CONSULTING

analysys mason

REPORT FOR THE TELECOM INFRA PROJECT

THE ECONOMIC IMPACT OF OPEN AND DISAGGREGATED TECHNOLOGIES AND THE ROLE OF TIP

David Abecassis, Michael Kende, Shahan Osman, Isabella Kriegler,
Caroline Gabriel, Roberto Kompany

MAY 2021

analysysmason.com

Contents

Disclaimer and acknowledgements

This report was commissioned and sponsored by the Telecom Infra Project (TIP), and written by Analysys Mason, a global consultancy specialising in telecoms, media and technology.

Analysys Mason is grateful for all inputs during the research and preparation of this report, including discussions with a number of organisations including Baicells, DISH, Dublin City Council, Edgecore Networks, Ooredoo, Parallel Wireless, Tech Mahindra, TIM Brasil, Vodafone, VTS, and others.

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

Analysys Mason Limited
North West Wing, Bush House
Aldwych
London WC2B 4PJ
UK
Tel: +44 (0)20 7395 9000

london@analysysmason.com

www.analysysmason.com

Registered in England and Wales No. 5177472

1 Executive summary

Since the start of the Covid-19 pandemic, it has become clear just how vital the telecoms industry has become to the functioning of our societies. From Oslo to Santiago, San Francisco to Manila, every person with the means to connect to the internet now relies heavily on the fibre, copper and radio networks that carry work, social, leisure and other vital information.

In advanced economies, mobile operators are on the cusp of introducing 5G, whilst in emerging markets, many people still cannot access, or afford, mobile broadband. Meanwhile, operators' margins are under pressure, due to commoditisation, competition and upwards pressure on investments brought about by explosive demand growth, an increased focus on security and resilience of networks, and tight and concentrated equipment supply chains.

The move to 5G is particularly challenging for operators: the business case remains unproven, especially when considering the range of new services that 5G is envisioned to support in future, and the investments required are large.[1] Improved network cost efficiency is key to making these investments possible, in particular through infrastructure sharing, carve-out of passive infrastructure[2] and radio access network (RAN) sharing models, including innovations such as network-as-a-service.

Telecoms stakeholders are also coming together in a number of industry initiatives to open up and standardise interfaces between different network components, which would allow solutions from different vendors to work together or 'interoperate'. Traditional networks today are mostly supplied by one main vendor for each operator, while a network that is made up of numerous interoperable components from multiple vendors is referred to as a disaggregated network. These disaggregated networks could allow operators to deploy new network functions more quickly and flexibly to support new and improved services.

Since early 2016, the Telecom Infra Project (TIP) has brought together telecoms stakeholders, including operators, vendors, systems integrators and policy makers, to drive the transformation of equipment supply chains in a way that facilitates the implementation of disaggregated, multi-vendor networks based on open interfaces. TIP endeavours to play a unique role as an entity that focuses not on developing telecoms standards per se, but on driving the conceptualisation, development, testing and deployment of actual products and solutions in the market. TIP acts as a neutral industry facilitator of collaboration between stakeholders, on the definition of product roadmaps, testing of solutions against common requirements, and sharing of knowledge and information among demand- and supply-side market participants.

TIP emphasises the importance of full openness and interoperability, and the need to avoid fragmentation, in order to achieve economies of scale and develop a critical mass of viable open network solutions. This transformation provides new opportunities for different types of participants in the supply chain, including the entry of new companies into verticals that were previously off limits, and the opportunity for incumbents to focus on key strategic priorities, for vendors to emerge in local markets previously importing all equipment, and for systems integrators to offer an expanded scope of services.

Standardised solutions, built by a range of suppliers based on industry requirements, could unlock greater cost efficiency and faster deployment of new network functions than proprietary solutions

[1] Annual global spend on 5G mobile capex is expected to exceed USD100 billion per annum by 2025, according to Analysys Mason Research forecasts, available at https://www.analysysmason.com/research/content/regional-forecasts-/mobile-capex-forecast-rma18/

[2] A passive infrastructure 'carve-out' in the mobile sector usually refers to a process where a mobile operator sells some or all of its towers to a third-party infrastructure provider, who then markets tenancies on these towers to all operators in the market, facilitating infrastructure sharing

The ability to deploy better networks more quickly and within or below existing cost envelopes would enable operators to expand rural coverage more readily, particularly in countries where this is lacking, while also introducing more advanced network features and services in urban areas ahead of schedule, which could start to alleviate some of the pressure on margins.

More cost-efficient and flexible networks, as well as improved coverage and greater innovation in services offered by operators, would in turn unlock broader economic benefits for society. This could be in the form of new business models that could be realised for infrastructure players and non-traditional operators, better access to existing and emerging online services for consumers, and accelerated digitalisation of industry sectors through new enterprise and smart-city use cases that would be enabled by a faster transition to advanced technologies.

Supplier diversity could also mitigate security risk through rigorous testing to ensure that security standards are designed into vendor product roadmaps, and improve supply-chain resilience given the option to replace suppliers should a deployed solution be deemed unsuitable due to security, performance, or other reasons. A more open and egalitarian global supply-chain ecosystem would also present opportunities for more countries to develop new capabilities in input provision, manufacturing and software design, to improve employment, workforce development and economic growth.

More needs to be done to speed up the development and adoption of innovative and cost-efficient solutions based on open and disaggregated network principles

We have identified three main areas of focus for the industry, which will accelerate technology deployment, and allow operators to have confidence in deploying disaggregated technologies at scale.

First, an expansion of platforms for testing and integration of disaggregated solutions through more active collaboration between operators, vendors and systems integrators, is key to accelerate time to market and deployment of new solutions. This is being facilitated by entities such as TIP. Actions taken by operators to support full adherence to open standards and interoperability of solutions, such as the Memorandum of Understanding between five major European operators to implement Open RAN,[3,4] help to provide the incentives necessary for new vendor investments.

Second, facilitators of product development and testing such as TIP Community Labs should likewise ensure that implementations tested are fully interoperable, to prevent fragmentation of standards and 'proprietary 'creep'.[5] These facilitators would need to place an added emphasis on testing for security and resilience requirements, particularly as networks are increasingly deployed to support mission-critical use cases. Knowledge sharing between testing facilitators would also lead to reduced duplication of effort and would allow the ecosystem as a whole to validate and deploy solutions more quickly.

Finally, policy makers across the globe can play a significant role in supporting the development of the open ecosystem by promoting adoption and international alignment of open standards and interfaces, to amplify economies of scale that could be achieved in the supply chain. Some policy makers have also started to introduce policies in support of supply-chain resilience, which range from providing funding and platforms for testing new solutions, to fostering collaboration between local talent, suppliers and service providers to stimulate innovation, research, and local manufacturing. Forums to enhance knowledge sharing between policy makers could further stimulate the adoption of emerging technologies to improve living standards for citizens through enhanced connectivity and service innovation.

Today, TIP and its participants play an active role in building platforms and conducting activities needed for the industry to achieve commercialisation and deployment of open solutions at scale. More active participation in the open ecosystem by companies and policy makers will further accelerate the development of the multi-vendor supply chain, which would be crucial for maximising the potential benefits of open and disaggregated technologies. This is particularly important to enable new, smaller vendors to gain a foothold in markets despite lacking scale initially – in

[3] See https://www.telefonica.com/en/web/press-office/-/major-european-operators-commit-to-open-ran-deployments

[4] See https://www.gruppotim.it/en/press-archive/corporate/2021/PR-TIM-ORAN-en.html

[5] Refers to the possibility that implementing solutions with proprietary interfaces in certain parts of the network could lead to less interoperability, and limit the number of compatible solutions that could be used in other parts of the network.

this context, financial support commensurate with strategic objectives such as supply chain diversification and resilience could be a powerful policy tool.

Economic benefits from Open RAN could reach USD285 billion cumulatively from 2021–30, an impact that could more than double in a scenario where supply conditions allowed faster adoption

In this report, we have sought to quantify several of these benefits specifically in the context of Open RAN, the broader movement to open up interfaces and create interoperable RAN solutions. A baseline estimate, given ongoing initiatives by entities such as TIP, the O-RAN Alliance and others, suggests that Open RAN could add USD285 billion in real gross domestic product (GDP) globally, in addition to USD19 billion in real consumer surplus gains, over the next ten years (2021 to 2030). By the end of this period, Open RAN could add USD91 billion to global GDP annually.

Our baseline scenario assumes a slow but steady adoption of open and disaggregated network solutions, which are assumed to overtake proprietary vendor solutions around 2028. We have conservatively modelled only limited benefits from Open RAN in terms of reducing overall operator cost levels, and instead see the benefits of Open RAN primarily as creating a more robust and competitive supply chain that is responsive to operators' needs and results in lower price points for open and disaggregated solutions in the market. This would help mitigate the cost of the more performant, resilient and secure wireless networks that will be required in the near future. The exact impact of Open RAN could be significantly higher depending on factors such as cost-efficiency improvement relative to solutions with proprietary interfaces, the ability of Open RAN to support and accelerate the adoption of new technologies, and the pace and level of adoption by operators.

TIP plays a key role in bringing together stakeholders to accelerate development of a critical mass of open and disaggregated network products and services in response to operators' needs, with the aim of driving adoption and advancing global connectivity. Other organisations in the ecosystem, and indeed equipment vendors, operators and policy makers, are all critical to the success of open and disaggregated network technology, by addressing important challenges. Proactive involvement of policy makers in helping to facilitate development of the open ecosystem could unlock even larger economic benefits. Conversely, a lack of co-ordination on key issues such as alignment in the adoption of open standards and refragmentation resulting in implementations that are not interoperable, would result in a reduction in the potential for open and disaggregated technologies to generate the envisioned impact and to help achieve policy objectives.

The impact of open and disaggregated technologies and the contribution of TIP and other industry initiatives

FUTURE TELECOMS NETWORK REQUIREMENTS CAN BE BETTER MET WITH AN OPEN AND DISAGGREGATED SUPPLY-CHAIN ECOSYSTEM

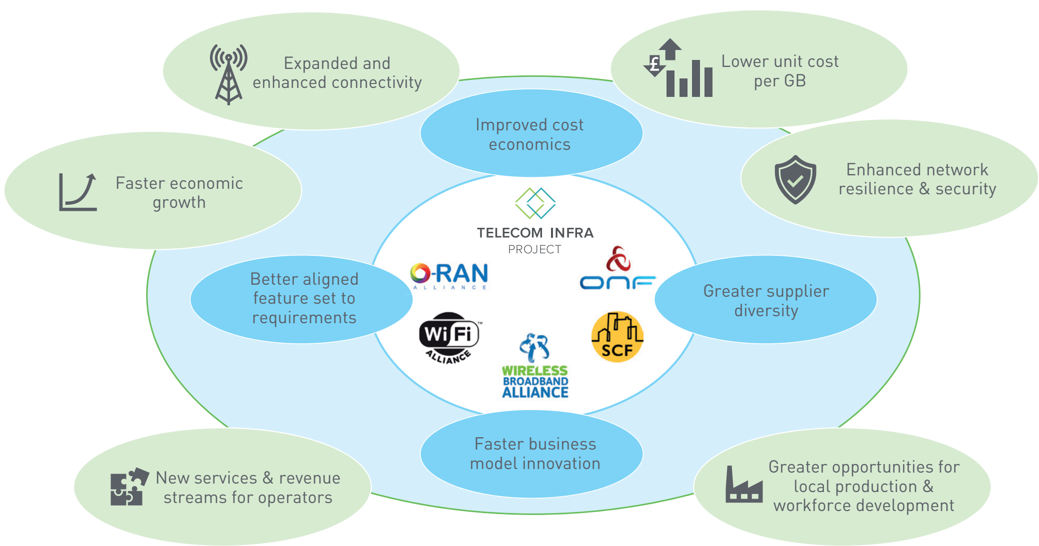
Priorities driving future telecoms network development

- Introducing advanced technologies and new use cases for individuals and enterprises
- Improving connectivity in rural areas where people lack access and affordability
- Ensuring that networks can cope with demand due to unexpected events such as Covid-19

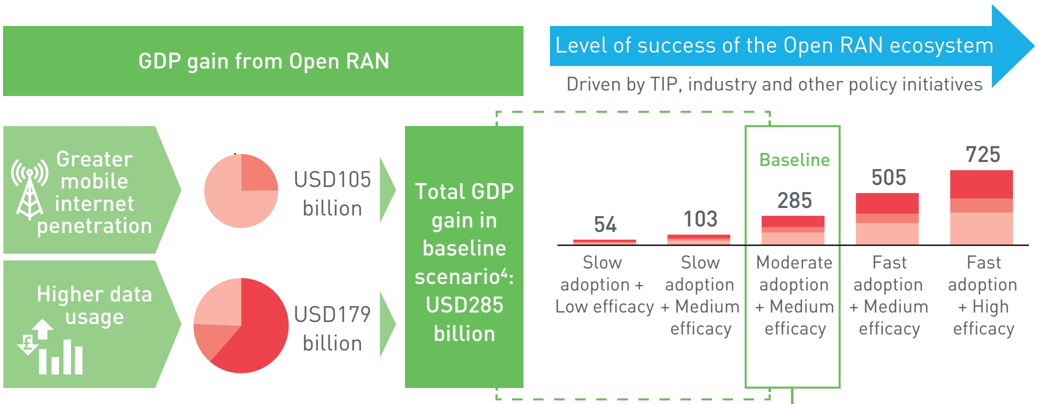
Differences between closed and open supply chains

	Closed Environment	Open, disaggregated
Vendors	Few	Many
Interfaces	Proprietary	Open
Roadmap	Vendor led	Operator led
Resilience	Vendor-dependent due to lock-in	Improved from greater choice
Innovation	Business as usual	Faster, more diverse

TIP DRIVES DEPLOYMENT OF OPEN AND DISAGGREGATED SOLUTIONS, AND WORKS ALONGSIDE OTHER ENTITIES[1] TO REALISE BENEFITS



THE BENEFITS OF OPEN AND DISAGGREGATED SOLUTIONS TRANSLATE INTO HIGHER GDP[2], AN ECONOMIC IMPACT THAT CAN BE FURTHER ACCELERATED BY INITIATIVES SUCH AS TIP[3]



Adoption inputs	Fast	Moderate	Slow
Percentage of subscribers served with Open RAN networks (end of 2030)			
High-income countries	81%	51%	24%
Middle-income countries	86%	54%	26%
Low-income countries	90%	57%	27%

Efficacy inputs	High	Medium	Low
RAN cost intensity reduction vs. counterfactual[5] (%)			
RAN opex (2030)	-15%	-10%	-5%
RAN capex (2030)	-30%	-20%	-10%
Acceleration of 4G/5G take-up[6] vs. counterfactual (years)			
By 2030	1.5	1.0	0.5

Across countries within each group: High-income countries | Middle-income countries | Low-income countries

POLICY MAKERS ARE EXPLORING WAYS TO SUPPORT SUPPLY-CHAIN DIVERSIFICATION TO BUILD NETWORK RESILIENCE AND IMPROVE CONNECTIVITY

Stakeholder co-ordination

Foster collaboration among operators, vendors, and government to launch testbeds and to inform policy approaches

Fiscal tools

Consider fiscal tools (e.g. R&D incentives, development financing) to stimulate supply and demand

International alignment

Share and adopt best practices on policy initiatives, aligning approaches to avoid market fragmentation and achieve economies of scale

For more details please see:

https://www.analysysmason.com/impact-of-open-and-disaggregated-technologies-and-TIP

[1] All entities shown are key to driving open standards and disaggregation. TIP focuses on driving actual product development and testing to accelerate deployment

[2] Measured in real USD billion (2020 prices)

[3] Sensitivity analysis is used to illustrate the impact of slower or faster adoption of Open RAN, and how effective Open RAN can be in driving cost efficiency and adoption of advanced technology, stimulated in part by TIP

[4] Total GDP gain from greater mobile internet penetration (USD105.2 billion) and higher data usage (USD179.4 billion) adds up to USD285 billion when rounded

[5] The impact assessment approach used involves assuming a change in certain operational metrics in a scenario with Open RAN compared to a scenario without Open RAN (called the 'counterfactual'), and estimating the resulting incremental impact on macroeconomic indicators such as GDP

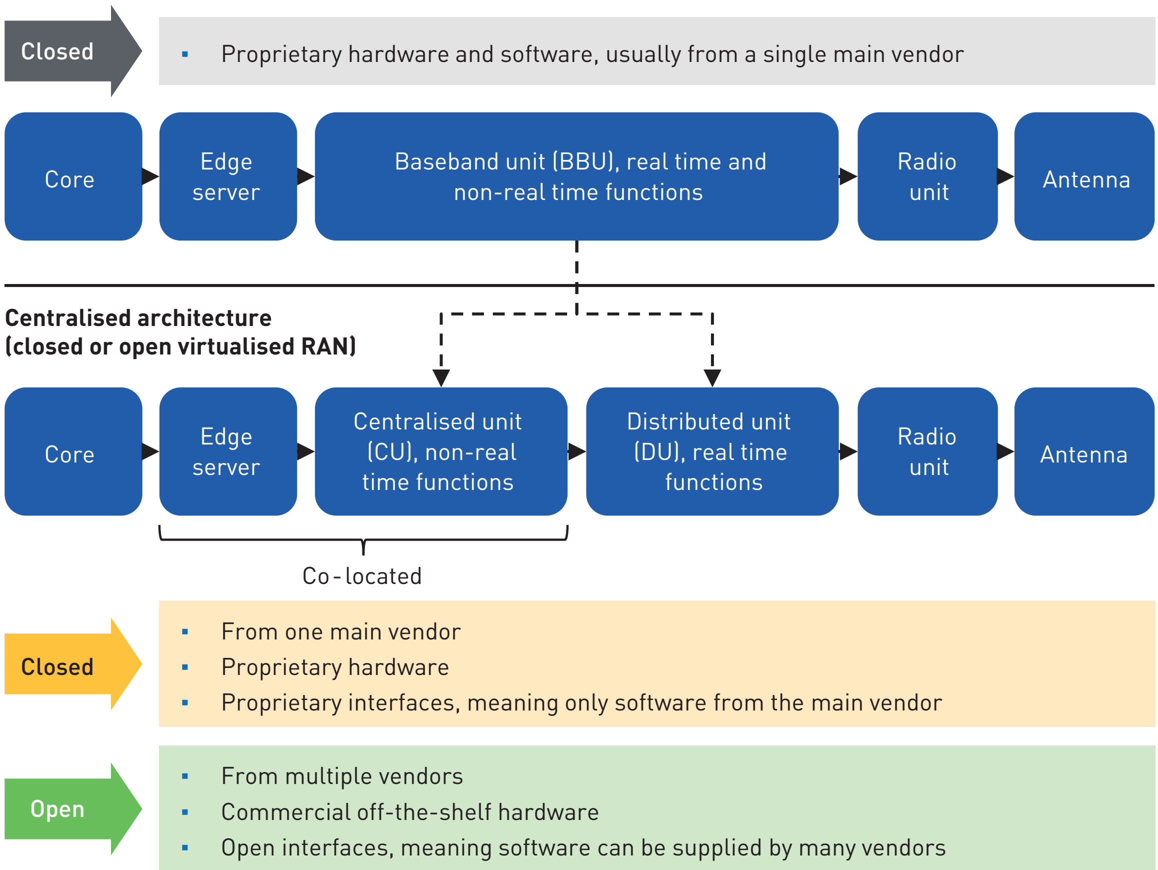
[6] Accelerating the take-up of advanced technologies such as 4G and 5G would increase data usage in the market, which has a positive impact on GDP

2 TIP provides a platform for accelerating the deployment of open telecoms infrastructure to drive global connectivity

Telecoms networks have played an increasingly important role in our lives over the past few decades, and will continue to do so in future, as developed economies look to introduce new use cases through 5G. This is in contrast with emerging countries, where a significant share of the population still lacks access to affordable broadband. Telecoms operators across the globe are facing critical decisions regarding future network deployment, particularly as they continue to cope with pressure on margins brought about by rapid growth in demand for data in recent years, a need to improve network security and resilience as connectivity affects more lives more directly, and a supply-chain ecosystem that has been dominated by a small number of vendors providing solutions with proprietary interfaces.

Across the industry, many stakeholders, including mobile operators, hardware and software vendors, as well as systems integrators, have called for a transformation of the telecoms equipment market by adopting open principles and standards, and disaggregating network components. This transformation mainly involves the adoption of open interfaces, which would allow network components from different vendors to work together, or 'interoperate',[6] as opposed to closed proprietary interfaces. The example of Open RAN, a host of initiatives aiming to bring these principles to radio access networks (RANs), is shown in Figure 2.1.

FIGURE 2.1: ILLUSTRATION OF OPEN INTERFACES AND DISAGGREGATION LEADING TO SUPPLIER DIVERSITY IN OPEN RAN [SOURCE: ANALYSYS MASON, 2021]



[6] It should be noted that open-source software is a related but different concept, which refers to the free distribution and modification of original source code for various uses. While open interfaces can result in the use of open-source software as part of a multi-vendor network, it does not always follow that open and disaggregated telecoms networks use open-source software, as many new software vendors aim to offer proprietary software solutions on top of open interfaces that are able to interoperate with other hardware and software components.

This transformation across many parts of the network would increase supplier diversity and improve operator choice, which would in turn stimulate competition and innovation in the equipment supply chain and maximise the potential of emerging technologies. This has resulted in the establishment of initiatives aimed at driving the development of an open ecosystem, including TIP (the Telecom Infra Project), the O-RAN Alliance, the Open RAN Policy Coalition, and others.

TIP's specific role in this ecosystem is to drive and accelerate actual commercial deployment, by enabling the emergence of fit-for-purpose, validated products and solutions. To address this need, TIP has set up a wide range of project groups targeting many network developments based on operator requirements, and drives progress through a highly structured process, supported by a number of platforms for collaboration, testing and demonstration of viable results. Several of TIP's project groups have made significant progress, showing signs of change in a deeply conservative segment of the industry.

2.1 Telecoms operators' continued investment in a wider variety of innovative, resilient network technologies would benefit from a more diverse supply-chain ecosystem

Public telecoms networks are based on highly complex, interconnected infrastructure. Traditionally, the hardware and software that ran these networks was developed, manufactured and integrated by a small number of large vendors that guaranteed the end-to-end integrity and interoperability of the solutions they developed for operators. They designed, deployed and maintained networks on behalf of many of their clients, providing 'turn-key' solutions that allowed operators large and small, with or without internal resources, to operate reliable networks around the world.

Today, despite the emergence of software-defined networking and the commoditisation of the underlying hardware, most networks remain 'locked in' to (i.e. are dependent on) one or two vendors that provide end-to-end solutions. This dependency on a small number of vendors, and the primarily closed environments that they deploy and maintain, limits the ability of operators to experiment with new suppliers or more innovative architectures. Limited choice also creates vulnerability in supply chains, and could prevent equipment prices from decreasing as rapidly as they would under a more competitive supply-chain scenario.

A more diverse, more interoperable equipment supply chain would contribute to the telecoms sector unlocking the full potential of 5G and expanding coverage to unconnected areas of the world. Higher levels of competition and innovation in network equipment and software would allow operators to deploy more cost-efficient and flexible networks to support new services more quickly, and to roll out services in new areas more cheaply. Greater supplier diversity can only be achieved if network components are connected via interoperable interfaces. Interoperability is enabled by widespread adoption of public standards, which are developed and driven by various standards-setting bodies and other collaborations. TIP contributes to this effort by facilitating testing and validation of end-to-end solutions and also promotes commercialisation of open solutions.

2.1.1 Operators are looking to emerging technologies such as 5G and network automation to enable new services in developed markets and to expand connectivity more broadly across the globe

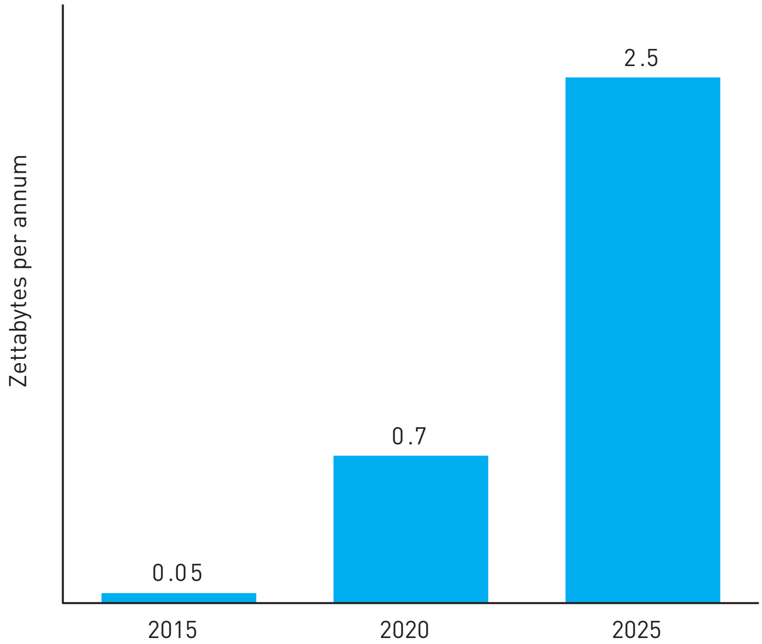
In recent years, mobile operators across the globe have seen tremendous growth in mobile data consumption. This growth will continue unabated, according to Analysys Mason Research data.[7] This rapid increase in demand, accompanied by stagnant or falling mobile average revenue per user (ARPU) levels, puts pressure on operator profitability. In this context, 5G provides an opportunity for operators to develop new revenue streams, especially in developed, digitally advanced economies.

Concurrently, more than half of the world's population does not regularly use mobile internet and 7% is living outside areas served by mobile broadband networks.[8] To unlock the advantages of a digital-based economy, widespread access to the internet is necessary. However, it is often not profitable for operators to expand into areas with low population density and where citizens with low incomes are less able to afford mobile services. The prospect of new models for deploying networks would be welcome to help close the digital divide.

[7] Analysys Mason Research. (2020), Wireless network data traffic: worldwide trends and forecasts 2020-25. Available at https://www.analysysmason.com/research/content/regional-forecasts-/wireless-traffic-forecast-rdnt0/

[8] GSMA. (2020), The State of Mobile Internet Connectivity 2020. Available at https://www.gsma.com/r/wp-content/uploads/2020/09/GSMA-State-of-Mobile-Internet-Connectivity-Report-2020.pdf

FIGURE 2.2: GLOBAL CELLULAR DATA TRAFFIC FORECAST [SOURCE: ANALYSYS MASON RESEARCH WIRELESS NETWORK DATA TRAFFIC FORECASTS 2020-25]



Consequently, operators across the globe continually search for new ways to manage costs while deploying and upgrading their networks to meet the ever-growing demand for data. In recent years, operators have engaged in more infrastructure sharing (both passive and active),[9] often through independent tower companies, in order to control costs. There have also been several instances of operators divesting towers to these independent tower companies and opting for a leaseback model, where operators would start paying rental fees for these sites in future, in order to raise capital in the short term. Operators are also looking to the potential of virtualised mobile networks as a means to deploy networks with more flexibility and the capability to support a wider array of services, while also embedding higher levels of automation and embedded intelligence, in order to deploy network resources in a more cost-efficient manner. Network virtualisation involves replacing physical hardware used for certain components in legacy networks with network functions that can run as software on general 'commercial off-the-shelf' (COTS) hardware.

2.1.2 Maximising the potential of emerging technologies requires overcoming structural challenges in existing network supply chains

While the separation of hardware and software has already started to enable a shift from physical to virtual network control and operation, further disaggregation of the supply chain will be key to delivering on the full promise of network virtualisation. An operator with a disaggregated supply chain would be able to source different network components from a wider variety of vendors to best suit its requirements, as long as solutions from different vendors are interoperable.[10] More competition between vendors in the supply chain would drive down hardware costs and spur the development of a vibrant and innovative software ecosystem that caters to a diverse range of needs.

At present, the network equipment market is highly concentrated, with a small number of large, global vendors providing products and solutions to most operators. Those operators are often 'locked in' to solutions from their main vendor, as solutions are not sufficiently interoperable and vendors often handle integration and maintenance of their own network equipment (but not of other vendors'). Although this model simplifies network integration and management, operators end up with less bargaining power when negotiating equipment purchases, and less network flexibility. Large vendors are likely to

[9] Passive infrastructure sharing usually refers to sharing of physical space and power systems, while active infrastructure sharing refers to sharing of active equipment such as antennas and transceivers

[10] Analysys Mason. (2020). Open, disaggregated networks will transform MNO's 5G business cases, available at https://www.analysys.com/research/content/white-papers/5g-open-networks-rma18/

prioritise the development of end-to-end solutions that appeal to a broad customer base, and would not necessarily have incentives to invest in a wide array of software solutions to suit diverse needs.

A disaggregated and more competitive supply chain is more likely to deliver more innovation, as has been seen in other industry verticals. New entrants would have the opportunity to provide new innovative solutions, and large vendors could also be incentivised to provide open network solutions of their own, or to open up their interfaces fully if there is sufficient pressure from operators to make interfaces truly open. The example of the semiconductor industry described in the case study below illustrates how disaggregation can stimulate innovation, which would be beneficial even if consolidation would occur later on.

Case study: Specialisation, consolidation and ongoing disaggregation in the semiconductor industry

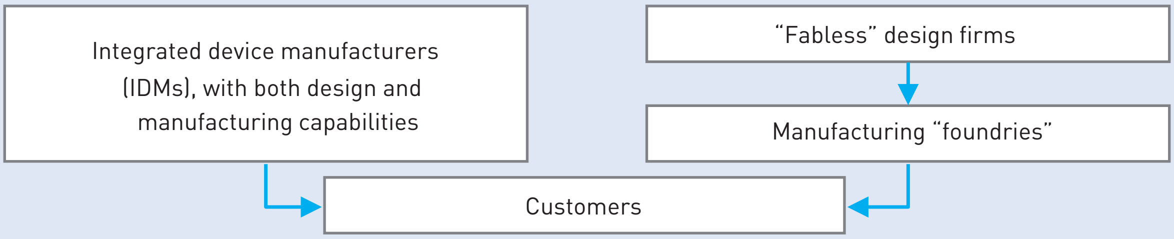
The semiconductor industry started to develop from the late 1950s, when the first firms that specialised in semiconductor components entered a market that previously consisted of larger integrated producers such as AT&T and IBM that manufactured both electronic systems and the semiconductor components that were used in the systems.[11]

In the 1980s, the supply chain for semiconductors began to disaggregate into specialisations.[12] The shift allowed more companies to compete in each category, triggering accelerated innovation from specialisation, particularly by separating the design and manufacturing of semiconductor components. As a result, many "fabless"[13] semiconductor firms were able to enter the market and competed on having more innovative designs and faster delivery, while contracting "foundries" that specialised in process engineering and manufacturing. Several integrated device manufacturers, with both design and manufacturing capabilities, continued to compete in the market as well.

Disaggregation during the 1980s and 1990s increased the efficiency of the semiconductor industry by introducing competition at different stages of the supply chain, resulting in an increased pace of innovation and better economies of scale due to specialisation.

More recently, the semiconductor industry has been going through a phase of consolidation after the benefits of specialisation have been realised in earlier decades and as firms aim to compete across a wider range of verticals. However, a new wave of specialisation linked to 5G could also emerge in areas such as power electronics or specific system-on-chip (SoC) solutions for Open RAN small cells. The potential for new open solutions and disaggregation continues to be relevant for the industry, as companies such as SiFive have begun to offer open-source hardware (e.g. following the RISC-V architecture) that reduces development costs and time to market, while others have been promoting the use of pre-verified chiplets that can serve a similar purpose.[14]

Disaggregation in telecoms networks could result in similar benefits, with greater supplier diversity leading to more competition that drives down the cost of generic hardware components, and stimulates the development of more innovative software solutions that can be brought to market more rapidly than in an environment dominated by proprietary systems.



[11] See https://core.ac.uk/download/pdf/7123143.pdf

[12] DaxueConsulting. (2020), China's Semiconductor Industry: 60% of the global semiconductor consumption. Available at https://daxueconsulting.com/chinas-semiconductor-industry/

[13] A semiconductor fabrication plant is commonly referred to as a "fab".

[14] See https://www.rambus.com/blogs/monetizing-semiconductors-silicon-services/

2.1.3 Interoperability between different vendors through widespread adoption of open standards is essential to allow a more diverse, sustainable supply chain to emerge

Disaggregation is in turn enabled by opening up and standardising the interfaces between different network components, allowing equipment and solutions from multiple vendors to work together, or 'interoperate'. Open standards must see sufficiently widespread adoption to allow more vendors into the supply chain, and so enable more systematic innovation of a wider variety of solutions.

Today, interfaces between different components of hardware and software exist throughout the telecoms network, some of which are open and interoperable, such as the 3GPP-based interfaces.[15] However, much of the network is still connected by proprietary implementations of standard interfaces, that are specific to the original vendor. For example, within the RAN, there are interfaces which have traditionally been safeguarded by individual vendors. The Open RAN movement aims to open up and disaggregate the telecoms network, for instance, through the standardisation of interfaces that have thus far been optional, leading to proprietary implementations.[16,17]

In the past few years, several standards bodies have been formed with the aim to produce standards and specifications based on open principles in various networking fields. The activities of some of these organisations are summarised in Figure 2.3 below.

FIGURE 2.3: INITIATIVES THAT DRIVE OPEN NETWORKING PRINCIPLES, INCLUDING STANDARDS-SETTING BODIES
[SOURCE: ANALYSYS MASON, 2021]

Collaborating group	Main activities
O-RAN Alliance (O-RAN)	Formed after the merger of C-RAN Alliance and the xRAN Forum and consists of over 230 operators, vendors and research and academic institutions. The group is focused on publishing new RAN specifications, releasing open software and providing support for Open RAN trials.[18]
Small Cell Forum	Consists of operators that establish requirements and have driven the standardisation of elements of small-cell technology.[19] The Small Cell Forum is also working towards enabling Open RAN by developing standards for the interface between a Distributed Unit and Centralised Unit in a small-cell RAN.[20]
Open Networking Foundation (ONF)	Open Networking Foundation (ONF) Supports a number of projects generally focused on building mobile & 5G and broadband solutions. ONF initiated the Software Defined Networking (SDN) movement, upon which network programmability depends.[21] The ONF also developed Stratum, an operating system used by the TIP Cassini device, discussed in Section 2.3.1.
OpenConfig	Informal working group of operators that aim to shift networks towards a more dynamic, programmable infrastructure by adopting SDN principles.[22] OpenConfig develops vendor- neutral programmatic interfaces and management tools.
Wi-Fi Alliance	A global group of companies that drives Wi-Fi adoption through spectrum advocacy, and industry-wide collaboration. The group works on developing new technologies, consolidating requirements and test programs to support reliable Wi-Fi delivery.[23]
Wireless Broadband Alliance	The Wireless Broadband Alliance aims to drive seamless and interoperable service experiences via Wi-Fi, with its main work groups focusing on 5G, IoT, NextGen Wi-Fi, roaming, as well as testing and interoperability.[24]

[15] 3rd Generation Partnership Project (3GPP) is a group of standards organisations that develop protocols in mobile telecommunications, such as those for the air interface and the S1 interface in the RAN 4G/ LTE architecture.

[16] The first is the CPRI interface between BBU software and the Remote Radio Head (RRH), or RU. The second is the X2 interface which has been defined by 3GPP, but is optional and has been implemented with proprietary messages by some legacy vendors. Opening up the X2 interface is particularly necessary to ensure that operators are not locked in to existing 4G LTE vendors for deployment of 5G technology.

[17] The Fast Mode. The Ultimate Guide to Open RAN: Why do interfaces need to be Open? Available at https://www.thefastmode.com/expert-opinion/17877-the-ultimate-guide-to-open-ran-why-do-interfaces-need-to-be-open

[18] See https://www.o-ran.org/about and https://www.telecomtv.com/content/open-ran/o-ran-alliance-boasts-new-specifications-expands-board-40093/

[19] See https://www.smallcellforum.org/about-us/

[20] The Fast Mode. The Ultimate Guide to Open RAN: Why do interfaces need to be Open? Available at https://www.thefastmode.com/expert-opinion/17877-the-ultimate-guide-to-open-ran-why-do-interfaces-need-to-be-open

[21] See https://opennetworking.org/onf-sdn-projects/

[22] See https://www.openconfig.net/ and https://www.openconfig.net/docs/faq/

[23] See https://www.wi-fi.org/who-we-are

[24] See https://wballiance.com/wba-program-overview-2021/

These organisations produce important standards that are necessary for interoperability to be achieved. However, they play a limited role in driving the creation of actual new products and services based on those open standards. TIP takes this effort forward by bringing operators and solution providers together to define requirements and to build and test viable products and solutions based on open standards defined by the standards organisations. TIP also works collaboratively with standards bodies to identify standards that are ready to be taken forward into actual solutions, and to identify new areas where standardisation would be required, based on emerging operator needs.

2.2 TIP aims to accelerate the deployment of new solutions by fostering collaboration between key industry stakeholders in a structured process

TIP was set up to facilitate the creation of interoperable network components (both hardware and software), and to accelerate the deployment of new solutions in actual networks. Different project groups within TIP focus on bringing to market products for different sections of the telecoms network, enabled by an array of TIP-hosted activities for facilitating collaboration, trials and sharing of information.

TIP provides a platform that allows operators, vendors and other stakeholders in the telecoms industry to collaborate and deploy more cost-efficient and flexible networks

TIP has been set up with 'Together We Build' as its mission statement, and is unique as an entity in that it has developed the scale and resources to foster deployment-focused collaboration among a wide range of stakeholders, and bridges the gap between the definition of standards and enabling practical availability of disaggregated solutions. As a vehicle, TIP aims to reduce operator procurement and deployment risk by lowering barriers to entry for vendors and reducing the time it takes for technically and commercially viable disaggregated solutions to reach the market.

An increasingly open ecosystem would support a more diverse range of commercial solutions on the market, including more solutions developed by local producers in-country. The resulting increase in competition will also generate cost savings for operators as they deploy futureproof networks, and allow for more network investment and service innovation that would benefit consumers.

Case study: The self-governing architecture of the internet

The internet is a perfect example of a platform that has benefitted from input from a global base of stakeholders. Its design was publicly available and shared from the beginning of its development.[25] The decision to build the internet reflected early coders' priority to preserve the potential for future innovation in the network as well as their resource constraints.

Today, the Internet Engineering Task Force (IETF) is a group of network designers, operators, vendors and researchers all concerned with optimising the architecture of the internet. The group aims to improve the internet's functioning by producing technical documents that influence the way people design, use and manage the network. Like the network itself, the group operates on open principles, allowing any interested person to participate in the group's decisions, and access and deploy the resulting specifications.

TIP similarly aims to foster collaboration between a community of stakeholders on developing, testing and validating commercial solutions for telecoms networks,[26] to an extent that has thus far not been required or possible in a closed and proprietary system. Progress made to date suggests that operators, vendors and systems integrators have an interest in contributing to the broader development of the open ecosystem given emerging market requirements.

[25] Jonathan Zittrain. (2008), *The Future of the Internet and How to Stop It.*

[26] Based on specifications developed by other initiatives and standards bodies.

TIP hosts a wide range of project groups, which focus on bringing new products, end-to-end solutions and software to market

Each TIP project group focuses on a specific objective, with participants able to contribute to several project groups of interest. At present, TIP hosts three types of product project groups, namely access, transport, and core and services, as shown in the figure below.[27] Product project groups target a distinct part of the value chain, and develop requirements documents, white papers, leading to the development of hardware and software products that can be trialled in lab and field settings, before eventually being deployed in actual commercial settings.

TIP has also established several solution project groups, which have a broader scope and are focused on end-to-end implementations for specific use cases, using products that have been created, tested, and validated from the product project groups. These include the Connected City Infrastructure, Network as a Service (NaaS) and Open Automation solution project groups.[28] Finally, TIP has also started to set up software project groups to develop open-source software that can run on disaggregated network elements, starting with the Open Converged Wireless project group, that designs, develops and tests software for Wi-Fi and small cells.[29] A full list of active project groups is provided in Figure 2.4 below.

FIGURE 2.4: TIP PROJECT GROUPS [SOURCE: TIP, ANALYSYS MASON, 2021]

Product project groups

Access	Transport	Core and services
▪ Open Cellular ▪ OpenRAN ▪ Wi-Fi	▪ Non-Terrestrial Connectivity Solutions ▪ Open Optical & Packet transport (OOPT) ▪ Wireless Backhaul	▪ Open Core Network

Solution project groups	Software project groups
▪ Connected City Infrastructure ▪ Network as a Service (NaaS) ▪ Open Automation ▪ 5G Private Networks	▪ Open Converged Wireless

To date, TIP has set up a wide range of project groups to drive innovation across telecoms networks, in response to actual operator demand for new network functionality.

TIP adopts a structured process across project groups and provides an end-to-end framework aligning a diversity of skills and creating economies of scale to accelerate commercial solutions

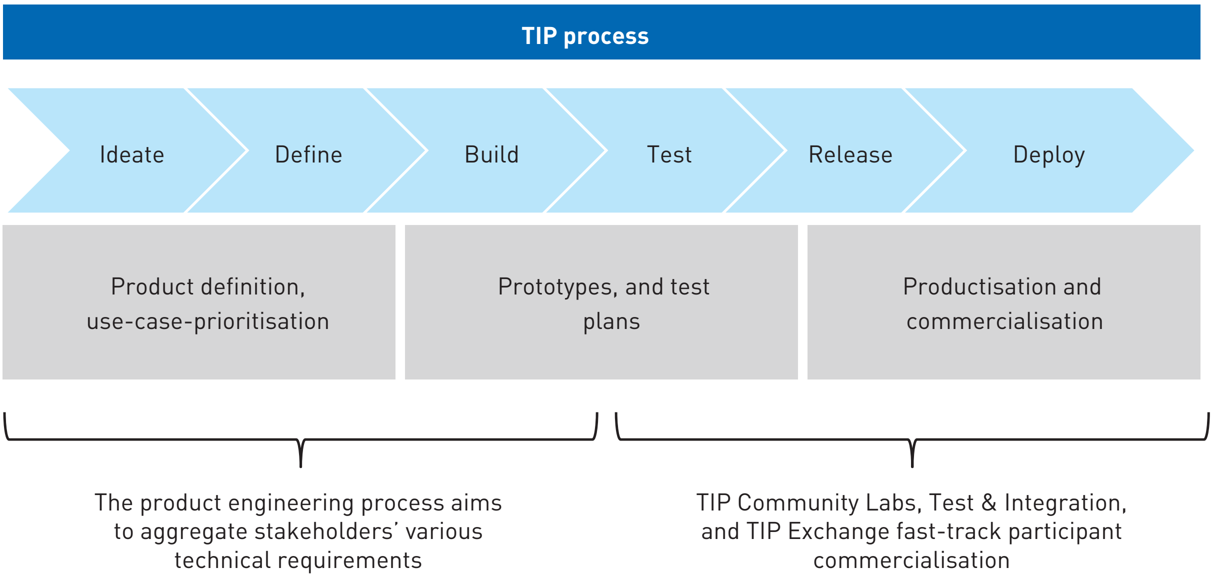
The TIP process consists of core activities defined to produce multiple deliverables at each of the various steps, as illustrated in Figure 2.5 below. The TIP model is designed to expand the supply chain and drive innovation across the entire telecom landscape - collectively designing, building, and testing technologies that are more efficient and interoperable across the whole product lifecycle.

TIP project groups are the initial starting place for the TIP process. As part of what TIP calls "Ideate" and "Define", TIP identifies the best market opportunities for connectivity from operators and other connectivity stakeholders, and prioritises business-driven use cases, aligning on high-level technical requirements to address these use cases.

[27] See https://telecominfraproject.com/project-groups/
[28] See https://telecominfraproject.com/project-groups/#solutionpgs
[29] See https://telecominfraproject.com/open-converged-wireless/

Within "Build" and "Test", TIP's "Test & Validation" framework measures and tests network elements, network products, or end-to-end configurations against project group requirements. Through TIP Community Labs (and authorised third-party labs), participants collaborate to produce and validate project group solutions, lab test plans, exit reports, and specifications. TIP's lab and testing environment results in badges highlighting conformance and maturity and are detailed on the TIP Exchange.

FIGURE 2.5: THE TIP PROCESS FOR PRODUCT ENGINEERING AND COMMERCIALISATION
[SOURCE: TIP,[30] ANALYSYS MASON, 2021]



Test and validation framework

Activities	Descriptions
TIP Community Labs	Physical spaces set up to facilitate participant collaboration, sponsored by individual TIP participant companies
TIP Test and Integration	Programme focused on validating multi-vendor network components, as well as end-to-end solutions for common network environments or use cases
TIP Exchange	Distills TIP-qualified offerings for TIP participants to showcase products and solutions, and for service providers to easily evaluate connectivity solutions

[30] See https://telecominfraproject.com/test-validation/ and https://telecominfraproject.com/how-we-work/

Final validation and best practice sharing of commercial deployments of open disaggregated network components, configurations, or end-to-end solutions are part of "Release" and "Deploy".

2.3 Significant progress is being made across several key project groups, resulting in a strong pipeline of lab and field trials, and several commercial deployments to date

Recent and upcoming developments in the Open Optical and Packet Transport (OOPT), Open RAN and Wi-Fi project groups illustrate TIP's real-world impact:

- OOPT deliverables have helped TIP participants commercialise several products that have already been adopted by operators globally.
- OpenRAN is currently being trialled and has the potential to enable new use cases and services to the benefit of mobile operators and end users.
- Open Wi-Fi, meanwhile, aims to stimulate innovation in an essential technology that has been relatively stagnant in recent years, but is expected to have a significant impact in future following the release of new unlicensed spectrum.

2.3.1 The OOPT project group has successfully taken a number of products and solutions to market, with adoption from major operators across the globe

OOPT accelerates innovation in optical and IP networks and is composed of subgroups with varying remits. The different subgroups focus on the development of solutions in the network supply chain in response to operator demand.

An example of OOPT's practical success is the commercialisation of TIP-developed Disaggregated Cell Site Gateways (DCSG). As mobile traffic increases, operators also require more capacity from existing devices, especially as networks are upgraded for 5G, and most cell-site routers deployed at present are unsuitable for traffic likely to be generated by 5G base stations. High operational overheads and slow installation also mean that traditional transport devices are costly to upgrade. Altogether, these factors provided potential for high-impact intervention by TIP.

Initially, Vodafone, Telefónica, Orange and TIM Brazil each contributed to defining the necessary specifications for various DCSG use cases.[31] DCSG decouples hardware and software, with open application programming interfaces (APIs) which operate on an SDN. The resulting configuration allows operators to mix and match hardware and software according to their unique requirements, reduces operational costs, and allows quicker upgrades, as well as automated life-cycle management.

To date, industry support for the DCSG solution has been widespread, with commercial deployments of major operators announced in Germany,[32] Ecuador,[33] Peru,[34] South Africa[35] and Taiwan.[36]

Moving forward, the OOPT project group intends to further the deployment of the DCSG and the Cassini

FIGURE 2.6: OOPT SUBGROUPS [SOURCE: TIP, ANALYSYS MASON, 2021]

Subgroups addressing discrete components / functions within the transport network

Disaggregated Cell Site Gateways	Disaggregated Open Routers	Disaggregated Optical Systems (e.g. transponders)	Physical Simulation Environment

Subgroups addressing end-to-end transport network requirements

Network Operating Systems (NOS)	Converged Architectures for Network Disaggregation & Integration (CANDI)	Mandatory Use Case Requirements for Software Defined Networking for Transport (MUST)

[31] TIP press release, see https://telecominfraproject.com/four-major-operators-collaborate-through-the-telecom-infra-project-to-disaggregate-cell-site-technology/

transponder at scale. Collaborations on the Phoenix optical transponder and several types of disaggregated open routers are currently in progress and these products are on track to become generally available in 2021. The group has also published documents on Mandatory Use Case requirements for SDN for Transport (MUST), which presents a selection of the most relevant SDN interfaces that need to be standardised across the industry to guide the development of software-controlled solutions.[42]

Case study: Virtual Technologies and Solutions (VTS)

VTS is an internet services provider which offers high-speed broadband to businesses and individuals in Burkina Faso.[37] Since its launch in 2016, the local wireless operator's business has seen significant growth, enabled by TIP-developed equipment.

Traditionally, smaller operators depend on regional incumbents to transit their data to provide internet services to end customers. As Burkina Faso is landlocked, relying on others' infrastructure means paying steep margins to local monopolists and those in neighbouring countries for IP transit. The prospect of these high costs led VTS to invest in its own infrastructure.

In October 2020, VTS extended its capacity from the West Africa Cable System, ACE and MainOne in a 200km roll-out of 200Gbit/s fibre, to interconnect the capital Ouagadougou with Dakola. This project crucially used the Disaggregated Optical Systems subgroup's Cassini, which is an open packet transponder, originally provided by Edgecore Networks, that provides a mix of 100Gigabit Ethernet packet switching ports and 100/200Gbit/s coherent optical interfaces.[38] Cassini supports a variety of operating systems, including Stratum, an open-source switch operating system, developed by ONF's Open and Disaggregated Transport Network initiative,[39] as well as IPInfusion's OcNOS, which is the current option used by VTS.[40]

The decision to use Cassini instead of proprietary alternatives has given VTS flexibility to deploy additional capacity at lower cost, and without having to complete the laborious design, RFP and build process which might take up to six months, thus reducing time to market for new capacity and improved service.

Additionally, VTS has also adopted DCSG as part of its transport disaggregation journey, which combined with the Cassini deployments, has contributed to generating capex and opex savings. Abdou Dia, VTS CEO, commented during the AfricaCom event that was held in November 2020,[41] that operating in a landlocked country involved significantly high costs for capacity due to the need to traverse other countries, and that open and disaggregated solutions from the TIP community were needed to help cut cost per bit down by factors of 25 to 50 times, in order to produce a viable business case.

[32] Infinera press release, see https://www.infinera.com/press-release/TIP-Infinera-and-Edgecore-Networks-Mark-Milestone-in-Open-Mobile-Transport-with-First-DCSG-Commercial-Deployment

[33] Light Reading. (2019), TIP advances give router vendors another wake-up call, available at https://www.lightreading.com/optical-ip/tip-advances-give-router-vendors-another-wake-up-call/d/d-id/755598

[34] Infinera press release, see https://www.infinera.com/press-release/infinera-tip-telefonica-collaborate-to-expand-dcsg-drx-series-deployments-to-peru

[35] TIP press release, see https://telecominfraproject.com/vodafone-launches-commercial-trials-of-tip-incubated-dcsg-solution-in-south-africa/

[36] TIP press release, see https://telecominfraproject.com/tips-dcsg-solution-to-be-deployed-at-scale-in-5g-network-in-taiwan/

[37] See https://www.vts.bf/services

[38] See https://telecominfraproject.com/vts-launches-first-commercial-deployment-of-tips-cassini-solution-in-africa/

[39] ONF press release, see https://opennetworking.org/news-and-events/press-releases/onfs-stratum-open-source-switch-os-now-available-on-cassini-hardware-from-tip-2/

[40] See https://www.ipinfusion.com/news-events/vts-selects-ip-infusion-for-first-commercial-deployment-of-tips-cassini-solution-in-africa/

[41] See https://vimeo.com/478575811

[42] See https://telecominfraproject.com/oopt/

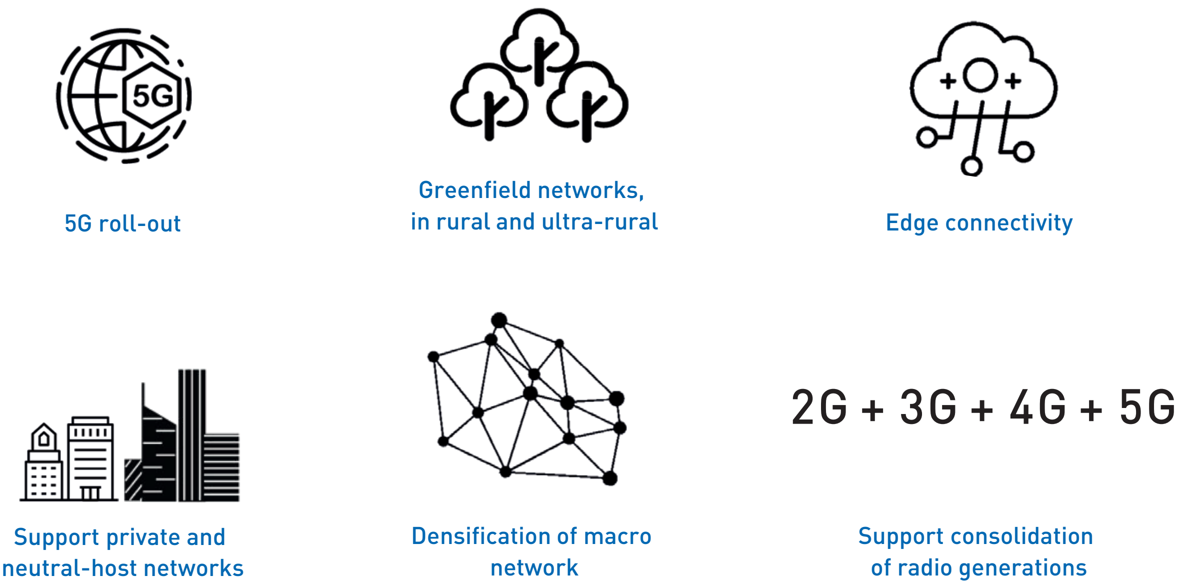
2.3.2 Developments in the OpenRAN project group promise to deliver improvements in network economics that would enable innovation in telecoms markets for years to come

Significantly, the RAN, which connects individual devices, such as mobile phones or SIM-enabled tablets, to the core network via radio frequencies, accounts for over 60% of the total cost of ownership of a network.[43] The opportunity to commodotise hardware and automate networks in the RAN could have a significant impact on operators' ability to deploy larger and better-performing networks at existing cost levels.[44] Further, achieving greater cost efficiency could also improve the business case for expanding greenfield coverage[45] to rural and ultra-rural areas and for using 5G small cells as a route to urban densification.[46] Section 4 explores the potential economic impact of the Open RAN movement in more detail using a quantitative model, and also considers the influence that TIP and other industry facilitation initiatives could have on outcomes.

TIP's OpenRAN project group aggregates and publishes technical requirements from operators and gathers a community of vendors and systems integrators to collaborate on trials of new RAN technology. The OpenRAN project group should not be confused with the broader Open RAN (with a space) movement, which aims to drive adoption of open standards. Of the industry bodies contributing to the wider Open RAN movement, the TIP OpenRAN project group is most focused on bringing products and solutions to market.

On 20 January 2021, four of Europe's largest operators – Deutsche Telekom, Vodafone, Orange and Telefónica – signed a memorandum of understanding (MoU) committing each to the implementation and deployment of Open RAN technology.[47] TIM subsequently joined the initiative in February 2021.[48]

FIGURE 2.7: KEY USE CASES OF INTEREST TO OPENRAN [SOURCE: ANALYSYS MASON, 2021]



[43] Samsung. The Open Road to 5G. Available at https://image-us.samsung.com/SamsungUS/samsungbusiness/pdfs/Open-RAN-The-Open-Road-to-5G.pdf

[44] Accenture. (2019), OpenRAN: The Next Generation of Radio Access Networks, available at

https://www.accenture.com/_acnmedia/PDF-113/Accenture-Open-RAN-The-Next-Generation-Radio-Access-Network.pdf

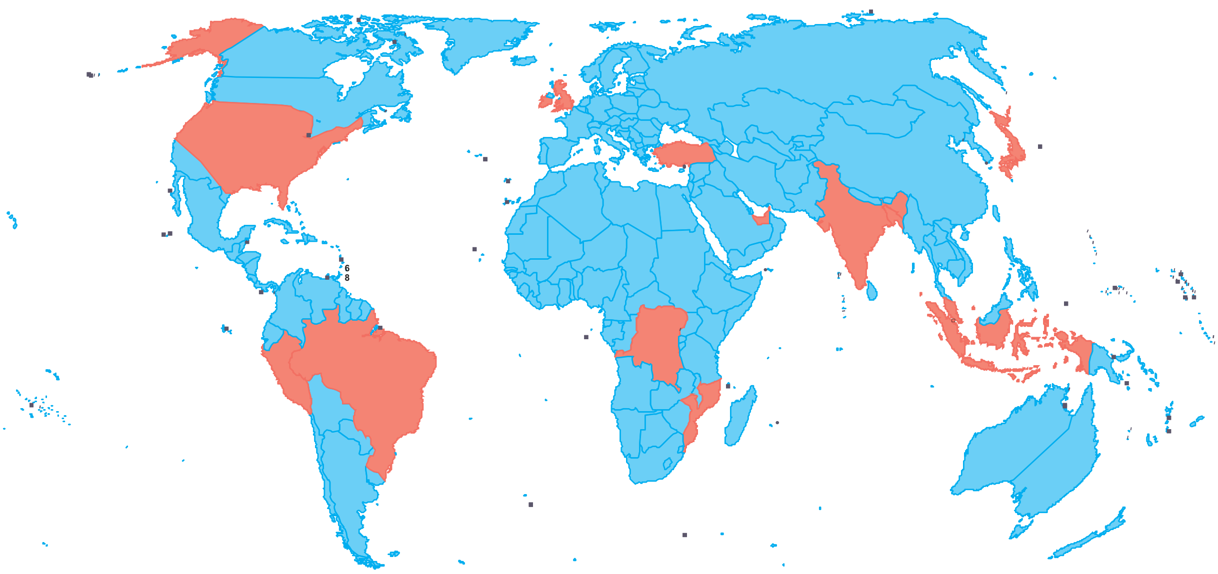
[45] Expanding greenfield coverage involves deploying sites in locations that were not previously built on before

[46] Analysys Mason. (2020), Open, disaggregated networks will transform MNO's 5G business cases, available at https://www.analysys.com/research/content/white-papers/5g-open-networks-rma18/

These operators have also been involved in TIP activities – for example, teams from Vodafone and Parallel Wireless developed a playbook outlining the learnings from an OpenRAN trial conducted in Turkey.

This MoU entails co-ordination between the operators, policy makers, O-RAN Alliance and TIP in an effort "to ensure open RAN reaches competitive parity with traditional RAN solutions".[49] Soon afterwards, the Open RAN Policy Coalition (see Section 5.3.2), together with TIP, GSMA and other critical industry stakeholders announced their joint intention to actively promote policies to international governments which might aid the transition to an open network.[50] The announcements reiterate the importance of the OpenRAN project group, which is critical to the TIP agenda because of the impact its adoption could have on telecoms markets and global connectivity.

FIGURE 2.8: OPENRAN IS ALREADY BEING TRIALLED AND DEPLOYED GLOBALLY, INCLUDING IN THE COUNTRIES HIGHLIGHTED IN RED BELOW[51] [SOURCE: TIP, ANALYSYS MASON, 2021]



[47] Orange press release, see https://www.orange.com/en/newsroom/press-releases/2021/major-european-operators-commit-open-ran-deployments

[48] See https://www.gruppotim.it/en/press-archive/corporate/2021/PR-TIM-ORAN-en.html

[49] See https://www.vodafone.com/news/press-release/major-european-operators-commit-open-ran-developments

[50] Open RAN Policy Coalition press release, see https://www.openranpolicy.org/category/newsroom/

[51] See https://telecominfraproject.com/tip-openran-project-group-is-streamlined-to-accelerate-development-and-deployments/

Case study: The Vodafone Turkey and Parallel Wireless 'playbook'

In September 2020, a playbook developed by teams from Vodafone Turkey and Parallel Wireless was released, following a trial deployment of OpenRAN in Turkey.[52] The trial integrated 2G/3G/4G OpenRAN solutions to 25 sites in rural, urban and semi-urban areas, to improve existing 2G and 3G connectivity, add LTE capability, and manage all technologies from a single virtualised RAN controller. Parallel Wireless was responsible for providing solutions, while a local third party was subcontracted to manage installation and drive testing.

The playbook explains the organisational structure of the parties involved, the different activities carried out by each, and the deployment approach which was followed. It provides some information on the vendor equipment and solution architecture, a final high-level economic assessment, as well as benchmarking procedures to evaluate the overall process.

The playbook can be used as a resource to guide the set up of other Open RAN trials, and provides insight into potential challenges that other operators might face. The lessons derived from testing, evaluating and deploying open solutions would be able to provide guidance on dealing with common challenges. Initiatives such as this playbook could play an important role in helping other operators to gain comfort in the viability of these solutions, which would in turn, drive demand for open solutions and allow vendors to realise greater economies of scale.

2.3.3 Several initiatives driven by the Wi-Fi project group are likely to take off in the short term, given ongoing developments regarding the availability of spectrum in the 6GHz band

In 2020, the US regulator, the Federal Communications Commission (FCC), approved the use of the 1200MHz of spectrum available in the 6GHz band for unlicensed technologies, which will significantly increase the amount of spectrum available to Wi-Fi in the USA.[53]

Around the world, regulatory bodies are similarly allowing Wi-Fi access to the 6GHz band, including those in Brazil, Chile, the European Union, Japan, Mexico, South Korea, Taiwan, the UAE and the UK. In response, semiconductor manufacturers such as Broadcom[54] and NXP [55] have developed chipsets capable of operating in the 6GHz band, which promise increased capacity and performance to enable a variety of compelling use cases.[56]

[52] Telecom Infra Project. (2020), Playbook – OpenRAN Trials w/ Vodafone Turkey", available at https://cdn.brandfolder.io/D8DI15S7/as/c5tx5crn45cch6w3nrz39s/OpenRAN_VF_TK_Playbook_FINAL.pdf

[53] FCC press release, see https://docs.fcc.gov/public/attachments/DOC-363945A1.pdf

[54] See https://www.broadcom.com/company/news/product-releases/52926

[55] See https://media.nxp.com/news-releases/news-release-details/nxp-unlocks-6ghz-spectrum-wi-fi-6e-tri-band-chipset-access

[56] Wi-Fi Alliance press release, see https://www.wi-fi.org/news-events/newsroom/wi-fi-alliance-delivers-wi-fi-6e-certification-program

Recent developments suggest that the work of the TIP Wi-Fi project group will have a substantial impact. TIP's Wi-Fi project group looks at end-to-end use cases to drive Wi-Fi network monetisation and to bring solutions with a positive return on investment to the owners of Wi-Fi networks, particularly in the enterprise segment (which requires more features and controls to manage a larger number of access points than in typical residential settings).[57] Several settings in which enterprises would demand these types of Wi-Fi services are illustrated in Figure 2.9 below.

FIGURE 2.9: OPEN WI-FI TARGETS KEY ENTERPRISE USE CASES [SOURCE: ANALYSYS MASON, 2021]

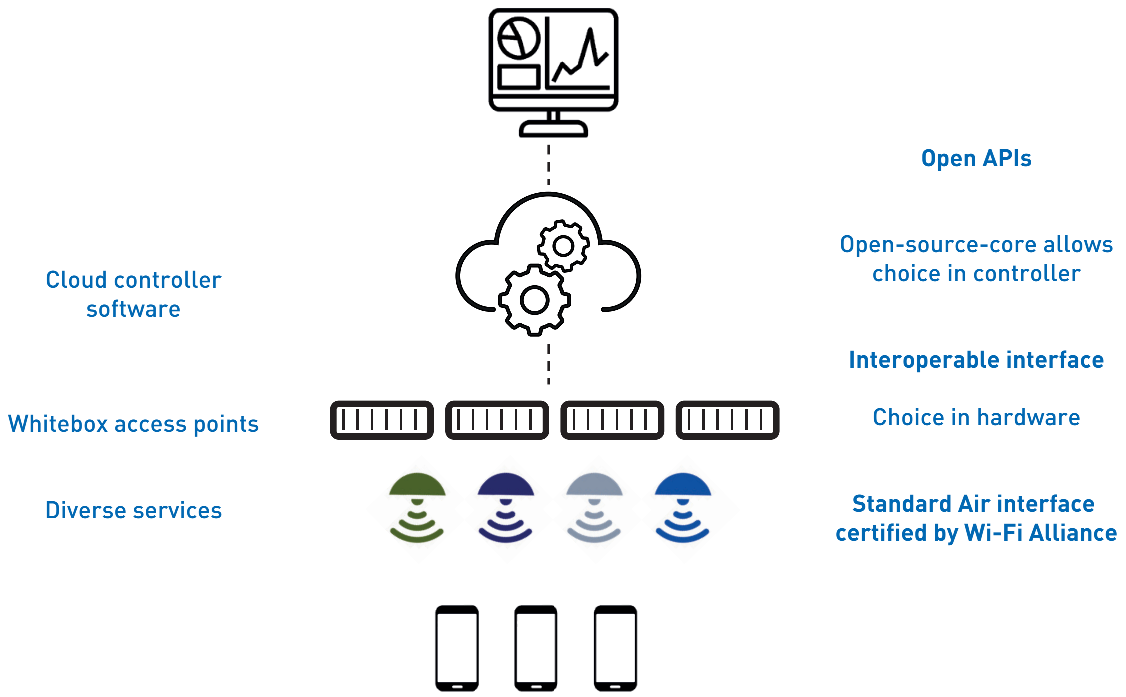
Today, vendors of 'carrier-grade'[58] enterprise Wi-Fi "lock in" Wi-Fi service providers with proprietary controller interfaces and functions, and generate large margins on hardware. As a result, the vendor market for these solutions is relatively concentrated, and customer choice, in terms of both access point hardware and software functions, is limited. The TIP Wi-Fi project group aims to transform the ecosystem by opening up the interfaces along the value chain, allowing multiple vendors to contribute royalty-free software and COTS enterprise-grade access point hardware. An open-source cloud controller capable of managing thousands of access points allows the system to be scaled according to customer needs, which would be critical for emerging use cases that depend on Wi-Fi for connectivity.

The TIP Wi-Fi project group is also fostering an open-source community to pool the skills of a diverse engineering team. A common code base will allow wide access to specialised providers who can all contribute to a robust, community-developed tech stack. This allows specialised vendors to innovate in smaller research and development (R&D) teams, while the backbone of the ecosystem is preserved. TIP also plans to incorporate automated testing as part of a certifying process that would help operators to deploy Open Wi-Fi based solutions with added confidence, while saving time and cost on more interoperability testing.

[57] See https://telecominfraproject.com/wifi/

[58] These typically require integration with core or back-end systems which are not part of the usual Wi-Fi standard and are therefore vendor specific.

FIGURE 2.10: OPEN WI-FI OPERATES ON DISAGGREGATED HARDWARE AND SOFTWARE [SOURCE: TIP, ANALYSYS MASON, 2021]



The TIP Wi-Fi community already brings together hundreds of participants, with stakeholders including Tier 1 operators, independent software vendors, managed service providers, original equipment manufacturers, original design manufacturers, silicon merchants and systems integrators. Over time, innovation driven by the Wi-Fi project group for the enterprise segment is also expected to have an impact on features available for residential Wi-Fi users.

3 Telecoms markets can benefit broadly from greater competition and innovation in the network supply chain

The ability of operators to build networks based on disaggregated components depends on a restructuring of the network equipment supply chain through interfaces that are truly open and interoperable. Restructuring the network equipment chain to enable operators to build networks based on truly open, disaggregated, and interoperable components would deliver the following impacts:

- new participants would be able to enter the market by specialising in parts of the supply chain
- incumbent vendors would have less control over operator roadmaps, but could find new ways to remain competitive in the ecosystem
- systems integrators would play a critical role in helping to deploy and manage operators' end-to-end networks.

As a result, operators, in turn, will enjoy an ecosystem that is characterised by greater cost efficiency and continuous technology upgrades, with software ready to be deployed as soon as it is market-ready. This would enable an expansion of connectivity, accelerated network upgrades and the generation of new revenue streams, while individuals and businesses benefit from new services and lower unit data prices (e.g. per GB). A more diverse supply chain could also mitigate security risk and enhance consumer privacy and safety through testing of adherence to industry security standards,[59] as well as the use of cloud-native features that allow for more automated and flexible monitoring of network security. Supply-chain resilience would also be improved, protecting operator investments. Over time, a vibrant open ecosystem could also present opportunities for new business model innovation and broader economic benefits for society.

- Infrastructure players could expand their offerings and add value in new ways, while non-traditional operators such as local municipalities and other start-ups could also discover opportunities in a fragmented supply-chain ecosystem.
- Accelerated development of emerging technologies such as 5G and Wi-Fi would have a broader impact on economic growth by facilitating greater use of online services and the digitalisation of industry and society.
- Countries could also capitalise on an open supply chain to bolster local manufacturing and software design capabilities, which would involve job creation and skills development.

3.1 An open environment presents opportunities for new vendors, incumbent vendors and systems integrators to specialise and expand their offerings

An open and interoperable network provides opportunities for new vendors to enter specific segments of the value chain, where previously they were excluded by proprietary interfaces. Although incumbent vendors might see an open network as a threat to their current market position and success, a more interoperable equipment market could also allow them to invest more in developing targeted, profitable areas in which they could retain a competitive advantage.

Opening up the network will mean that many operators may be more reliant on systems integrators that might see an opportunity for expansion. The new configuration also means that operators will be able to continuously test and rapidly deploy system upgrades and new solutions.

3.1.1 In the open, disaggregated and interoperable environment envisioned by TIP, a wide array of new and existing companies could enter the network equipment market with new solutions

Historically, integrated end-to-end networks privileged solutions provided by a single vendor, for large parts of an individual network.[60] Opening up and standardising network interfaces allows more new providers to slot in to targeted sections of the value chain. Niche entrants are thus able to enter the market by initially targeting one or two segments of the network, and can also specialise in either hardware or software as integrated solutions are no longer required. These entrants offer new solutions to operators, allowing them to upgrade their networks more frequently, and expand into alternative 'secondary' networks and offer more niche services to customers.

[59] For example, the O-RAN Alliance is in the process of specifying and developing security requirements through its Security Task Group, see https://www.gsma.com/futurenetworks/wp-content/uploads/2021/01/Open-Source-Software-Security_v1.0.pdf.

[60] Networks today are already interoperable to a limited extent, to allow different RAN vendors in different regions of the same country, or for core and RAN solutions to be provided by different vendors; however, many of these solutions are offered in bundles by large vendors, which include integration services.

The impact of these new vendors is limited by the relatively closed environments they have to try and break into. With increased openness in the ecosystem, these new vendors could exploit economies of scale while specialising on particular aspects of the value chain without the burden of needing to supply an end-to-end solution.

New vendors increase the diversity of the supply chain, and compete on multiple dimensions. For instance, new manufacturers of generic hardware could emerge in markets with a lower cost base to compete on price, and new software vendors could emerge that compete on functionality and ease of use, enabled by the publication of operators' specific use-case requirements. Some of these vendors might also have already been present in the market, but with limited visibility if they were previously focused on supplying components into a larger integrated solution.

Case study: Mavenir

Mavenir was launched in 2017 as a merger of Xura, Mitel Mobile and Ranzure, and has focused its efforts to become a leading player in virtualised, 5G-ready software solutions. The vendor develops solutions for each layer of the network and aims to enable operator customers to drive service innovation, and handle traffic growth.[61]

TIP offers the opportunity for new solution providers to foster a relationship with large operator customers and to work with systems integrators and other critical partners. In 2018, Mavenir partnered with ADVA and BT on a research project in TIP's UK Community Lab to test and validate the benefits of Cloud Ran (vRAN).[62] More recently, Mavenir has also been involved in the Evenstar project, having announced the launch of the Evenstar remote radio head (RRH) in 2020, in collaboration with a number of other participants of the TIP community.[63]

Large companies that have been active in other market verticals also have the opportunity to cross-over into verticals that they previously not competed in as extensively. For example, Dell, which joined TIP, is investing in solutions compatible with a disaggregated network model for 5G technology, as it anticipates a need for increased innovation to enable automation for its operator customers, for services such as zero-touch provisioning and deployment, and aims to capitalise on this requirement.[64] These existing firms looking to enter new verticals have the potential to further increase supplier diversity more rapidly than start-ups. They bring years of experience and large R&D budgets, and can help stimulate innovation and competition faster across more parts of the supply chain. This in turn can lead to greater choice, speed to market, and cost efficiency for operators.

[61] Mavenir press release, see https://mavenir.com/press-releases/xura-now-mavenir/

[62] Mavenir press release, see https://mavenir.com/press-releases/adva-bt-mavenir-collaborate/

[63] Mavenir press release, see https://mavenir.com/press-releases/mavenir-collaborates-with-partners-to-launch-the-evenstar-remote-radio-head-family/

[64] Dell Technologies – "Where We are and Where We're Heading", 14 September 2020, see https://www.delltechnologies.com/en-us/blog/5g-where-we-are-where-were-heading/

FIGURE 3.1: EXAMPLES OF VENDORS IN OPENRAN AND OOPT WITH SOLUTIONS LISTED ON THE TIP EXCHANGE MARKETPLACE[65] [SOURCE: TIP, ANALYSYS MASON, 2021]

	Hardware	Software
OpenRAN	▪ **Baicells** – Base stations and remote radio units ▪ **Benetel** – Remote radio units	▪ **Mavenir** – Mobile access & edge open vRAN solutions ▪ **Parallel Wireless** – OpenRAN controller
OOPT	▪ **Edgecore** – Packet transponder and cell site gateways ▪ **UfiSpace** – Cell site gateways and core/edge routers	▪ **ADVA** – Ensemble Activator (NOS) ▪ **Infinera** – Converged Network Operating System

3.1.2 Incumbent vendors can be more selective about areas in which to build an advantage

Traditionally, a small number of large 'incumbent' vendors have played a central role in defining network roadmaps for operators. However, as operators look to introduce higher levels of virtualisation and automation to their networks, they are considering a greater variety of solutions, from whichever vendors are able to satisfy their needs best. In response, vendors across the ecosystem, including incumbents, have started to build capabilities to develop software solutions that will respond to operators' requirements.

As the ecosystem diversifies, incumbent vendors may find it difficult to maintain their market position by sticking too rigidly to a traditional strategy of offering integrated end-to-end solutions with bundled hardware and software. A recent survey of 60 mobile operators (including Tier-1 and Tier-2 MNOs and new entrants) found that about 85% of respondents consider disaggregated architecture to be either 'essential' or 'important' for their next-generation end-to-end networks,[66] which suggests that operators would either rely more on new challengers, or demand that incumbents also provide solutions that are interoperable.

For incumbents, embracing a future where competitiveness is defined by the ability to develop innovative software would allow incumbent vendors to capitalise on existing relationships with operators and maintain a competitive advantage in specific segments, despite increased competition – all to the ultimate benefit of the ecosystem, as the introduction of new suppliers and more innovative network solutions would benefit telecoms operators and the network supplier industry as a whole. A disaggregated network also gives incumbents the flexibility to focus on areas with the most profitability or strategic importance for them.

[65] See https://exchange.telecominfraproject.com/marketplace

[66] Analysys Mason. (2020). Open, disaggregated networks will transform MNOs' 5G business cases. Available at https://www.analysysmason.com/research/content/white-papers/5g-open-networks-rma18/

Case study: Nokia

Nokia's active participation as the co-chair of O-RAN Alliance workgroup 3 (WG3) has led to the development of a prototype near-real-time RAN Intelligent Controller (RIC) platform. The RIC is targeted to become a key element in enabling new opportunities such as network slicing, advanced optimisation and dynamic enterprise network-as-a-service for Open RAN deployments.[67] Nokia completed a limited live trial with AT&T to demonstrate their first xApp[68] in a commercial 5G network, and has contributed selected portions of its software to the O-RAN Software Community.[69]

The company has also announced its intention to be a technology leader in the areas in which it chooses to compete, with an emphasis on "critical networks", that Nokia defines as "advanced networks that run mission-critical services for companies and societies".[70]

Incumbent vendors that are able to adjust and compete on software effectively are not only likely to be successful in the future, but would also continue to play a significant role across the industry by accelerating network virtualisation and the development of new functionalities further. Incumbents have strong existing relationships with operators that trust their experience, and also possess large R&D budgets that would provide resources to conduct extensive R&D that can accelerate the development of solutions that have positive effects on the ecosystem as a whole. Incumbent vendors that embrace the open ecosystem can also better facilitate the transition of existing networks to be more open and disaggregated by improving interoperability between new solutions with equipment that has already been deployed.

3.1.3 Multi-vendor networks require higher levels of testing, validation and integration, which presents opportunities for systems integrators

Disaggregation allows new network components and functions to be embedded and upgraded in the system continuously, as soon as operators are confident that targeted upgrades meet certain specifications and requirements. This is not the case in legacy networks, where operators rely on their single, large vendors to provide periodic, system-wide upgrades to refresh their offering.

Case study: IBM

In the 1960s, computers were completely vertically integrated, which is similar to telecoms networks in the present day. Firms leased IBM mainframes on a monthly basis, including hardware, software, maintenance and training, allowing them the convenience of a "one-stop-shopping" experience. However, any improvements had to be formally negotiated between IBM and the client.[71] IBM eventually unbundled its offerings, allowing customers to buy IBM computers separately from its software and catalysing the evolution towards in-house programming talent and third-party software.

Then IBM introduced the personal computer (PC), with the operating system provided by Microsoft, and effectively disaggregated the market for software and peripherals. Today, we regularly get upgraded features on our own PCs at home, and can conveniently switch software without buying a new PC. The functionality of these miniature networks can also easily be expanded, for example, by plugging in printers or speakers, without having to consult any one of the hardware or software providers.

TIP and other organisations driving the adoption of open and disaggregated technologies envision a similar effect of disaggregation on telecoms networks, where hardware and software solutions from a wider array of vendors can be integrated into networks easily, allowing for more frequent upgrades of the network to support increasingly demanding and numerous use cases.

[67] See https://www.nokia.com/networks/portfolio/radio-access-networks-ran/open-ran/

[68] "xApp" refers to external applications. The ones used in the trial were designed to improve spectrum efficiency, offer geographical and use case-based customisation, as well as rapid feature onboarding.

[69] Nokia press release, see https://www.nokia.com/about-us/news/releases/2020/06/18/nokia-and-att-run-successful-trial-of-the-ran-intelligent-controller-over-commercial-5g/

[70] Nokia press release, see https://www.nokia.com/about-us/news/releases/2020/12/16/nokia-provides-a-mid-point-update-on-strategy-and-operating-model/

[71] Jonathan ZIttrain. (2008), The Future of The Internet and How to Stop It.

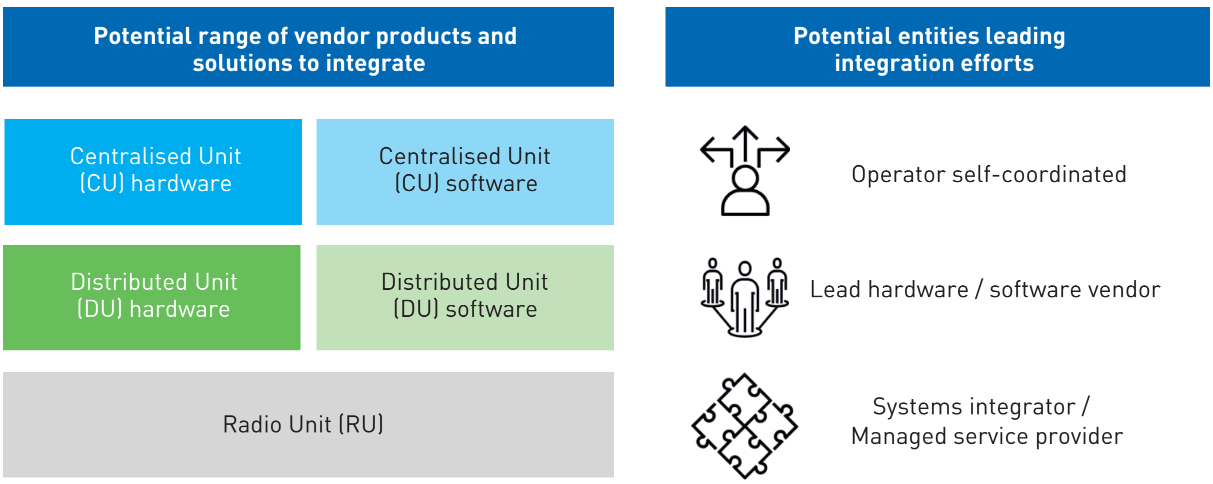
For a disaggregated, multi-vendor network to be viable, operators will need guarantees that solutions from a wider variety of vendors can be seamlessly integrated, with no detrimental impact on performance and features. Even if the individual solutions are 'best of breed' and interoperable, different network configurations require customised network architecture, which need to be managed as a whole, covering instalment, configuration, maintenance, operations and security.

In legacy networks, systems integration would typically be managed for operators by the vendor that provides the equipment for a given part of the network. Large incumbent vendors typically provide end-to-end, fully integrated solutions, and are able to effectively bundle equipment in various parts of networks, including access, core, transmission and support systems.

In a transition towards a more open ecosystem, it is likely that third-party systems integrators or managed service providers will play a larger role in helping operators to integrate a wider variety of solutions into their networks, given that many operators have been reliant on incumbent vendors for integration for many years and lack (or do not wish to develop) the in-house expertise needed to integrate a multi-vendor network, particularly in the short term. For instance, Telefónica/O2 is partnering with the systems integrators NEC Corporation in its German Open RAN roll-out[72] and Vilicom in its future UK deployment.

Over time, some operators might also opt to in-source larger portions of the network integration function, particularly larger operators for which the scale of integration needed could make it worthwhile to develop a competitive advantage in the area. Vodafone, while still collaborating with several systems integrators for the testing of new solutions, is also actively developing internal skills to take a leading role in the integration and management of a wide variety of new open, disaggregated and interoperable technologies.

FIGURE 3.2: POTENTIAL INTEGRATION MODELS FOR OPEN RAN [SOURCE: ANALYSYS MASON, PARALLEL WIRELESS,[73] 2021]



[72] NEC press release, see https://www.nec.com/en/press/202012/global_20201216_01.html; O2 press release, see https://news.o2.co.uk/press-release/o2-successfully-tests-open-radio-access-network-technology-ran-from-vilicom/

[73] See https://www.thefastmode.com/expert-opinion/18162-the-ultimate-guide-to-open-ran-openran-integration-part-2-integration-stages-and-models

TIP pools resources and stakeholders to speed up the validation of new solutions, which generates pre-configured and tested combinations of solutions that could be more easily integrated. This allows vendors and systems integrators to demonstrate capabilities while reducing risk for operators. Initiatives that facilitate the process of getting solutions from the conceptualisation stage to commercial deployment faster, such as field trials, end-to-end solution groups and listing on TIP Exchange, allow operators to quickly identify both individual solutions and combinations of solutions that have been tested and are commercially sound, which would increase the speed of deployment of new technologies. More generally, TIP facilitates activities to improve the viability of the following integration models to suit different requirements, where operators and enterprises either:

- co-ordinate network deployment, management and operations internally
- outsource deployment, management and operations to a single provider (lead vendor/systems integrator/ managed service provider), or
- adopt a hybrid model of controlling and managing certain network components while outsourcing others.

Ultimately, the choice of integration model depends on operator or enterprise capability, business case viability, and preference for either retaining or relinquishing control; TIP's activities are aimed at enabling all three options for operators and enterprises.

To date, operators have been able to quickly deploy products developed with collaboration from the TIP community, particularly in the OOPT project group. For instance, route planning and optimisation tools[74] for multi-vendor networks have been used by Orange in the West African backbone project to quickly assess bidder designs, which have experienced more rapid development and adoption through TIP-enabled activities.[75] Within OpenRAN, the first version of a continuous integration, continuous delivery (CI/CD) platform was developed in partnership with Telefónica and Tech Mahindra, and was released to the wider TIP community in late 2020.[76] CI/CD platforms are expected to be key in automating the integration and deployment of new network functions and solutions on an ongoing basis.

Over time, systems integrators that are able to better manage the complexity inherent in a richer and more fragmented value chain will not only be better equipped to compete for new business, but would also be able to enable solutions that are powerful and easy to deploy for a wider variety of operators.

3.2 A more diverse supply chain facilitates expansion and service innovation of more secure and resilient networks

More competition and innovation in a vibrant multi-vendor supply chain could allow operators to deploy new network functions more quickly and at greater cost efficiency than by relying on solutions using proprietary interfaces, which would also benefit consumers in being able to enjoy better prices for data. These effects would enable greater expansion of connectivity into rural areas by enhancing coverage and affordability, while also improving the business case for 5G to speed up the development and deployment of new services. Supplier diversity can also mitigate security risk and add resilience to operator supply chains.

3.2.1 Greater cost efficiency would allow operators to offer consumers 'more for less' and improve the business case for coverage in rural and remote areas

Opening up interfaces means that specialised research will be undertaken by a variety of different vendors, anchored by open standards and requirements. The competition between vendors at each stage of the value chain could drive down unit costs. This involves the commoditisation of hardware and the use of general-purpose processing platforms, as well as the deployment of software for network automation.

Several sources have touted the potential for Open

[74] Developed using the Gaussian Noise model in Python (GNPy) open-source library developed within TIP, see https://telecominfraproject.com/orange-steps-towards-open-optical-networks-with-gnpy/

[75] TIP press release, see https://telecominfraproject.com/orange-steps-towards-open-optical-networks-with-gnpy/

[76] TIP press release, see https://telecominfraproject.com/tip-openran-project-group-makes-first-version-of-openran-ci-cd-platform-available-to-tip-community/

RAN to reduce the total cost of ownership (TCO) by up to ~40%.[77,78] Rakuten, which has built an end-to-end cloud-native network on the basis of interoperable solutions, cites cost savings of 40% in capex and 30% in opex due to the approach taken for deploying this new greenfield network compared to alternatives.[79] However, it is unlikely for overall RAN costs to decline to 60–70% of the levels seen today with the advent of Open RAN, as operators would need to continue investing significant amounts in order to meet ever-growing demand for data, and to ensure that networks continue to gain new flexibility and functionality to remain competitive.

Instead, it is more likely that over the long term, operators would be able to deploy network equipment and functions more cost efficiently, and to roll out networks that are more performant and flexible at a given cost level using solutions produced by a vibrant open ecosystem, compared to a network produced solely using proprietary technologies. Furthermore, it is likely that cost savings would be of a smaller magnitude in legacy networks; however, there remains significant potential for operators to expand coverage and capacity within existing cost envelopes in an open and disaggregated environment.

In rural and remote areas, the cost of deploying mobile networks to serve end users is prohibitively high, given low population density in these areas. Open and disaggregated systems have the potential to decrease unit costs for operators through hardware commoditisation and automation using software, and can also enable more effective sharing of network infrastructure with the development of more advanced controls. In December 2020, TIP announced the launch of a Total Site Solution (TSS) for ultra-rural network deployment following lab and field trials with TIM Brasil, with a market trial planned for the first half of 2021. Site design and construction was optimised for cost and tailored specifically for rural deployment, containing elements such as low-power equipment, off-grid energy and satellite backhaul.[80] Activities like these help to improve the business case for expanding coverage, and could result in more deployments to new areas. This has particularly positive implications for developing countries, with low incomes and widely dispersed populations that lack access to mobile and mobile broadband services.

However, unless the affordability gap also starts to close, it is possible that effective cost management alone might not be enough to drive greater adoption of mobile broadband in rural areas. Although the high cost of devices is a key barrier for most of those unconnected to the internet,[81] the affordability gap might be partially addressed if operators transfer some of the benefit of greater cost efficiency to customers in the form of lower effective prices for data. The extent to which an operator can simultaneously lower prices and roll out coverage to remote areas will depend on the financial health of the company and the level of competition in the market. Ultimately, the combined effect could result in more affordable data for low-income users and provide mobile access to marginal individuals who might otherwise have been excluded.

It should be noted that in competitive markets, reductions in cost are always beneficial to end users, even in the urban centres of developed countries. When costs fall, operators lower the price of data due to competition and offer better network quality and capacity, while consumers benefit from increased operator cost efficiency in the form of higher levels of consumer surplus, as consumers would be able to receive a given level of service at an even lower price than they would otherwise have been willing to pay.

3.2.2 Open networks enable accelerated deployment of new functions, allowing innovation in services, with the potential to generate new revenue streams for operators

Competition between vendors and systems integrators is also likely to raise the quality and widen the range of the products and solutions available to operators. Vendors will be looking to differentiate themselves from their competitors, leading to increased innovation in each segment of the value chain. Operators will thus be able to select the 'best of breed' from a wide range of providers for intended use cases.

[77] See https://mavenir.com/press-releases/ran-tco-study-savings/

[78] See https://www.adlittle.com/sites/default/files/reports/adl_mobile_network_architecture.pdf

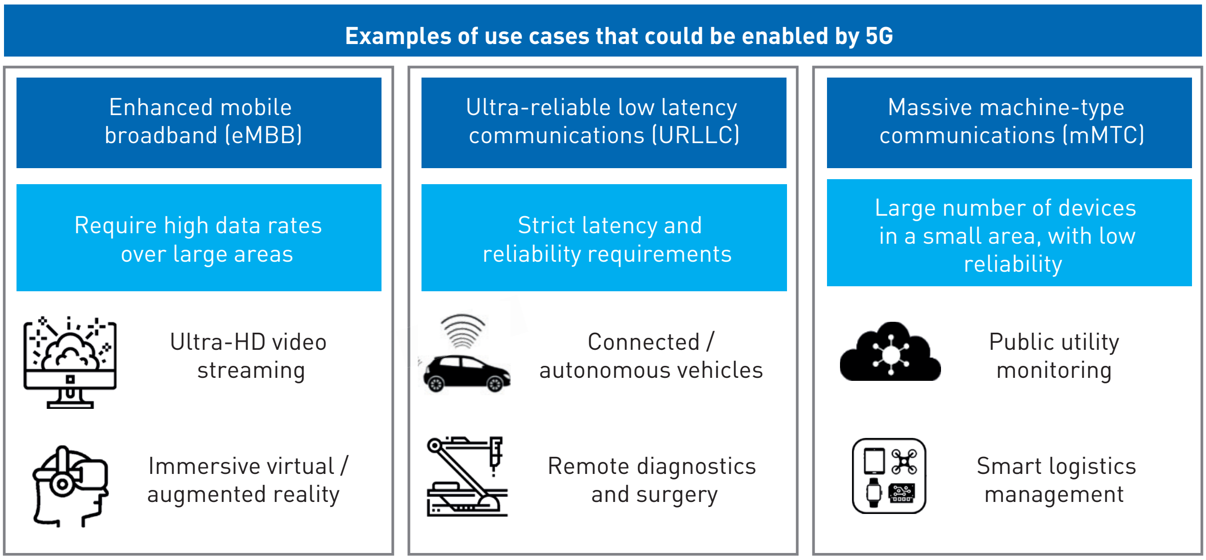
[79] See https://rethinkresearch.biz/articles/rakuten-reiterates-capex-gains-of-its-platform-could-export-it-abroad/

[80] See https://telecominfraproject.com/tip-launches-total-site-solution-for-ultra-rural-network-deployments/

[81] GSMA. (2020), State of Mobile Internet Connectivity Report 2020.

A broader array of products and solutions will also give operators access to new tools for innovative service delivery through network virtualisation and automation to improve on existing revenue streams or to generate new ones. The accelerated roll-out of 5G specifically will benefit society by speeding up the delivery of a wide variety of new use cases. Over 70 use cases are predicted to result from the roll-out of 5G, which are typically divided into three main categories of services, as shown in Figure 3.3 below.[82]

FIGURE 3.3: 5G CONNECTIVITY PROMISES A VARIETY OF NEW USE CASES FOR END USERS [SOURCE: ANALYSYS MASON, 2021]



The realisation of many of these new services will require co-ordination between several different stakeholders, including service providers, connectivity providers and infrastructure owners, to test and refine solutions.

In September 2020, TIP launched 'solution groups' that are aimed at bringing together a wider range of stakeholders to test and refine network solutions and business models for targeted deployment scenarios.[83] Successful end-to-end implementations can serve as examples for other similar deployments worldwide. A key leader in one of these groups is the Dublin City Council, which has facilitated many smart-city initiatives over the past half decade, and recognises the potential for collaboration with TIP to accelerate the deployment of advanced connectivity for new use cases.[84]

[82] 5G.co.uk. (2018), What is enhanced Mobile Broadband? Available at https://5g.co.uk/guides/what-is-enhanced-mobile-broadband-embb/
[83] See https://telecominfraproject.com/tip-launches-solution-groups-to-define-and-validate-end-to-end-open-network-solutions/
[84] See: https://telecominfraproject.com/connected-city-infrastructure/

Case study: Deployment of Narrowband IoT for flood monitoring in Dublin

Smart Dublin is a collaboration of technology providers, academia and citizens aimed to transform public services in the city.[85] Operators can capitalise on and assist with the city's drive to improve connectivity.

For instance, Vodafone Ireland is a key connectivity enabler to the Docklands Smart District, where it has rolled out Narrowband IoT. One of the first technologies deployed on this network is an innovative sensor product created by Voguetek that monitors water levels in gullies and reports on flooding. Vodafone and Dublin City Council have also announced a support initiative for start-ups to test proof-of-concept projects.[86] IoT networks are necessary for many of Smart Dublin's local initiatives, including drones for emergency response, and future mobility services. Working with the city provides opportunities for operators to branch into new service provision.

As a key contributor to the TIP Connected City Infrastructure solution group, the Dublin City Council, through its smart-city initiatives, provides a good example of a collaborative platform that can generate new services for citizens by fostering collaboration between stakeholders, having access to the latest technologies, and testing and refining actual solutions.

While new revenue streams would be beneficial to operators, the services that drive new revenue would have even more far-reaching implications for customers of these services, and or society as a whole, as discussed further in Section 3.3.2.

3.2.3 Supplier diversity can mitigate security risks and improve the resilience of supply chains

Enhanced connectivity promises significant improvements to quality of life, but can also introduce risk if networks are not secure. The GSMA characterises security management as an interaction between people, processes and technology, that covers service definition, deployment, operation, and decommissioning.[87] Changes to any one of these aspects of the network would also affect system-wide security.

Mobile networks already carry a wealth of data, including sensitive information about individuals, transactions and national security. With the promise of greater integration with the physical world and industrial processes through 5G, the resilience and security of wireless networks will become ever more important. Access to IoT devices, from critical cardiac devices to simple webcams, could give hackers the opportunity to cause severe damage in personal lives. As such, improved network security is consequential for operators, as they wish to avoid the logistical and reputational damage associated with harmful incidents on their networks, and for a connected society.

[85] See https://smartdublin.ie/

[86] Smart Docklands. (2018), Vodafone launch NB-IoT in the Docklands, available at https://smartdocklands.ie/vodafone-launch-nb-iot-docklands/

[87] GSMA. (2021). Mobile Telecommunications Security Landscape. Available at https://www.gsma.com/security/wp-content/uploads/2021/03/id_security_landscape_02_21.pdf

Case study: Policy actions regarding vendors deemed to be 'high risk'

Concerns regarding network security have led certain countries to adopt policies that restrict local operators from using equipment from vendors deemed to be 'high risk'. Examples of these policies include the Telecoms Security Bill in the UK,[88] the Clean Network programme in the United States,[89] and the mobile network security law in France.[90]

The costs of such restrictions are significant, with the impact of excluding high-risk vendors in the UK estimated to cost over GBP2 billion in present value terms over a 10-year period, for replacing already deployed equipment, and incurring higher alternative costs of deployments and upgrades in future.[91]

In the UK, the government has also announced a '5G Supply Chain Diversification Strategy' in December 2020, aimed at expanding the telecoms supply chain to ensure resilience to future threats and risks.[92] The strategic approach adopted revolves around the following three 'strands of activity':

- **Supporting incumbent suppliers to ensure resilience, sufficient supply, and ability to transition to a new market structure**
- **Attracting new suppliers to the UK market to build resilience and to generate new competition**
- **Accelerating open-interface solutions and deployment to prevent lock-in and to stimulate innovation**

An argument in favour of open networking is its ability to improve network security through transparency and testing at scale. If more stakeholders are involved in testing the security of network components, it would be more likely for vulnerabilities to be detected quickly, and it will be important for security standards to be built into vendor product roadmaps. According to the Open RAN Policy Coalition, open interfaces could provide operators with direct access to more data regarding network performance and security, enable security analytics to be distributed more widely throughout the network, allow operators to select from a wider range of security solutions, and accelerate the automation of network management functions to minimise security risks.[93] Meanwhile, the O-RAN Alliance is in the process of specifying and developing additional security requirements through its Security Task Group (STG), and also argues that new cloud-native security attributes such as automated security testing and automatic reconfiguration would improve vulnerability management and security configuration.[94]

A multi-vendor ecosystem also provides long-term resilience to operators' supply chains. If the equipment or solutions provided by a particular vendor are deemed unsatisfactory or no longer suitable and cannot be easily solved with a software upgrade, it would be easier and less costly for the operator to switch supplier, compared to legacy networks where solutions are integrated end-to-end.

3.3 A vibrant open ecosystem could enable new operating models and stimulate broader economic growth

The open ecosystem provides new opportunities for not only incumbent and challenger vendors, but also for infrastructure providers and non-traditional operators to create and deliver new services and business models.

[88] UK government. (2020), Roadmap to remove high risk vendors from telecoms network. Available at https://www.gov.uk/government/news/roadmap-to-remove-high-risk-vendors-from-telecoms-network

[89] U.S. Department of State. The Clean Network. Available at 2017-2021.state.gov/the-clean-network/index.html

[90] See https://www.legifrance.gouv.fr/dossierlegislatif/JORFDOLE000038360175/

[91] See https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/938036/The_Telecommunications_Security_Bill_2020___National_security_powers_in_relation_to_high_risk_vendors_-_FINAL_upload.pdf

[92] See https://www.gov.uk/government/publications/5g-supply-chain-diversification-strategy/5g-supply-chain-diversification-strategy#resilience-across-the-supply-chain-and-building-uk-capability

[93] Open RAN Policy Coalition. (2021). Open RAN Security in 5G. Available at https://www.openranpolicy.org/wp-content/uploads/2021/04/Open-RAN-Security-in-5G-4.29.21.pdf

[94] See https://www.gsma.com/futurenetworks/wp-content/uploads/2021/01/Open-Source-Software-Security_v1.0.pdf

On a national scale, accelerated take-up of mobile internet services driven by disaggregation and innovation can also stimulate economic growth and pave the way for a more vibrant digital economy. Policy makers could also capitalise on emerging opportunities for hardware manufacturing, software design to boost local production and skills development.

3.3.1 A dynamic and innovative ecosystem offers opportunities for infrastructure players and non-traditional operators

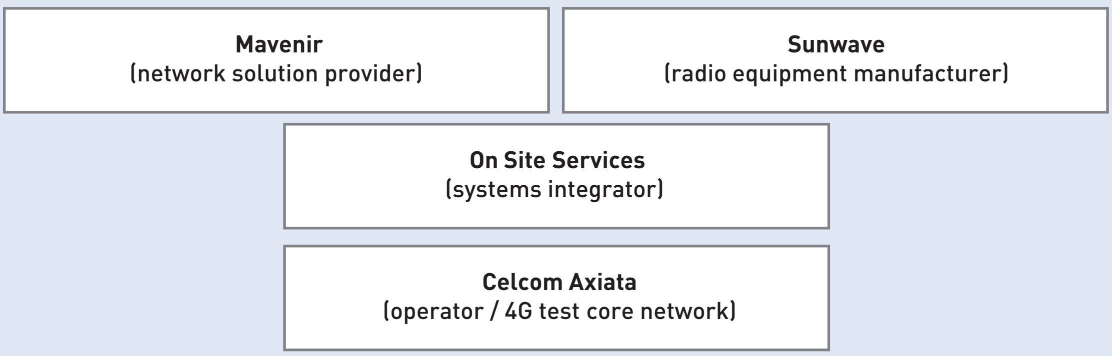
As capacity requirements continue to grow, operators need to find new ways to densify networks in urban environments in a cost-effective manner. In recent years, operators have increasingly turned to infrastructure providers as a means to manage costs, by sharing infrastructure with competitors through an independent entity. Infrastructure sharing can take place at various levels. Sharing of passive infrastructure is most straightforward, with infrastructure providers typically leasing out space on physical locations for operators to install their equipment (e.g. antennas). Several operators in a market can save costs by sharing the passive infrastructure instead of maintaining separate physical tower portfolios. A further step in infrastructure sharing would involve the sharing of active equipment, such as the antennas themselves. This would be made possible through increased virtualisation of networks, as the separation of hardware and software would make it more possible for capacity on shared antennas to be allocated to operators in a way that was not previously possible.

For infrastructure providers, the option to control the allocation of capacity on shared antennas provides an opportunity for business model innovation, in moving away from pricing structures that are determined primarily by physical space, to a 'network-as-a-service' business model that charges operators for capacity on shared active equipment. This generates benefits for operators, as sharing active equipment in addition to physical space would do more to manage the cost burden that comes with additional capacity requirements, and might also give operators confidence in using multi-vendor networks with the presence of an independent tower company to help resolve integration issues. The case study below describes a 'network-as-a-service' trial conducted by edotco in collaboration with the TIP community. Other infrastructure players such as American Tower, Cellnex, Crown Castle and Dense Air are also involved in promoting this model through a 'neutral-host' group launched by the Small Cell Forum in January 2021.[95]

Case study: edotco

edotco is a leading telecoms infrastructure provider in Asia, boasting a portfolio of over 31 500 towers.[96] The company has collaborated with TIP to further its growth objectives, including finding an Open RAN solution to enable a multi-operator neutral-host model. This collaboration has already resulted in the publication of a successful OpenRAN lab trial report in late 2020.[97] The trial involved deploying 4G OpenRAN solutions for a single mobile network operator, and involved a number of other stakeholders as well, as illustrated below.

Following the successful OpenRAN lab trial, edotco and TIP have since announced intentions to deploy and trial OpenRAN 4G sites in a network-as-a-service (NaaS) environment in selected high-traffic areas in Malaysia.[98] Through this deployment, edotco would offer wholesale mobile service to operators, starting with Celcom Axiata, and extending to other operators over time.



[95] Small Cell Forum press release, see https://www.smallcellforum.org/press-releases/small-cell-forum-launches-neutral-host-group-to-capture-technology-requirements-for-alternative-deployment-models-serving-enterprise-and-communities/

[96] See https://edotcogroup.com/about-us/

[97] See https://cdn.brandfolder.io/D8DI15S7/as/x66s9bbcbpw8kq544mq6t8vf/OpenRAN_Test_Bed_Trial_-_Final.pdf

[98] edotco. (2020), edotco and Telecom Infra Project collaborate to address connectivity gaps available at https://edotcogroup.com/media/edotco-and-telecom-infra-project-collaborate-to-address-connectivity-gaps/

As part of the Connected City Infrastructure project group, TIP is also exploring the viability of a business model for municipalities to manage and operate retro-fitted street assets (such as lamp posts and bus stops) to host LTE/5G small cells and Wi-Fi hotspots, while generating appropriate revenue streams, paving the way for new non-traditional operators or infrastructure providers to benefit from growing demand for future connectivity.[99]

Disaggregation of hardware and software is also enabling business model innovation in the Wi-Fi arena, with new solutions from companies such as NetExperience, Indio Networks, Edgecore Networks and VVDN among others, emerging to fill this new space.[100] The open-source software stack for Wi-Fi enables companies such as KloudSpot, SAM Seamless Network and Ananda Networks to develop and run commercial analytics applications on top of it.

An open ecosystem that grows in diversity is likely to include not only incumbent vendors and new challengers that are able to specialise in specific niches, but also a wider array of stakeholders that would not typically be considered as part of the existing supply-chain framework. These include infrastructure providers, local municipalities and other companies that would be able to realise new opportunities by helping operators to navigate the multi-vendor environment while deploying new and better services.

3.3.2 Accelerated next-generation mobile broadband take-up and adoption of new use cases for 5G and Wi-Fi are expected to have a positive impact on economic growth

As discussed in Section 3.2.2, open networks would be able to facilitate accelerated service innovation and the generation of new revenue streams for operators. These new services, while potentially beneficial for operators, also have the potential to unlock benefits for the rest of society more broadly.

A recent Analysys Mason study in conjunction with Ericsson and Qualcomm estimates that full-5G networks would deliver over EUR160 billion in net benefits (benefits less costs) for Europe between 2025 and 2040, not counting costs and benefits from initial 5G deployment for consumer use.[101] The study set out a wide range of innovative use cases for full-5G networks, including in smart production and logistics, smart rural connectivity (FWA/agriculture), smart urban connectivity (smart automotive/dense areas/ construction) and smart public services.

In emerging markets, achieving greater cost efficiency could enable more greenfield coverage deployment, and accelerate brownfield upgrades,[102] which would lead to an increase in the percentage of the population that would be covered by infrastructure capable of supporting mobile broadband services. The combination of accelerated network deployment and the potential lowering of effective prices could also enable faster growth in take-up of next-generation mobile broadband services, as these become more widely available and affordable to consumers. Evidence suggests that in Africa a 10% increase in mobile broadband penetration leads to a 2.5% change in gross domestic product (GDP) per capita.[103]

The economic benefits unlocked by open and disaggregated technologies extend beyond the mobile network. Katz and Callorda published an assessment of the value of Wi-Fi, concluding that the total economic value in the USA in 2018 amounted to USD499.09 billion – about the same size as Belgium's GDP.[104] Most of this value is economic surplus to producers and consumers, although a significant USD20.16 billion was calculated as contribution to GDP. This included the value of bringing coverage to rural and isolated areas, the value of increased internet speed, and the revenue of companies that provide Wi-Fi. This also provides an indication of the potential magnitude of TIP's contribution to the economy in accelerating innovation in enterprise Wi-Fi. In future, enterprises are also expected to be able to have the flexibility to use both 5G and the next-generation Wi-Fi 6, depending on whichever technology is most appropriate for a given use case.

[99] See https://telecominfraproject.com/connected-city-infrastructure/

[100] Based on input from TIP.

[101] Analysys Mason. (2020), Further investment in 5G infrastructure could lead to over EUR160 billion of benefits for Europe. Available at https://www.analysysmason.com/about-us/news/newsletter/5g-spectrum-investment-quarterly-jan2021/

[102] Brownfield upgrades refer to the deployment of new (usually more advanced) equipment on existing site locations

[103] ITU Publications. (2019), Economic contribution of broadband, digitisation and ICT regulation.

[104] Telecom Advisory Services. (2018), The Economic Vlaue of Wi-Fi: a global view (2018 and 2023).

3.3.3 Demand for multi-vendor solutions drives opportunities for more countries to develop new capabilities and jobs in manufacturing and solution design

Open and interoperable standards and supply-chain disaggregation allow for the emergence of new specialised hardware and software vendors, as well as for design and manufacturing of these solutions to take place in a wider variety of countries than in the past. The production of generic hardware, for instance, is more straightforward than the development of end-to-end network solutions, and presents an opportunity for markets looking to develop a local manufacturing base. In India, for instance, the state-owned electronics manufacturing firm ITI (Indian Telephone Industries) has announced that it aims to produce eNobeB and 5G NR products as part of a mission to provide end-to-end solutions for 4G and 5G networks using an ecosystem of local technologies.[105] As such, an open ecosystem that provides the opportunity for local production is particularly attractive. Baicells, a participant in TIP's OpenRAN project group, boasts local manufacturing capabilities in several Asian countries.

Local producers looking to benefit from an open ecosystem are also likely to pick and choose different market needs to focus on. A firm aiming to develop or expand an export base could focus on products and solutions that require limited customisation, while others might emerge that aim to suit more local or regional needs, for instance, in the design of radio units that could be tailored more closely to local spectrum allocations and requirements. The opportunity for these manufacturers to specialise in customised equipment for local operators is directly enabled by the standardisation and opening up of interfaces between network components. Some operators might also be more comfortable partnering with familiar distributors, systems integrators and other participants of the local or regional ecosystem.

Employing local labour to build and run manufacturing businesses creates jobs and can contribute to human capital development, in terms of technical and commercial knowledge which would stimulate the potential for innovation and development in the telecoms sector and other related industries.

[105] The Economic Times. (2020), ITI in talks with Indian companies to provide complete 4G, 5G network gears, available at https://economictimes.indiatimes.com/industry/telecom/telecom-news/iti-in-talks-with-indian-companies-to-provide-complete-4g-5g-network-gears/articleshow/79102907.cms

Case study: Making Indonesia 4.0

In April 2018, the Indonesian government launched an industrial strategy called 'Making Indonesia 4.0', which aims to transform the country into a digital, knowledge-based economy. A critical prerequisite of this transition is widespread, high-speed connectivity. To support economic growth, the government aims to improve coverage, quality and affordability of access to internet. As such, the mission to open and disaggregate telecoms networks is particularly attractive.

As part of the task to connect Indonesians to the internet, the Indonesian government is launching a multi-year collaboration between GSMA, TIP, Telkom University, local mobile operators and original equipment manufacturer (OEM)/systems integrator (SI) partners in an effort to improve connectivity in the country. The collaboration has launched a TIP Community Lab, as well as the Centre of Excellence at Telkom University, with plans to hold test and validation activities in the future.[106] The TIP Community Lab and wider programme aim to:

- **Evaluate and validate solutions developed by TIP participants**
- **Accelerate the transition from lab to field trials of TIP-enabled solutions**
- **Provide training to support local SIs and service providers**
- **Provide workshops, hackathons and bootcamps to introduce new technologies and methodologies to spread others' learnings**
- **Stimulate the local start-up ecosystem and foster local talent**

TIP will also provide the opportunity for producers in Indonesia to learn from trials in countries with similar geographies and demographics, to drive the production of the types of solutions that are necessary in the Indonesian context. The Indonesian Community Lab will create awareness for open networking in the region, inspiring others to participate in the effort to accelerate adoption and improve the capabilities of open technology.

[106] TIP press release, see https://telecominfraproject.com/new-industry-collaboration-to-improve-connectivity-in-indonesia-and-drive-economic-growth/

4 Open RAN has the potential to drive significant economic benefit for consumers and society in the coming years

Supply-chain disaggregation is already having an impact on optical and transport networks, but clearly much of the attention is now directed towards the RAN and the Open RAN evolution. The RAN represents a very significant share of network costs, at over 60% of the total cost of ownership, and still drives the bulk of network upgrade and expansion costs. By adopting and deploying Open RAN, mobile operators globally can improve their network economics, which would also benefit consumers in the form of lower unit prices and should in turn drive greater adoption and usage of mobile data and advanced services.

Improvements in connectivity generate socioeconomic benefits for individuals and enterprises, through the increased availability of information, services and digital capabilities. For example, individuals with increased access to information and services could improve their income prospects, and achieve improved quality of life, as well as better health and education outcomes. Enterprises, meanwhile, would be able to use better access to information and new digital tools and channels to improve operational efficiency, expand reach, and improve service provision for customers. These connectivity improvements would ultimately be reflected in the impact on economic indicators such as GDP.

Open RAN has the potential to accelerate improvements in connectivity and generate an economic impact, which we estimate could add USD91 billion to global GDP annually by 2030, in a conservative baseline case. Between 2021 and 2030, the cumulative GDP impact of Open RAN could reach USD285 billion.

This number could be significantly higher: if the work driven by TIP and other participants in the ecosystem is successful in accelerating the availability of Open RAN solutions and their adoption by operators, we estimate that benefits could be more than double those in the baseline case, reaching USD228 billion by 2030 and USD725 billion between 2021 and 2030.

An overview of the methodology used for this impact assessment can be found in Annex A.

4.1 The development and adoption of Open RAN over the next decade will unlock innovation and efficiency benefits for operators

As Open RAN evolves to fulfil most mobile deployment use cases (i.e. greenfield and brownfield, dense urban and rural, mass market and specialised enterprise requirements), adoption and roll-out by operators around the world will accelerate throughout the 2020s.

This will unlock benefits for operators, which will be able to source equipment and solution from a more diverse, more innovative, and ultimately more robust and competitive supply chain. This will play a key role in mitigating the cost of ever-increasing demands on mobile networks, not just in terms of volumes of data, but also the resilience and robustness that will be required as 5G networks handle more varied and critical use cases.

Utlimately, this will benefit consumers, as well as operators. Better economics should translate into lower unit prices for services, leading to greater demand for connectivity and increased consumer surplus.

4.1.1 Operators around the world will adopt Open RAN progressively, with a tipping point once the technology is able to handle mass-market use cases

Based on extensive discussions and interviews with operators and vendors in the Open RAN ecosystem,[107] we estimate that Open RAN solutions will be able to satisfy mass-market use cases (including 5G dense urban deployments) from 2023.

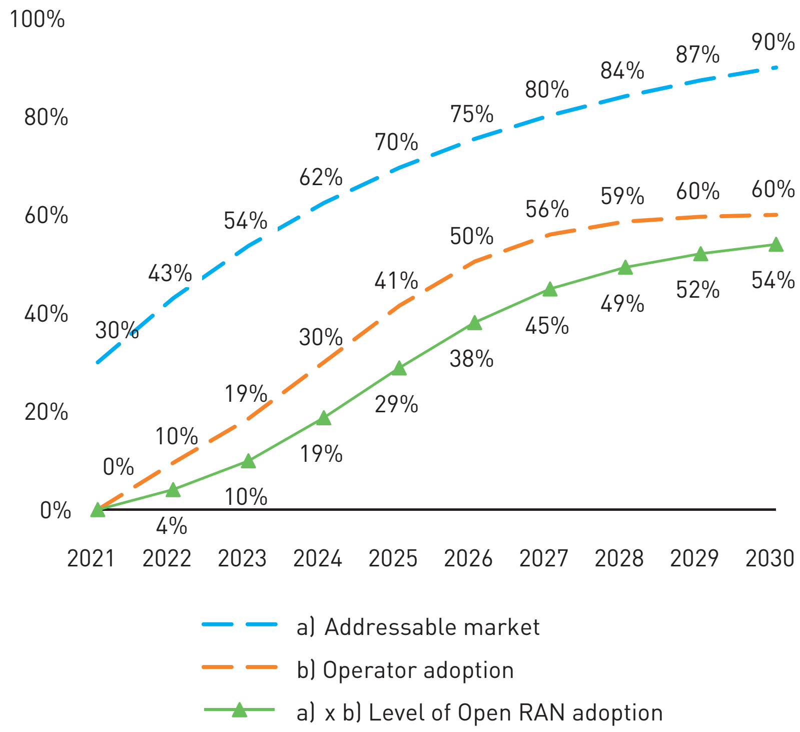
Our baseline case assumes that operators would start adopting Open RAN solutions a bit earlier, in 2022, for a subset of deployment scenarios. By the end of 2025, we estimate that about 70% of mobile subscribers will be able to be served with Open RAN solutions, and that adoption levels would lead to 40% of those needs to actually be served by Open RAN. This would result in about 30% of global mobile subscribers being connected via an Open RAN solution, including open and interoperable solutions provided by incumbent vendors.

[107] See Annex B for more information on the interview programme.

By 2030, we have projected that open and disaggregated solutions would be suitable to address the needs of 85% of mobile users in high-income countries, 90% of requirements in middle-income countries, and 95% of requirements in low-income countries.[108] In order to account for the potential limitation of Open RAN in achieving feature and performance parity across necessary use cases,[109] particularly in high-income countries where deployments of mission critical or advanced network functions might still be met by proprietary technologies. We assumed that at that point in time (2030), about 60% of mobile users whose needs can be served by Open RAN will be connected to an Open RAN solution. Overall, this means that about 55% of global mobile demand will be carried over an open and disaggregated RAN by 2030.

Figure 4.1 shows the resulting level of Open RAN adoption in the market for middle-income countries in our baseline case. We have also run a sensitivity analysis to investigate how the resulting economic impact changes when considering different scenarios for Open RAN adoption, as detailed further in Section 4.3.2.

FIGURE 4.1: LEVEL OF OPEN RAN ADOPTION IN THE MARKET FOR MIDDLE-INCOME COUNTRIES IN BASELINE CASE [SOURCE: ANALYSYS MASON, 2021]



108 Countries in the 'middle-income' bracket are defined as those with GDP per capita (PPP) of between USD12 000 and USD22 000, while countries above and below that range are in the 'high-income' and 'low-income' brackets respectively.

109 This estimate considers parity of features that operators actually demand, and not necessarily the full range of features that incumbent vendors would offer. Based on interviews, it is understood that incumbents have historically included features in bundles that operators do not require.

4.1.2 Operators can achieve greater cost efficiency through the deployment of Open RAN solutions, mitigating the impact of greater demands on mobile infrastructure over time

Over the coming years, operators are expected to adopt a number of network deployment strategies that will result in better economics as the demand for mobile services keeps increasing. These strategies include increased network sharing (both passive and active), network virtualisation and automation, all of which will be enabled by proprietary as well as Open RAN solutions.

In the short term, implementing these strategies may lead to an increase in some costs.[110] Over time, however, costs (primarily opex) are expected to decrease as a share of revenue, even with traditional proprietary vendor solutions. In the medium to long term, Open RAN solutions are likely to further mitigate network costs, through increased innovation and greater impact from virtualisation and automation. This will allow some operators to operate the same networks more cheaply, and others to build a more performant and flexible network at constant cost levels.

In the model we developed for this study, we have modelled these benefits through a further reduction over time in the intensity of RAN costs (opex and capex) as a share of recurring revenue due to Open RAN, compared to a scenario where only traditional solutions are available (we call this scenario the 'counterfactual' in the remainder of this section). We note that the model only covers the costs supporting recurring mobile revenue that is generated at present, and does not consider additional costs needed to support new services and revenue streams that could emerge in coming years, which could be significant (e.g. costs to serve specialised enterprise requirements through 5G).

For our baseline case, we have assumed that RAN capex will be 15% lower for a comparable network by 2025, and 20% lower by 2030, and RAN opex will be very slightly lower (3%) for a comparable network by 2025, with savings increasing to 10% by 2030.[111]

These assumptions reflect our view that cost savings from hardware elements are expected to be realised more quickly, while cost benefits from automation are expected to be realised only in the medium term. Taking account of these assumptions, we have run a sensitivity analysis under various efficacy scenarios, as discussed in Section 4.3.1.

FIGURE 4.2: MODEL COST INPUTS FOR MIDDLE-INCOME COUNTRIES[112] [SOURCE: ANALYSYS MASON, 2021]

As a share of recurring revenue (as a share of total revenue, assuming constant recurring share	2020	2030 (counterfactual)	Open RAN by 2030 vs. counterfactual	2030 (baseline)
Opex				
Network (RAN) opex	34% (27%)	31% (25%)	–10%	28% (23%)
Network (non-RAN) opex	21% (17%)	18% (14%)	Not captured in model	18% (14%)
Non-network opex	29% (23%)	27% (22%)		27% (22%)
Total opex	84% (67%)	76% (61%)		73% (58%)
Capex				
Network (RAN) capex	11% (9%)	11% (9%)	–20%	9% (7%)
Network (non-RAN) opex	9% (7%)	9% (7%)	Not captured in model	9% (7%)
Non-network opex	5% (4%)	5% (4%)		5% (4%)
Total capex	25% (20%)	25% (20%)		23% (18%)
Total cost				
Total opex + capex	109% (87%)	101% (81%)		96% (77%)

[110] The initial increase in cost intensity is expected from the initial shift towards cloud-based systems before the benefits of virtualisation and automation start to become more apparent.

[111] Based on data from Analysys Mason Research DataHub (for historical total cost levels), Analysys Mason Research reports (for future evolution) and GSMA Intelligence (for recurring share of total mobile revenue), and calibrated such that RAN share of network costs is ~60%.

[112] Slight variations are used for high-income and low-income countries, based on operator benchmark data.

As discussed in Section 3.2.1, it is unlikely that savings captured in this model (which relate to the types of services supporting recurring mobile revenue today) would necessarily translate into higher profits for telecoms operators, as the savings in these areas are likely to be offset by new investments and costs incurred to support new types of services in the future. In competitive markets, further savings for operators will also likely be counterbalanced by lower prices for consumers, increasing consumer surplus.

4.1.3 Operators will transfer some of the cost benefits to their customers, leading to lower unit prices and greater demand for connectivity

In competitive mobile markets, operators cannot retain the full benefit of greater cost efficiency. As more operators adopt open and disaggregated technologies, price competition will allow unit prices to fall, compared to the counterfactual.

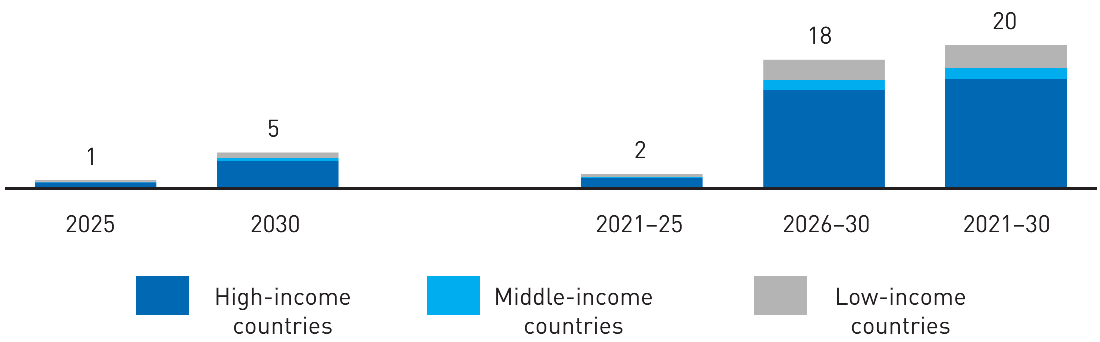
In the baseline case, where Open RAN allows for more cost-efficient network deployment, consumers will be able to enjoy more data at the same price, or a lower price for the same amount of data as in a counterfactual scenario where the network of the future is deployed entirely using proprietary technologies. Given current trends, lower unit prices should lead to continued increases in data consumption, with average revenue per user (ARPU) remaining relatively stagnant.

For modelling purposes, we have linked the level of price decline to the level of competition in the market, measured using the Herfindahl-Hirschman Index (HHI),[113] as well as the long-term level of Open RAN adoption in the market. A more competitive market (with lower HHI), and a higher long-term level of Open RAN adoption in the market, will yield greater benefits to consumers.[114]

We have then modelled an elasticity level of –0.5.[115] This means that consumers will spend half of the cost saving from lower prices to consume more data, which would have an impact on GDP as discussed in Section 4.2.2. The other half would be saved, and translate into slightly lower ARPU, which would result in an increase in consumer surplus.[116]

We calculated that RAN cost efficiency benefits could result in total costs across markets falling by ~2.7% relative to a counterfactual,[117] which would in turn lower ARPU by ~0.8% (after accounting for part of the benefit that translates into larger data packages) and result in a benefit of close to USD5 billion (real at 2020 prices) in incremental consumer surplus across the country sample per annum by 2030, with the bulk of the impact coming from high-income countries, where ARPU levels are higher. Over a 10-year period, the total consumer surplus benefit is expected to reach USD20 billion (real at 2020 prices).

FIGURE 4.3: IMPACT OF OPEN RAN ON REAL CONSUMER SURPLUS BY COUNTRY GROUPS, 2021–30 (REAL 2020 USD BILLION) [SOURCE: ANALYSYS MASON, 2021]



[113] The Herfindahl-Hirschman Index is a common measure of concentration in a market, and is calculated as the sum of the square of each firm's market share, with a higher HHI indicating a more concentrated (and probably less competitive) market.

[114] Operators in a competitive market with low concentration would be under pressure to gain or retain market share, and operators in a market where most other operators also adopt Open RAN solutions would have less of a competitive advantage due to Open RAN.

[115] Using an elasticity parameter of –0.5, which would be conservative, based on Dewenter & Haucap (2007) Demand Elasticities for Mobile Telecommunications in Austria.

[116] The model conservatively accounts for ARPU reductions for subscribers served by Open RANs only, although increased pressure on the market could also result in other operators reducing ARPU levels as well.

[117] In a scenario where efficiencies do not result in a more performant network than in the counterfactual.

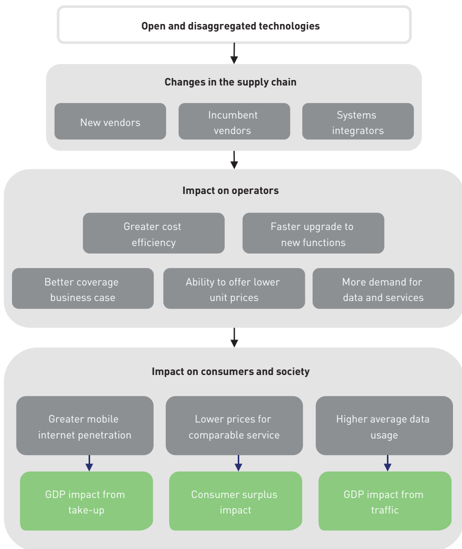
4.2 Open RAN can accelerate improvements in connectivity and generate USD91 billion in GDP impact globally per annum by 2030, and USD285 billion from 2021–30

Many of the benefits discussed in Section 3 are applicable to Open RAN, and several are quantified explicitly, or captured implicitly in quantitative metrics within this next section in an attempt to measure the potential economic benefit of Open RAN over the period 2021–30. This benefit is quantified relative to a 'counterfactual' scenario in which only proprietary systems are available to operators.

Figure 4.4 below provides an overview of the benefits that we have considered in our model. We have reflected the prospect for Open RAN to accelerate the deployment of new network equipment and functions, with greater cost efficiency. The improved connectivity resulting from this has a macroeconomic impact in the form of additional GDP.

FIGURE 4.4: OVERVIEW OF THE MODELLING FLOW AND THE POTENTIAL BENEFITS OF OPEN AND DISAGGREGATED TECHNOLOGIES THAT ARE QUANTIFIED FOR OPEN RAN [SOURCE: ANALYSYS MASON, 2021]

Report section	Benefits considered	Treatment in model
Changes in the supply chain		
3.1.1	• More vendors can enter the market with new solutions	• Not modelled explicitly, but implicitly assumed
3.1.2	• Incumbent vendors can focus on strategic opportunities	• Not modelled explicitly, but implicitly assumed
3.1.3	• System integrators have more scope to add value	• Not modelled explicitly, but implicitly assumed
Impact on operators		
3.2.1	• Cost efficiency enables lower prices and greater coverage	• Modelled explicitly
3.2.2	• Deployment of new functions enables new services	• Captured in data usage, not explicitly modelled in detail
3.2.3	• Supplier diversity improves security and resilience	• Not modelled
Broader industrial and economic benefits		
3.3.1	• Scope for infrastructure and non-traditional operators	• Not modelled
3.3.2	• New use cases can stimulate broader economic growth	• Implicitly captured to some degree in incremental GDP
3.3.3	• Opportunities to develop local production and skills	• Implicitly captured to some degree in incremental GDP



4.2.1 Open RAN can drive GDP growth in every region of the world by increasing mobile internet penetration in lower-income markets

The ability to deploy networks with more flexibility and with greater cost efficiency will improve the economics of increasing mobile internet penetration, by enabling more cost-efficient deployment of coverage, and also by reducing price levels to offer affordable mobile internet services in areas where affordability presents an additional barrier to take-up.

Coverage can be expanded either through the deployment of new 'greenfield' site locations, or through 'brownfield' upgrades of existing mobile site locations capable of supporting only basic (i.e. 2G) mobile services at present. In the model, we estimate that a 10% reduction in the cost of rural deployment could result in a 1 percentage point increase in viable mobile internet coverage (as a percentage of the population) in middle-income countries, and a 2 percentage point increase in low-income countries, based on the improvement to deployment economics.[118]

Although challenging rural network economics are still likely to prevent ubiquitous availability of mobile internet services, particularly in low-income and middle-income countries, it is possible that Open RAN would allow operators to realise a positive business case in more areas through more cost-efficient

[118] Based on recent Analysys Mason project experience related to the viability of rural connectivity solutions, that involved calculating net present value of rural deployments, accounting for costs and revenue potential.

deployment, as well as a reasonable reduction in price levels where feasible. The World Bank Broadband Strategies toolkit[119] finds that a 10% price decline in mobile broadband plans could generate an increase in penetration ranging between 2.35% and 3.20%. The application of these assumptions in the model for Open RAN impact is summarised in Figure 4.5 below.

FIGURE 4.5: OVERVIEW OF FACTORS THAT CONTRIBUTE TO INCREMENTAL GDP FROM INCREASED MOBILE INTERNET PENETRATION [SOURCE: ANALYSYS MASON, 2021]

High-income countries	Middle-income countries	Low-income countries
Coverage		
Percentage point (p.p.) increase in viable mobile internet coverage (% of population) for a 10% reduction in cost of rural deployment		
No impact	1 p.p.	2 p.p.
Take-up in covered areas		
Percentage (%) increase in penetration (% of covered population) from a 10% decline in mobile broadband plan prices		
No impact	2.35%	3.20%

An increase in mobile internet penetration compared to a counterfactual, driven by both an increase in coverage, and increase in penetration of covered areas, has a broader impact on economic growth. A 2018 study by the ITU[120] used econometric analysis of data from countries across several regions around the world to determine that a 10% increase in mobile broadband penetration would yield a 1.8% increase in GDP per capita in a given year for middle-income countries and a 2.0% increase for low-income countries, over and above the counterfactual GDP growth projected.

The potential for Open RAN to improve rural deployment economics is currently being explored in trials, for instance, by mobile operators in Indonesia aiming to expand access to mobile internet across the extensive rural population.[121]

Modelling suggests that across the sample of countries considered, mobile internet penetration could increase by ~0.34 percentage points in middle-income countries and ~0.48 percentage points in low-income countries by 2030, resulting in 24 million more unique mobile internet subscribers due to Open RAN by 2030. This would generate an annual GDP uplift over a counterfactual of USD29 billion (real at 2020 prices) per annum by 2030. Over 2021–30, the total benefit is estimated to reach USD105 billion (real at 2020 prices).[122]

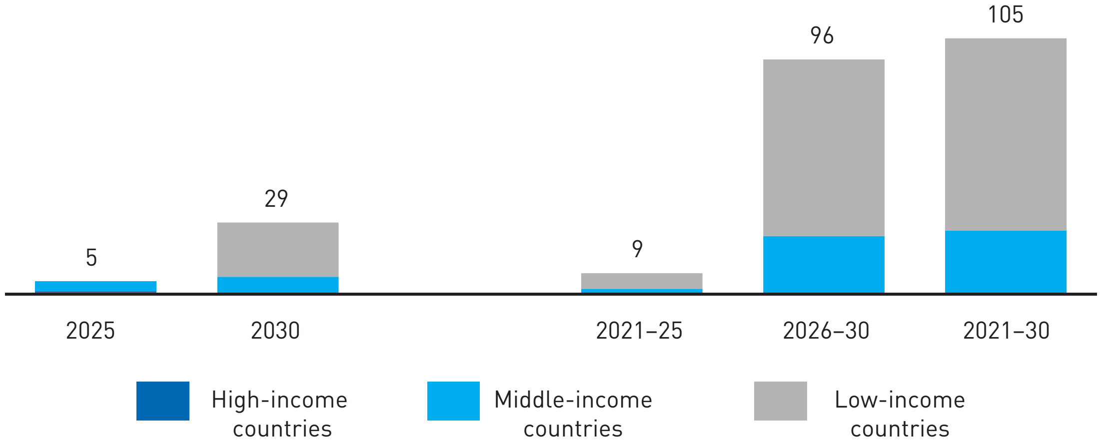
[119] World Bank Group. Broadband Strategies Toolkit. Available at https://ddtoolkits.worldbankgroup.org/broadband-strategies

[120] International Telecommunication Union. (2018). The economic contribution of broadband, digitalization and ICT regulation. Available at https://www.itu.int/pub/D-PREF-EF.BDR-2018

[121] See https://www.telecomtv.com/content/open-ran/indonesian-operators-put-open-ran-to-the-test-40766/

[122] This effect is not relevant for high-income countries due to high existing internet availability.

FIGURE 4.6: IMPACT OF OPEN RAN ON REAL GDP DUE TO INCREASED MOBILE INTERNET PENETRATION BY COUNTRY GROUPS (USD BILLION) [SOURCE: ANALYSYS MASON, 2021]



4.2.2 Greater data usage driven by lower effective prices and accelerated take-up of advanced mobile technologies would stimulate economic growth

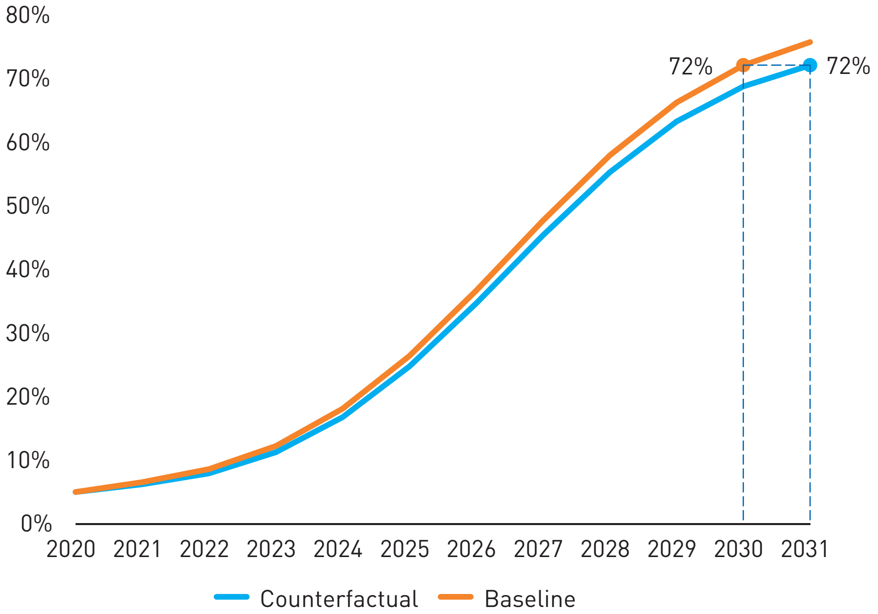
As discussed in Section 4.1.3, a share of any cost savings that operators can realise from Open RAN will be transferred to consumers in the form of lower ARPU, resulting in increased consumer surplus but also in greater consumption of mobile services. Increased mobile data consumption has been shown to lead to faster GDP growth, by a study prepared for the GSMA in 2012.[123] A more recently developed endogenous growth model, published in a study commissioned by Google in 2020, suggests that doubling data usage per mobile internet connection would lead to a 0.8% year-on-year increase in GDP per capita.[124]

The potential to deploy new network functions more cost efficiently could also accelerate the deployment of advanced technologies, which would further accelerate data usage growth. If Open RAN enables more rapid deployment of advanced technologies, it is likely that consumers would be able to access these advanced technologies more quickly, and would start to use larger amounts of data than in a counterfactual. For modelling purposes, we have assumed that the share of 4G and 5G SIMs would be brought forward by half a year in the baseline case compared to a counterfactual by 2025, and by a full year by 2030. This means, for instance, that a market where the share of 5G SIMs in a counterfactual would reach 70% in 2030 and 72% in 2031, would instead see the share of 5G SIMs reaching 72% in 2030 with Open RAN.

[123] Deloitte. (2012). What is the impact of mobile telephony on economic growth? Available at https://www.gsma.com/publicpolicy/wp-content/uploads/2012/11/gsma-deloitte-impact-mobile-telephony-economic-growth.pdf

[124] Analysys Mason. (2020). Economic impact of Google's APAC network infrastructure. Available at https://www.analysysmason.com/consulting-redirect/reports/impact-of-google-network-APAC-2020/

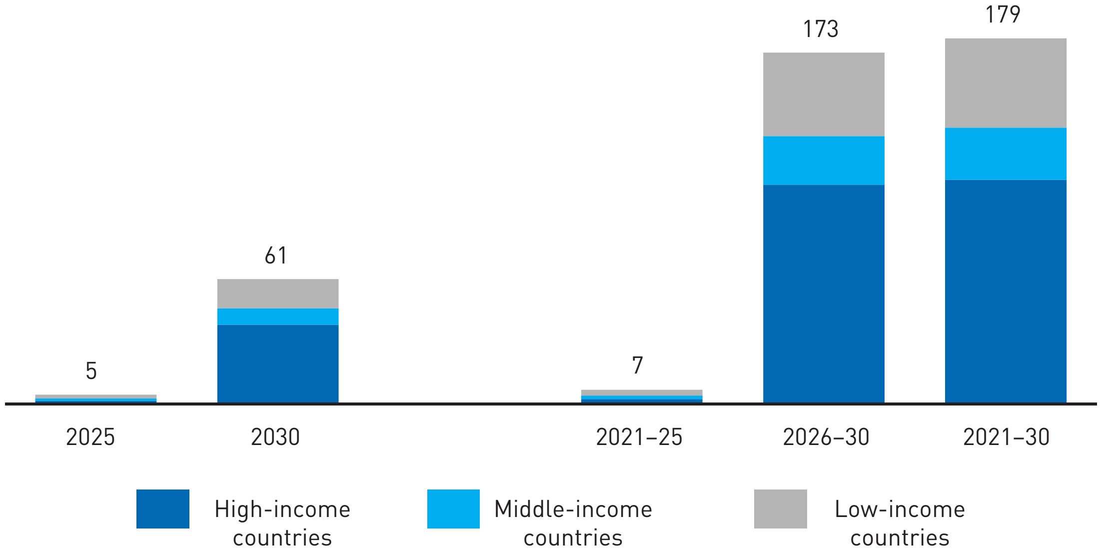
FIGURE 4.7: ILLUSTRATION OF ADVANCED TECHNOLOGY TAKE-UP ACCELERATION [SOURCE: ANALYSYS MASON, 2021]



The effect is expected to be more pronounced in 5G for high-income countries, and in 4G for low-income countries. These parameters are adjusted in an 'efficacy' sensitivity that will be considered later on in the report. We have also assumed that advanced technology take-up acceleration does not start in high-income countries until after 2025, due to uncertainty regarding the potential of Open RAN solutions to reach performance parity on features that are actually required by MNOs, including 5G massive MIMO solutions, compared with proprietary alternatives.

Lower effective prices and an acceleration in take-up of advanced technologies could result in a ~2.5% increase in data usage per mobile internet connection over a counterfactual by 2030 across total markets, which would generate an additional ~USD61 billion in GDP (at real 2020 terms) per annum compared to a counterfactual. The total impact on GDP over the 10-year period would reach ~USD179 billion (in real 2020 terms).

FIGURE 4.8: IMPACT OF OPEN RAN ON REAL GDP DUE TO ACCELERATED GROWTH IN DATA USAGE BY COUNTRY GROUPS (USD BILLION) [SOURCE: ANALYSYS MASON, 2021]



4.2.3 Greater internet penetration and data consumption will drive incremental GDP growth, with over 60% of this growth accruing in low- and middle-income countries

Over the period 2021–30, we estimate that Open RAN could generate USD285 billion in incremental real GDP (at 2020 prices), by accelerating growth in mobile internet penetration and data usage. Our modelling assumes a progressive adoption of Open RAN over time, and most of the benefits are generated in the last few years of the model, from 2025 onwards. As a result, the economic impact of Open RAN in 2030 will be significant: we model the annual impact on global GDP to reach USD91 billion in 2030 (in real 2020 terms), with that figure expected to be even higher in subsequent years.

Most of this quantifiable economic impact would be generated in low-income countries (43%),[125] where mobile internet penetration and usage is expected to grow significantly over the next decade. Middle-income countries contribute about 18% of total economic impact, with the remaining 39% occurring in high-income countries, where mobile internet penetration and data demand are both already relatively high.

FIGURE 4.9: MODELLED GLOBAL GDP IMPACT OF OPEN RAN (REAL 2020 USD BILLION) [SOURCE: ANALYSYS MASON, 2021]

	GDP gain from increased mobile internet penetration (2021–30)	GDP gain from increased data usage (2021–30)	Total GDP gain (2021–30)	Total GDP gain (2030)	Percentage of total GDP in counterfactual (2030)
High-income countries	0	110	110	39	0.06%
Middle-income countries	26	26	52	15	0.19%
Low-income countries	79	44	123	37	0.30%
Total	**105**	**179**	**285**	**91**	**0.10%**

As mentioned in Section 4.1.3, incremental consumer surplus from Open RAN could reach USD20 billion in real GDP (at 2020 prices) between 2021 and 2030. The majority of this impact will come from high-income countries, which have the highest ARPU levels. This analysis is conservative in that it only considers the consumer surplus benefit of reducing prices for existing customers, and does not include consumer surplus from new customers that might enter the market due to lower prices.[126]

FIGURE 4.10: MODELLED CONSUMER SURPLUS IMPACT OF OPEN RAN 2021–30 (REAL 2020 USD BILLION) [SOURCE: ANALYSYS MASON, 2021]

	Consumer surplus gain from price reduction (2021–30)	Consumer surplus gain from price reduction (2030)
High-income countries	15	4
Middle-income countries	2	0
Low-income countries	3	1
Total	**20**	**5**

[125] A total of 184 countries are included, accounting for over 80% of global GDP and population, grouped into 'low-income', 'middle-income', and 'high-income' categories using thresholds from an ITU study on the impact of mobile internet penetration on GDP per capita, referenced in the report in Section 4.1.3

4.3 Initiatives to increase adoption by operators and supply-chain development could accelerate and more than double the economic benefits from Open RAN by 2030

TIP, together with other organisations in the open and disaggregated network ecosystem, is working hard to get solutions to market faster, and to stimulate a more dynamic, innovative and competitive supply ecosystem.

If successful, these efforts will improve the outcome of Open RAN in two ways. First, they could result in greater 'efficacy', by which we mean a greater impact of Open RAN on key drivers such as cost reductions and technology take-up acceleration, which are uncertain at present. Second, these efforts could accelerate and increase the overall 'adoption' of Open RAN solutions by operators around the world.

We have modelled these impacts through sensitivities in our model, separately and cumulatively, as these effects are likely to be correlated: more announcements from operators in support of Open RAN adoption could stimulate higher levels of investment in the supply chain, which could result in even greater cost efficiency and shorter time to market for new solutions than anticipated.

Greater efficacy and adoption could combine to more than double the economic impact of Open RAN, and triple its impact on consumer surplus, resulting in an estimated incremental real GDP of ~USD725 billion and consumer surplus gains of ~USD60 billion over the period 2021–30 in the most optimistic case considered.

4.3.1 Ongoing ecosystem development will reduce the level of uncertainty regarding the potential for cost-efficiency improvements and acceleration of new technology take-up

The baseline case makes several assumptions with regard to the potential impact of Open RAN over the long term, which have been informed by conversations with stakeholders in the Open RAN space, while recognising the presence of significant uncertainty regarding the magnitude of impact that could ultimately be achieved.

In reality, several factors could influence the extent of the impact that Open RAN could have in terms of potential cost reduction or acceleration of advanced technology take-up compared to a counterfactual, including future network requirements, and the level of innovation achieved by the vendor ecosystem. For example, Open RAN might have a higher impact on cost efficiency if operators would be required to invest heavily in future networks due to growing network security concerns, which a more diverse vendor ecosystem might be able to address with more cost-efficient solutions than a proprietary system. The pace at which other network elements beyond the RAN (e.g. core, transport) are opened up could also affect the efficacy of Open RAN in achieving cost savings or acceleration of advanced technology take-up.[127]

Performing sensitivity analysis on these key assumptions produces a range for the impact that could be generated, depending on the success of Open RAN solutions, in terms of cost efficiency, and ability to accelerate take-up of advanced technologies. The table below illustrates the parameters adjusted in the 'high' and 'low' efficacy cases compared to the 'medium' efficacy assumptions used in the baseline case.

[126] This effect is expected to be small as any incremental subscribers joining the market due to price reductions would have low willingness to pay and would thus generate limited consumer surplus (which is the difference between benefit received and willingness to pay).

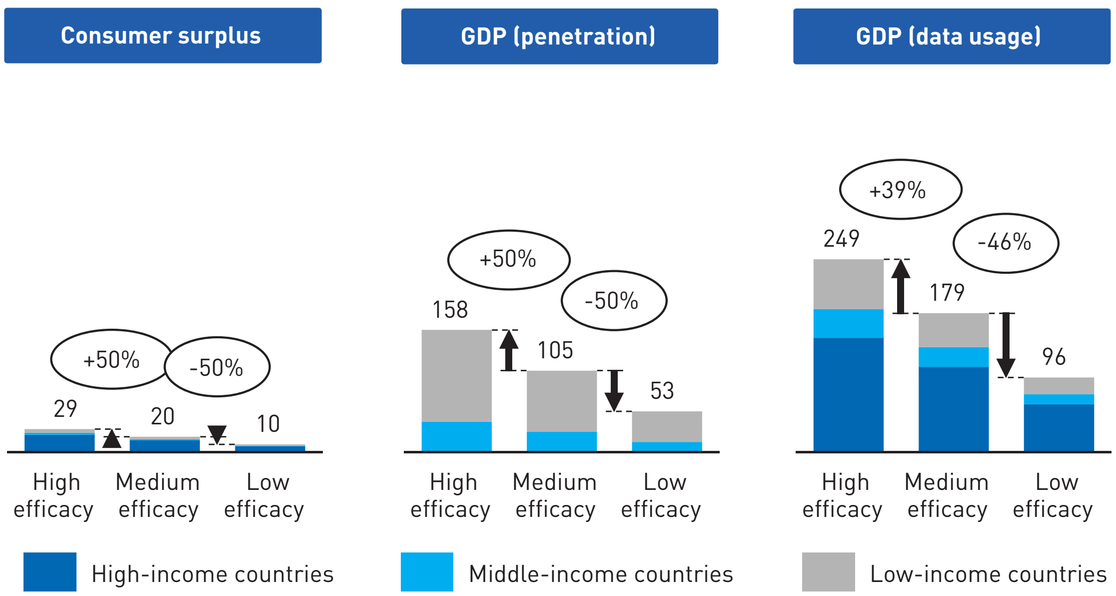
[127] These are not explicitly modelled in the analysis, although it is generally understood that the RAN has been the most challenging to open up to date.

FIGURE 4.11: ASSUMPTIONS USED FOR HIGH- AND LOW-EFFICACY POTENTIAL CASES RELATIVE TO BASELINE [SOURCE: ANALYSYS MASON, 2021]

	High efficacy	Medium efficacy (baseline)	Low efficacy
RAN cost levels vs. counterfactual (%)			
RAN opex (2025)	–4.5%	–3.0%	–1.5%
RAN opex (2030)	–15.0%	–10.0%	–5.0%
RAN capex (2025)	–22.5%	–15.0%	–7.5%
RAN capex (2030)	–30.0%	–20.0%	–10.0%
Acceleration of 4G/5G take-up vs. counterfactual (years)[128]			
By 2025	0.75	0.50	0.25
By 2030	1.50	1.00	0.50

Compared to the baseline case, the high-efficacy case results in a 50% increase in incremental consumer surplus from price reductions and GDP from mobile internet penetration, while the low-efficacy case results in a 50% decrease in both metrics. Sensitivity of incremental GDP from higher data usage (driven by a change in pace of technology acceleration) is in the same order of magnitude, resulting in a 39% increase for the high-efficacy case and a 46% decrease in the low-efficacy case compared to the medium-efficacy baseline case.

FIGURE 4.12: SENSITIVITY ANALYSIS ON HIGHER- AND LOWER-EFFICACY POTENTIAL OF OPEN RAN ON ECONOMIC BENEFIT METRICS, 2021–30 (REAL 2020 USD BILLION) [SOURCE: ANALYSYS MASON, 2021]



[128] Does not apply for high-income countries until after 2025 due to uncertainty on the potential of Open RAN solutions to reach performance parity on 5G massive MIMO solutions, compared with solutions on proprietary interfaces.

4.3.2 Accelerating the adoption of Open RAN through platforms such as TIP and other interventions could result in significant gains in consumer surplus and GDP

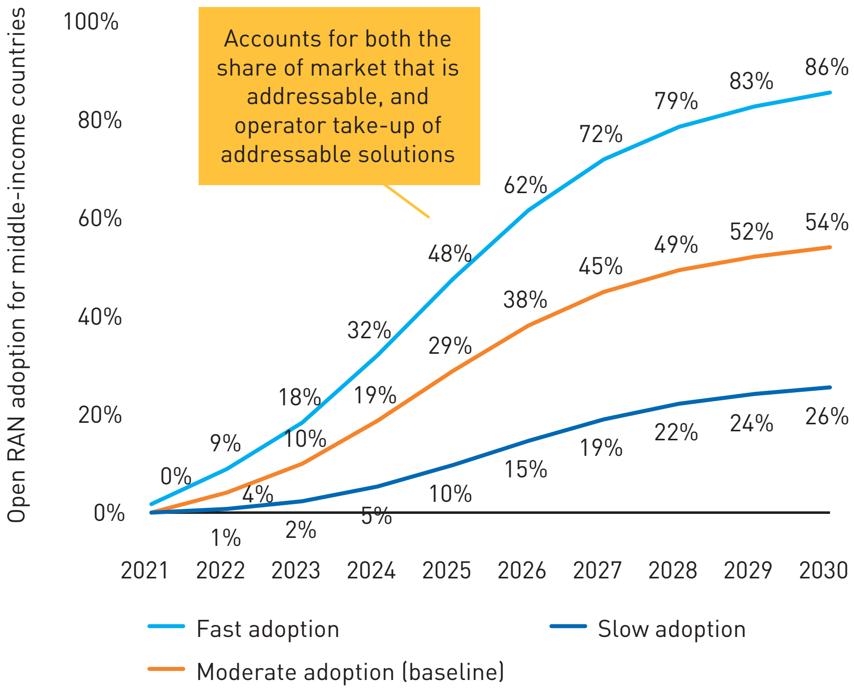
The baseline case also makes certain assumptions regarding the maturity of Open RAN solutions relative to proprietary technologies, the extent to which operators are expected to adopt open solutions (including those by incumbent vendors) over the long term, and the pace at which that level of adoption is reached. These assumptions reflect a scenario where the development of Open RAN continues apace and achieves feature parity with proprietary technologies for most network use cases in the medium to long term. This is driven by recent large operator commitments to invest in open and disaggregated technologies, as well as opportunities enabled by TIP that would allow operators, vendors, and systems integrators to collaborate in order to address many concerns related to testing and integration.

The table below illustrates the parameters adjusted in the 'fast' and 'slow' adoption cases compared to the 'moderate' adoption assumptions used in the baseline case.

FIGURE 4.13: ASSUMPTIONS USED FOR HIGH- AND LOW-ADOPTION CASES RELATIVE TO BASELINE
[SOURCE: ANALYSYS MASON, 2021]

	Fast adoption	Moderate adoption	Low adoption
Share of market that is addressable (Open RAN maturity/feature parity with proprietary solutions)RAN opex (2025)			
Share of market that is addressable (2021)	Middle-income: 35% High-income: 30% Low-income: 40%	Middle-income: 30% High-income: 25% Low-income: 35%	Middle-income: 25% High-income: 20% Low-income: 30%
Share of market that is addressable (2030)	Middle-income: 95% High-income: 90% Low-income: 100%	Middle-income: 90% High-income: 85% Low-income: 95%	Middle-income: 85% High-income: 80% Low-income: 90%
Operator take-up of the share of market that is addressable			
Long-term operator take-up target	90% of addressable share of market	60% of addressable share of market	30% of addressable share of market

FIGURE 4.14: RESULTING LEVEL OF OPEN RAN ADOPTION IN THE MARKET, ACCOUNTING FOR BOTH SHARE OF MARKET THAT IS ADDRESSABLE, AND OPERATOR TAKE-UP, BY ADOPTION SCENARIO FOR MIDDLE-INCOME COUNTRIES
[SOURCE: ANALYSYS MASON, 2021]



Compared to the moderate-adoption baseline case, the fast-adoption case assumes that Open RAN solutions would reach feature parity[129] for more use cases, and that operators would embrace Open RAN solutions (including those provided by incumbent vendors) more quickly and to a larger extent over the long term. This would reflect a scenario where Open RAN developments are accelerated compared to the current pace of development, and would likely be due to factors such as increased government intervention, decisions by incumbent vendors to open up more of their portfolios, or breakthroughs in the supply chain to overcome current uncertainties regarding Open RAN.[130]

Meanwhile, the slow-adoption case reflects a scenario where Open RAN solutions take longer to mature and reach commercial deployment due to lingering operator concerns with regard to integration, and a lack of avenues for new vendors to demonstrate capabilities and achieve economies of scale. In reality, this scenario would be more likely to take place if platforms such as TIP did not exist or failed to gain traction with operators, vendors and systems integrators in the attempt to accelerate the commercial deployment of open and interoperable solutions through adherence to fully open and interoperable standards. This scenario also reflects the risk of fragmentation, if open standards are not fully adhered to, and if customisation in specific implementations of 'open' solutions leads to sufficient "proprietary creep"[131] to prevent the vendor ecosystem from generating the level of competition and innovation envisioned for Open RAN.

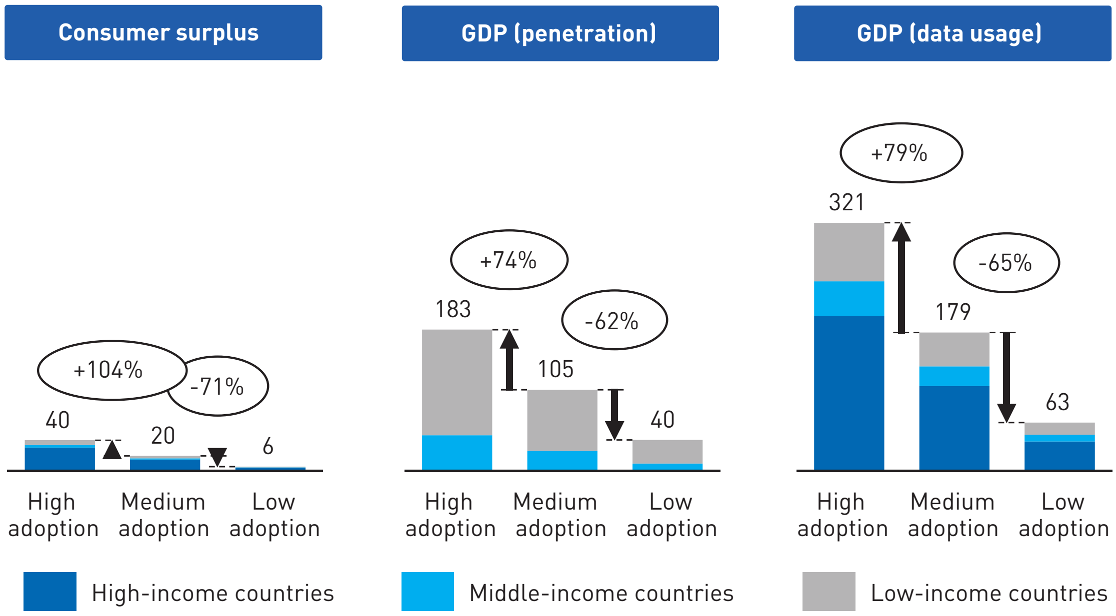
The fast- and slow-adoption cases modelled result in significant changes to output economic impact metrics compared to the moderate-adoption baseline case, as can be seen in Figure 4.15 below. This suggests that addressing operator concerns regarding the viability of multi-vendor supply chains through platforms such as TIP, or achieving feature parity of Open RAN solutions more quickly through incentivising the development of strong new Open RAN vendors or convincing incumbents to open up their portfolios, could generate significant economic benefit.

[129] Refers to features that operators actually demand, not necessarily the full list of features that incumbents might provide.

[130] For example, chipset manufacturers could supply application-specific integrated circuits (ASICs) for Open RAN, which could significantly accelerate feature parity of Open RAN solutions in 5G massive MIMO and mission-critical networks.

[131] Refers to the possibility that implementing solutions with proprietary interfaces in certain parts of the network could lead to less interoperability, and limit the number of compatible solutions that could be used in other parts of the network.

FIGURE 4.15: SENSITIVITY ANALYSIS ON FASTER- AND SLOWER-ADOPTION OF OPEN RAN ON ECONOMIC BENEFIT METRICS, 2021–30 (REAL 2020 USD BILLION) [SOURCE: ANALYSYS MASON, 2021]

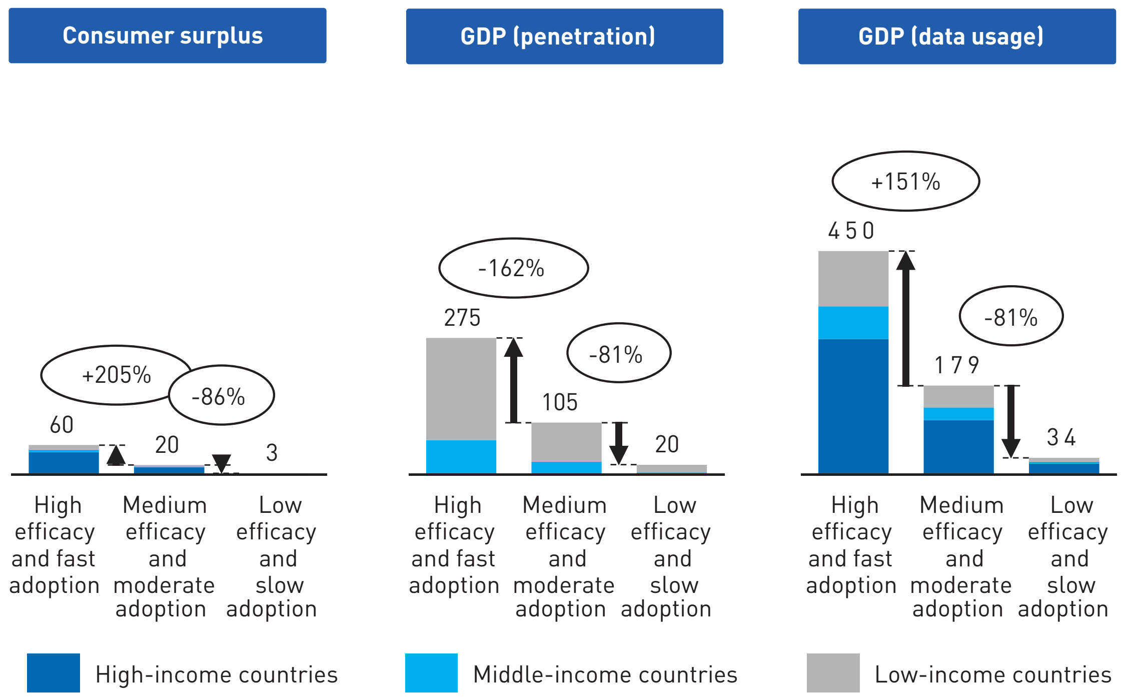


4.3.3 Sensitivities considered are not mutually exclusive, and the interaction of adoption and efficacy from demand or supply boosts could result in greater economic benefits

It is worth noting that the two sensitivities are not fully independent. A situation where more operators commit up front to Open RAN investments would likely result in a stronger supply chain with more suppliers having confidence to enter and compete in the market given the larger potential for reaping economies of scale. This could, in turn, result in more efficacious Open RAN solutions, in terms of higher cost efficiency or faster deployment of new technologies. Similarly, a boost to investment levels in the supply chain through initiatives such as incentives for R&D could also speed up the development of viable and innovative solutions, which would in turn accelerate adoption by operators.

The combinations of efficacy and adoption sensitivity parameters result in a wide range of outcomes, with the most extreme combinations being that of the 'high efficacy–fast adoption' case and the 'low efficacy–slow adoption' case, as shown below, compared to the 'medium efficacy–moderate adoption' baseline case that has been considered for most of this report.

FIGURE 4.16: SENSITIVITY ANALYSIS ON HIGHER- AND LOWER-EFFICACY POTENTIAL AND FASTER- AND SLOWER-ADOPTION OF OPEN RAN ON ECONOMIC BENEFIT METRICS, 2021–30 (REAL 2020 USD BILLION) [SOURCE: ANALYSYS MASON, 2021]



The open ecosystem is one that is interdependent, and depends on the actions of multiple stakeholders to drive a virtuous cycle of development. In this environment, TIP plays an important role in fostering collaboration between stakeholders, accelerating product and solution development, ensuring interoperability and adherence to open standards and principles in actual implementations, and facilitating the testing and integration needed to build operator confidence in multi-vendor supply chains.

Policy makers also have the potential to accelerate the development of the open ecosystem, through interventions such as tax incentives for R&D, or the setting up of local collaborations between operators, vendors, labour organisations and local authorities. These interventions have the potential to drive connectivity benefits such as wider availability of high-quality mobile internet service and greater consumption of online services, which can also stimulate further economic growth and sector development.

Policy makers should also be mindful that a policy and regulatory environment that does not support the development of the open ecosystem could put the modelled baseline case at risk and result in an outcome closer to the low end of the range presented above. This might occur particularly due to poor alignment in the adoption of open standards, either from refragmentation in implementations by industry players, or by insufficient international co-ordination on how to promote adoption of aligned standards globally. These uncertainties regarding the future development of the ecosystem, and key factors that would address them, are discussed further in Section 5.

5 Addressing barriers to a successful open ecosystem is essential to drive incentives for innovation, competition and adoption

While open and disaggregated technologies have the potential to result in significant benefits to the telecoms industry and the wider global economy, there remain several uncertainties and risks that need to be addressed for these benefits to be realised.

First, the benefits of an open and disaggregated system are unlikely to be realised in the near term while the technology is being refined and some operators will be cautious of experimentation. Second, customised implementations and differing perspectives, for example on what constitutes a secure network, might lead vendors to retain proprietary interfaces. Third, co-ordination on the international stage will further enhance the potential for the open ecosystem to deliver benefits, as solutions that are interoperable worldwide would allow vendors to reap larger economies of scale, and policy makers that are familiar with global best practice would also be able to best capitalise on emerging technologies.

These risks can be effectively mitigated through continuous co-ordination between industry players, to unlock the full economic potential of an open and disaggregated ecosystem. Meanwhile, progressive policy makers around the world are exploring approaches to facilitating supply chain diversification to improve resilience and to accelerate sector development and local production.

The extent to which these risks are effectively addressed would result in varying connectivity outcomes and economic impact, as illustrated in the sensitivity analysis on the economic impact of Open RAN considered in Section 4.

5.1 Accelerating the maturity of the open ecosystem is a precondition to broader adoption

Concerns about immature technologies and complex systems integration might prevent risk-averse operators from migrating to an open network in the near term, which would in turn limit its potential benefits. Efforts by TIP to test and validate solutions are critical in driving operator comfort and demand for open solutions, which would in turn provide the necessary incentives for the supply chain to invest in new cost-effective and innovative solutions, and in the context of the modelling for Open RAN done in Section 4.3, would have positive effects on both the 'adoption' and 'efficacy' sensitivity dimensions.

5.1.1 Expected benefits of open and disaggregated technologies might only materialise in the medium term, unless more is done to accelerate adoption

While many operators expect the value chain to become more diverse over time in order to supply increasingly virtualised, flexible and automated networks, there is a belief that many of the touted benefits of a multi-vendor supply chain would apply mainly to new technologies, and would thus only emerge over the medium term.

Although greenfield mobile networks such as the one being deployed by Rakuten in Japan have resulted in significant reported cost savings from Open RAN technologies,[132] analysts are more sceptical about the pace at which cost savings can be realised,[133] particularly in the short term for operators with legacy networks.[134] While cost savings for new solutions are expected, there is uncertainty over the amount of time that it will take Open RAN solutions to be as performant and cost efficient as legacy solutions provided by integrated vendors, given that the latter have been in development for many years and would already have reaped the benefits of maturity and scale. For example, there are concerns that the lower energy efficiency of general-purpose hardware would lead to higher opex for an Open RAN product compared to a solution from an incumbent vendor.[135] Profit margins on each component of a disintegrated solution could also accumulate, resulting in a relatively expensive end-to-end stack.

There are also concerns about the ability of newer Open RAN vendors to be able to deliver solutions that are as performant and reliable as what incumbent vendors would be able to deliver for mission-critical networks where safety depends on ultra-reliable low-latency communication (e.g. intelligent transport,

[132] Fierce Wireless. (2020), Rakuten Mobile signs on to O-RAN Alliance, unveils fee cut, available at https://www.fiercewireless.com/financial/rakuten-mobile-signs-to-o-ran-alliance-unveils-fee-cuts

[133] See https://www.lightreading.com/open-ran/open-ran-might-not-save-you-much-after-all/a/d-id/765800

[134] Based on interviews with operators and vendors conducted by Analysys Mason, see Annex B for more information.

[135] See https://www.lightreading.com/open-ran/open-ran-and-mission-to-crack-massive-mimo/d/d-id/768081

remote surgery), as well as for 5G massive MIMO, which would require significant development in both software and hardware, including in semiconductor chipsets. It is likely that Open RAN would only be able to catch up in these areas after several years.[136] Operators that have already reached agreements with incumbent vendors for proprietary 5G solutions are also unlikely to consider Open RAN solutions for 5G before the next replacement cycle, which means that Open RAN might only be more prevalent during a second wave of 5G deployment.

Another concern that might prevent operators from realising the benefits of an open and disaggregated network is that incumbent vendors might be resistant to opening up the interfaces of their legacy networks, which would hinder the interoperability of new-generation technologies with older generations in a legacy network. However, the shift toward standalone (SA) 5G network cores, which are independent of LTE, could allow operators to start deploying 5G using Open RAN solutions without the same interoperability concerns.

Over the long term, operators are expecting their networks to contain more open and disaggregated solutions, particularly given that such an environment would allow for more frequent upgrades of the network and integration of new functions, and also allow for more seamless transitions to future technology generations. This implies that operators would also expect their vendors, including incumbents, to be able to provide interoperable solutions.

The work done by standards bodies to facilitate standards alignment, and by TIP to co-ordinate testing and validation, is helping industry players to reach this anticipated future more quickly.

5.1.2 Systems integration using approved, tested and validated solutions that can be supported by specialised providers is critical for smaller operators

Operators have outsourced many integration functions to vendors and managed service providers for years, and the shift toward managing a multi-vendor ecosystem requires changes in capabilities and supplier relationships. Operators would have to choose between assuming full responsibility for these functions on one extreme, and depending fully on systems integrators to meet the entire range of operator demands on the other. There is the risk that the complexity of this new landscape, and the overwhelming increased optionality, would discourage some operators from embracing an open ecosystem.

To take on the main integration responsibility themselves, operators would need to build up internal capabilities. Operators such as Vodafone and Rakuten have been recruiting heavily to build these functions up in-house, but still engage systems integrators to help with their initial deployments, and might continue to do so in the long run.[137]

Smaller operators may not have the scale to justify taking on the bulk of integration work internally, and would have to rely on their systems integrators to adhere to fully open principles in their search for the best solutions. In early deployments, systems integrators may use pre-integrated stacks with multiple options and skews, in order to build operator comfort with the process of multi-vendor procurement in the short term.

There is a risk that systems integrators might prefer to rely on a short list of preferred vendors, which would limit flexibility to a degree. Recent examples of systems integrators investing in vendors to gain practical experience (e.g. Tech Mahindra into Altiostar) have also attracted criticism regarding a potential lack of impartiality on behalf of the systems integrator when it comes to selecting vendors to meet operator demands. However, it is likely that the systems integrators that would excel in future are those that are quick and consistent in embracing open principles as these would be the ones that would be able to offer a wider variety of solutions to meet specific operator demands in terms of cost and functionality.

Systems integrators that are part of TIP are able to gain valuable experience in working in this new environment to develop a competitive advantage. Over time, reliance on pre-integrated stacks might also decline as operators become more sophisticated in understanding and articulating their requirements. In any case, operator insistence on interoperability would be important to maintain a vibrant and open ecosystem.

[136] See https://www.telecomtv.com/content/open-ran/5g-massive-mimo-is-open-ran-s-tough-nut-says-vodafone-s-tenorio-40304/

[137] RCR Wireless News. (2020), Open RAN 101 – Integration and beyond: Why, what, when, how? Available at https://www.rcrwireless.com/20200723/opinion/readerforum/open-ran-101-integration-and-beyond-why-what-when-how-reader-forum

5.2 Adherence to fully open and interoperable standards and solutions is crucial for avoiding proprietary creep

Individual vendors might start to diminish the effective openness of the network by customising the implementation of their solutions. Larger players might thus cultivate their own ecosystems at the exclusion of other vendors. Different perspectives on network security might also lead certain vendors to prefer single-vendor implementation, which would enable proprietary creep.

For individual operators, proprietary creep would result in a reduction in resilience if implemented solutions are more difficult to replace later on should they be deemed inadequate. Across the vendor ecosystem, proprietary creep could result in even larger indirect effects, in the form of a reduction in incentives for the supply chain to invest and innovate due to diminished economies of scale. The impact this could have on the supply chain for Open RAN is illustrated in the 'low-efficacy' sensitivity in Section 4.3.1.

It is therefore important that operators demand full interoperability from their vendors and systems integrators, and that providers of testing platforms such as TIP address security of implementations as a priority.

5.2.1 Stakeholders need to emphasise and demand full interoperability to avoid a re-fragmentation of standards due to customisation in specific implementations of multi-vendor networks

The process of creating customised solutions for operators could lead to proprietary creep, in cases where vendors and systems integrators work on implementations that can be labelled 'open', but that are not fully interoperable, in the sense that they might work better with other specific elements provided by a smaller pool of vendors.

For instance, the recently launched Rakuten Communications Platform (RCP),[138] which aims to allow operators and enterprises around the world to draw on network designs used by Rakuten Mobile, is a collaboration between Rakuten and its vendor and systems integration partners, and to an extent can be considered its own ecosystem. This has drawn criticism from other vendors, claiming that offering the communications platform to other operators would create some form of 'lock-in' to the partners involved in setting up RCP, or at least, to make it more complicated for a customer of RCP to swap out specific elements for its own preferred vendors[139] Rakuten itself has since joined the O-RAN Alliance[140] (see Section 2.1.3), which aims to promote standards that allow the RAN industry to move towards being fully open and interoperable, and it remains to be seen whether concerns about proprietary creep due to the RCP offering will be realised. Other operators such as NTT Docomo and Reliance Jio have also announced the development of custom solutions that are intended to be turned into 'open' platforms.[141,142] The solutions developed by these companies may not be fully interoperable with one another, which could also introduce the potential for scope creep.

A sufficient number of fragmented implementations that limit openness could raise barriers to entry for new entrants in the ecosystem relative to a fully open environment. These concerns would be compounded further if 'semi-open' ecosystems do not achieve expected levels of performance due to bias created in the procurement process, and end up serving as a negative example for the concept of open and disaggregated technologies as a whole, which could further hinder the progress of other genuinely open and interoperable solution providers.

Ecosystem builders such as TIP and the O-RAN Alliance therefore need to continue emphasising the importance of adherence to fully open standards, while operators need to demand full interoperability from their partner vendors and systems integrators, in order to preserve proper incentives for competition and innovation in the broader ecosystem, which would enable the realisation of cost-efficiency and time-to-market benefits over the long term.

5.2.2 Testing platforms need to place an emphasis on security to alleviate operator concerns regarding threats to multi-vendor supply chains

Open solutions allow for more entities to be involved in the testing of solutions to identify security issues, which should enable vulnerabilities to be addressed more efficiently. However, this would not necessarily guarantee that security breaches would not occur, given that a move towards disaggregation and the use

[138] Rakuten. (2020), Rakuten Mobile Plands to Acquire Innooeye to support Rakuten Communications Platform Launch, available at https://global.rakuten.com/corp/news/press/2020/0513_02.html

[139] Light Reading. (2020), Is open RAN a protectionist scam?, available at https://www.lightreading.com/open-ran/is-open-ran-protectionist-scam/d/d-id/765161

[140] Rakuten Mobile press release, see https://corp.mobile.rakuten.co.jp/english/news/press/2020/1104_03/

[141] See https://www.nttdocomo.co.jp/english/info/media_center/pr/2021/0208_00.html

[142] See https://www.qualcomm.com/news/releases/2020/10/20/qualcomm-and-reliance-jio-align-efforts-5g

of more virtual tools for network management and monitoring could increase the 'surface area' that could be exploited by potential attackers.[143] It is also possible that new vulnerabilities could emerge from specific combinations of network elements, which would require secure integration to mitigate. Operator concerns around maintaining security through complex integrations could also strengthen the argument for specific implementations put forth by groups of vendors and integrators. Although these implementations are likely to be tested more extensively, they might also lead to fragmentation in the ecosystem if implementations are not fully interoperable.

Smaller operators that are heavily dependent on outsourcing may also prefer solutions from an integrated provider as accountability for network security would lie directly with one company, which would simplify the approach to managing incentives and corrective action. Regardless, operators would ultimately be best able to demand accountability from providers if they are not locked in to a given solution. The flexibility to change providers adds resilience to the supply chain and incentivises vendors to continually improve service provision and security.

Platforms set up to test viability of multi-vendor solutions, such as TIP Test and Integration or local labs launched by policy makers, need to ensure that network security is prioritised alongside network performance. The benefits of open and disaggregated solutions for security management, such as better visibility of network security threats, and accelerated automation of network management functions, should also be exploited so that any new potential threats are adequately mitigated.[144]

5.3 Greater co-ordination between industry and policy will allow the ecosystem to scale

To reduce the challenges associated with insufficient adoption of open and disaggregated networks, and refragmentation of standards, policy makers should collaborate with industry parties to align standards, requirements and incentives in order to optimise potential ecosystem benefits. It is important for co-ordination to take place on the international stage, as market-specific standards would diminish the economies of scale that vendors can achieve when developing new solutions. The ability to test solutions against a common set of standards and requirements globally would allow vendors to serve a larger target market, and would allow operators to consider solutions from a wider range of suppliers across the globe.

5.3.1 Aligning open standards and principles beyond local borders would allow for greater impact

A crucial factor for the development of the multi-vendor supply chain would be for new hardware and software vendors to achieve economies of scale while specialising in discrete parts of the supply chain. This would require interoperability requirements to be met across different geographical regions, in order for greater scale to be achieved. Without sufficient scale, vendors might not be able to enter the market if they are unable to recover investment into R&D and product development.

On a related note, policy makers that are aiming to capitalise on an open ecosystem to boost local production and develop skills in the technology sector could consider policies that support the export of locally made products and solutions to the broader global market, in addition to meeting any local demand where local specialisation would be warranted. The viability of policy interventions to stimulate local production would be limited without the global interoperability needed to enable firms to provide solutions to customers in other countries and regions.

Policy makers that view open and disaggregated technologies as an opportunity for local telecoms sector development are also monitoring developments in the global technology ecosystem and policy arena for further assurance. While initiatives such as facilitating co-operation between stakeholders at a local level are straightforward, policy makers may be hesitant to commit to more substantial policies such as tax incentives as the precise benefits of doing so are still unclear. There is also the further challenge of ensuring that actions taken by policy makers in other countries are in line with local priorities.

5.3.2 An expansion of forums for knowledge sharing across more stakeholder types would allow for better adoption of global best practice by policy makers

The open ecosystem has the potential to unlock various benefits for stakeholders in the telecoms industry and

[143] GSMA. (2021). Mobile Telecommunications Security Landscape. Available at https://www.gsma.com/security/wp-content/uploads/2021/03/id_security_landscape_02_21.pdf

[144] Open RAN Policy Coalition. (2021). Open RAN Security in 5G. Available at https://www.openranpolicy.org/wp-content/uploads/2021/04/Open-RAN-Security-in-5G-4.29.21.pdf

for the economy as a whole, but also requires a level of co-ordination with regard to testing and integration that stakeholders have not engaged in before.

A similar argument could be made about the challenges that policy makers face in trying to develop an approach to open and disaggregated technologies. While policy makers do interact and share best practice on issues such as spectrum management,[145] the set of issues that need to be addressed for open and disaggregated technologies would not be entirely familiar for many policy makers.

Most regulators do not typically monitor the development and adoption of commercial standards, which makes it difficult to determine if or how to assess whether operators would keep to potential commitments regarding interoperability. Policy makers might instead establish interventions that would allow local firms to take concrete steps to develop capabilities to be competitive in the global marketplace in the long run, such as tax incentives for local R&D, or production quotas with gradually increasing targets.

While 'best practice' for incentivising the development of open and disaggregated technologies is still being defined, several progressive policy makers across the world have already been able to foster vibrant local ecosystems, which can serve as examples for others to follow and improve upon in their own countries and cities. Dublin, for instance, has made significant strides as a technology hub in recent years, and has developed a smart-city programme that has won numerous awards.[146] As part of this initiative, the city has emphasised its commitment to providing, managing and co-ordinating the ownership of fair and equitable assets for network equipment, such as lamp posts and other urban infrastructure.[147] Policy makers in the USA and the UK have also shown support for open and disaggregated solutions, with the National Defense Authorization Act for 2021 in the USA authorising two funds that can support the development of multi-vendor networks,[148] and the 5G Supply Chain Diversification Strategy in the UK, which emphasises supporting incumbent vendors, attracting new vendors and accelerating open-interface solution adoption.[149]

Case study: Open RAN Policy Coalition

The Open RAN Policy Coalition is a group of organisations formed to promote policies which advance the adoption of open, disaggregated and interoperable solutions in the RAN.[150] In December 2020, the coalition published a Policy Roadmap which outlines various policy tools for different strategies that international governments might follow to achieve objectives that altogether intend to accelerate adoption of open standards in the RAN. These objectives are to:

- **Support the emergence of new infrastructure vendors**
- **Accelerate demand for solutions**
- **Catalyse investment in technical capabilities**
- **Support operators as they develop an approach to managing multi-layer network architecture**
- **Establish an approach to oversee multi-vendor network architecture**
- **Engage with international allies to share information**

145 For example, see GSMA – "An Introduction to the WRC, a beginner's guide to the World Radiocommunication Conference", February 2017, see https://www.gsma.com/spectrum/wp-content/uploads/2017/02/An-Intoduction-to-the-WRC.pdf

146 See https://smartdublin.ie/

147 See https://telecominfraproject.com/connected-city-infrastructure/

148 See https://www.congress.gov/116/bills/hr6395/BILLS-116hr6395enr.pdf

149 See https://www.gov.uk/government/publications/5g-supply-chain-diversification-strategy/5g-supply-chain-diversification-strategy

150 Open RAN Policy Coalition press release, see https://www.openranpolicy.org/open-ran-policy-coalition-releases-new-policy-roadmap/

Policy tools are divided into fiscal, regulatory and convening categories, with several examples below:

Fiscal	**Stimulate supply**	▪ Provide incentives for R&D ▪ Financing for start-ups
	Stimulate demand	▪ Purchase telecoms equipment ▪ Development financing
Regulatory	**Align with objectives**	▪ Update regulations ▪ Avoid mandating tech standards
	International coordination	▪ Harmonize spectrum bands ▪ Align approach to security risk
Convening	**Technical collaboration**	▪ Partner with academia & industry ▪ Pilots & testbeds
	Policy development	▪ Stakeholder input to guide policy ▪ Formal partnerships with allies

The recommended tools are applicable to countries globally, with illustrative examples of actions governments have taken to stimulate supply and demand for the Open RAN project in the UK and Japan.

TIP, which focuses on practical delivery, can also serve as a platform for policy makers to exchange insight, as well as a vehicle to support delivery of policy objectives. Policy makers involved with TIP, such as those in Dublin and Indonesia (as discussed earlier in this report), are able to capitalise on the TIP community to further their policy objectives, and can also provide lessons for other like-minded policy makers in other countries looking to open and disaggregated technologies as a key enabler of connectivity and economic growth in the future.

Annex A Impact assessment methodology

This annex details the methodology used to estimate the impact of Open RAN. This approach relies on the establishment of a counterfactual scenario in terms of macroecnomic and telecoms market forecasts, based on third-party data.[151] Changes to telecoms market metrics due to the impact of Open RAN are then estimated for a 'baseline' case. The differences in telecoms market metrics in the baseline and counterfactual cases are then used to estimate the Open RAN impact on macroeconomic metrics such as GDP, based on existing literature connecting connectivity and economic indicators.

Countries are grouped into 17 income-region groups.[152] Input macroeconomic and telecoms market data is aggregated for each of these 17 groups, to which various assumptions and calculations are applied, resulting in output metrics. All resulting financial and economic metrics referenced in the modelling section of this report are in real United States Dollars, based on 2020 prices. Conversions from nominal and purchasing power parity (PPP) values are used where necessary.

A.1 Selecting and grouping countries in the sample

A total of 184 countries are included in the sample, mainly based on the availability of macroeconomic and telecoms market data required for analysis. In addition, China is also conservatively excluded from the sample, given that Chinese operators have largely already committed to 5G deployments using proprietary interfaces and solutions.[153] We do note, however, that Chinese companies have been active in Open RAN groups such as the O-RAN Alliance for several years,[154] and there is a possibility that Chinese operators could seek interoperable solutions during the next replacement cycle in half a decade or so. Incumbent Chinese vendors might start to offer interoperable solutions as well, although this appears unlikely in the short run.[155] These possibilities would represent an upside to the cases modelled in this report. Collectively, the countries included in the sample account for roughly 80% of global population and GDP as of 2020.

Countries were then grouped by income level, based on the same classification thresholds used in the global ITU study on the impact of mobile internet penetration on GDP per capita (PPP).[156] The number of countries included in each income group, by region, can be seen in Figure A.1 below. The country group thresholds used also resulted in differentiation of countries on the basis of mobile internet penetration levels, which indicates that the grouping thresholds are suitable for the analysis considered. A distribution of mobile internet penetration[157] by countries within each income group can be found in Figure A.2 below.

[151] From Euromonitor International, GSMA Intelligence and Analysys Mason Research. It is assumed that third-party data accessed for this analysis accounts for only a limited influence of Open RAN.

[152] Three income levels and six regions considered result in 18 possible combinations; however, selected threshold levels do not result in any countries falling within the hypothetical middle-income Middle East combination, leaving just 17 total combinations.

[153] See https://www.rcrwireless.com/20200427/carriers/huawei-zte-already-secured-over-80-china-5g-contracts-report

[154] The O-RAN Alliance was formed in 2018 through the merger of Chinese-led C-RAN Alliance and the xRAN Forum, which was mostly American; see https://www.parallelwireless.com/understanding-the-different-open-ran-groups-in-the-telecoms-industry/

[155] See https://www.lightreading.com/open-ran/huawei-gives-another-thumbs-down-to-open-ran---or-so-it-says/d/d-id/768660

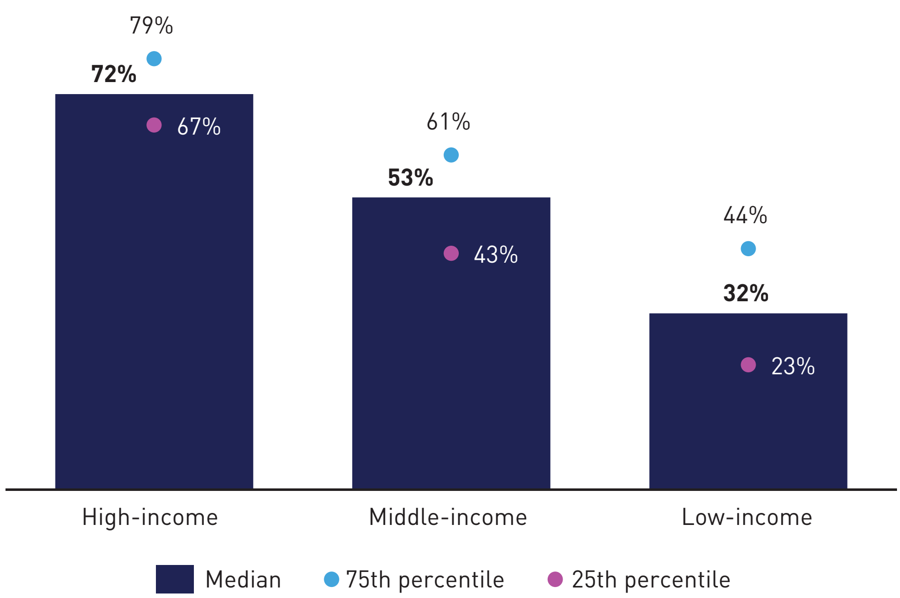
[156] International Telecommunication Union. (2018). The economic contribution of broadband, digitalization and ICT regulation. Available at https://www.itu.int/pub/D-PREF-EF.BDR-2018

[157] Unique mobile internet subscribers divided by population, calculated using data from Euromonitor International and GSMA Intelligence

FIGURE A.1: NUMBER OF COUNTRIES INCLUDED IN SAMPLE, BY REGION AND INCOME LEVEL
[SOURCE: ANALYSYS MASON, EUROMONITOR INTERNATIONAL, 2021]

	High-income countries	Middle-income countries	Low-income countries	Total	% of sample population	% of sample GDP
2020 GDP per capita (PPP)	More than USD22 000	USD12 000 to USD22 000	Up to USD12 000			
Africa	1	4	47	52	21%	3%
Americas	9	15	11	35	16%	39%
Asia–Pacific	10	5	19	34	44%	22%
CIS	2	6	4	12	5%	3%
Europe	32	5	1	38	10%	28%
Middle East	7	-	6	13	4%	4%
Total	61	35	88	184	100%	100%
% of sample population	24%	17%	59%	100%		
% of sample GDP	81%	9%	11%	100%		

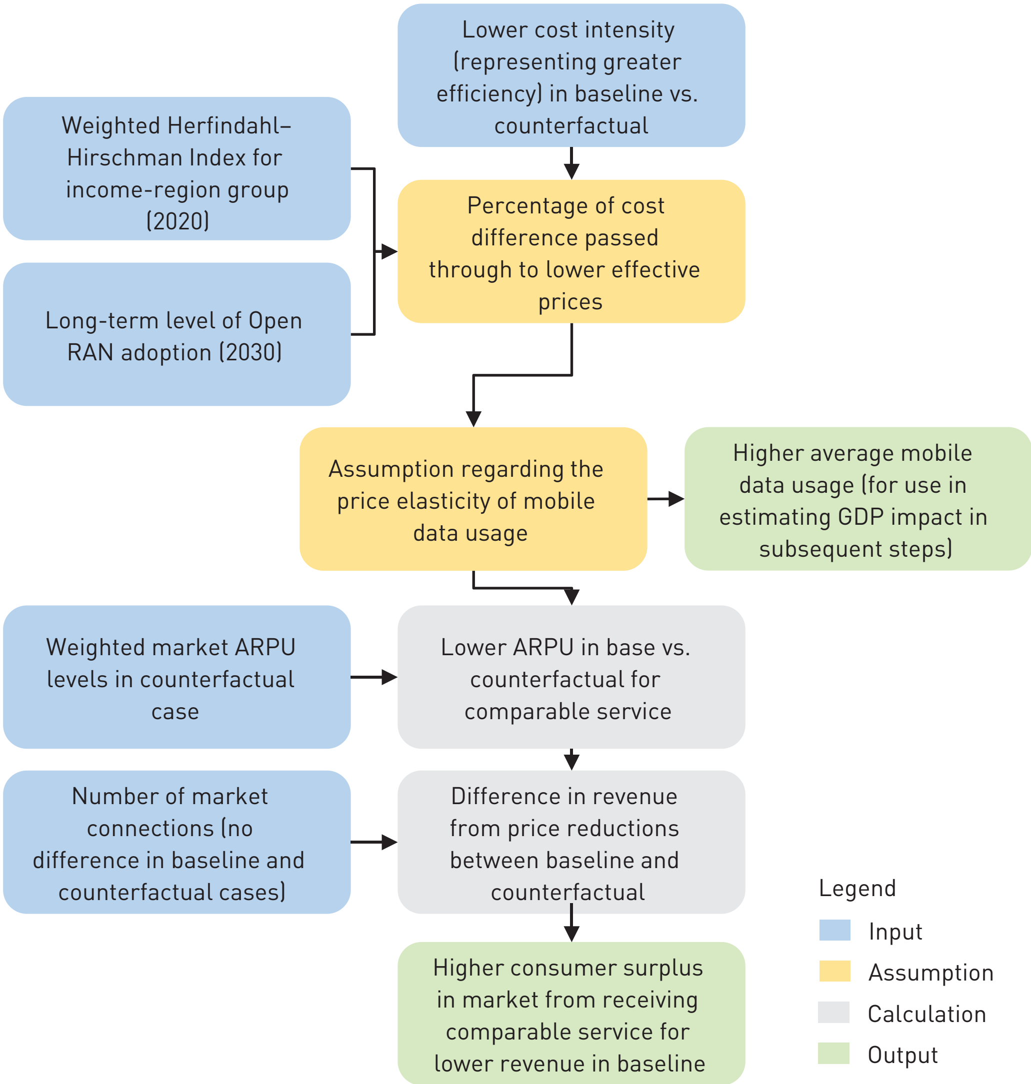
FIGURE A.2: DISTRIBUTION OF MOBILE INTERNET PENETRATION FOR COUNTRIES WITHIN EACH INCOME GROUP
[SOURCE: ANALYSYS MASON, GSMA INTELLIGENCE, 2021]



A.2 Estimating the impact of Open RAN on consumer surplus

The steps used to estimate the impact of Open RAN on consumer surplus are illustrated in Figure A.3 below.

FIGURE A.3: CALCULATING INCREMENTAL CONSUMER SURPLUS DUE TO TRANSFER OF COST-EFFICIENCY BENEFITS TO LOWER ARPU [SOURCE: ANALYSYS MASON, 2021]



For a given level of cost-efficiency improvement (using lower costs as a share of recurring revenue[158] in the baseline case compared to a counterfactual as a proxy), we estimate a percentage of the benefit that would be transferred to consumers in the form of lower effective prices for a comparable service. An assumption that the price elasticity of mobile data[159] is –0.5 is applied in order to reflect that half of the benefit of lower effective prices would result in lower ARPU, while the remaining half would result in larger data allowances for the same ARPU.[160] The difference in ARPU levels for a comparable service in the baseline and counterfactual cases would result in lower revenue paid to operators for a comparable service when considering all connections in a given market, and represents the incremental consumer surplus generated by Open RAN, as the difference between what consumers would have been willing to pay in the two cases for the same level of service.

The parameter used to represent the percentage of cost-efficiency benefits that are passed through to customers in the form of lower effective prices accounts for weighted HHI[161] in 2020 for a given income-region group, as well as the assumption on the level of Open RAN adoption achieved in the scenario by 2030. Both of these factors provide indications of how competitive dynamics in a market would affect the ability of operators to retain benefits of cost efficiency, and operators would likely have to pass more of the benefit to customers in less concentrated markets (higher HHI) and in markets where a smaller share of operators intend to use open solutions over the long term. The percentage pass through parameter is calculated as:

$$\%\ \text{pass through} = \left(\frac{10\,000 - \text{Weighted HHI}}{10\,000}\right)^{0.5} \times \text{Long term Open RAN adoption}^{0.5}$$

Figure A.4 below illustrates the resulting parameter of cost-efficiency benefit passed through to customers in the form of lower effective prices, for different combinations of weighted HHI and level of Open RAN adoption inputs.

FIGURE A.4: POSSIBLE PASS THROUGH PARAMETERS FOR DIFFERENT WEIGHTED HHI AND LEVEL OF OPEN RAN ADOPTION COMBINATIONS [SOURCE: ANALYSYS MASON, 2021]

	Level of Open RAN adoption in market (accounting for addressable market and operator take-up)										
Weighted HHI by archetype-region group (an example of an archetype-region group is low-income Asia-Pacific)	-%	10%	20%	30%	40%	50%	60%	70%	80%	90%	100%
-	-%	32%	45%	55%	63%	71%	77%	84%	89%	95%	100%
1000	-%	30%	42%	52%	60%	67%	73%	79%	85%	90%	95%
2000	-%	28%	40%	49%	57%	63%	69%	75%	80%	85%	89%
3000	-%	26%	37%	46%	53%	59%	65%	70%	75%	79%	84%
4000	-%	24%	35%	42%	49%	55%	60%	65%	69%	73%	77%
5000	-%	22%	32%	39%	45%	50%	55%	59%	63%	67%	71%
6000	-%	20%	28%	35%	40%	45%	49%	53%	57%	60%	63%
7000	-%	17%	24%	30%	35%	39%	42%	46%	49%	52%	55%
8000	-%	14%	20%	24%	28%	32%	35%	37%	40%	42%	45%
9000	-%	10%	14%	17%	20%	22%	24%	26%	28%	30%	32%
10 000	-%	-%	-%	-%	-%	-%	-%	-%	-%	-%	-%

[158] Data on recurring revenue, ARPU and mobile SIMs from GSMA Intelligence, extrapolated over forecast period.

[159] Using a conservative elasticity parameter, based on Dewenter & Haucap (2007) *Demand Elasticities for Mobile Telecommunications in Austria*.

[160] The part of the benefit that goes to larger data packages is used as an input to calculating the GDP impact of increased mobile data usage in Section A.4.

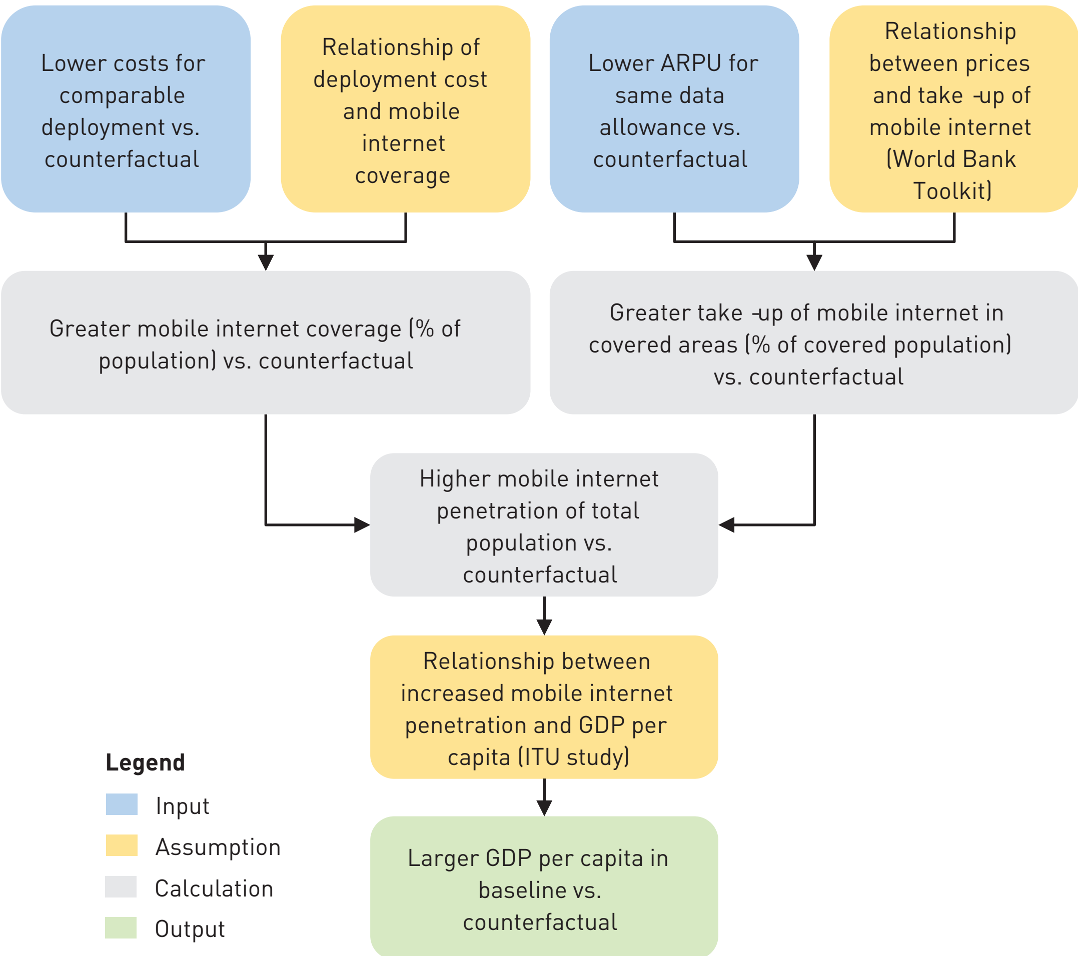
[161] The highest possible HHI, of 10 000, represents a monopoly.

This approach conservatively excludes potential consumer surplus gains from new subscribers that are induced to enter the market from lower prices, although it is worth noting that the amount of incremental consumer surplus from these subscribers is expected to be minimal, as the marginal subscriber would have a consumer surplus of close to zero, if the market price is barely higher than the amount they were willing to pay for the service.

A.3 Estimating Open RAN impact on GDP due to greater mobile internet penetration

The impact of Open RAN on GDP due to mobile internet penetration (unique mobile internet subscribers as a percentage of population[162]) is estimated by first estimating the effect that Open RAN could have on mobile internet penetration, via wider coverage and higher take-up within covered areas, which together result in an indication of the impact of Open RAN on mobile internet penetration. Following this, a study exploring the relationship between mobile internet penetration and GDP per capita (PPP) is cited in order to convert the greater penetration from Open RAN into higher GDP levels.[163] These steps are illustrated in Figure A.5 below.

FIGURE A.5: CALCULATING INCREMENTAL GDP DUE TO GREATER LEVELS OF MOBILE INTERNET PENETRATION [SOURCE: ANALYSYS MASON, 2021]



[162] Data on population is from Euromonitor International, while data on unique mobile internet subscribers is from GSMA Intelligence, extrapolated over the forecast period.

[163] Conversions from GDP in PPP terms to real terms are applied as required.

For the purposes of this model, we estimate that a 10% reduction in the cost of rural deployment of mobile broadband sites could result in a 1 percentage point increase in mobile internet coverage (share of population covered) in middle-income countries, and a 2 percentage point increase in mobile internet coverage in low-income countries, based on the improvement to deployment economics.[164]

Meanwhile, the World Bank Broadband Strategies toolkit[165] suggests that a 10% price decline in mobile broadband plans would generate a penetration increase ranging between 2.35% and 3.20%. These parameters are applied in our model to middle-income and low-income countries respectively.

Finally, a 2018 study by the ITU[166] used econometric analysis of data from countries across several regions around the world to determine that a 10% increase in mobile broadband penetration would yield a 1.8% increase in GDP per capita in a given year for middle-income countries and a 2.0% increase for low-income countries, over and above the counterfactual GDP growth projected.

A.4 Estimating the impact of Open RAN on GDP from higher average mobile data usage

The impact of Open RAN on GDP is not limited to the impact of greater mobile internet penetration, but also extends to the potential of achieving increased average data usage per mobile internet (3G+) SIM due to lower effective prices, as discussed in Section A.2, and by accelerating the deployment and take-up of advanced technologies (4G/5G).

This approach involves extrapolating forecasts of the share of total SIMs by technology and data usage per SIM by technology over the entire forecast period considered, to establish a counterfactual level of data usage per mobile internet SIM.[167] Once this is done, input assumptions on the benefits of cost efficiency which are passed through to lower effective prices and larger data allowances are applied to the counterfactual to arrive at a data usage per mobile internet SIM figure for the baseline case.

Following this, assumptions on the acceleration of technology take-up for 4G and 5G are applied, which would result in a larger share of SIMs with more advanced technologies in a given year for the baseline case compared to the counterfactual. This would result in a mix of subscribers that leans more heavily towards advanced technologies, generating a blended average data usage per mobile internet SIM figure across technologies that is even higher in the baseline case than in the counterfactual after accounting for both the effects of lower effective prices and technology acceleration.

Finally, higher average data usage levels in the baseline case relative to the counterfactual would result in higher GDP levels, as found by a study for the GSMA by Deloitte from 2012.[168] For this model, we adopt results from a more recently developed endogenous growth model used in another Analysys Mason report, which suggests that a doubling of mobile data leads to a 0.8% increase in GDP per capita.[169]

These steps are illustrated in Figure A.6 below.

[164] Based on recent Analysys Mason project experience related to the viability of rural connectivity solutions, that involved calculating net present value of rural deployments, accounting for costs and revenue potential

[165] World Bank Group. Broadband Strategies Toolkit. Available at https://ddtoolkits.worldbankgroup.org/broadband-strategies

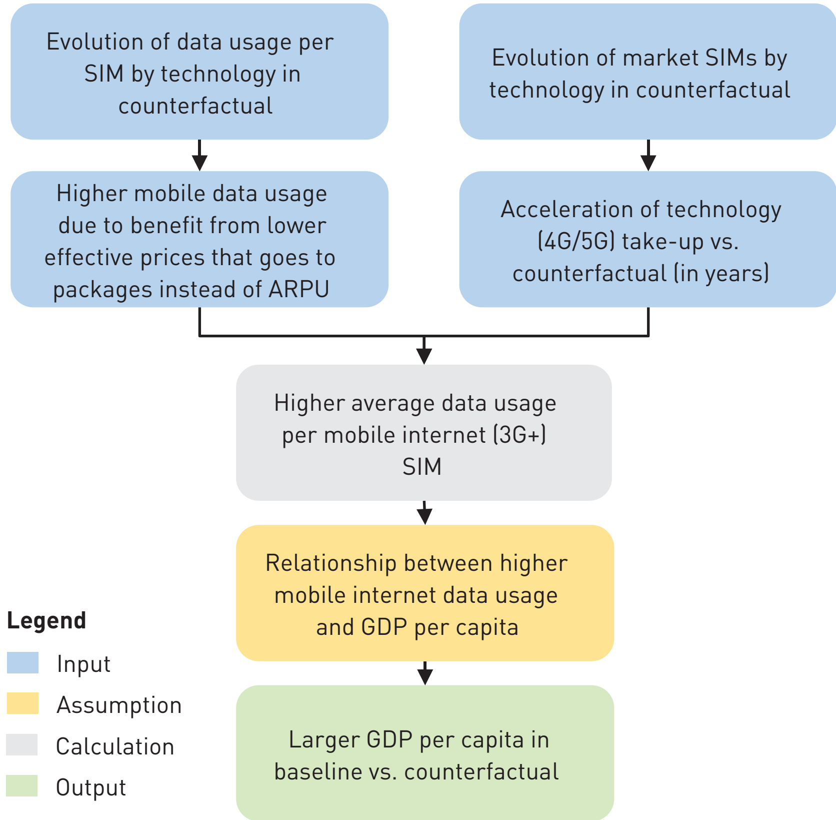
[166] International Telecommunication Union. (2018). The economic contribution of broadband, digitalization and ICT regulation. Available at https://www.itu.int/pub/D-PREF-EF.BDR-2018

[167] Data on SIMs by technology from GSMA Intelligence, and on data usage per SIM from Analysys Mason Research, extrapolated over the forecast period.

[168] Deloitte. (2012). What is the impact of mobile telephony on economic growth? Available at https://www.gsma.com/publicpolicy/wp-content/uploads/2012/11/gsma-deloitte-impact-mobile-telephony-economic-growth.pdf

[169] Analysys Mason. (2020). Economic impact of Google's APAC network infrastructure. Available at https://www.analysysmason.com/consulting-redirect/reports/impact-of-google-network-APAC-2020/

FIGURE A.6: CALCULATING INCREMENTAL GDP DUE TO HIGHER LEVELS OF MOBILE DATA USAGE
[SOURCE: ANALYSYS MASON, 2021]



Annex B Interview programme

As part of the process of conducting research for this report, we interviewed individuals from 19 different organisations that are likely to be affected by the development of the open and disaggregated ecosystem in coming years. Each interview lasted between 30 to 60 minutes, and involved interviewees sharing their views on potential benefits that open and disaggregation technologies could bring to their organisations, concerns or barriers affecting future development of the open and disaggregated ecosystem, as well as other related topics.

The organisations represented include vendors, operators, systems integrators, and policy makers, and many interviewees had previous engagement with TIP or were at least aware of TIP and its activities.

Figure B.1 below provides an overview of the organisations interviewed, and perspectives obtained.

FIGURE B.1: OVERVEW OF INTERVIEWS CONDUCTED [SOURCE: ANALYSYS MASON, 2021]

Organisation type	Interviews conducted	Brief description
Vendors	7	• We interviewed several providers of disaggregated solutions (some focusing on hardware and others on software) • Together, the portfolios of our interviewees include solutions for radio access and transport networks • We also spoke with large incumbent vendors as part of the process
Operators / ISPs[170]/ Infrastructure providers	7	• Together, the group of organisations interviewed serve customers in Africa, Asia–Pacific, Europe, Middle East, Latin America, and North America
Systems integrators	2	• Both companies have a wide presence, serving customers from across the globe
Policy makers	3	• We spoke with policy makers in Asia–Pacific and Europe • We received input from the government ministry, telecoms regulator, and city council perspectives

[170] ISP stands for internet service provider.

analysys mason

Stay connected

You can stay connected by following Analysys Mason via Twitter, LinkedIn and YouTube.

- linkedin.com/company/analysys-mason
- @AnalysysMason
- youtube.com/AnalysysMason
- analysysmason.podbean.com