monitoring of business performance. Since its business was scaling rapidly, Traveloka saw the need to evolve its data analytics architecture and outlined the following requirements to support its growth:

- Low end-to-end latency within a guaranteed service-level agreement
- Fully managed infrastructure, providing resilience/99.9% end-to-end system availability and auto-scaling of storage and compute

Traveloka eventually opted for and deployed GCP solutions, namely 'Cloud Pub/Sub', 'Cloud Dataflow' and 'BigQuery' to meet its performance requirements.[97] Supported by Google's network infrastructure, these GCP solutions allowed Traveloka to not only meet its end-to-end availability requirement but also to manage large volumes of data quickly and handle changes in volume and throughput. Empowered with faster speed, greater reliability and enhanced availability through the resilient network infrastructure underpinning GCP, Traveloka is now well-positioned for the next phase of its business expansion.

Besides improving the performance of cloud services, Google's network investments underpin, at the infrastructure layer, a wide suite of cloud security controls and tools.[98] This is an important factor driving cloud adoption (see quote).

> "a CTO of a large retailer in Australia told us that security was a key reason the company decided to migrate to the cloud."
>
> **Boston Consulting Group**
> "Ascent to the Cloud" report

GCP customer traffic carried on Google's own network is shielded from internet exposure, making it less likely that it will be attacked, intercepted or manipulated by malicious actors. Google has also taken a proactive stance in demonstrating its compliance to regulatory security requirements in key APAC economies. These documents can be found on the Google Cloud Blog.[99]

95 Defined as a start-up company with a value of over USD1 billion

96 Bangkok Post – "Traveloka widens to lifestyle", Nov 2019; see https://www.bangkokpost.com/business/1792399/traveloka-widens-to-lifestyle

97 Traveloka, Google Cloud – "Traveloka's journey to stream analytics on Google Cloud Platform", Apr 2018; see https://medium.com/traveloka-engineering/travelokas-journey-to-stream-analytics-on-google-cloud-platform-3d013d6bf7c9

98 See https://cloud.google.com/security/overview

99 See https://cloud.google.com/security/compliance/offerings#/regions=Asia_Pacific

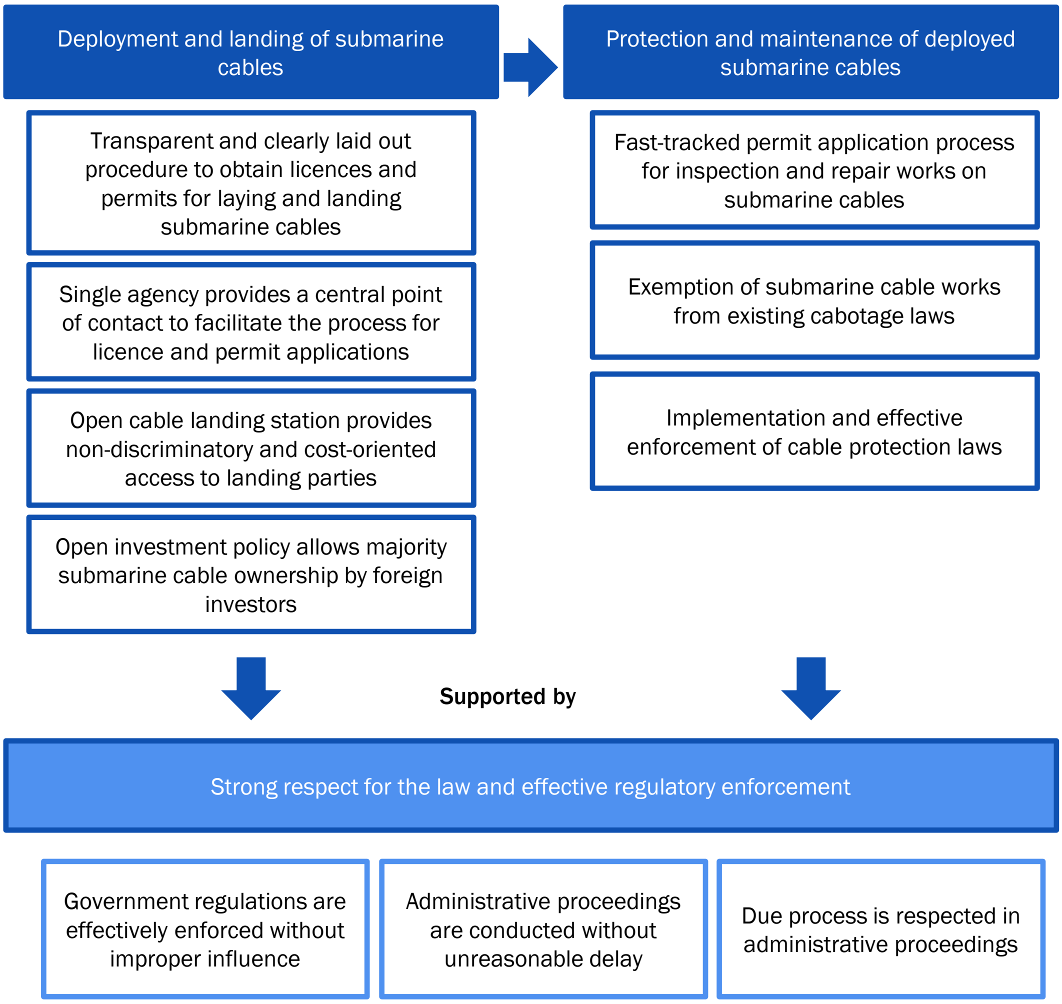
5 The importance of supportive regulatory and investment regimes for submarine cable investment in APAC

The regulatory and investment regimes across APAC play a critical role in influencing the supply of submarine cables in each economy. Economies with strong international connectivity typically have regulatory frameworks that, include clear licensing procedures, relatively straightforward licensing processes, open foreign investment policies, cable protection laws and flexible cabotage[100] provisions for cable repairs and maintenance. They also have strong regulatory enforcement principles with adherence to lawful procedures.

Such regulatory and investment environments improve the attractiveness of an economy for submarine cable investment. As described in the previous section, attracting more cables can unlock significant economic benefits. Conversely, policies that deter investments in new cables are slowing down increases in internet take-up and usage of new internet applications by consumers and businesses. A summary of the best practices observed in the APAC region are summarised in Figure 5.1 below.

[100] Cabotage laws refer to the governance of domestic maritime activities that favours a nation's own citizens and is applicable to territorial waters; see https://3snn221qaymolkgbj4a0vpey-wpengine.netdna-ssl.com/wp-content/uploads/2018/09/World-Cabotage-Study_Overview_Final.pdf

Figure 5.1: Best practices in regulatory and investment factors relating to submarine cable investments [Source: Analysys Mason, 2020]



This section, we explore how regulatory and investment regimes in APAC economies support or hinder:

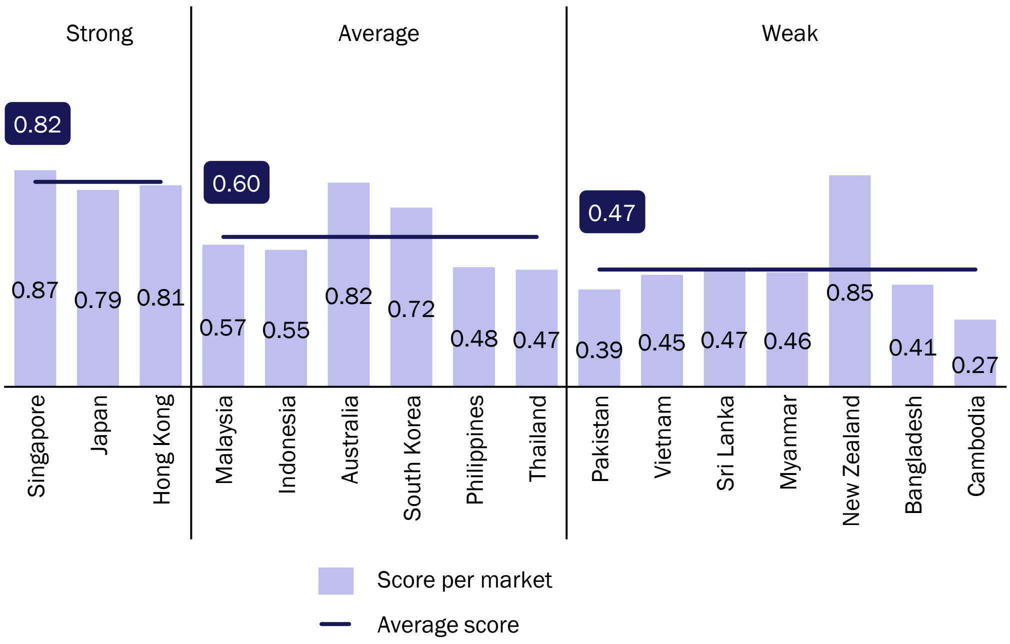
- the relative positioning of APAC economies with respect to the extent to which regulations are fairly and effectively implemented and enforced (Section 5.1)
- the initial deployment and landing of submarine cables (Section 5.2)
- the protection and ongoing maintenance of submarine cables after launch (Section 5.3).

5.1 Strong regulatory enforcement and respect for due process boost investors' confidence in the country

Deployment of network infrastructure assets, in particular for submarine cables, are capital - intensive investments. A business-friendly environment is essential to providing investors with the confidence to make these long-term financial commitments.

Strong adherence to legal due process is also important in the event of any disputes between submarine cable owners and other parties. Therefore, countries with strong supply of international connectivity tend to score highly on the Rule of Law Index, showing the positive correlation between an effective regulatory environment and the quantum of submarine cable infrastructure investments (Figure 5.2). New Zealand has such an environment, but relatively few cables due to its unique geography.

Figure 5.2: Rule of Law Index – Regulatory Enforcement factor score[101] [Source: World Justice Project, 2020]



It is therefore advisable for countries looking to stimulate submarine cable investments to ensure that the law and regulations are aligned with international practices, and enforcement processes are maintained at high standards. This would provide investors with a higher level of confidence to invest.

5.2 Investment decisions are affected by the level of ease and certainty of the cable laying and landing process for submarine cable owners

Submarine cables typically traverse a long path across international waters before branching off to land in a CLS in the APAC region. Various licences and permits issued by regulatory authorities from each individual country will be required for both the laying and landing process, and there will be varying levels of complexity, restriction on foreign ownership and time required to receive approvals.

Open CLSs are a growing trend, and there are a few examples of these within the region. An open CLS provides for non-discriminatory access to the CLS for all submarine cable owners (hence the

101 World Justice Project – "Rule of Law Index 2020", see https://worldjusticeproject.org/our-work/research-and-data/wjp-rule-law-index-2020

term "open"), and the price of accessing and using facilities in the CLS is typically cost-oriented, with the availability of multiple terrestrial backhaul options to PoPs in the cities.

Procedures to obtain licences or permits for laying and landing submarine cables should be transparent and clearly laid out

A 'transparent' regime offers clear and easily accessible guidance, criteria and procedures for the application of licences and permits. This enables investors to build business cases that are more robust, and to obtain permits and licences efficiently; conversely, a less transparent environment often means that submarine cable owners need to commit significant resources to identify the appropriate parties to work with and navigate the uncertainty regarding the process and outcome. In some cases, approval criteria are not transparent, which exposes investors to political risk.

Leading regulators in APAC provide publicly available documentation on the required licences and permits as well as the procedures to obtain them. Examples of best practices are provided below:

- In **Singapore**, IMDA publishes the key steps and relevant stakeholders for the deployment of submarine cables in a single document.[102]
- In **Hong Kong**, information on permits and procedures relating to laying, landing and repairing submarine cables are publicly available on OFCA's website.[103]
- In **Japan and Taiwan**, the application procedures for licences and permits are mature and well-established, providing cable owners certainty on the outcome of their applications.

Streamlining often complex licensing / permitting processes help investors shorten the time required to plan and launch new submarine cables

Obtaining a licence/permit to lay a submarine cable can often be a complex process because it involves multiple stakeholders with potentially very different requirements. In practice, cable owners often have to seek permission from a fragmented number of government bodies - approvals are required from the land, marine, environmental and urban planning departments in each country the submarine cable passes through and lands in. The same challenges apply to repair permits. Ease and consistency and transparency of permitting is a consideration for many submarine cable investors.

In some cases, submarine cable owners also have to receive approval from private parties, such as the fishery industry. We understand from discussion with industry participants that in such cases, due consideration must be given for private fishing agreements, including compensation, to be made

102 Infocomm Media Development Authority (IMDA) – "Guidelines on deployment of submarine cables into Singapore", see https://www.imda.gov.sg/-/media/imda/files/regulation-licensing-and-consultations/codes-of-practice-and-guidelines/subcablelanding.pdf?la=en

103 Office of the Communications Authority (OFCA), see https://www.ofca.gov.hk/en/industry_focus/telecommunications/facility_based/infrastructures/submarine_cables/index.html

with the fishery industry, typically without government intervention. This represents an additional layer of uncertainty and adds to the time and costs required to plan and deploy a new submarine cable.

There have also been legitimate concerns that the laying of submarine cables could have a negative impact on the marine environment. In some APAC economies, regulators have imposed measures on submarine cable owners as precursors to permit approvals such as environmental impact assessments. The nature of these requirements may sometimes be inconsistent in practice with internationally agreed standards (as provided for in the United Nations Convention on the Law of the Sea (UNCLOS)) and could result in long delays. It is important to encourage dialogues between regulators, submarine cable industry players and environment organisations to ensure alignment and understanding of industry developments and regulatory best practices.[104] This would help achieve the dual goals of protecting and preserving the marine environment and enable a more efficient permitting process.[105]

The telecoms regulators in leading APAC economies adopt a proactive stance in co-ordinating and assisting investors with this process. The following can be considered as examples of best practice:

- In **Singapore**, IMDA acts as the lead agency to facilitate the process for application of licences and permits. This includes outlining the key steps, helping to co-ordinate with relevant stakeholders and providing procedural guidance to interested parties for the deployment of submarine cables, all of which reduces complexity for investors.
- In **Hong Kong**, OFCA provides a single-point-of-contact service to provide a centralised contact point to co-ordinate applicants and the relevant government parties.

Open cable landing stations encourage a broader range of investors to take a role in new submarine cables, and are conducive to better connectivity outcomes from new cables

CLSs are a key component of submarine cable systems. Once the submarine cable owners receive the necessary permits to lay and land the submarine cable, a branch of the cable is deployed in domestic waters, lands in a coastal location (at a 'beach manhole') and terminates at a CLS, where the power feed equipment is located. In the CLS, the submarine cable interconnects with inland terrestrial networks, bringing capacity to domestic telecoms providers and corporate users of bandwidth on the cable.

Recent regulatory actions have created an environment that allows foreign submarine cable owners to operate CLSs and facilitates open access to international cables, supporting non-discriminatory access and cost-oriented pricing principles.

104 The submarine cable industry, together with environmental regulators, have put in place a series of measures to reduce any impact on vulnerable ecosystems

105 The International Cable Protection Committee (ICPC) encourages scientific research into the interactions between submarine cables and the marine environment, including collaborating with the United Nations Environment Programme (UNEP), see Submarine cables and the oceans: connecting the world, ICPC

The following are examples of economies adopting an open CLS regime:

- In **Singapore**, **Hong Kong** and **Japan**, foreign-owned, non-incumbent operators are allowed to operate CLSs as long as the operator fulfils the prerequisite conditions, such as obtaining a facilities-based operator licence.
- In **Singapore**, the IMDA takes an active role in regulating interconnection agreements involving a dominant licensee via the Reference Interconnection Offer (RIO) requirement to ensure non-discriminatory terms and rates.[106]
- In **Hong Kong**, the OFCA has the power to determine interconnection rates for CLS access via a cost-based approach.[107]
- In **Pakistan**, the Karachi CLS was launched in 2019 as the first carrier-neutral and open-access CLS, signifying a move towards creating a more open environment.[108]

Restrictions on foreign investments tend to hinder submarine cable investments

In most economies, restrictions on foreign ownership take the form of a simple limit on the share of equity that non-residents are allowed to hold; in other economies, there are mechanisms to scale down the foreign ownership over time, whether through an eventual public offering or through a concessionary arrangement with the regulator.

Foreign ownership equity caps could have implications in relation to the viability of the business case and operating model of a submarine cable venture. Submarine cable investors have to evaluate whether the equity benefits are commensurate with the operating risks and consider the availability of suitable local partners. In some economies with mandatory local-majority ownership, investors would also need to consider relinquishing management control and transferring asset titles to the local partner. The presence of these constraints could ultimately make foreign investors more hesitant to invest.

- APAC economies with a strong supply of submarine cables, such as **Australia**, **Singapore**, **Japan** and **Hong Kong**, all have open investment policies and no foreign equity limits for submarine cable ownership.
- In **economies with greater restrictions**, local investors play a major role in funding and enabling new cables. This puts these economies at a disadvantage when it comes to realising the economic benefits of increased connectivity.

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106 IMDA, see https://www.imda.gov.sg/-/media/Imda/Files/Regulation-Licensing-and-Consultations/Frameworks-and-Policies/Interconnection-and-Access/RIO-Agreements-with-FBOs/Main.pdf

107 OFCA, see https://www.ofca.gov.hk/filemanager/ofca/en/content_757/traac4_2019.pdf

108 ProPakistani, see https://propakistani.pk/2019/04/17/pakistan-to-get-its-first-carrier-neutral-submarine-cable/

5.3 Adequate protection of submarine cables and ability to perform timely maintenance are also essential for both submarine cable owners and for users of bandwidth

Submarine cables are essential to the delivery of internet traffic globally, but they are also susceptible to damages from natural disasters and human activities. Cable disruptions can result in network congestion issues such as higher latency and lower speeds for internet services. In the worst-case scenario, the total loss of network transmission could cut off affected countries from the internet entirely, as occurred in Bangladesh in 2007;[109] and in other cases, end users experienced severe disruptions to their use of internet, such as that in Taiwan in 2015 and Australia in 2017.[110] The failure of the internet in APAC countries today would have a severe impact on both businesses and consumers who are increasingly reliant on it for daily activities. Therefore, it is in the interest of countries to expedite the permit process for submarine cable repairs with ASEAN member states encouraged to reduce the permit issuance process to within seven to ten working days.[111]

Once deployed and launched, submarine cables rely on cable protection legislation for protection from human activities that may damage the cable, such as bottom trawl fishing, ship anchoring and sand dredging. In the event of any disruption, submarine cable owners would need to be able to launch timely responses to identify the location of the fault and send repair ships to repair the faults.

Cable protection laws should be strengthened and enforced

Cable protection laws serve to reduce the risk of cable damage caused by human activities within territorial waters. In some countries, activities in areas with submarine cables are controlled by law via designated zones. Prohibited activities typically include fishing and anchoring, which have historically been one of the key causes of cable damage, especially in economies with strong fishery and maritime industries.[112] Damage to submarine cables can also be criminalised, with harsh penalties in place for human activities that causes damage.[113]

- **Australia** has implemented legislation to protect submarine cables in its Exclusive Economic Zone (EEZ) – this includes cable protection zones and active compliance monitoring.
- Advanced APAC economies such as **Singapore**, **Australia** and **Hong Kong** have established criminal penalties for submarine cable damage.[114]

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109 Harvard Kennedy School – "Cyberspace in deep water"; see https://www.belfercenter.org/sites/default/files/legacy/files/PAE_final_draft_-_043010.pdf

110 See https://www.linkedin.com/pulse/world-class-subsea-network-darrin-webb/ (Taiwan) and https://www.straitstimes.com/singapore/cables-hit-by-typhoons-but-internet-links-here-intact (Australia)

111 https://asean.org/storage/2012/05/ASEAN-Guidelines-for-Strengthening-Resilience-and-Repair-of-Submarine-Ca....pdf

112 International Cable Protection Committee – fishing and anchoring activities make up 70% of all cable faults; see https://www.iscpc.org/documents/?id=1753

113 UNCLOS Article 113; see https://www.un.org/depts/los/convention_agreements/texts/unclos/unclos_e.pdf

114 Asia-Pacific Economic Cooperation (APEC) – "Submarine cable information sharing project: Legislative practices and points of contact"; see http://publications.apec.org/-/media/APEC/Publications/2012/3/Submarine-Cable-Information-Sharing-Project/2012_tel_submarineproject.pdf

Repair works on submarine cables should be exempt from existing cabotage laws

Cabotage laws include restrictions such as the need to fly the national flag of a country, to have local crews, and to impose caps on foreign ownership for vessels, for these vessels to be allowed to engage in any form of economic activity within territorial waters, including repairing submarine cables. These requirements add additional layers of operational considerations which could discourage foreign submarine cable investors due to potentially higher operating expenditure and loss of quality control in local territorial waters.

An important point to note is that submarine cable repair ships are highly specialised, purpose-built vessels and typically serve multiple countries in a region. It is not practical for each country to have its own vessels, as the utilisation will likely be low if these vessels can only serve one economy. It is therefore good practice to exempt submarine cable repair activities from existing cabotage laws. This exemption also shortens the time required to repair the fault and bring international capacity back online.

- In **Malaysia**, the government recognises the need to expedite submarine cable repairs and made an exemption to the cabotage policy on foreign vessels conducting such repairs in 2019.
- In **Australia**, the government has effectively deregulated cabotage laws in relation to critical infrastructure, including submarine cables.

Permit application processes for inspection and repair works on submarine cables need to be faster

Damage to submarine cables reduces the supply of international bandwidth, and negatively impacts local ISPs' ability to serve traffic to end users, which has an economic cost as discussed in this report. Before a ship can enter the national waters of any country, it will have to receive the necessary permit(s), typically with the maritime authority. This is required even if there is exemption of cable repair works from cabotage laws as the relevant government agency will need to know the location and duration of the repair works as well as the particulars of the ships engaged to perform such repairs. Governments should therefore shorten the process for submarine cable owners to receive the necessary permits to start repair works as soon as possible (i.e. seven to ten working days has been identified as the best practice target by the ASEAN[115]), should damage occur.

- In **Hong Kong**, OFCA co-ordinates with other government departments to expedite the application processes for statutory approvals during events requiring emergency repairs.
- In **Taiwan**, there is an "approval in principle" approach for submarine cable repair works which vastly reduces the time to receive permits.[116]

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115 See https://asean.org/storage/2012/05/ASEAN-Guidelines-for-Strengthening-Resilience-and-Repair-of-Submarine-Ca....pdf

116 Based on interviews with key telecoms operators in Taiwan, the Ministry of the Interiors and Maritime Port Bureau provides a "approval in principle" which enables repairs to be performed by telecoms operators without requiring additional permits in a specified time window

Annex A Economic impact assessment methodology

This annex details the methodology used in estimating the GDP and job impact from Google's network infrastructure investments. Our work draws upon expertise within Analysys Mason, with expert advice from economists Dr Michael Kende (Senior Advisor) and Prof Neil Gandal. Prof Gandal is a microeconomist with 40-years' experience in econometric techniques (see bio below).

Professor Neil Gandal is the "Henry Kaufman Professor in International Capital Markets" in the Berglas School of Economics at Tel Aviv University. He received his B.A. and B.S. degrees from Miami University (Ohio) in 1979, his M.S. degree from the University of Wisconsin in 1981, and his Ph.D. from the University of California-Berkeley in 1989. He is also a research fellow at the Centre for Economic Policy Research (CEPR).

Professor Gandal has published numerous empirical papers using econometrics in industrial organization, the economics of information technology, the economics of the software & Internet industries, and the economics of cybersecurity and cryptocurrencies. His papers have received more than 6000 citations at Google Scholar.

In his capacity as managing editor at the International Journal of Industrial Organization (IJIO) from 2005-2012, he edited many empirical papers using a wide range of econometric techniques. Following his editorship at the IJIO, he was named "Honorary Editor" of the journal. He is the only honorary editor in the history of the IJIO.

Our approach uses econometrics modelling to develop supply-side and demand-side equations linking Google's investments in submarine cables to outcomes in the connectivity ecosystem. These outcomes are demonstrably positive: Google's investments are strongly correlated with more usage of the internet. We then developed an endogenous growth model to measure the impact of connectivity-related variables to GDP. This is discussed in detail in Annex A.1.

The effects of Google's edge network investments on the connectivity ecosystem and the economy are estimated based on an inductive modelling approach described in Annex A.2. This modelling focuses on usage of Google's services. We use the same endogenous growth model in order to assess the impact of these investments on GDP.

Based on this GDP impact, we estimation a job impact, associated with the broader economic impact of Google's network infrastructure investments. This is developed detailed in Annex A.3. Finally, we discuss the sensitivity of the economic impact results to various statistical scenarios in Annex A.4.

The approach we have taken is different from recent analysis conducted by Copenhagen Economics to assess the economic impact of Google's broader infrastructure investments in Europe.[117] That

[117] Copenhagen Economics – "Google's hyperscale data centres and infrastructure ecosystem in Europe"; see https://www.copenhageneconomics.com/dyn/resources/Publication/publicationPDF/0/500/1569061077/copenhagen-economics-google-european-dcs-infrastructures-impact-study_september2019.pdf

analysis relied on input-output models and found that the cumulative EUR2.0 billion of investments made by over the 2007–2018 period yielded an estimated EUR2.7 billion in indirect and induced GDP. The difference in methodology reflects a different scope: most of the investment value considered in the European study related to Google's data centres, and specifically to the impact of building a data centre in a specific local economy. The global nature of data centres is very different from the more localised nature of submarine connectivity, and the spill-over effects identified reflected a narrower scope of benefits.

For the avoidance of doubt, the economic impact estimates on the APAC region exclude China and India which were not part of the scope of our assessment.

A.1 Econometric model assessing the impact of Google's submarine cable investments

In this section, we first introduce the econometric modelling used, and then describe the data and the results. The model relies on three stages of estimation:

- Part A: We first estimate the impact of an increase in submarine cable supply from Google investments in submarine cables (the 'supply-side') on both (i) end-user latency[118] and (ii) internet bandwidth.[119]
- Part B: Next, we estimate the impact that end-user latency and internet bandwidth have on (iii) mobile data traffic and (iv) internet penetration (the 'demand-side').
- Part C: Lastly, in equation (v) we estimate the GDP impact linked to an increase in mobile data usage, using an endogenous growth model.[120]

Before we delve into each part of the estimation process, we first provide some brief background on why we modelled the process in the way we did. Consumer demand for the internet is essentially a demand for speed: there is a clear link between consumer engagement and total usage on the one hand, and how responsive and fast the internet is perceived to be. Speed itself depends on both latency and bandwidth. The following quotes are representative.

"While bandwidth plays a big role in how fast webpages load, the journey from one machine to another takes time to traverse. No matter how much data you can send and receive at once, it can only travel as fast as latency allows."[121]

[118] The average round trip time taken for each portion of the speed test to complete, based on "rtt_avg" metric, M-lab

[119] The sum of capacity of all internet exchanges offering international bandwidth; International Telecommunication Union (ITU) World Telecommunication/ICT indicators (WTI) Database 2019

[120] Our modelling also considered the impact of internet penetration on GDP for emerging economies and noted that the result was close to the impact based on mobile data usage and therefore decided to simplify the GDP impact modelling to be based on use mobile data usage across all economies

[121] Understanding Network Bandwidth vs Latency, by Cody Arsenault, 3 August 2017; see: https://www.keycdn.com/blog/network-bandwidth

"True internet speeds come[s] down to a combination of bandwidth and latency."[122]

Hence, on the supply side, we wanted to determine how Google investments in submarine cables affect latency and internet bandwidth. Then, on the demand side, we wanted to determine how (i) latency and (ii) internet bandwidth affect (iii) mobile data usage[123] and (iv) internet penetration. Combining supply and demand equations enables us to determine how Google investments affect demand. The last step examines how changes in demand affect GDP.

Thus we estimate five equations: two supply equations, two demand equations, and an endogenous growth model.

The data for this analysis consists of panel data from 20 countries or territories in Asia, for which data is available at least in part from 2010–2019. In the context of this analysis, 'panel' means repeated observations over time for the countries in the analysis. We do not have complete observations on all of the variables for some of these 20 countries: this is what is referred to as an 'unbalanced panel'. However, we have a relatively large dataset, which enables precise and statistically robust estimates of the key effects.

Having a panel rather than cross-sectional data is advantageous, since a cross-section cannot control for time-invariant 'country'[124] effects; the latter are included in the error term in cross-sectional analysis. If these unobserved effects are correlated with the right-hand-side variables (i.e. the explanatory variable), the estimates from the cross-sectional analysis will be biased; we eliminate this problem by using 'fixed-effects models'. This is explained in more detail below.

We illustrate the importance of using a fixed-effects model by employing the demand model we use for mobile data usage:

$$\text{(iii)} \qquad D_{it} = \alpha_i + X_{it}\omega + \varepsilon_{it}.$$

The variable D_{it} is total cellular data traffic, both downstream and upstream, generated by all cellular devices (including fixed wireless devices) in country/territory *i* in year *t*.[125]

The vector $\alpha_i \equiv \alpha + A_i'\delta$ is such that α is a constant, and A_i is a vector of unobserved time-invariant country factors. The variables in X_{it} are observable time-varying factors (like bandwidth and latency) and ω are coefficients to be estimated. Finally, ε_{it} is an error term.

122 What is Latency – How is Latency Different from Bandwidth; see: http://www.plugthingsin.com/internet/speed/latency/

123 We do not have sufficient data observations to estimate fixed data usage. In our opinion, this does not pose a problem because (i) mobile data usage is a better indicator of overall internet usage in some countries with weak fixed penetration and (ii) there is a high positive correlation between fixed and mobile data usage.

124 We use country broadly in this annex, to include territories that may not be defined as countries under some conventions.

125 This variable includes both business and residential segments.

There are likely many important unobserved time-invariant country factors in the vector A. Given these unobserved time-invariant country factors, equation (iv) should be estimated using a fixed-effects model in which $\alpha_i \equiv \alpha + A_i'\delta$ are parameters to be estimated. As Angrist and Pischke[126] note, treating α_i as a parameter to be estimated is equivalent to estimating in deviations from the mean.

We employed these fixed-effects models for equations i–iv. In all cases, we tested the fixed-effects model against the alternative to a fixed-effects model, which is a random-effects model. The Hausman test (the standard test for determining which model is appropriate) strongly rejects the random-effects model in favor of a fixed-effects model in all four cases. Hence, the fixed-effects model is appropriate for all of these equations. In Section A.1.3, we discuss the endogenous growth equation employed in equation (v).

A.1.1 Part A: Supply-side estimation

The goal in this section is to examine how submarine cable supply affect end-user latency and internet bandwidth.

We have two supply equations:

(i) end-user latency

(ii) internet bandwidth

We begin with equation (i) end-user latency

(i) $L_{it} = \alpha_i + \beta^* C_{it} + \gamma G_{it} + \varepsilon_{it}.$

Where

- L_{it} is the natural logarithm of end-user latency in milliseconds for round-trip time as of December of each year (except 2019, for which available data ends in November)
- C_{it} represents the number of international submarine cables landing in a country or territory. It is defined as the natural logarithm of the total number of international submarine cables (SMC) plus one in the country/territory at a point in time: $C_{it}=\ln(SMC_{it}+1)$
- G_{it} represents the proportion of these cables that are 'Google-invested cables'. To calculate this parameter, we first calculate the percentage of SMCs in country/territory i at time t in which Google is an investor, which we call $Q_{it.}$ If there are no cables with Google investments at all in country/territory i at time t, this percentage is set equal to zero. Then, G_{it} is the natural logarithm of "one plus Q_{it}:": $G_{it} = \ln(Q_{it} + 1)$

126 Angrist, J., and Pischke, J. 2009. "Mostly Harmless Econometrics", Princeton University Press, Princeton, New Jersey, page 167.

The results are shown in the first regression in Figure A.1 below. The negative coefficients on both explanatory variables are intuitive: end-user latency (measured in milliseconds) falls when the number of submarine cables increases. Controlling for this effect, latency also falls as the percentage of Google cables increases, where Google cables are defined as above. Both coefficients are statistically significant at the 99% level of confidence.

Since all of the variables are in (natural) logarithms, the coefficients are elasticities and can easily be interpreted. For example, the –1.3 means that a 1% increase in the number of submarine cables reduces latency by 1.3%.

Similarly, the –3.0 means that a 1% increase in '1+the percent cables that are Google cables' leads to a reduction in latency of 3.0%.

We now estimate equation (ii), the internet bandwidth equation.[127]

(ii) $IBW_{it} = \alpha_i + \beta^* C_{it} + \gamma G_{it} + \varepsilon_{it}$.

Where

- IBW_{it} = is the natural logarithm of the total used capacity of international internet bandwidth; measured as the sum of capacity of all internet exchanges offering international bandwidth.[128]
- C_{it} and G_{it} are the same explanatory variables we used in equation (I).

The results are shown in the second regression in Figure A.1. The positive coefficients on both of the explanatory variables are as expected. Internet bandwidth increases when the number of submarine cables increases. Controlling for this effect, internet bandwidth also increases as the percentage of Google cables increases, where Google cables are defined as above. Both coefficients are statistically significant at the 99% level of confidence.

Figure A.1: Fixed-effects supply-side regressions: explaining latency and internet bandwidth [Source: Analysys Mason, 2020]

	Regression (I) Explaining latency Estimates (std. error)	Regression (II) Explaining internet bandwidth Estimates (std. error)
C (defined above)	-1.36*** (0.17)	4.05*** (0.34)
G (defined above)	-3.01*** (0.99)	2.07*** (1.70)
Observations	178	154

* p < 0.10, ** p < 0.05, *** p < 0.01

127 The coefficients (α ,β, γ) represent different things in the different equations. We use the same notation for simplification and clarity.

128 International Telecommunication Union (ITU) World Telecommunication/ICT indicators (WTI) Database 2019

Since all of the variables are in (natural) logarithms, the coefficients are elasticities and can easily be interpreted. For example, the 4.05 means that a 1% increase in the number of submarine cables increases internet bandwidth by 4.05%.

Similarly, the 2.07 means that a 1% increase in '1+the percent cables that are Google cables' leads to an increase in internet bandwidth of 2.07%.

A.1.2 Part B: Demand-side estimation

We now estimate equation (iii), the demand-side equation for mobile data traffic. We use this demand equation primarily for developed countries.

(iii) $D_{it} = \alpha_i + \beta^* IB_{it} + \gamma L_{it} + \delta P_{it} + \varepsilon_{it}.$

Where

D_{it}: this measures total cellular data traffic (downstream and upstream) generated by all cellular devices (including fixed wireless devices), excludes Wi-Fi offload, and includes both business and residential segments for country/territory i at time t. We call this variable mobile internet data traffic or use.[129]

IB_{it} is internet bandwidth, as defined above.

L_{it} is latency, as defined above.

We do not have a useable panel of price data for internet services to business or residential segments. For slightly less than 50% of the observations, we have data on IP transit prices. This is the price for a data rate of 1Gbit/s. The prices are for the fourth quarter of each calendar year with the exception of 2019 (third quarter); prices by country/territory refer to the average of weighted median prices of carrier postings across all cities.

We make the following assumptions in order to be able to estimate equation (iii):

1. There is monopolistic competition in the provision of IP transit data. This means that the price (P_{it}) in country/territory i at time t is a multiple (greater than one) of the marginal cost (MC) of the provision of IP transit data in country/territory i at time t.

2. The MC of the provision of internet service to business or residential segments is a constant multiplied by the price of IP transit data: $MC_{it} = \tau P_{it}$.

3. We assume that there is also monopolistic competition in the provision of internet services. Thus the price is a multiple of the MC, where the multiple (ξ) is greater than one.

129 Data points for mobile data traffic are primarily sourced from Analysys Mason DataHub, with supplementary data points from ITU and GSMA for some markets.

Taken together, these three assumptions mean that the price of the provision of internet service, PIS_{it}, is a multiple of the price of IP transit.

In other words, $PIS_{it} = \xi \times \tau \times Pit$ where the price of IP transit data itself is a function of its MC.

We assume that the MCs are determined by technology, which is exogenous to the equation we are estimating. The price of the provision of internet services is therefore exogenous. This is important because it means that we do not have simultaneous equations bias. Such bias occurs when the price is endogenous.

The constants ξ or τ are unknown. Since our equation is in logarithms, the following identity holds: $\ln(PIS_{it}) = \ln[\xi \times \tau \times Pit)] = \ln(\xi) + \ln(\tau) + \ln(Pit)$. Since ln(ξ) and ln(τ) are constant, they become part of the coefficient of the constant and are not necessary for our estimation. Hence, we can estimate equation (iii) above without knowing ξ or τ.

The results of the estimation of equation (iii) are shown in the first column of Figure A2. The coefficients on all of the explanatory variables are reasonable. Mobile internet data use increases when internet bandwidth increases. Controlling for this effect, mobile internet data use increases when latency decreases. Finally, mobile internet data use increases when the price falls. All three of the coefficients are statistically significant at the 99% level of confidence.

Since all of the variables are in (natural) logarithms, the coefficients are elasticities and can easily be interpreted:

- The estimated 0.63 coefficient on internet bandwidth means that a 1% increase in internet bandwidth leads to a 0.63% increase in mobile internet data use.
- Similarly, the estimated –0.54 coefficient on latency means that a 1% decrease in latency leads to a 0.54% increase in mobile internet data use.
- Further, the –0.54 coefficient on price means that a 1% decrease in price leads to a 0.54% increase in mobile internet data use.

We now estimate equation (iv), the demand-side equation for the penetration rate (Rit) which is the percentage of internet users in the population that are internet users in country/territory i at time t.

(iv) $R_{it} = \alpha_i + \beta^* IBU_{it} + \gamma L_{it} + \varepsilon_{it}$.

- IBU_{it} is the internet bandwidth per user. It makes sense to use this variable when explaining the penetration rate.
- L_{it} is latency, as defined above.

We do not have access to enough robust pricing data for most of the emerging economies. Hence, we estimate equation (iv) without price as independent variable.[130] We report out results in the second column in Figure A.2.

The coefficients on the explanatory variables are as expected. The penetration rate increases when internet bandwidth per user increases. Controlling for this effect, the penetration rate increases when latency decreases. The coefficient on latency is statistically significant at the 99% level of confidence, while the coefficient on internet bandwidth is significant at the 95% level of confidence.

Since all variables are in (natural) logarithms, the coefficients are elasticities and can easily be interpreted:

- The estimated 0.12 coefficient on internet bandwidth per user means that a 1% increase in internet bandwidth leads to a 0.12% increase in the penetration rate.
- Similarly, the estimated –0.24 coefficient on latency means that a 1% decrease in latency leads to a 0.24% increase in the penetration rate.

Figure A.2: Demand-side regressions: explaining (III) mobile internet data use and the penetration rate [Source: Analysys Mason, 2020]

	Regression III Explaining mobile internet data use Estimates (std. error)	Regression IV Explaining the penetration rate Estimates (std. error)
Internet bandwidth	0.63***(0.12)	
Internet bandwidth (per user)		0.12** (0.060)
Latency	-0.54*** (0.18)	-0.24*** (0.084)
Price	-0.54***(0.16)	
Observations	89	154

* p < 0.10, ** p < 0.05, *** p < 0.01

A.1.3 Part C: Impact on GDP from change in mobile data usage

Endogenous growth models became popular in the 1980s. Such models are different from traditional (classical) growth models because endogenous growth models assume that growth is an endogenous outcome, not the result of, for example, external technological progress. Paul Romer provides a survey on these models in the Journal of Economic Perspectives.[131]

130 When we include price and include observations where the penetration rate is less than 75%, we have a much smaller sample (N=48). Importantly, the coefficients on internet bandwidth per user and latency are virtually unchanged. Thus we are confident that our results are robust.

131 Romer, P., 1994, "The Origins of Endogenous Growth," Journal of Economic Perspectives, Volume. 8, No. 1, Winter 1994, 3–22

In the telecoms literature, endogenous growth models have been used to examine the relationship between changes in telecoms use and economic growth.

The model we employ comes from an IMF paper by Andrianaivo and Kpodar.[132] In that paper, they examined how ICT and financial inclusion affect economic growth in African economies. A modified version of the model used by Andrianaivo and Kpodar (2011) was also employed by the Deloitte/GSMA study[133] in order to estimate the impact of mobile telephony on economic growth. Hence it seems appropriate to employ this model.

The model can be written

(v) $Y_{it} = \alpha_i + \rho^* y_{i,t-1} + \beta DU_{it} + \gamma X_{it} + \varepsilon_{it},$

Where

- Y_{it} is the GDP per capita in country i at time t
- $Y_{i,t-1}$ is the GDP per capita in country i at time t-1
- DU_{it} is as defined as mobile internet data usage which is the mobile data traffic (D_{it}) defined earlier in Annex A.1.2 divided by the number of mobile subscribers in the country.

The variables we employ in X_{it} are:

- Ratio_govt_gdp = the ratio of government expenses to GDP in country i at time t
- Ratio_trade_gdp = the ratio of international trade to GDP in country i at time t
- The unemployment rate.

These variables were also used in the Deloitte/GSMA (2012) model. As in that model, we use a six-year horizon for the estimation of the endogenous growth model. Hence, we include data from 2014–2019.

All of the variables are in natural logarithms. Hence, the coefficients can be interpreted as elasticities.

This is a dynamic panel data (DPD) model, since the lagged value of GDP ($Y_{i,t-1}$) appears on the right-hand side. The empirical model we employ is due to Arellano and Bond[134] and Holtz-Eakin,

132 Andrianaivo, M. and Kpodar, K., 2011.. "ICT, Financial Inclusion, and Growth: Evidence from African Countries", IMF Working Paper WP/11/73.] Their work, in turn, is based on (I) Barro, R., 1991. "Economic Growth in a Cross Section of Countries," The Quarterly Journal of Economics, 106(2), pp. 407–43.and (II) Waverman, L., Meschi, M. and Fuss, M., 2005. "The Impact of Telecoms on Economic Growth in Developing Countries," The Vodafone Policy Paper Series, (2), pp. 10–23

133 Williams, C., Solomon, G., and Pepper, R., 2012. "What is the impact of mobile telephony on economic growth: A report for the GSM Association", GSM report, 2012, available at https://www.gsma.com/publicpolicy/wp-content/uploads/2012/11/gsma-deloitte-impact-mobile-telephony-economic-growth.pdf

134 Arellano, M., and Bond, S. 1991. "Some tests of specification for panel data: Monte Carlo evidence and an application to employment equations." Review of Economic Studies 58: 277–297

Newey and Rosen.[135] It uses a generalised method of moments (GMM) approach. It addresses the endogeneity problem of $y_{i,t-1}$.

By construction, the residuals of the differenced equation ($Y_{it} - Y_{i,t-1}$) should be auto-correlated of order one, i.e. an AR(1) process of serial correlation. But if the maintained assumption of serial independence in the original errors (ε_{it}) is true, the differenced residuals should not exhibit significant AR(2) behavior. If a significant AR(2) statistic is found, the second lags of the endogenous variable will not be appropriate instruments for their current values and we cannot use the model. This leads to a test, called the Arellano-Bond test, which we describe below.

We employ the estimation procedure in Stata, denoted as 'xtabond'.[136]

The results are shown in Figure A.3 below. Since all of the variables are in (natural) logarithms, the coefficients have an elasticity interpretation. The estimate of our coefficient of interest is the one on mobile data usage. The value of 0.008, which is significant at the 95% level of confidence, means that a doubling of mobile data use leads to a 0.8% increase in GDP per capita.

Figure A.3: Endogenous growth model: (V) Explaining GDP growth per capita [Source: Analysys Mason, 2020][137]

	Regression V explaining GDP growth per capita Estimates (std. error)
GDP per capita (lagged)	0.90***(0.056)
Mobile data usage	0.0080**(0.0032)
Ratio_Govt_GDP	0.015 (0.020)
Ratio_Trade_GDP	0.021*** (0.0068)
Unemployment rate	–0.032 (0.051)
Observations	77

* p < 0.10, ** p < 0.05, *** p < 0.01

Figure A.4: Arellano-Bond test for zero autocorrelation in first-differenced errors [Source: Analysys Mason, 2020]

Order	Z	Prob > Z
1	-1.90	0.06
2	-1.07	0.29

135 Holtz-Eakin, D., Newey, W., and Rosen, H. 1988. "Estimating Vector Autoregressions with Panel Data," Econometrica, vol. 56, issue 6, 1371-95

136 https://blog.stata.com/2015/11/12/xtabond-cheat-sheet/

137 Recall that all variables are in natural logarithms

Since we cannot reject the null hypothesis that there is second-order autocorrelation, as seen from Figure A.4, the assumptions of the model hold.

A.2 Approach to estimating impact of Google's edge investments

In this section, we describe our approach and assumptions used to derive the economic impact of Google's investment in edge infrastructure in APAC.

Edge network investments affect Google traffic primarily. If Google had not invested in edge infrastructure, several scenarios are possible: a third-party may have done so and charged Google or ISPs for the caching service, ISPs may have done had to carry the traffic at their own cost, or ISPs may have decided to constrain the amount of traffic they delivered to end users. In this last scenario, it is possible that ISPs would have chosen to pay to fetch Google's traffic from overseas PoPs, at the expense of other content. We have chosen to model a scenario whereby a proportion of mobile traffic, related to the proportion of Google traffic that is cached, would not be delivered by ISPs.

The model can be described in three parts:

- Part A: We first develop country/territory-level projections of traffic generated on mobile networks across APAC economies and estimate the share of Google traffic within mobile networks.
- Part B: Next, we estimate how Google mobile data traffic delivered in each country/territory is split into different traffic types that are served through (i) Google Global Cache nodes deployed in APAC (ii) Google PoPs deployed in APAC and (iii) Google PoPs deployed outside APAC.
- Part C: Lastly, we estimate the amount of mobile traffic that might be lost if the Google's network infrastructure were not present in APAC and run it through the endogenous growth model described in Annex A.1.3 above.

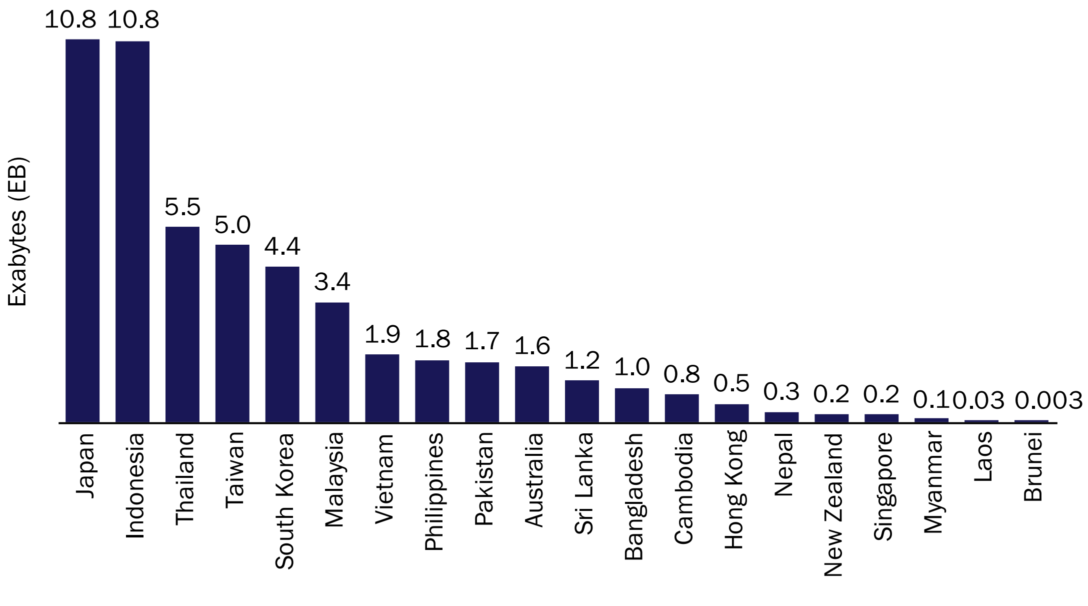
A.2.1 Part A: Estimation of Google mobile date traffic in APAC

We first compiled the mobile data traffic across 20 APAC countries or territories, based on a variety of sources (Figure A.5), with a total estimate of 51EB generated across mobile networks in APAC for 2018 (Figure A.6).

Analysys Mason DataHub[138]	ITU[139]	Analysys Mason estimates[140]
Australia	Cambodia	Nepal
Bangladesh	Laos	Sri Lanka
Hong Kong	Myanmar	Brunei
Indonesia		Vietnam
Japan		
South Korea		
Malaysia		
New Zealand		
Pakistan		
The Philippines		
Singapore		
Taiwan		
Thailand		

Figure A.5: Data sources on mobile data traffic in APAC [Source: Analysys Mason estimates, 2020]

Figure A.6: Mobile data traffic in APAC countries in 2018 [Source: Analysys Mason DataHub, ITU, Analysys Mason estimates, 2020]



138 From Analysys Mason DataHub; Definition: Total cellular data traffic (downstream and upstream) generated by all cellular devices (including fixed wireless devices). Excludes Wi-Fi offload. The sum of business and residential segments.

139 From ITU; Definition: Mobile-broadband Internet traffic refers to broadband traffic volumes originated within the country or territory from 3G networks or other more advanced mobile networks, including 3G upgrades, evolutions or equivalent standards in terms of data transmission speeds.

140 Analysys Mason bottom-up calculations based on subscriber and data usage estimates.

Based on research from Sandvine, around 40% of mobile network traffic is for Google services and we apply this percentage to the mobile data traffic shown above to derive the amount of Google mobile data traffic for each of the listed APAC markets.[141]

A.2.2 Part B: Estimation of Google mobile data traffic served through PoPs and caches

Once access to Google services is requested by a customer on the mobile network, the MNO will have to collect the content from Google through interconnecting with Google at the edge infrastructure. This can be in the form of cache nodes deployed by Google within the MNO's network or interconnection facilities in Google PoPs. If a Google PoP is available in the same country or territory, the MNO can readily collect the traffic from the in-country PoP with some costs incurred for domestic connectivity. However, if there are no Google PoPs available within the country or territory, the MNO will have to incur significantly higher international bandwidth costs to collect the traffic from a Google PoP in a nearby country or territory. Based on insights drawn from discussions with both MNOs as well as with the Google team, we applied the following assumptions on Google traffic for each APAC country or territory.

- Google Global Caches accounts for 65–75% of traffic, and countries/territories where content is primarily from a single-language other than English majority (e.g. Indonesia) typically have a higher cache rate.
- In countries/territories where Google deployed PoPs, all of the remaining traffic not served through caches would be served through these PoPs.
- In countries/territories where Google does not currently have PoPs deployed, we assume that the majority of the remaining traffic is served through a PoP in a nearby APAC countries/territories with a small proportion (~2%) of traffic served through PoPs outside APAC (e.g. Pakistan collects traffic from the Middle East).

A.2.3 Part C: Mobile data traffic enabled by Google's edge infrastructure

Based on our discussions with MNOs, they typically have a fixed budget to manage bandwidth requirements, and the investments made by Google on caches and PoPs in APAC would therefore have enabled these operators to serve a greater volume of traffic that they would have been able to compared to the scenario where they had to collect the traffic from PoPs outside APAC. It is therefore reasonable to expect that a significant proportion of traffic would be lost if the investments had not been made by Google over the last ten years. We expect that, on a blended basis, around 45% of current Google mobile data traffic in APAC would be affected by these network infrastructure investments (this represents 18% of total data traffic based on Sandvine's estimates). The assumptions are listed below:

141 Sandvine - 2020 Mobile Internet Report; see: https://www.sandvine.com/phenomena

- ***Traffic served by APAC caches:*** Given that caches are deployed by Google within MNOs' networks, the expenses incurred by MNOs to serve this traffic are limited to the costs of supporting the operations and maintenance of the infrastructure. This is typically a trivial cost to the MNOs. In the absence of the cache infrastructure, MNOs would have to incur significantly higher costs to collect the traffic from a PoP and incur international bandwidth charges. We expect a significant proportion of traffic (~50%) to be affected.

- ***Traffic served by APAC PoPs:*** MNOs currently incur a mixture of domestic and international bandwidth costs to collect traffic from Google's APAC PoPs to serve traffic to end users. In the absence of the PoP infrastructure in APAC, MNOs would have to collect traffic from PoPs that are located further away, in Europe or the Americas. The additional costs incurred varies by the degree of connectivity of each market: MNOs in internet hubs (such as Singapore and Japan) would incur lower costs per unit of traffic to connect to markets outside APAC than an MNO in a less well-connected markets. Based on the varying cost of international connectivity for each APAC market, we expect 20–50% of traffic in each of the markets to be affected by Google's investments.

Finally, we pass the mobile data impact through the endogenous growth model discussed earlier in Annex A.1.3 in order to estimate the GDP impact from Google's edge network investments.

A.3 Assessing the impact of Google's network infrastructure investments on jobs

Our approach to estimating the impact of Google's network infrastructure investments on jobs involves three key steps:

- Part A: We first translate the GDP impact into the gross value added (GVA) impact
- Part B: Next, we estimate the average GVA per job affected by Google's investments in network infrastructure
- Part C: Lastly, we estimate the job impact by dividing the GVA impact by GVA per job assumptions.

A.3.1 Part A: Estimation of GVA impact

We first estimate the gross value added (GVA) effect of the GDP impact calculated above, for each country/territory, using a GDP-to-GVA ratio.[142] This allows us to relate economic impact at national level to an industry-level metric which is more directly related to factors of production including labour and therefore jobs. For forecast years from 2020 to 2024, we use the 2019 GDP-to-GVA ratio.

142 Gross value added (GVA) is a measure of contribution to GDP made by an individual industry; GDP-to-GVA ratio is derived from Euromonitor's database

A.3.2 Part B: Estimation of GVA per job

Next, we estimate the GVA per job for industries likely to be most affected by developments in broadband connectivity, for each country/territory, in each year. Equinix's Global Interconnection Index[143] suggests that the primary beneficiaries of an increased consumption of internet data traffic are likely to be the 'manufacturing', 'transport, storage and communications' and 'financial intermediation' industries.[144]

We then take the simple average of the GVA per job of these three industries for each of the respective countries. Based on the historical GVA per job estimates, we assumed that GVA per job would continue to increase in line with historical growth rates through the forecast period. Figure A.7 (next page) provides the average GVA per job for industries impacted by internet consumption assumption applied for each APAC country, with developed countries having higher GVA per job than developing countries.

A.3.3 Part C: Estimation of job impact

Lastly, we divide the GVA impact by the calculated GVA per job for each country to estimate the number of new jobs that have been created with the higher GVA. These country-level job impact estimates are then aggregated to form the overall impact of Google's network infrastructure investments on jobs in the APAC region.

143 Equinix – "Global Interconnection Index"; see https://www.equinix.com/gxi-report/

144 Based on the list of industries available as part of Euromonitor's gross value added dataset

Figure A.7: Average GVA per job in impacted industries by APAC countries by year (USD thousand) [Source: Analysys Mason, 2020]

	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024
AUS	137	142	146	154	160	164	161	171	174	177	181	185	189	193	197
BGD	4	4	5	6	6	8	9	10	11	13	15	17	19	22	26
BRN	162	198	205	200	190	159	135	147	159	146	153	158	164	168	172
KHM	5	6	7	7	8	8	9	10	11	12	13	14	15	17	19
HKG	87	87	89	93	98	102	109	113	119	121	126	132	137	143	149
IDN	12	11	11	12	13	14	15	16	17	17	18	19	20	22	23
JPN	101	94	91	91	93	98	94	95	94	94	95	95	95	96	96
Laos	16	18	21	23	19	24	26	29	32	34	38	42	47	53	59
MYS	32	33	35	37	39	39	41	44	45	46	48	50	52	54	56
MMR	2	3	3	3	4	4	5	5	5	6	7	7	8	9	10
NPL	5	8	10	11	14	16	19	24	30	36	44	53	64	77	93
NZL	87	90	91	92	104	107	107	112	114	118	121	124	127	130	134
PAK	6	7	7	7	7	7	7	7	8	9	9	9	10	10	10
PHL	16	16	17	19	20	21	22	24	26	27	29	31	33	35	37
SGP	97	93	96	100	106	116	124	133	142	147	156	167	178	189	202
KOR	65	66	66	66	69	74	75	80	82	81	84	86	89	92	95
LKA	14	15	18	18	18	19	22	25	27	28	30	33	35	39	42
TWN	50	50	51	53	57	61	61	64	65	67	69	71	74	76	78
THA	31	33	38	37	35	37	41	44	47	49	52	56	60	64	68
VNM	3	4	5	5	5	5	5	6	6	7	7	8	8	9	10

A.4 Econometric modelling scenarios

The GDP impact indicated in the main report section is based on a selection of the base-case coefficients (see Annex A.1.2) for the independent variables in the supply-side and demand-side equations within a 95% confidence interval. While the GDP impact econometric modelling analysis showed high statistical significance in the historical period, the estimation for the forecast period 2020 to 2024 is likely to entail a greater degree of uncertainty.

In Figure A.8, we provide a matrix table showing the range of GDP impact from 2020 to 2024. These values are based on modelling scenarios by varying the applicability of connectivity components (bandwidth and usage of the internet, IP transit price and latency) and the range of coefficients used in the demand equation within a 95% confidence interval. Based on these scenarios, we estimate that the GDP impact could range between USD118 billion and USD896 billion from 2020 to 2024.

Figure A.8: Increase in real GDP from 2020 to 2024 attributable to Google's network infrastructure investments in APAC by modelling scenarios and connectivity components [Source: Analysys Mason, 2020]

Drivers of data traffic impacting GDP	Conservative	Base-case	Aggressive
Bandwidth and edge impact + IP transit price + Latency impact	220	415	896
Bandwidth and edge impact + IP transit price impact	205	360	756
Bandwidth and edge impact only	118	253	597