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GSMA

The Impact of Licensed Shared Use of Spectrum

A REPORT FOR THE GSM ASSOCIATION | 23 JANUARY 2014
PREPARED IN COLLABORATION WITH

realwireless
independent wireless experts

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Executive Summary

The GSMA has commissioned a study to scope and model the strategic and economic impact on the mobile industry of Licensed Shared Access (LSA), a spectrum sharing approach in which an incumbent licensed user is permitted to sub-license and share spectrum access with LSA licensees. The assessment focuses on "vertical" sharing between non-mobile network operator incumbents and a mobile network operator (MNO) sharer. This is seen as the more significant and realistic mid-term sharing opportunity for addressing spectrum needs of the wireless industry.

A FRAMEWORK TO EVALUATE THE STRATEGIC IMPLICATIONS OF SPECTRUM SHARING

Given the diverse sharing approaches, environmental circumstances and interdependencies of bandwidth sharing between heterogeneous incumbents and MNOs, a common framework is presented that can be applied for defining and analysing spectrum sharing scenarios.

This framework should account for:

KEY PARTIES TO SPECTRUM SHARING FOR MNO USE

the incumbent non-MNO spectrum users, the regulatory bodies and policy makers that oversee and influence spectrum sharing approaches and outcomes, the MNOs and the surrounding mobile ecosystem, and the mobile end users. All four parties are crucial players in the spectrum sharing ecosystem. If any party is not properly incentivised to support spectrum sharing, with benefits outweighing the costs and risks, the opportunity may remain purely theoretical.

DYNAMIC NATURE OF SHARING

The feasibility, level of complexity, and certainty of use for an MNO to share spectrum with an incumbent will be significantly impacted by the dynamic nature of the sharing arrangement. The most significant dynamics will likely be measured across two dimensions – time and geography – and as the dynamic nature of the arrangement increases, the MNO's ability to effectively value and use the spectrum decreases while operational complexity and cost to manage the arrangement increases.

KEY SHARING TERMS AND CONSIDERATIONS

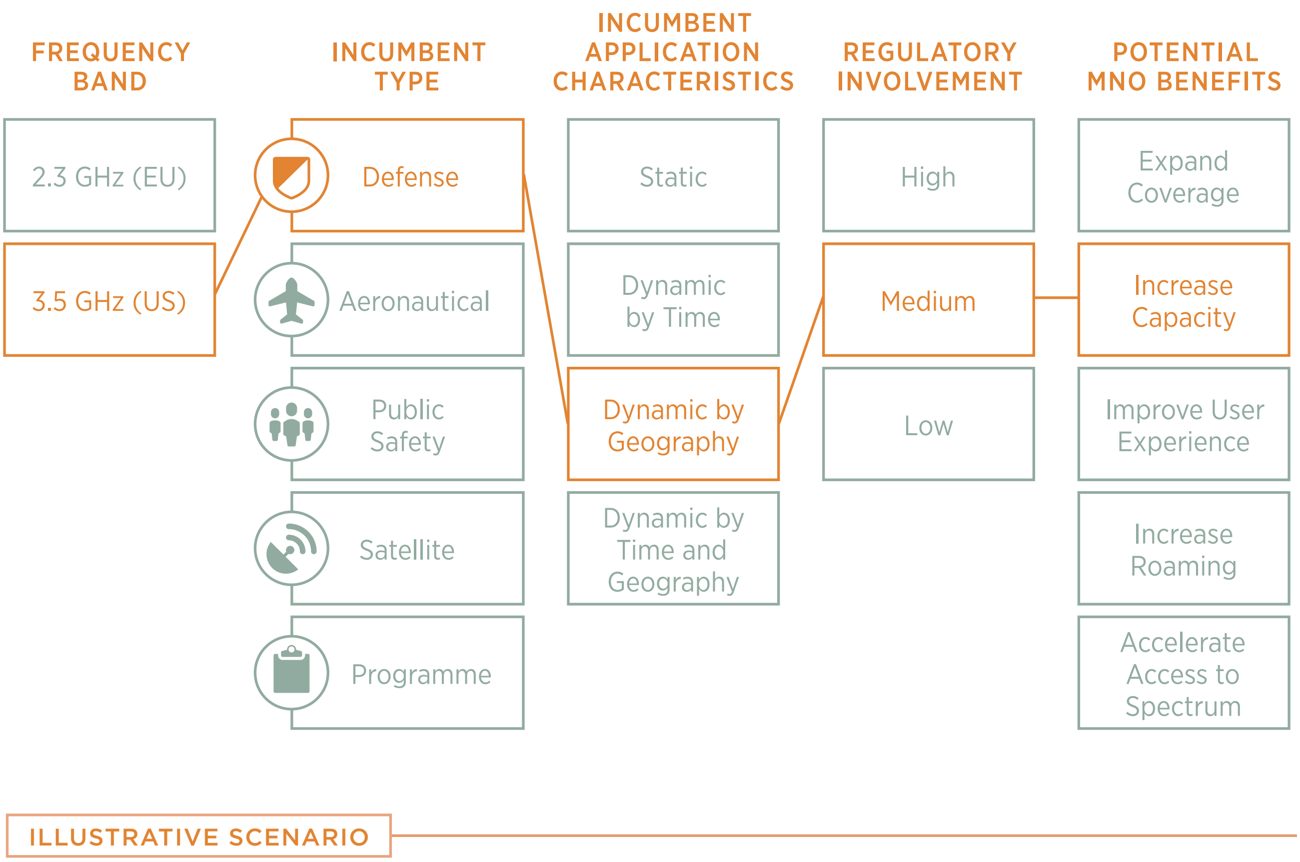
Sharing will require the incumbent and MNO to reach negotiated agreement on a variety of terms and conditions. Some conditions, such as geographic restrictions or dynamics, will generally arise directly from the characteristics of the incumbent use profile and create little latitude for tailoring. Other conditions, such as frequency block size and contract term, are more likely to be negotiable.

From an MNO's perspective, sharing terms can be loosely grouped into three categories: value driving (e.g., frequency range, block size, permitted use by geography or time), cost driving (e.g., spectrum rights fees, sharing access control), and risk and uncertainty driving (e.g., number of sharing licences, term length, incumbent renegotiation rights). It will be critical for the MNO to evaluate each term in the agreement from two perspectives:

The relationship between term value changes and business case results: to what extent a linear change in term value results in a linear, non-linear or step-function change in business case value.

The relationship between term certainty and business case risk: to what extent lack of specificity or clarity in a term creates exposure and risk for an MNO to proceed with the investment.

By combining these three factors into a common framework, a spectrum sharing scenario can be defined as a specific combination of the following elements:



All elements are material for determining the benefits and costs of a spectrum sharing scenario. Any attempt to determine the value of spectrum sharing without considering all of these dimensions will be inherently limited. Further, the need for precisely defined sharing relationships points to the importance of negotiations between the incumbent user, the new user(s) and the regulator being conducted on a voluntary basis to allow maximum flexibility and innovation in finding solutions that maximize potential for the shared use. Mandated or prescribed approaches will necessarily be restrictive in nature and reduce the probability of a successful negotiated outcome.

APPLYING THE STRATEGIC FRAMEWORK TO SCENARIOS IN THE US AND EU

In the US, the 3.5GHz band was identified as a priority band by both the President's Council of Advisors on Science and Technology (PCAST) and the National Telecommunications and Information Administration (NTIA). As such it is useful to study this band as an example sharing scenario.

Having reviewed the band characteristics, a primary potential benefit for MNOs is in providing localised capacity in busy locations, especially in indoor applications such as public buildings, healthcare and leisure environments. A secondary benefit is that the band could be available across all operators, opening up increased opportunities for national roaming between operators which has hitherto been challenging due to complexities in the existing 700MHz band plan.

However, challenges and trade-offs exist. An incumbent use is Department of Defense (DoD) Naval radar. A preliminary FCC calculation has concluded macrocell exclusion zone to avoid radar interference would exclude approximately 60% of the US population. An alternative regulatory restriction to reduce the exclusion zone via use of small cells might reduce the utility of the band in locations with little incumbent usage, but accepting the limitations of such an approach could provide for more rapid access to the band and provide confidence to incumbent users of a reduced interference probability.

In the European Union (EU), the European Commission (EC) has strongly advocated spectrum sharing as an "essential solution to dealing with the wireless crunch". The 2.3GHz band has been identified as the highest priority band for spectrum sharing. However, existing users are highly variable across Europe and an EU-wide sharing solution will require negotiated approaches for a variety of sharing circumstances spanning numerous incumbents and regulatory bodies.

POTENTIAL PRIMARY BENEFITS TO MNOS INCLUDE:

CAPACITY

e.g. increasing offload potential and performance with harmonised indoor and outdoor small cells or increasing the general capacity of existing macrocells.

HARMONISATION

e.g. leveraging the existing supply chain for 2.3GHz mobile devices, or increasing the opportunity for EU MNOs to promote roaming on both an incoming and outgoing basis. Harmonisation is thus both a precondition to enable EU-wide spectrum sharing as well as a potential benefit where the frequency is already in use elsewhere.

Coverage is not a natural application for 2.3GHz as a higher frequency band, nevertheless the band could potentially be used via small cells deployed outdoors to increase the depth of urban indoor coverage, enhancing the capacity offload potential.

A FRAMEWORK FOR THE ECONOMIC ANALYSIS OF SPECTRUM SHARING

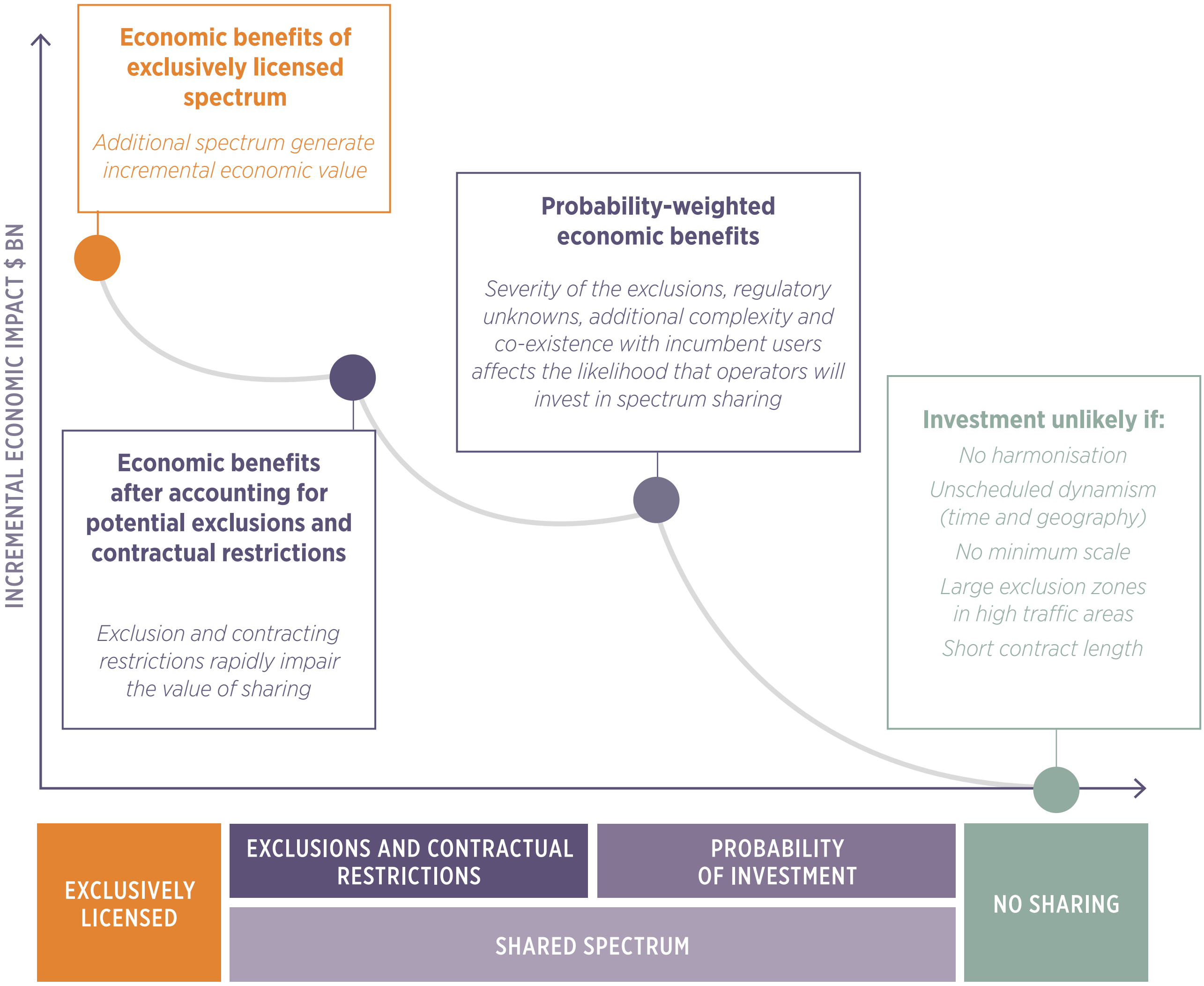
Limited analysis has been undertaken to date on the wider impact of spectrum sharing, i.e., considering the macroeconomic impact of spectrum as opposed to the benefits of investment from the point of view of a single operator or investor. The existing analysis appears to assume that shared spectrum for mobile usage is as economically useful as any other spectrum, implicitly disregarding the potential restrictions imposed on use or the frequencies offered and, importantly, that operators will necessarily invest and make use of the shared spectrum whenever it is offered.

While equating the benefits of shared spectrum to those of exclusive spectrum can be a useful starting point in the analysis, careful consideration must be given to two factors that differentiate shared spectrum from exclusive spectrum:

- Unless the incumbent has no use of the spectrum, coexistence of multiple users, potential exclusions and contractual restrictions always reduce the usefulness and the economic benefits of the shared spectrum.
- The increased complexity, uncertainty and the extra risks that sharing generates for MNOs are likely to decrease the probability that operators would invest in shared spectrum. While governments and regulators typically assume the investment in shared spectrum will necessarily occur, the existing uncertainties and complexities of spectrum sharing suggest that the probability that investment will not take place should be explicitly included as a discount by governments and regulators when evaluating the economic benefits of spectrum ex-ante, at least until these uncertainties are significantly reduced. While operators will reflect these risks in their business plans and incorporate them in the price they are prepared to pay for the spectrum, or their decisions to invest at all, a similar process could be considered by governments when evaluating the total economic benefits of shared spectrum.

These factors, which will be specific to each sharing scenario examined, are incorporated in the analysis as follows:

- The economic benefits that would accrue to the economy if the spectrum was provided on an exclusive basis are taken as an upper bound of the benefits that shared spectrum can provide.
- From this maximum value, a number of impairment discounts are applied to reflect how specific terms and conditions of the sharing agreement, such as time and population exclusions and other contracting limitations, impair the benefits. Provided that operators will invest, this produces a range of economic benefits of the shared spectrum.
- There are a number of scenario-specific conditions that should also be considered with regard to operators' likelihood to invest. The factors that potentially reduce the likelihood of investment are size of the exclusions, contract length, scale of operation (in Europe), harmonisation, and the level of sharing dynamism. Additionally, factors relating to increased complexity, uncertainty and extra risks also contribute to increase the likelihood that investment will not occur. In order to reflect the possibility that, under certain conditions, investment in spectrum sharing may not occur, the range of benefits obtained should be properly weighted and discounted. In practice, a higher discount rate (compared to exclusive spectrum) is used in the calculation of the present value of the benefits.



For example, if the economic impacts of exclusive spectrum amount to $100bn, a geographic/time limitation excluding 40% of traffic could reduce the benefits to $60bn while in the short term other severe uncertainties could lead to a probability of 10% of an operator investing in the spectrum. While the final outcome is binary (if investment occurs the benefits would amount to $60bn, but would amount to $0 if investment does not materialise), the probability weighed benefits amount to $6bn.

Overall, the economic value that can be generated through spectrum sharing requires appropriate discounting of these benefits to reflect exclusions and contractual restrictions. In addition, it is critical to closely reflect in the evaluation all the conditions that will affect the probability of investment by MNOs. This could drive the economic value to zero, either through lack of licence bidding or lack of investment post-licence purchase.

Considering these uncertainties and complexities from both a microeconomic and macroeconomic point of view, operators have noted that in general a solution whereby the incumbent migrates into a subset of frequencies which it retains under exclusive usage to allow exclusive licensing of the remaining frequencies for MNOs is likely to be more efficient and potentially produce a better result for the economy than sharing the entire band.

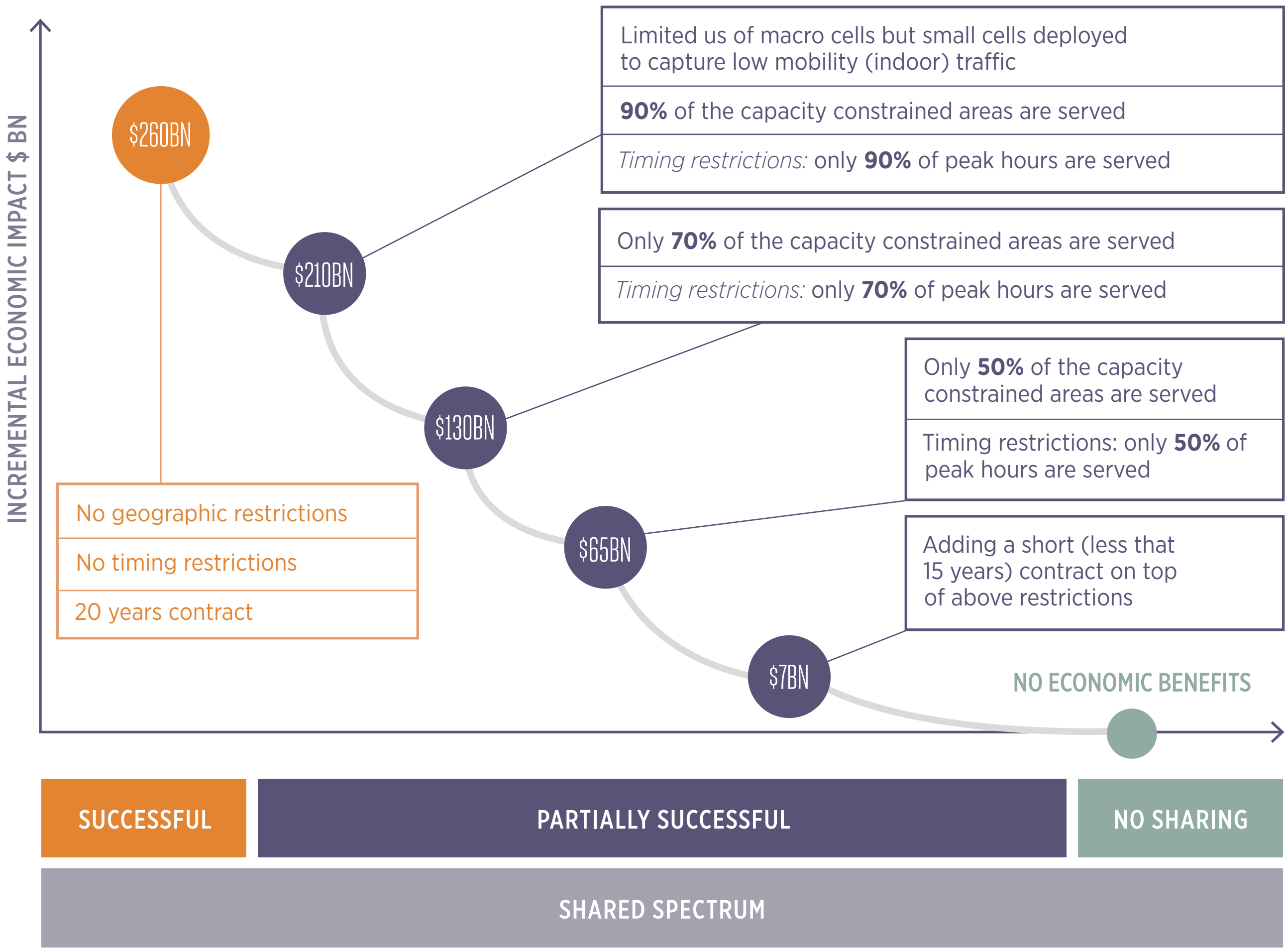
APPLYING THE ECONOMIC ANALYSIS FRAMEWORK TO SCENARIOS IN THE US AND EU

This study has assessed the band-specific incremental benefits that shared spectrum could generate when used to provide capacity for mobile broadband networks. The additional benefits of shared spectrum up to 2030 have been estimated in relation to two illustrative specific scenarios: that 100MHz of spectrum are shared in the US in the 3.5GHz band from 2016, and that 50MHz of spectrum are shared in the EU28 in the 2.3GHz band from 2020.

By explicitly considering exclusions and contractual restrictions that could be associated with shared spectrum, as well as the likelihood of investment by operators, the study finds that:

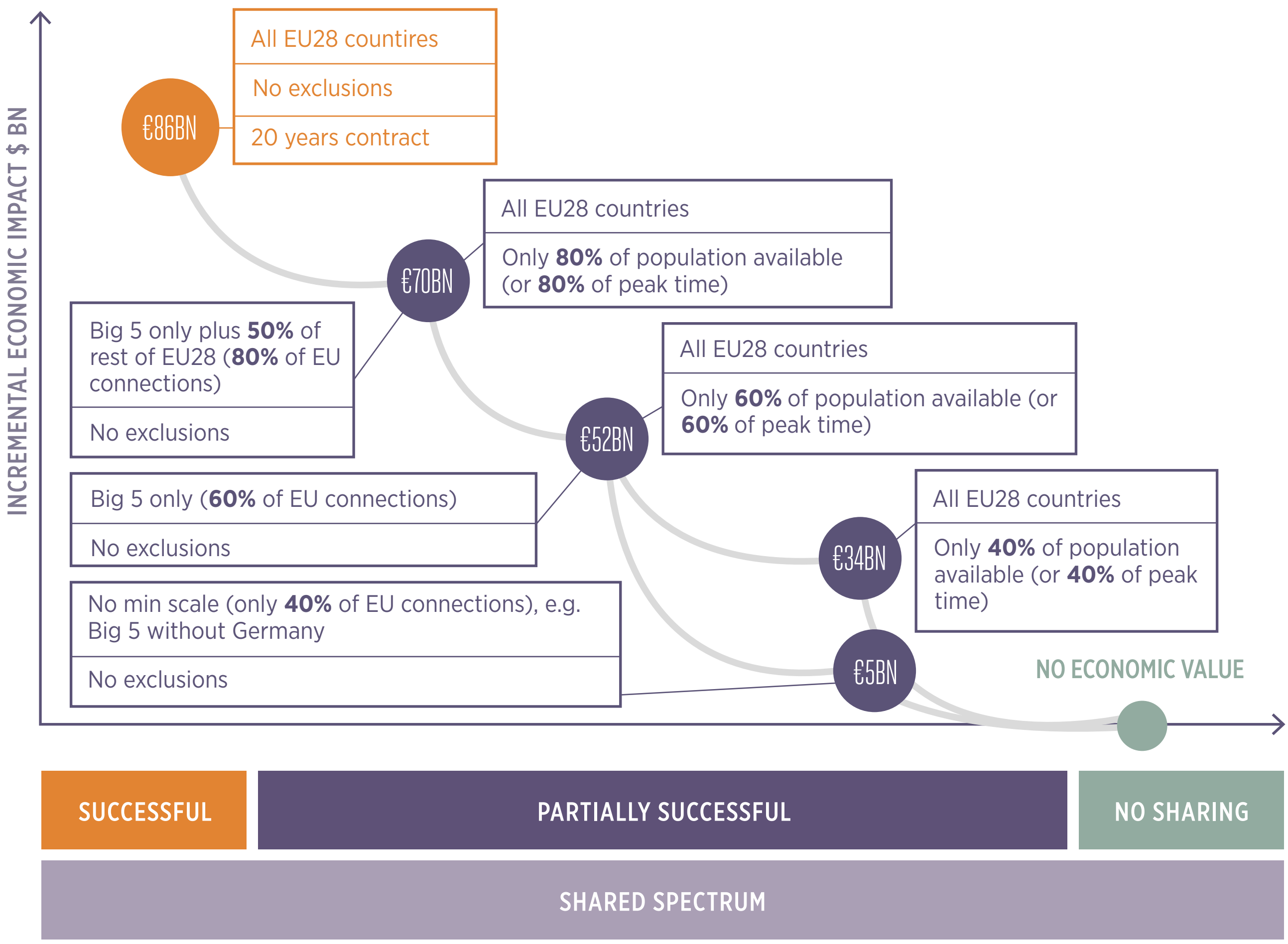
US

In the US, up to $260bn of value add could be generated across the US economy over 2016-2030. *This rapidly decreases to zero as geographic and timing exclusions and contracting limitations become more severe.*



EU

In the EU, up to €86bn of value add could be generated over the period.
This rapidly decreases if a common approach across states is not implemented, and also as geographic and timing exclusions and contacting limitations become more severe.



KEY STRATEGIC CONSIDERATIONS FOR THE DEVELOPMENT OF MNO VERTICAL SPECTRUM SHARING WITH INCUMBENTS

1	Sharing opportunities and value should be defined case-by-case	The many variables involved necessitate terms specific to each sharing opportunity. No generalised approach is possible.
2	Certainty is critical for establishing shared spectrum value	Sharing terms must be comprehensive, unambiguous and wit a multi-year valuation for MNOs to justify investments and manage risk
3	Less dynamic sharing arrangements are more feasible and attractive	Dynamic sharing crates inherent complexities and risks in both spectrum valuation and sharing execution
4	Incumbent must be properly incented to participate	Sharing by its nature creates value loss for incumbents, and proper incentives will be necessary to motivate successful voluntary incumbent participation

ECONOMIC IMPACT ANALYSIS: KEY FINDINGS

1 The economic benefits from adding spectrum for network capacity is unavoidable when spectrum is shared	While sharing will not be the main driver of mobile broadband, it may complement exclusive spectrum to provide capacity in congested areas and potentially deliver significant benefits
2 A discount on the economic impact is unavoidable when spectrum is shared	• Additional risk and complexities associated with spectrum sharing make investment by mobile operators less certain compared to the case of exclusive spectrum • An impairment discount should be explicitly accounted for when considering the benefits of shared spectrum • After accounting for this discount, the benefits of spectrum sharing are significantly reduced
3 The size of exclusions and contracts length can rapidly impair the economic benefits	As sharing conditions and service exclusions become more severe, the effects of shared spectrum deteriorate and the economic benefits are rapidly reduced
4 Increased sharing dynamism is likely to result in no economic benefit	Sharing is unlikely to occur if unscheduled outages or dynamic conditions are too restrictive, if harmonisation and minimal scale are not present, and if contracts with primary users are too onerous. Additional economic benefits should not be assumed in these circumstances

1. Introduction

1.1 BACKGROUND

Mobile broadband usage continues to grow rapidly throughout the world, primarily driven by the continued growth in:

- Smartphone and tablet-fuelled data usage.
- Device penetration (to above 100% of the population in many markets).
- Machine to Machine (M2M) applications and devices.

This dramatic growth has placed pressure on Mobile Network Operators (MNOs) to ensure adequate capacity and performance, and on regulators to provide access to the additional spectrum critical to capacity expansion.

An adequate monitoring of the spectrum requirements and management of frequency allocations to ensure adequate spectrum supply would result in significant positive implications for the mobile industry as a whole as well as the growing number of industries that are increasingly dependent on mobile services. Example industry applications include mobile payment or point of sale solutions, telematics, mHealth, usage-based insurance, utility smart grids, facility and home automation, location based services, and worker productivity apps. This, is turn, could have a positive effect on a country's economy, on the level of employment, and overall competitiveness.

Governments and regulators around the world are working to bring more spectrum to market for the mobile industry but are grappling with how to identify enough viable spectrum that can be exclusively licensed in the timeframe necessary to meet the anticipated demand. More positively, on-going technology developments are opening new opportunities for parties to viably share a common spectrum band. This creates a potential avenue for regulators to complement exclusively licensed spectrum. There is, however, a significant amount of uncertainty as to how such sharing might work, and the value of such spectrum to the marketplace.

1.2 THIS REPORT

The GSMA commissioned Deloitte, supported by Real Wireless, to explore the opportunity to mitigate the spectrum crunch through spectrum sharing. The key questions posed here are to assess the high level impact of vertical spectrum sharing – between a non-commercial or governmental incumbent and an MNO – and the economic impact of this.

This report provides a general framework that operators and governments/regulators can use to evaluate multiple and different spectrum sharing types. The framework is then applied to two specific bands that are currently being considered for sharing in the US and the EU.

This report is structured as follows:

SECTION 2
Provides an introduction to spectrum sharing, discussing types of licensed sharing and sharing user classes.

SECTION 3
Outlines a framework for the development and analysis of spectrum sharing scenarios, describing the sharing ecosystem, sharing approaches, and key terms and considerations for the mobile industry and regulators. It also describes how MNO-specific sharing scenarios can be constructed and provides an overview of current and contemplated international mobile bands that could be assigned for sharing.

SECTION 4
Provides a framework for the analysis of the incremental economic impact of spectrum sharing, outlining the key differences with the approach that has been employed for exclusive spectrum.

SECTION 5
Applies both the strategic and economic framework to two bands in the EU and US, to analyse risks and opportunities in these bands and to estimate the economic benefits and limitations associated with sharing in these bands.

SECTION 6
Provides key findings and conclusions from the study.

The paper is also supported by several appendices that provide background information on the study and modelling approach.

2

Introduction to spectrum sharing

This section provides an overview of what spectrum sharing is and discusses the various types of licensed sharing and sharing user classes.

2.1 WHAT IS SPECTRUM SHARING?

Spectrum sharing is the collective use of a given portion, i.e., frequency band, of the electromagnetic spectrum by two or more parties. From a regulatory perspective this sharing can be licensed or licence-exempt:

LICENSED SHARED ACCESS

An individual licensed regime of a limited number of licensees in a frequency band, already allocated to one or more incumbent users, for which the additional users are allowed to use the spectrum (or part of the spectrum) in accordance with sharing rules included in the rights of use of spectrum granted to the licensees, thereby allowing all the licensees to provide a certain level of QoS.

LICENCE-EXEMPT ACCESS

A largely unregulated approach by which all parties use a band of spectrum as a common and shared resource without need for a licence. Parties typically are subject to regulatory-defined mandatory constraints such as radiated power and to protocols that serve as "politeness rules" for the commons. There is no hierarchy of use and spectrum availability is achieved on a best effort basis.

This report focuses on Licensed Shared Access (LSA) as the more robust and attractive sharing opportunity for MNOs to complement their portfolios of exclusive spectrum. Licence-exempt access, while attractive and beneficial for certain carrier applications and conditions, such as data-offloading, enables only best effort access and performance. It is thus relatively ill-suited for carrier-grade mobile service applications in which reliability and performance are key competitive dimensions.

2.2 TYPES OF LICENSED SHARING

Licensed sharing can be "horizontal" – frequency sharing between two similar types of parties – or "vertical" – frequency sharing between two different types of parties.

SHARING TYPES: HORIZONTAL AND VERTICAL

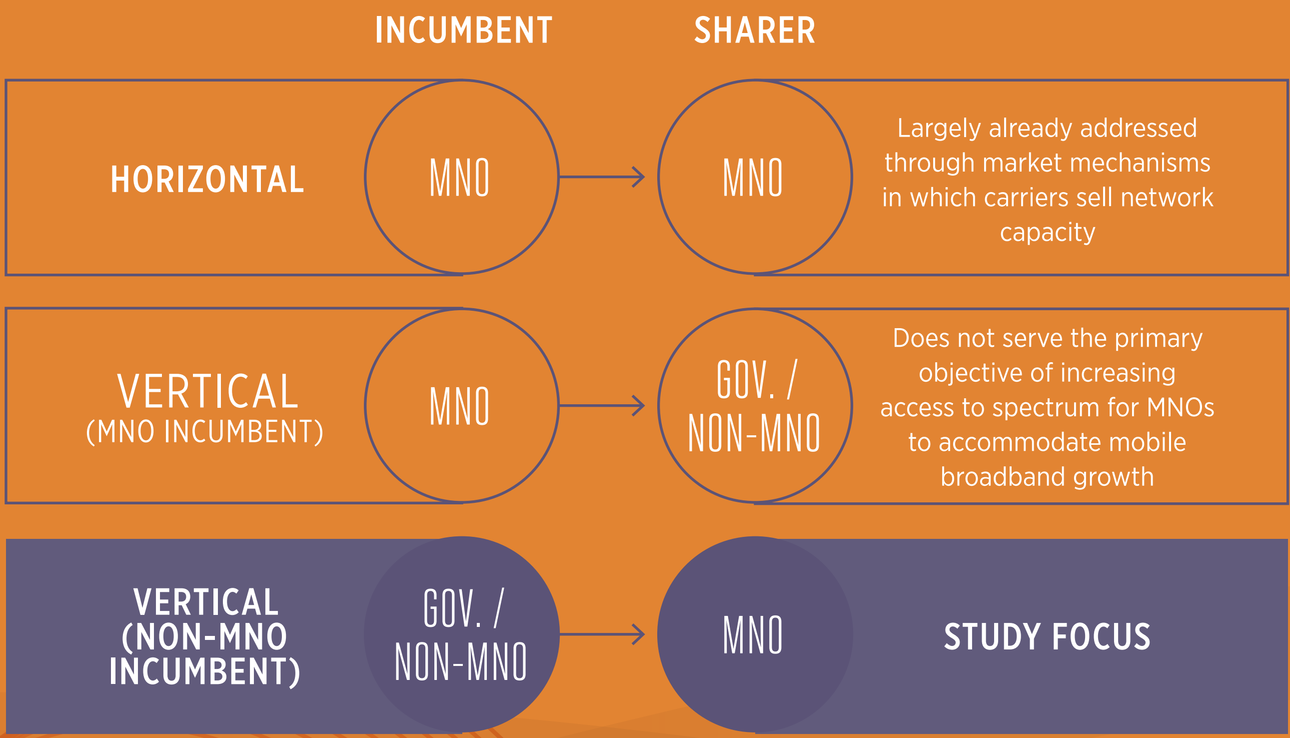


Figure 1

Source: Deloitte analysis

There are two ways MNOs can access additional spectrum through sharing.

HORIZONTAL SHARING

Horizontal sharing involves an MNO with underutilised spectrum providing access for one or more other MNOs to use the underutilised resource on a shared basis. Horizontal sharing opportunities for growing mobile broadband supply are largely already addressed through well-established market mechanisms in which carriers buy and sell network capacity in lieu of spectrum capacity. These network sharing arrangements have proven successful and are rather efficient relative to the costs and complexities of designing, permitting, building and operating parallel mobile network facilities. Edge cases will presumably exist in which MNO to MNO spectrum sharing is relevant but these should be viewed as exceptions relative to network capacity sharing.

VERTICAL SHARING

Vertical sharing is the sharing of spectrum between an MNO and a non-MNO, typically a governmental or non-commercial entity such as the military, public safety organisations, or the science community. Either the MNO or the non-MNO could be the incumbent party that is sharing "vertically" with the other party type sharer.

- Vertical sharing opportunities in which MNOs share spectrum with non-MNOs are essentially counter to the objective of improving spectrum availability for addressing the mobile spectrum supply shortage – they reduce the amount of available spectrum in the hands of MNOs. Theoretically, one MNO sharing spectrum with a non-MNO could free up exclusive spectrum elsewhere for another MNO's use, but this rather complex reassignment of the spectrum map is better considered as a longer term opportunity once spectrum sharing is proven viable. Regardless, MNOs are largely considered to be efficient in spectrum use relative to other, largely governmental, users, and thus represent a less attractive opportunity to provide spectrum supply through sharing.
- Vertical sharing opportunities in which non-MNOs share spectrum with MNOs present the greatest potential to increase mobile spectrum supply. They are receiving significant attention by regulators as potentially attractive means to close the gap on anticipated mobile spectrum shortfalls. There are numerous examples of non-MNOs significantly under-utilising their allotted spectrum. Sharing this underutilised spectrum, with an approach that is properly constructed and executed, may create the opportunity to alleviate the mobile spectrum shortage, improve spectrum efficiencies and generate greater economic benefit while minimising impact to the services and societal benefits provided by the incumbents.

This study focuses on vertical sharing opportunities, and more specifically vertical sharing between a non-MNO incumbent and an MNO sharer.

2.3 SHARING USER CLASSES

For vertical sharing to be discussed, it is necessary to organise and describe the sharing parties within "user classes". These classes are a means to describe spectrum users who are subject to a particular set of sharing conditions and enjoy certain rights of protection against harmful interference from other users. For the purpose of this paper the terms "Incumbent" and "LSA licensee" are used to describe sharing user classes:

INCUMBENT USER

The incumbent to which the spectrum band was originally granted and that agrees to share the frequencies with other access seekers (LSA licensees).

LSA LICENSEES

Additional users that are allowed to use the spectrum (or part of the spectrum) in accordance with sharing rules included in the rights of use of spectrum granted to the licensees, thereby allowing all the licensees to provide a certain level of QoS.

In the case of non-MNO incumbents vertically sharing with MNOs, the non-MNOs are classified as incumbents, the MNOs as access seekers.

SHARING USER CLASSES: INCUMBENT, LSA LICENSEES

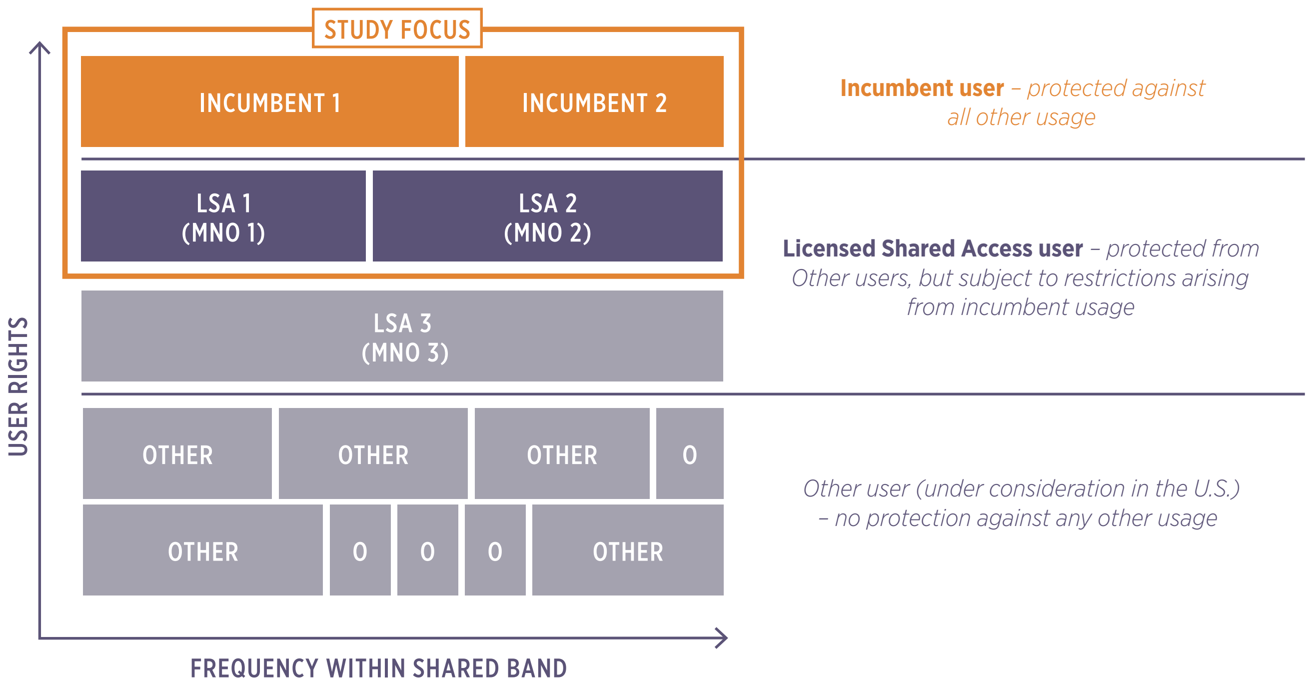


Figure 2

Source: Real Wireless

Multiple MNOs as LSA licensees within a given frequency band may eventually become part of the sharing landscape but this would add significant complexity in terms of the multi-party interplay in negotiated terms, technologies, and operations. This study focuses on the interplay between a single incumbent and MNO, which is the most probable and feasible initial step toward sharing. These multi-player sharing arrangements can be more realistically assessed and constructed once the two-player sharing concept becomes proven as commercially viable.

3

A framework for evaluating vertical spectrum sharing

This section defines a framework for the development and analysis of spectrum sharing scenarios. It describes the sharing ecosystem, sharing approaches, and key terms and considerations for the mobile industry and regulators. It also describes how MNO-specific sharing scenarios can be constructed and provides an overview of current and contemplated international mobile bands that could be assigned for sharing.

3.1 THE PARTIES INVOLVED

There are four key parties to spectrum sharing for MNO use: the incumbent non-MNO spectrum users, the regulatory bodies and policy makers that oversee and influence spectrum sharing approaches and outcomes, the MNOs and the surrounding mobile ecosystem, and the mobile end users. Each party has an important role to play in making spectrum sharing a successful reality for the industry:

- **The incumbent:** provides spectrum to be shared with the mobile industry and MNOs, and abides by sharing commitments.
- **The MNOs and the mobile ecosystem:** purchase spectrum sharing licences, provide infrastructure, abide by sharing terms, and effectively use the spectrum.
- **The regulator:** ensures adequate spectrum for all parties and encourages mobile competition.
- **The mobile industry customers:** continues to be a savvy mobile purchaser and rewards MNOs that provide the best offering.

As a necessary condition for sharing success, each of these constituent groups must view sharing as a net-positive outcome for their interests, in essence weighing the expected and real benefits against the anticipated and real costs and risks. As such it is valuable to explore each constituency in turn to understand their motivations and the underlying costs and risks that must be managed if sharing is to become a reality.

3.1.1 THE INCUMBENT

It is the incumbent's role to provide spectrum to be shared with the MNOs and to abide by the sharing commitments. By entering into a sharing agreement, an incumbent has several sources of potential benefit:

- Increased funding through proceeds from spectrum licensing auctions and/or fees.
- Avoided capital expenditures as costs become shared with MNOs.
- Reduced operating costs and/or enhanced services via offerings rendered by the sharing MNOs.
- Potential to upgrade technology and capabilities if sharing necessitates more advanced infrastructure or devices.

However, sharing also has the potential to bring significant costs and risks to the incumbent:

- Smaller geographic spectrum footprint and/or restrictions on day or time of use.
- Reduced freedom of choice and flexibility as to how the spectrum can be used.
- Increased operational costs and complexity to coordinate and manage use within a shared spectrum environment.
- Potential to be locked into legacy technology or added complexity to introduce new technology.
- Risk of degradation of incumbent services and capabilities if sharing arrangements do not conform to the regulated or negotiated performance levels.

To enable sharing, incumbents will be transitioning from an exclusively licensed spectrum environment to a shared environment, and thus inherently losing flexibility and freedoms of spectrum use. Given that there are considerable real and potential costs, complexities and risks associated with making this transition, incumbents must perceive the move to sharing as a net positive outcome for their organisation or they will be reluctant or even unwilling participants in the process. Incentives to assist incumbents in realising the benefits outlined above can take a variety of forms. One option proposed in the US by the President's Council of Advisors on Science and Technology (PCAST) is a "Spectrum Currency" that rewards agencies "that move quickly to promote more effective spectrum use by making some of their spectrum available for sharing with other Federal and non-Federal users."[1] Similarly in Europe, forms of Administered Incentive Pricing (AIP) provide a means to reward incumbents for making more efficient use of spectrum they hold by making available unused spectrum to commercial providers.

1. President's Council of Advisors on Science and Technology, "Realizing the Full Potential of Government Held Spectrum to Spur Economic Growth," p. ix, July 2012

3.1.2 THE REGULATOR

With respect to spectrum oversight and management, regulators around the world are generally charged with ensuring adequate and equitable spectrum supply for the commercial marketplace and for societal use at-large, e.g. defence and public safety. In the case of mobile services, regulators also often use spectrum management as a means to promote mobile competition. Spectrum sharing for MNOs could be a mechanism to help accomplish both fundamental goals, with potential to deliver the following benefits:

- Reduce spectrum shortages for the mobile industry and optimise spectrum efficiencies by meeting mobile spectrum needs sooner than might otherwise be achieved with exclusive spectrum, and expanding the total amount of available spectrum for mobile use.
- Encourage mobile service competition via mechanisms such as improved access to spectrum and "balancing" spectrum amongst carriers.
- Generate incremental government revenues through two means:
  - New monetisation of spectrum assets, for example via sharing access fees.
  - Growth in GDP, fuelled by growth of the mobile industry, of the mobile ecosystem and of industries that are increasingly dependent on mobile broadband services to drive business performance.

Regulators will also be cognizant of the risks they are undertaking as they pursue sharing solutions to bring additional spectrum to market:

- Potential for negative impact to the economy or mobile industry if spectrum sharing is unsuccessful or obtains only partial success.
- Potential for negative impact to incumbent services and capabilities – including critical public service functions such as defence and public safety – if spectrum sharing disrupts or interferes with incumbent operations.

Mobile operators and regulators agree that the mobile industry need for additional spectrum is real and time-sensitive. Regulators are under pressure to make spectrum timely available for mobile operations and ultimately will need to take calculated and carefully planned actions to mitigate the associated risks.

3.1.3 THE MNOS AND THE MOBILE ECOSYSTEM

MNO roles in spectrum sharing are to procure the sharing licences, provide the sharing infrastructure, abide by sharing terms, and effectively use the spectrum. By entering into sharing agreements, MNOs have the opportunity to realise several key benefits for meeting future demand needs:

- Enhanced capacity by adding spectrum in high density areas.
- Enriched user experience or quality of service (QoS).
- Increased coverage for rural or in-building service with improved access to lower frequency ranges, or by deploying small cells for small remote communities.
- Through band harmonisation, increased roaming support or access to improved or lower cost devices produced for regions where the band is widely available on an exclusive licensed basis.
- Improved time to market with these performance enhancements if sharing accelerates access to spectrum in lieu of full spectrum clearing, or as an interim step toward full spectrum clearing, for exclusive licensing.

However, spectrum sharing also creates significant costs and risks for MNOs:

- Fees and regulatory commitments for licensed sharing.
- Reliance on spectrum that is inherently less dependable than exclusively owned spectrum.
- Increased operational and technical complexity, and the associated capital and operational costs, associated with sharing operations.
- Potential device impact: Increased unit cost, reduced battery life or increased latency due to the addition of sharing frequency bands and inclusion of hardware and software for frequency sharing management.
- Potential limitations on the ability to differentiate: Shared spectrum, with its inherent restrictions, could limit how an MNO applies the spectrum to differentiate its services in the marketplace.

Ultimately, the greatest challenge for an MNO to achieve the benefits is any uncertainty associated with use of the shared band. Predictability of access to the spectrum will enable an MNO to more accurately value the spectrum for specific applications and circumstances, thereby reducing the MNO's investment risk and increasing the spectrum business case value. Mobile markets are inherently competitive and place high demands on MNO network performance. Uncertain access to an underlying capability – in this case shared spectrum – that directly affects product performance will motivate MNOs to devalue or avoid use of that asset. At best, an MNO might consider an uncertain asset as a means to differentiate on an unscheduled basis, e.g. offer "enhanced" QoS to serve customers when the spectrum can be used, and revert to "standard" QoS otherwise. MNOs must weigh these benefits, costs and risks when determining if sharing is worth the investment to realise the theoretical benefits.

3.1.4 THE MOBILE INDUSTRY CUSTOMERS

While not directly involved in spectrum sharing agreements, mobile customers have an important role to play in making spectrum sharing a reality by being savvy purchasers that reward the MNOs which provide the best offering. If sharing is implemented, customers have a reasonable expectation to receive a quality mobile experience, such as through improved coverage, better data speeds, or enhanced quality of service, at a fair price. MNOs that choose to include shared spectrum within their spectrum portfolio will ultimately be rewarded or penalised by customers exercising their right of carrier choice.

3.1.5 THE PARTIES AS A SHARING ECOSYSTEM

The roles and motivations of the four parties are summarised below in Figure 3.

ROLES, MOTIVATIONS AND COSTS FOR THE KEY SHARING PARTIES

	INCUMBENTS	REGULATORS	MNOS / MOBILE ECOSYSTEM	MOBILE INDUSTRY CUSTOMERS
ROLE	*Provide spectrum to be shared with MNOs, and abide by sharing commitments*	*Ensure adequate spectrum for all parties and encourage mobile competition*	*Purchase spectrum sharing licenses, provide infrastructure, abide by sharing terms*	*Be savvy mobile purchasers, reward MNOs that provide best offering*
MOTIVATION	*Compensation for providing access – revenue, reduces costs, services in-kind*	*Revenue through licensing and healthier industry, meet spectrum needs sooner*	*Additional financially viable spectrum to meet future demand needs*	*Improved mobile experience (speed, QoS, coverage) at an attractive price*
COSTS / RISKS	*Reduces freedom to use spectrum (e.g. time, geography, future needs)*	*Risk of negative impact to economy, incumbents and mobile industry if sharing fails*	*Reliance on non-exclusive asset, uncertainty in terms, infrastructure and operations investment*	*Reduced service performance from the selected carrier, switching costs*

Figure 3

Source: Deloitte analysis

All four of these parties, the incumbents, regulators, MNOs, and mobile industry customers, are crucial players in the spectrum sharing ecosystem. If any party is not properly incentivised to support spectrum sharing, with benefits outweighing the costs and risks, the opportunity will remain purely theoretical or at best play a secondary role in addressing the mobile spectrum supply shortfall and in optimising spectrum efficiency and availability for the mobile industry.

3.2 STATIC VS. DYNAMIC SHARING OPPORTUNITIES

The feasibility, level of complexity, and certainty of use for an MNO to share spectrum with an incumbent will be significantly impacted by the dynamic nature of the sharing arrangement. Frequency block size and the number of MNOs sharing within a given range will be major determinants of the sharing value and approach. Assuming those are determined at the outset, the most significant dynamics will likely be measured across two dimensions – time and geography – as shown in Figure 4.

DYNAMIC SPECTRUM SHARING

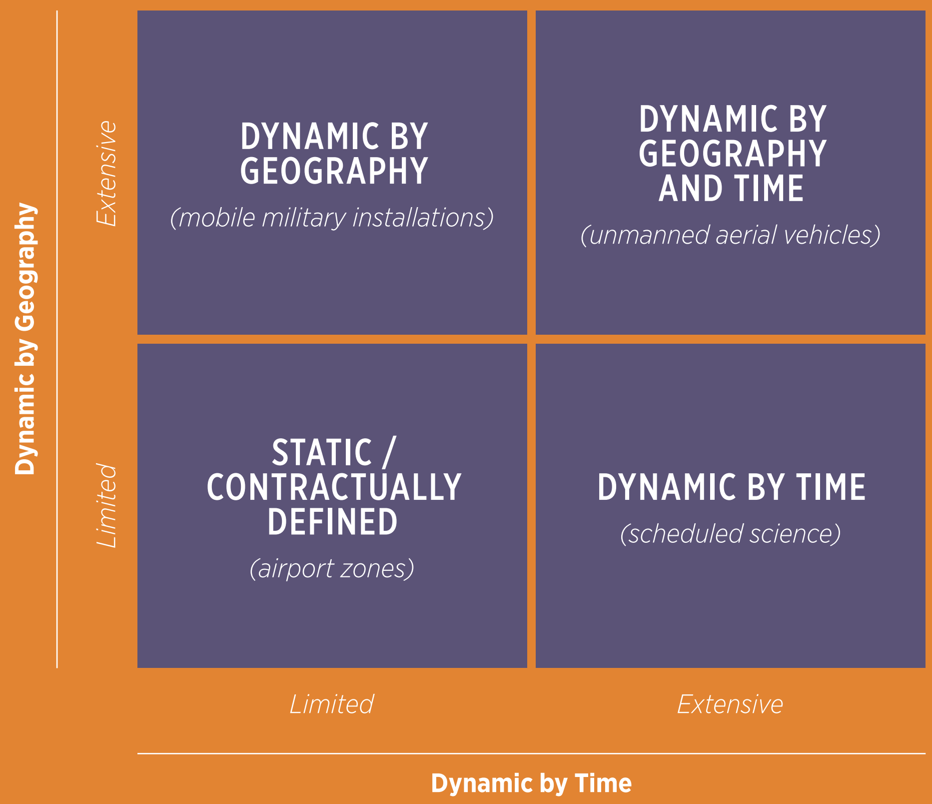


Figure 4

Source: Deloitte analysis

A relatively static sharing arrangement, such as one with exclusion zones around a commercial or military airport, enables an MNO to invest in, design, build and operate a network with a multi-year degree of certainty as to the spectrum-enabled performance of the operation. Conversely, as the dynamic natures of the arrangement increases, either in time or geography, the MNO's ability to effectively value and use the spectrum decreases while operational complexity and costs to manage the arrangement increase. A highly dynamic arrangement, such as one in which incumbent use of unmanned aerial vehicles dictates variability in spectrum access across both time and geographic dimensions, will present unique and challenging technological and operational challenges for making the arrangement work.

The inherent variability in applications and conditions between the incumbent and MNO will make each sharing arrangement unique. However, a reasonable rule of thumb is that the greater the dynamic nature of the arrangement, the greater the required sophistication of the technological and operational solution. Various dynamic sharing solutions have been proposed or are undergoing development and testing, e.g. sharing databases and sensing solutions, which will ultimately have to be integrated into joint incumbent-MNO negotiated solutions that enable dynamic sharing cooperation. These solutions will need to address a variety of operational, technological, governance and cost considerations, such as:

HOW DYNAMIC IS THE SHARING?

Will the dynamics be defined and scheduled contractually for the term of the agreement, managed via periodic centralised updates, or managed real-time and distributed? How frequent are the updates and how far in advance can they be determined? How are they derived, certified, deployed, accessed and maintained?

WHAT SOLUTION WILL BE NECESSARY TO MANAGE THE DYNAMICS?

Can the sharing be managed through a centralised database solution with device querying via the network, or a distributed intelligence solution in which devices autonomously or semi-autonomously "sense" the network conditions and adapt accordingly to minimise interference? How is this solution selected, designed, developed, tested, certified, deployed, and maintained? What are the implications in terms of network performance, device performance, cost, reliability, and the customer experience?

WHAT GOVERNANCE METHODS WILL OVERSEE THE SHARING OPERATIONS?

How will communications, decision-making, funding, certification, performance reporting, compliance management and escalation be handled between the incumbent and MNO?

3.3 KEY SHARING TERMS AND CONSIDERATIONS

When evaluating sharing opportunities, MNOs will need to consider the contractual terms that can be negotiated with the incumbents, and, as part of these terms, the conditions that drive value, costs and risks. These elements are discussed below.

3.3.1 DEVELOPMENT OF CONTRACTUAL TERMS

Sharing will require the incumbent and MNO to reach negotiated agreement on a variety of unique terms and conditions. Some conditions, such as geographic restrictions or dynamics, will generally arise directly from the characteristics of the incumbent use profile and create little latitude for tailoring. Others conditions such as frequency block size and contract term are more likely to be negotiable.

It will be critical for the MNO to evaluate each term in the agreement from two perspectives:

- The relationship between term value changes and business case results to what extent a linear change in term value results in a linear, non-linear or step-function change in business case value.
- The relationship between term certainty and business case risk to what extent lack of specificity or clarity in a term creates exposure and risk for an MNO to proceed with the investment.

Both factors are critically important from a valuation perspective for MNOs to successfully and materially pursue sharing. The generally high fixed cost and long term investment nature of the business means that a change in a critical parameter has the potential to turn the value from significant to low or zero for a given MNO. For example, if the shared spectrum is unavailable for 50% of the time, it is plausible, even likely, that this will reduce the spectrum value to the MNO by considerably more than 50%. If availability is during off-peak, when the spectrum has no incremental value within the MNO spectrum portfolio, the value can potentially be reduced to zero. These effects, and their potential impact on shared spectrum economic value, are further discussed in Section 4.2.2.

This point is equally valid for incumbents and indicates the importance of direct incumbent-MNO negotiations that increase the probability of arriving at highly tailored terms and conditions which maximise value for both parties. Further, the need for precisely defined sharing relationships points to the importance of negotiations between the incumbent user, the new user(s) and the regulator being conducted on a voluntary basis to allow maximum flexibility and innovation in finding solutions that maximize potential for the shared use. Mandated or prescribed approaches will necessarily be restrictive in nature and reduce the probability of a successful negotiated outcome.

From an MNO's perspective, sharing terms can be loosely grouped into three categories: value driving, cost driving, and risk and uncertainty driving. Figure 5 illustrates this framework for several of the more common terms likely in a sharing agreement.

TERMS AND CONDITIONS IN A POTENTIAL SHARING AGREEMENT

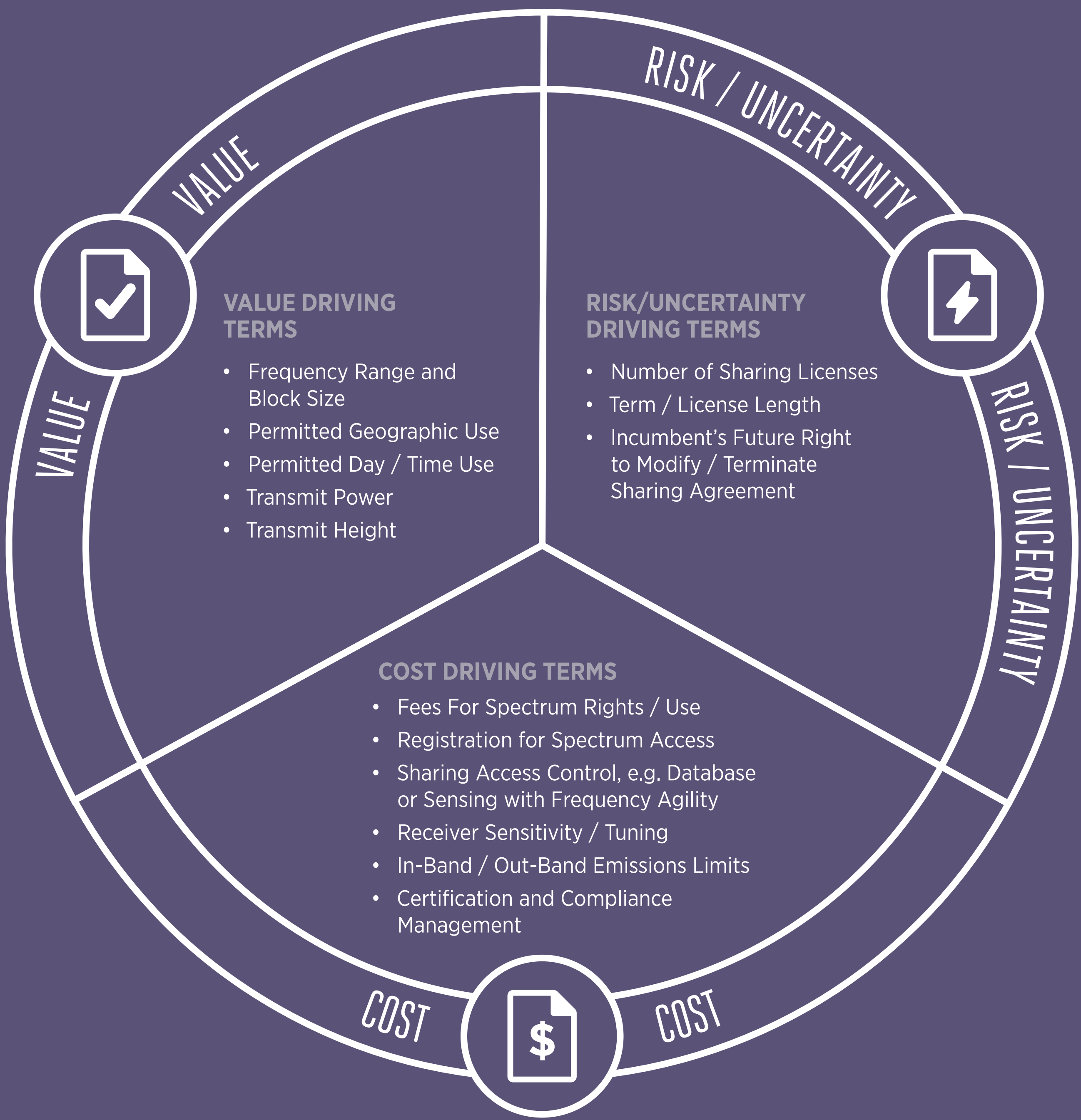


Figure 5

Source: Deloitte analysis

Each category and the associated terms are discussed below.

3.3.2 CONDITIONS THAT DRIVE VALUE

Value terms are the primary benefit drivers for MNOs. These terms largely determine how much and to what extent the spectrum can be used under the agreement, and thus ultimately bound how much value an MNO can extract from shared access to that spectrum.

FREQUENCY RANGE AND BLOCK SIZE:

- Lower frequencies, roughly less than 2GHz, are generally considered more valuable than higher frequencies due to their improved propagation characteristics.
- Larger block sizes – 20MHz and above – are more attractive for maximising LTE efficiency. Larger block sizes may also improve the probability that the shared spectrum will provide meaningful "critical mass" of supply under simultaneous sharing conditions.
- Band harmonisation, in which spectrum sharing bands are aligned across regions and/or aligned with exclusively licensed spectrum bands to achieve device economies of scale, may be a necessary condition for MNOs to pursue shared spectrum. This is especially relevant in the EU, in which scale benefits would largely be lost without a significant portion of the EU aligning to a common sharing band. Incorporating an additional band in a device can cost upwards of $10M in R&D and add several dollars to the unit cost of the device[2], making the regional use of sharing relatively infeasible if sharing bands are fragmented across the region.

PERMITTED GEOGRAPHIC USE

Excepting cases in which low frequency shared spectrum might improve coverage for select MNOs, shared spectrum will generally have greater utility in areas of heavy network loading and high density populations. Geographic exclusion zones that prevent use in these areas will correspondingly diminish the value of the spectrum. For example, the US is considering sharing in the 3.5GHz range; one of the incumbent uses is Naval radar. The FCC, using a conservative method, estimates that an average shoreline exclusion zone on the East, Gulf, and West coasts would exclude 60% of the US population, severely limiting the potential spectrum value for US urban coverage.[3] Furthermore, as previously discussed, dynamic geographic coverage that creates moving exclusion zones will further impair the spectrum value by creating uncertainty in use and increasing complexity and cost of the sharing arrangement. If dynamic geographic zones are contemplated, avoiding unscheduled or short notice dynamism, will improve MNOs' ability to effectively utilise, and therefore value, the shared spectrum.

PERMITTED TIME OF USE

Considerations for valuing time of day use are similar to those for valuing geographic use – value will be driven by spectrum that can be applied when needed, with certainty. Time of day restrictions that limit use during network peak load conditions or are dynamic will impair the value of the spectrum to the MNO.

An example of sharing with an incumbent public safety organisation illustrates the point: if an MNO is allowed to share a public safety spectrum band except during a public safety emergency, this band cannot be counted on to support peak loading precisely when needed, for public safety events typically generate high traffic conditions on mobile networks. Many such events could fall under a public safety definition, such as fires, earthquakes, accidents, weather events, terrorism, riots, public works outages and the like, and lead to a variety of operational management questions such as how the events' beginning and end time are defined, what network territory is affected, how MNOs are notified, and what MNO response time is required to avoid public safety impacts.

TRANSMIT POWER AND TRANSMITTER HEIGHT

If transmit power or transmitter height is limited so as to reduce potential interference with incumbent applications, the value of the spectrum to the MNO may be hindered, either through increased network investment in a denser grid or reduced coverage or performance with the shared spectrum.

2. Deloitte interview with a leading mobile device provider, August 2013
3. "Enabling Innovative Small Cell Use In 3.5 GHZ Band NPRM & Order", FCC December 2012

3.3.3 CONDITIONS THAT DRIVE COSTS

Cost driving terms determine the MNO investment and operational cost structure for implementation and use of the sharing agreement. Examples of such terms are provided below.

FEES FOR SPECTRUM RIGHTS AND USE

Licence fees for purchasing the shared access rights are the most immediate and direct investments for MNOs. Fee structures may take different forms based on the particular regulatory environment for the country or region. A spectrum auction process has become increasingly prevalent as the mechanism to award spectrum access rights at market prices; it is reasonable to expect that shared spectrum access rights will be awarded in a similar fashion, albeit with the added dynamic that auction proceeds will likely generate some type of incumbent incentive for providing the shared access. Regulators around the world are in the early stages of identifying spectrum sharing opportunities and little has been defined to-date in terms of award methods and fee structures for shared access.

REGISTRATION FOR SPECTRUM ACCESS

If shared spectrum access is managed on a case by case basis between a single incumbent and an MNO, access registration and certification may be relatively straightforward. These can be handled as a direct negotiation and operational coordination between the two parties. However, if governments open multiple spectrum bands with multiple incumbents and applications spanning multiple regions, it may be necessary for a central (at federal level in the US or national level in the EU) registry that acts as a clearinghouse for access registration. In the US, PCAST has recommended this type of approach for shared access: "The Secretary of Commerce working through the National Telecommunications and Information Administration (NTIA) and the FCC, should authorise and implement, directly or through commercial providers, a Federal Spectrum Access System (SAS) to serve as an information and control clearinghouse for the band-by-band registrations and conditions of use that will apply to all users with access to each shared Federal band under its jurisdiction."[4] Administration of and adherence to these types of registration requirements will be cost factors for MNOs.

SHARING ACCESS CONTROL

The technology and operational processes to implement sharing access control will be complexity and cost factors for the MNOs. As a rule of thumb, the greater the dynamic nature of sharing, the greater the complexity and cost for access control. Two approaches for managing shared access control are most commonly cited, although other methods may surface over time:

- Database spectrum access management.
- Spectrum sensing.

4. President's Council of Advisors on Science and Technology, "Realizing the Full Potential of Government-Held Spectrum to Spur Economic Growth," pg. xi, July 2012

DATABASE SPECTRUM ACCESS MANAGEMENT

This is a solution that allows for sharing of spectrum by tracking time and/or geographic use of spectrum by the incumbent in a centralised database, and allowing or disallowing MNO use accordingly. MNO devices would be required to query the database in advance of operation to obtain the spectrum access rights. An example of this database approach is already under development in the US, in which the FCC has adopted rules permitting unlicensed use within television broadcast "white space" spectrum when that spectrum is not used by licensed broadcasters.

For sharing that involves an incumbent and an MNO (no other participants), the need for database-driven spectrum access management and the level of sophistication or complexity of that approach is dependent on each specific sharing situation. A multi-year static sharing case, such as an exclusion zone for an airport, could be handled via contract documentation with little or no need for an active database capability, while a highly dynamic sharing case, such as a real-time change in the geographic or time of day exclusion zone for a remotely piloted vehicle, requires a much more complex, real-time database capability. Furthermore, the viability of these database-managed sharing situations should be considered in the broader operational context of both the incumbent and the MNO, considering factors such as how the dynamic database inputs are updated, redundancy and fail-safe protections, communication and escalation protocols between the incumbent and MNO, and the end-to-end technological and network management impact for dynamic, database-driven network operations.

SPECTRUM SENSING

Spectrum sensing is a means by which a device detects whether a radio is already present at a certain frequency, secures an open frequency, and then switches to that open frequency.

The theoretical advantage to spectrum sensing is that the device can autonomously obtain access to a spectrum frequency without causing harmful interference to incumbent applications. However, sensing has inherent performance limitations or flaws that likely make it infeasible in the near to mid-term, for three primary reasons:

1. If incumbent signals are weak the sensing system may not detect active nodes – referred to as a "hidden node" problem.
2. If a node is temporarily inactive, it will be deemed open even if incumbent use is imminent.
3. It may raise issues of confidentiality regarding the spectrum usage by the incumbents.

Furthermore, embedding these sensing capabilities into devices will have cost, battery life, and potential latency / response time implications that will need to be factored into the solution economics.

Sharing access control – both database and sensing driven – may also affect device performance and cost. Frequent device queries to a centralised database, or frequent device sensing for interference, could have battery life implications, with one device provider estimating that battery life could be reduced as much as 10-20%.[5] These querying and sensing actions also have the potential to create device latency and responsiveness issues.

RECEIVER SENSITIVITY AND TUNING, AND IN-BAND / OUT-OF-BAND EMISSION LIMITS

Sharing schemes will need to address both receiver and transmitter performance characteristics to ensure that interference remains below negotiated limits for both the incumbent and MNO. The performance and in-band / out-of-band sensitivity limits of adjacent band applications and devices may also impact the solution design. The specific sharing applications and frequency bands under consideration will dictate the required solutions and associated costs – which could be significant, for example, if legacy incumbent systems are relatively sensitive and require advanced solutions on the part of the MNO.

CERTIFICATION AND COMPLIANCE MANAGEMENT

A sharing agreement will require certification of network performance, coordinated sharing operations, and each device type prior to commencement of sharing operations. This joint certification will require an underlying coordinated process and management system to ensure compliance on behalf of both the MNO and the incumbent, and will be another investment and operational cost factor for the MNO.

5. Deloitte interview with international device manufacturer, August 2013

3.3.4 CONDITIONS THAT DRIVE RISK AND UNCERTAINTY

Risk and uncertainty driving terms are more likely to be determined by the regulator's or incumbent's preferred intent for a sharing approach versus driven by inherent application or technology constraints, and thus may be more negotiable. All of these terms are particularly important for managing investment risk and uncertainty for the sharing arrangement.

NUMBER OF SHARING LICENCES

For a given allocated frequency range for sharing between an incumbent and multiple MNOs, more sharing licences reduces the size of the spectrum block available to any single MNO and increases the risk of interference from adjacent users. Uncertainty on this dimension will largely negate the projected spectrum value for the MNO.

TERM AND LICENCE LENGTH

Longer licence lengths, on the order of 15 to 20 years, will generally be necessary for MNOs to apply business case time horizons that justify the substantial network and platform capital expenditures that enable sharing. Shorter lengths will restrict investment horizons and thus MNO potential for realising the benefits.

- The optimal sharing contract length should mimic the licence length of exclusive spectrum, i.e., a minimum of 20 years.
- Under a sharing agreement of less than 15 years, most MNOs may be unwilling to invest as this is generally viewed as an equipment depreciation threshold.
- Smaller, spectrum-constrained MNOs may choose to invest in contracts as short as 8 years to improve their position, as 8 years is typically the shortest depreciation cycle for mobile network components.

INCUMBENT'S FUTURE RIGHT TO MODIFY / TERMINATE SHARING AGREEMENT

Similar to term length, the incumbent's ability to renegotiate or terminate the agreement prior to the end of the contract term would likely place the MNO in a position of viewing the earliest possible renegotiation date as the end date for investment payback, again leading to a restricted investment horizon.

3.4 THE ROLE OF REGULATION

The primary regulatory objective for sharing is to address the expected mobile broadband capacity shortfall driven by rapid growth in data demand. Pursuing this objective with spectrum sharing also creates a parallel objective of ensuring existing licensed incumbents are equitably treated and that incumbent services subjected to sharing are adequately protected from MNO interference or interruption.

As previously discussed, spectrum sharing will take a variety of forms and will be highly dependent on the specifics of each sharing situation between an incumbent and the MNO. Because of this inherent need for customised solutions, regulators may want to be wary of becoming overly prescriptive in the sharing regulatory framework. Regulator-defined sharing terms, intended to apply across the many sharing circumstances, would have to be so broad as to materially reduce or largely neutralise the value of the spectrum to the MNO. Value will be maximised by incumbents and MNOs voluntarily crafting customised terms that enable both parties to maximise utility of the shared band.

While regulators should aim to provide a light regulatory touch to sharing solution definition and thereby leave the bulk of sharing negotiations to the incumbents and the MNOs, they nevertheless can play a variety of important roles in facilitating the sharing process:

- Identifying sharing opportunities.
- Facilitating band harmonisation and standardisation within and across countries.
- Converting or upgrading the licences of existing incumbent users to allow use of a band for telecommunications services on a shared basis.
- Structuring an incentive system to reward incumbent participation.
- Enabling MNOs to have market-based opportunities to purchase sharing licences.
- Guiding the negotiation and implementation processes and managing spectrum registration on a country or regional basis.

Regulators may also play critical roles in accelerating MNO access to spectrum in other ways. For example, in cases where incumbents will eventually vacate frequency bands but on a long time scale, regulators could accelerate MNO access to the spectrum by applying sharing as an interim step toward eventual exclusive licensing. Alternatively, regulators could accelerate the sharing process by authorising incumbents to sub-license spectrum to MNOs, thereby giving incumbents greater latitude to manage the sharing opportunity. Regulators may therefore also consider guidelines or approaches to reduce the possibility that customized sharing solutions hamper harmonization.

Regulators are also generally charged with promoting MNO competition. Regulatory application of sharing as a means to encourage competition should be viewed as a secondary objective and only to the extent that it does not interfere with the primary objectives. Shared spectrum will have little value in promoting new entrants or levelling the playing field:

PROMOTING NEW ENTRANTS

Shared spectrum will have little effect on increasing the number of MNOs given its inherent restrictions. A new entrant would be challenged to assemble a shared spectrum portfolio that would be competitively viable and robust. Furthermore, many markets effectively operate with at least four competitors, and the high fixed-cost nature of the business and related economies of scale make it unlikely that additional profitable competition is sustainable.

LEVELLING THE PLAYING FIELD

Competition could potentially be promoted via regulatory policies that attempt to level the playing field across the existing set of MNOs. This approach has ample precedent by placing asymmetric restrictions and conditions on MNOs to enable perceived disadvantaged MNOs to obtain preferential access to and use of shared spectrum. However, regulators will need to be cognizant of the potential risk of market distortion that could arise from applying different conditions, e.g. no coverage obligations for shared versus existing exclusive spectrum.

3.5 TIMING

Because of the many unknowns regarding sharing, operators largely remain focussed on the opportunities that exist today with exclusively licensed spectrum, and they view shared spectrum as a potential longer term but unproven complementary addition to their spectrum portfolios. Some expect commercial solutions to become available in the latter half of the coming decade, and the degree to which shared spectrum is deployed in the following years will be highly dependent on the degree of success in addressing the challenges noted in this report. Given the challenges it is likely that sharing will not be commonplace for a decade or longer, and the urgency at which sharing issues are addressed is likely to hinge on the degree to which exclusively licensed spectrum becomes available. If regulators are unable to ensure adequate supply of exclusively licensed spectrum to meet the high growth in mobile broadband demand, sharing may be viewed as an unavoidable if less palatable alternative to shore up network capacity and performance in high density areas.

3.6 SCENARIO CHARACTERISTICS

Given the considerations above, to analyse the consequences of vertical spectrum sharing on the MNO, a spectrum sharing scenario is defined as a specific combination of the following major elements:

FREQUENCY RANGE AND BANDWIDTH
Lower frequencies, harmonised bands and larger bands will tend to have greater business value and deliver different MNO benefits than higher frequency, unharmonised or narrow bands.

INCUMBENTS AND APPLICATIONS
Incumbents within the sharing frequencies will have specific applications and usage behaviours that drive sharing requirements, e.g. geographic or time-based service restrictions, interference limits, and sharing management methods.

REGULATORY LANDSCAPE
Regulatory oversight by region or country can range from high level regulatory guidance and facilitation to detailed prescriptive directives.

MNO APPLICATIONS AND BENEFITS
Each MNO has one or more specific objectives for sharing spectrum to address a perceived limitation in its existing spectrum portfolio, with a view to achieving benefits such as coverage, capacity, user experience, or harmonisation.

All of these elements are material for determining the benefits and costs of a spectrum sharing scenario, hence any attempt to determine the value of spectrum sharing without considering all of these dimensions will be inherently limited.

Sharing scenarios based on these characteristics can be very diverse. Figure 6 illustrates how one particular sharing scenario could develop based on the combination of these factors.

The economic impact of sharing are discussed in the next section, while Section 5 applies these analyses to two specific case studies in the US and EU.

TYPICAL SHARING SCENARIO CHARACTERISTICS

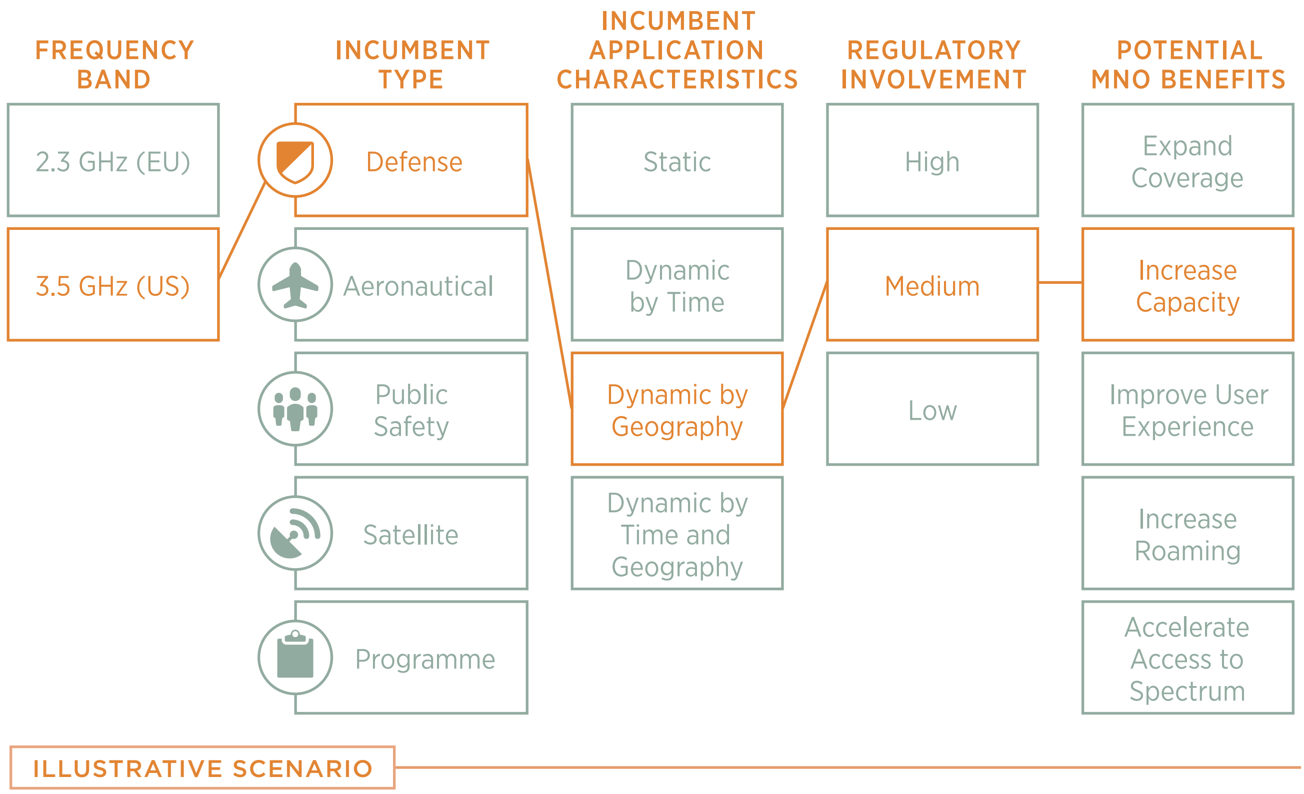


Figure 6
Source: Deloitte and Real Wireless analysis

3.7 INTERNATIONAL FREQUENCY BANDS

Deploying mobile services in shared spectrum is subject to the same economic and commercial constraints as with exclusive spectrum. In particular, this means that any shared spectrum must achieve a degree of international harmonisation including the need to be supported in standards, e.g. such as ITU frequency band allocations, and to be sufficiently widely adopted to support a high manufacturing volume necessary to achieve competitive economies of scale in mobile devices.

Table 1 identifies the bands currently available for International Mobile Telecommunications (IMT) use in the ITU Radio Regulations. Where these bands are assigned for mobile use at a national level, this is almost entirely on an exclusive basis, and exclusive assignments should continue to be preferred.

Immediate opportunities for sharing lie in frequency bands which already have an ITU IMT allocation but are not yet nationally assigned for mobile use due to incumbent usage. This condition varies on a country by country basis, even within an ITU region, and notably across countries in the EU.

Regulators and MNOs in a country where an IMT frequency band has not yet been assigned nationally could consider pursuing spectrum sharing as an option to accelerate access to the band in the short term, thus positioning the MNOs for exclusive access to harmonized ITU spectrum in the longer term if the band is eventually vacated by the incumbent.

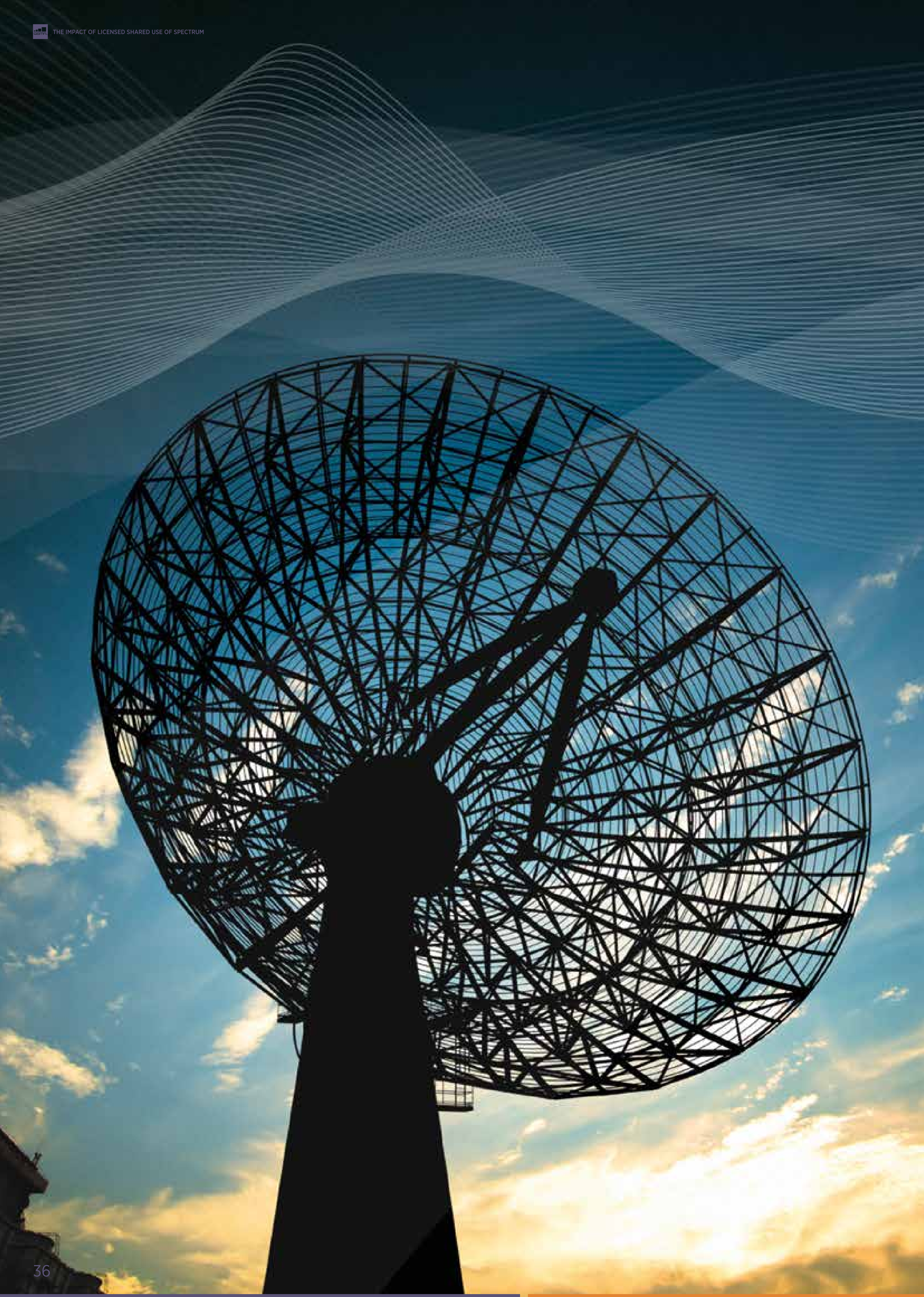
Going forward, additional bands are expected to be allocated for mobile services and identified for IMT use under an agenda item at the forthcoming World Radio Conference, WRC-15. The frequency ranges which have received proposals for study are shown in Table 2.

FREQUENCY BANDS ALLOCATED FOR INTERNATIONAL MOBILE TELECOMMUNICATIONS (IMT) USE, IN MHZ

THE AMERICAS REGION 2	EUROPE, MIDDLE EAST AND AFRICA REGION 1	ASIA AND AUSTRALASIA REGION 3
450 – 470	450 – 470	450 – 470
698 – 960	694 – 790	698 – 790
	790 – 960	
1710 – 1885	1710 – 1885	1710 – 1885
1885 – 2025	1885 – 2025	1885 – 2025
2110 – 2200	2110 – 2200	2110 – 2200
2300 – 2400	2300 – 2400	2300 – 2400
2500 – 2690	2500 – 2690	2500 – 2690
None above 2690	3400 – 3600	3400 – 3600

Table 1

Source: Real Wireless analysis



FREQUENCY RANGES UNDER CONSIDERATION AT ITU'S WRC-15, IN MHZ UNLESS OTHERWISE SPECIFIED

FREQUENCY RANGES

470 – 694	4400 – 4900
1300 – 1400	5350 – 5470
1427 – 1527	5850 – 5925
1452 – 1492	5925 – 6425
1695 – 1700	13.4 – 14GHz
2700 – 2900	18.1 – 18.6GHz
3600 – 3800	27 – 29.5GHz
3800 – 4200	38 – 39.5GHz

Table 2

Source: Real Wireless analysis

While exclusive use to MNOs is to be preferred for these bands, some of these bands will also likely provide an opportunity for mobile operators to gain access sooner and more widely on a shared basis, at least in the near to mid-term, until such time as the spectrum can be cleared for exclusive access.

Only the US and EU are taking initial public steps to consider sharing within selected bands in those respective territories, in parallel with the ITU initiative. In these regions two bands appear the most likely candidates for sharing in the near term:

- In the EU28, the 2.3GHz band is the most likely candidate band, although conditions and timings of the sharing vary greatly by country. The 3.8GHz band has also raised initial attention: in this band, mobile operators would share with satellites operators.
- In the US, the 3.5GHz band is currently being considered for sharing.

Other than these examples, only limited interest in spectrum sharing has been expressed so far by operators and regulators around the world in relation to other possible candidate bands.

These efforts to develop specific sharing opportunities are in the early stages with much yet to be defined. While little interest in spectrum sharing has been identified in other regions around the world, the US and EU developments can serve as useful cases for understanding how sharing may develop in those mature markets, and how it may emerge in other regions. These two cases are discussed in Section 5.

4

A framework for the economic analysis of spectrum sharing

While Section 3 presented a framework for the strategic impacts of spectrum from the industry viewpoint, this section provides a framework for the analysis of the economic impacts of mobile broadband from the point of view of governments and for the evaluation of the incremental economic impacts of spectrum sharing.

4.1 THE ECONOMIC IMPACT OF SPECTRUM FOR MOBILE BROADBAND

Spectrum is a vital asset to any economy and makes a significant contribution to economic activity through its commercial and public uses. A recent study[6] found that in the UK the contribution to GDP of spectrum use (across the whole spectrum band) amounted to £30.2bn in 2011 and to £485.8bn over the next ten years. Similar studies[7] undertaken at the EU level indicated that the economic activity generated as a result of public spectrum usage amounted to €261-269bn in 2013 and could potentially reach €477bn in 2023. In the US, investment in 4G mobile broadband networks[8], resulting from the availability of spectrum for mobile broadband services, are estimated to account for $73-$151 billion in GDP growth and 371,000–771,000 new jobs.

As the economic value of spectrum relates to the application for which spectrum is an essential input rather than to the spectrum per se, a number of studies[9] have consistently indicated that the great majority of spectrum value is delivered by public mobile networks, amounting for example to approximately 60% of the total value of the spectrum in the UK in 2011.

The economic value generated by mobile services is evolving rapidly as basic mobile services have been replaced by a host of high value services provided through mobile broadband. In the past, the great majority of the value was generated by voice services and SMS. Since mobile data has become widely available, the combination of mobile data services running on 3G and increasingly 4G networks using smartphones and tablets has greatly expanded the functionality of mobile services. As such, mobile broadband increasingly drives the economic contribution of the mobile industry. For example, a recent Deloitte/GSMA study[10], supported by Cisco data, has found that a doubling of mobile data use led to an increase in the GDP per capita growth rate of 0.5 percentage points in 14 countries in the years 2005 to 2010.

Figure 7 summarises the socio-economic impact of mobile broadband throughout the mobile ecosystem and the economy. More details on this are provided in Appendix A.

6. Analysys Mason (2012): "Impact of radio spectrum on the UK economy and factors influencing future spectrum demand".
7. Plum for the GSMA (2013), "Valuing the use of spectrum in the EU"; BCG for the GSMA, "Mobile Economy Europe 2013".
8. Deloitte Consulting. "The impact of 4G technology on commercial interactions, economic growth, and U.S. competitiveness" (2011).
9. Analysys Mason (2012). "Impact of radio spectrum on the UK economy and factors influencing future spectrum demand".
10. Deloitte/GSMA (2012). "What is the impact of mobile telephony on economic growth?" http://www.gsma.com/publicpolicy/wp-content/uploads/2012/11/gsma-deloitte-impact-mobile-telephony-economic-growth.pdf

SOCIO-ECONOMIC IMPACTS OF MOBILE BROADBAND

NARROWER IMPACT ↑ / BROADER IMPACT ↓

DIRECT IMPACT	The direct impacts generated by the investment and day-to-day activity of mobile operators. Investment is the main driver of economic growth in a market-based economy. It is from investment that an economy expands its capital base, gives a boost to productivity, and increases exports through greater competitiveness.
INDIRECT IMPACT	Indirect effects, accruing to third parties in the mobile ecosystem as a result of additional demand in the national economy enabled by the mobile operators' activities, or additional revenues generated for third parties (e.g. Value Added Services) available through the use of mobile broadband.
INDUCED IMPACT	Indices effects across the economy as a result of these direct and indirect activities.
JOB CREATION	Job creation both directly from mobile operators and indirectly in the ecosystem and the economy.
INCREASED GOVERNMENT REVENUES	Positive effects for governments through increased direct and indirect taxation.
INCREASED PRODUCTIVITY / CONSUMER SURPLUS	Broad effects accruing to third parties in the form of increased productivity and to consumers through surplus generated by higher consumption.

Figure 7

Source: Deloitte analysis

In addition to the economic benefits of mobile broadband, the sector delivers numerous social benefits, which have grown significantly in recent years. Through the increased availability of smartphones and tablets, these benefits not only include promoting communications and social cohesion, but also the proliferation of services such as m-health and m-education to be provided in rural and remote areas, with significant spillovers to societies and economies.

4.2 THE ECONOMIC IMPACT OF SPECTRUM SHARING

Limited analysis has been undertaken to date to estimate the wider macroeconomic impacts of spectrum sharing, and this analysis appears to assume that[11]:

- Shared spectrum for mobile usage is as economically useful as any other spectrum, implicitly disregarding the potential restrictions imposed on use or the frequencies offered.
- Operators will necessarily invest and make use of the shared spectrum whenever it is offered.
- The existing user creates no economic value and thus experiences no economic loss in giving up exclusive rights to enable sharing.

While equating the benefits of shared spectrum to those of exclusive spectrum can be a useful starting point in the analysis, careful consideration must be given to two factors that differentiate shared spectrum from exclusive spectrum:

- Unless the incumbent has no use of the spectrum, coexistence of multiple users, potential exclusions and contractual restrictions always reduce the usefulness and the economic benefits of the shared spectrum.
- The increased complexity, uncertainty and the extra risks that sharing generates for MNOs are likely to decrease the probability that operators would invest in shared spectrum.

Similarly to exclusive spectrum, the benefits of shared spectrum will also depend on certain technical characteristics of the band, such as block size and frequency. Contrary to exclusive spectrum, other factors should be included that have the potential to rapidly impair the benefits of the spectrum. These will be specific not just to the band examined, but also to factors such as the incumbent user, the size of the exclusions, the dynamism of the spectrum sharing and the terms of the contract with the incumbent user.

A key implication of existing uncertainty on spectrum sharing terms is the increased risk that investment may not occur. While governments and regulators typically assume the investment in shared spectrum will necessarily take place, the existing uncertainties and complexities of spectrum sharing suggest that the probability that investment will not take place should be explicitly included as a discount by governments and regulators when evaluating the economic benefits of spectrum ex-ante, at least until these uncertainties are significantly reduced. While operators will reflect these risks in their business plans and incorporate them in the price they are prepared to pay for the spectrum, or their decisions to invest at all, a similar process could be considered by governments when evaluating the total economic benefits of shared spectrum.

These factors, which will be specific to each sharing scenario examined, are incorporated in the analysis as follows:

- The economic benefits that would accrue to the economy if the spectrum was provided on an exclusive basis are taken as an upper bound of the benefits that shared spectrum can provide[12].
- From this maximum value, a number of impairment discounts are applied to reflect how specific terms and conditions of the sharing agreement, such as time and population exclusions and other contracting limitations, impair the benefits. Provided that operators will invest, this produces a range of economic benefits of the shared spectrum.
- There are a number of scenario-specific conditions that should also be considered with regard to operators' likelihood of investment. The factors potentially reducing the MNOs' likelihood of investment are the size of the exclusions, short contract length, scale of operation (in Europe), harmonisation, and the level of sharing dynamism.

11. See for example: SCF Associates (2012). "Perspectives on the Value of Shared Spectrum Access: Final Report for the European Commission." ec.europa.eu/information_society/policy/ecomm/radio_spectrum/_document_storage/studies/shared_use_2012/scf_study_shared_spectrum_access_20120210.pdf
12. These benefits are intended to be the additional benefits generated by using mobile broadband for a shared band. Section 4.2.3 discusses the costs for the economy of incumbent clearance. These should also be considered when undertaking cost-benefits analyses of shared spectrum.

Additionally, there will be factors relating to the increased complexity, uncertainty and the extra risks that sharing generates compared to exclusive use of spectrum. In order to reflect the possibility that, under certain conditions, investment in spectrum sharing may not occur, the range of benefits obtained should be properly weighted and discounted. In practice, a higher discount rate (compared to exclusive spectrum) is used in the calculation of the present value of the benefits.

This framework, which considers the macroeconomic impacts of spectrum as opposed to the benefits of investment from the point of view of a single operator or investor, is illustrated in Figure 8.

THE FRAMEWORK FOR THE MACROECONOMIC ANALYSIS OF SHARED SPECTRUM

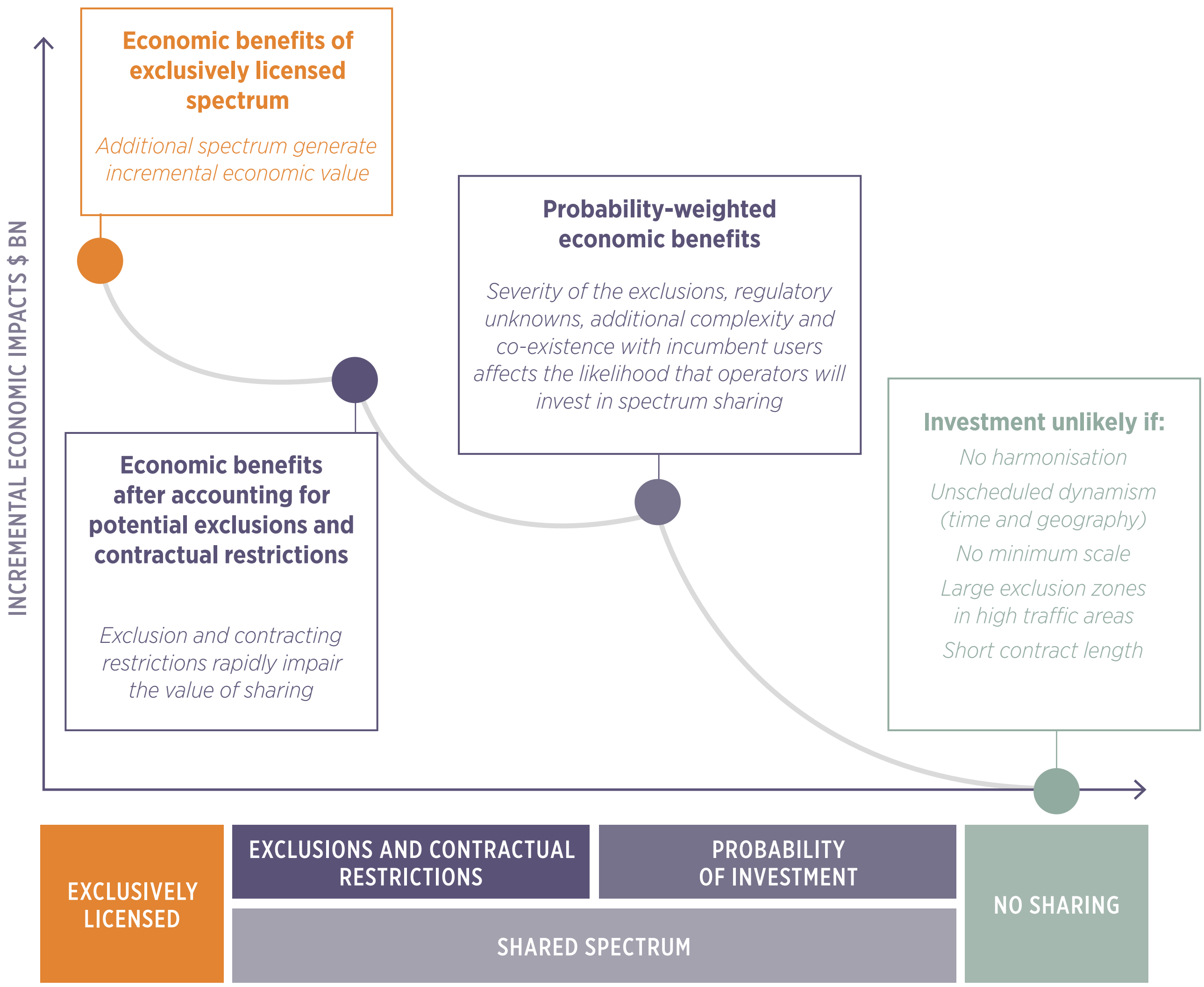


Figure 8

Source: Deloitte analysis

The details of how additional spectrum generates economic benefits, and of how rapidly this could be impaired as a result of spectrum sharing, are discussed in Section 4.2.1 and 4.2.2 below.

4.2.1 THE ECONOMIC BENEFITS GENERATED BY ADDITIONAL SPECTRUM

When additional spectrum is employed to provide incremental capacity in network congested areas, a number of key incremental economic benefits arise from the demand and supply side of the market:

- On the supply side, the increased amount of spectrum available allows operators to meet increased demand whilst generating network efficiencies and cost reductions, in turn leading to more investment and to an expansion in the supply of mobile broadband.
- On the demand side, the increased capacity allows operators to meet the increasing usage demand and to provide better service quality, e.g. in the form of faster connections and the development of new applications. This in turn increases consumers' willingness to pay and usage, leading to an expansion of demand.

These impacts can be quantified by estimating the links between the amount of spectrum shared and the resulting variations of supply and demand in the market for mobile broadband. Impacts will be specific to the band, as network efficiencies depend on the technical characteristics of the frequency band, on the spectrum block size, as well as on the existing availability of spectrum.

The additional spectrum triggers the following effects:

- Network efficiencies as a result of incremental spectrum reduce network costs.
- Harmonisation and scale economies also drive device efficiencies, reducing the cost of the devices consumers require for mobile broadband, and increasing the number of connections.
- Better, faster and more reliable mobile broadband also increases quality and usage per user.

These effects lead to a new market equilibrium whereby an increased number of connections, increased usage per user and lower unit price (that is, price per MB of mobile broadband provided) lead to higher market revenues and higher economic activity.

4.2.2 HOW RAPIDLY THE BENEFITS ARE IMPAIRED AS A RESULT OF SHARING

A number of factors and sharing conditions have the potential to reduce the benefits associated with the shared spectrum and these need to be explicitly accounted for.

PRE-CONDITIONS FOR INVESTMENT

There are a number of conditions under which operators are not likely to invest. These include:

- The lack of band harmonisation: Based on conversations with mobile operators, sharing in non-harmonised bands appears unlikely.
- In the EU, operators have noted that if the same band does not become available in a sufficient number of countries such that a minimum scale for the band use is not generated, it is unlikely that investment would become economical. In the absence of a minimum efficient scale of operation, economic benefits could be assumed to derive only from smaller spectrum-constrained national operators who would rely on sharing to improve their position.
- Sharing dynamism: while static sharing can be managed by operators, as sharing dynamism increases (dynamism in bandwidth variability, in the availability of geographic areas and time, and possibility of unscheduled interruptions), the likelihood of investment rapidly decreases, resulting in no economic benefits. Dynamic sharing would require a level of sophistication in the network equipment and devices which is not motivated by the benefits from sharing.

EXCLUSIONS

In the case that investment occurs, unless the incumbent makes no use of the spectrum, shared spectrum will always generate lower benefits than exclusive spectrum as even optimal sharing would always involve exclusion conditions. These exclusions reduce economic benefits proportionally to the size of the exclusion itself. There are a number of potential exclusions that should be considered:

- Geographic restrictions, leading to reductions in population served.
- Timing restrictions, leading to reductions in time available for spectrum usage.
- Restrictions on network deployment conditions, e.g. impossibility of using shared spectrum on macrocells, leading to the inability to serve certain types of traffic, such as high mobility traffic.

If these sharing exclusions prevent mobile operators from using the spectrum in network congested areas or during network peak times, economic benefits are likely to be greatly reduced.

In addition, another implicit exclusion condition is given by the length of the sharing agreement, which has the potential to affect investment levels and the related economic benefits. Short contracts imposed by incumbent users may discourage investment from larger operators, making the sharing agreement only appealing to new entrants or smaller network-constrained operators, and therefore reducing benefits over the period considered.

CO-EXISTENCE, ADDITIONAL COMPLEXITY AND UNCERTAINTY

Compared to exclusive spectrum, there are further risks associated with shared spectrum that generate a risk premium for operators' investment in a shared band:

- Co-existence risks, whereby the likelihood of success does not depend on MNOs only but on their interaction with the incumbent user.
- Risks of additional complexity from managing exclusions and other conditions that are inherently more complex and require extra activities from MNOs.
- Uncertainty associated with regulations. While this risk could be minimised by efficient regulatory approaches that are aimed at encouraging negotiations and incentivising incumbents to make the spectrum available, intrusive regulations, e.g. through the micromanagement of sharing arrangements, transmitting and power conditions and obligations on network design and the use of small cells, are likely to reduce the incentives to invest.

These factors act to reduce the likelihood of investment by the operators and this needs to be accounted for when calculating the present value of the spectrum sharing economic benefits. Practically, this could occur by applying a higher discount rate (compared to exclusive spectrum) to the calculation of the present value of the benefits.

SUMMARY

The magnitude of the economic benefits of spectrum sharing is driven by the MNOs' decision to invest. Each MNO will base its investment decision upon whether the returns of the investment outweigh the related costs. The investment returns will depend on the sharing terms and conditions (size of exclusions, contract length, etc.), as set out above. Further factors affecting the MNOs' investment decision relate to the overall perceived risks and additional complexities associated with sharing compared to exclusively licensed spectrum. As sharing conditions deteriorate, the likelihood of investment decreases, until a cut-off point beyond which no investment occurs, as illustrated in Figure 9. Each MNO's investment tolerance, valuation estimate and cut-off point will be unique, dependent on factors such as its current spectrum position, particular objectives for the shared spectrum, market position and risk tolerance.

FACTORS AFFECTING THE LIKELIHOOD OF INVESTMENT BY AN MNO (ILLUSTRATIVE)

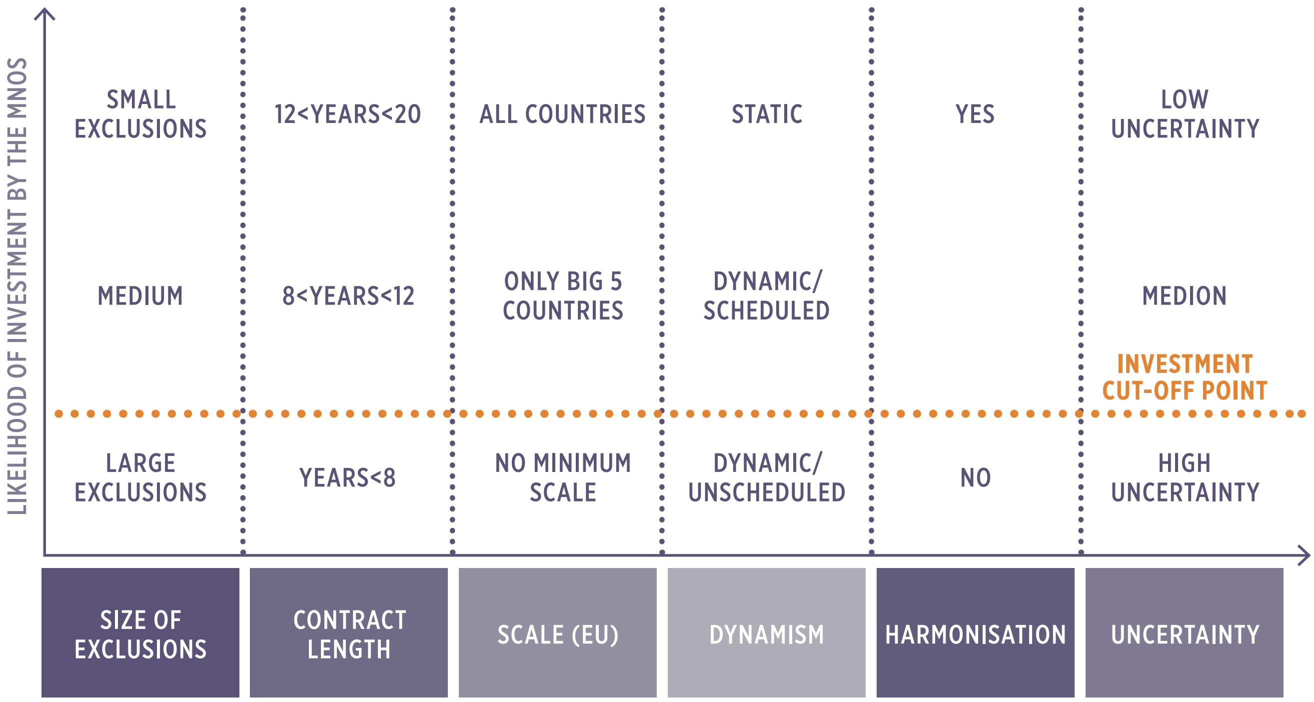


Figure 9

Source: Deloitte analysis

At macroeconomic level, capturing the overall economic benefits of spectrum sharing requires accounting for the likelihood of investment in aggregate by the MNO community. In order to reflect this probability, the range of economic benefits of spectrum sharing should be properly weighted and discounted. This approach is illustrated below.

- On the left hand side, the upper bound of the economic benefits is given by the value of the benefits if the spectrum was provided on an exclusive basis.
- From this position, a number of discounts are applied depending on the size of the time and population excluded from the service, the contract length and, in the case of the EU, the fragmentation in band harmonisation and use.
- On the right hand side, the lower bound of the benefits is given by a series of no-investment conditions, which lead to no economic benefits.

THE FRAMEWORK FOR THE ANALYSIS OF ECONOMIC IMPACTS OF SHARED SPECTRUM

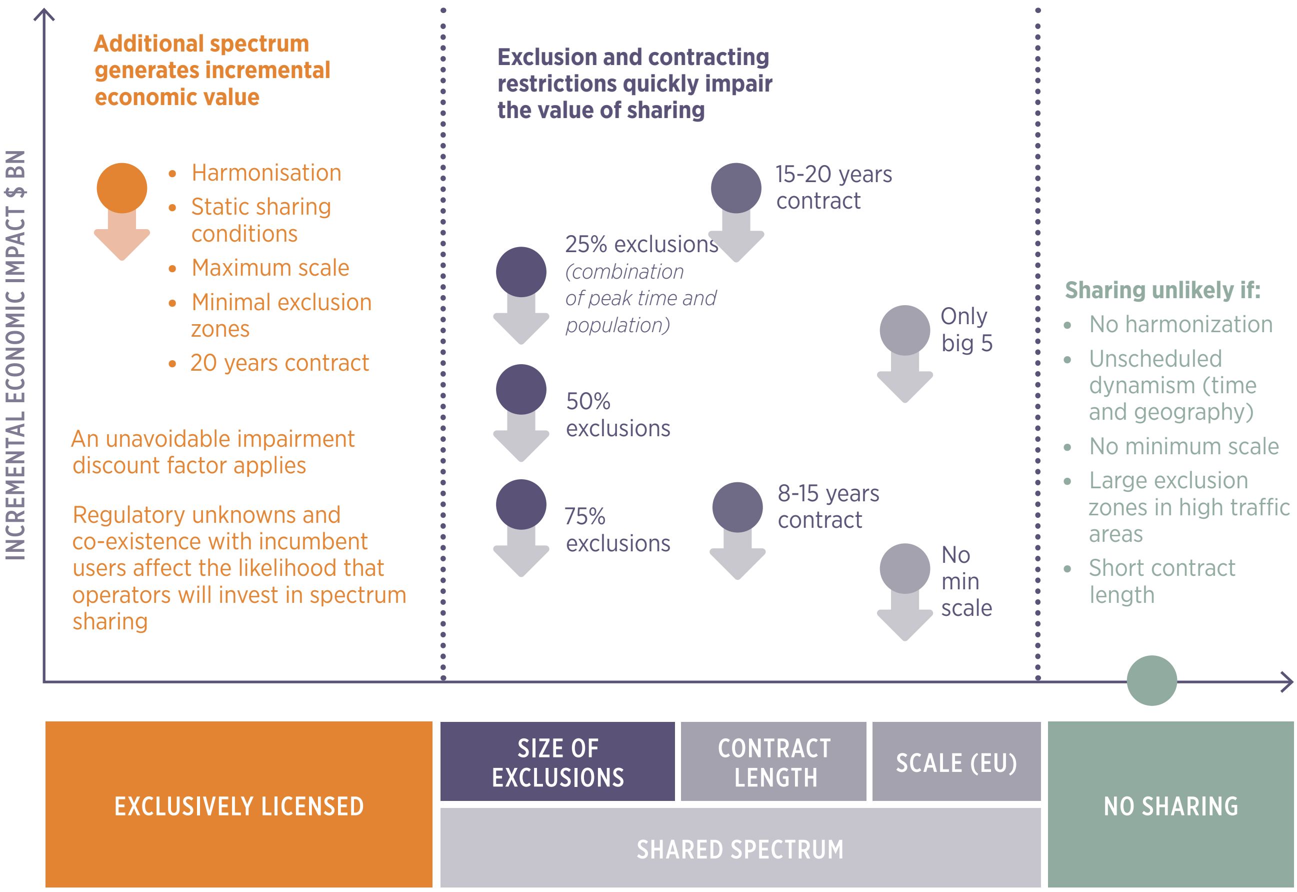


Figure 10

Source: Deloitte analysis

Overall, that the economic value that can be generated through spectrum sharing requires appropriately discounting these benefits to reflect exclusions and contractual restrictions.

In addition, it is critical to closely reflect in the evaluation all the conditions that will affect the probability of investment by MNOs. While operators will reflect these risks in their business plans and incorporate them in the price they are prepared to pay for the spectrum, or their decisions to invest at all, a similar process could be considered by governments when evaluating the total economic benefits of shared spectrum at least until the severe uncertainties reported by operators can be reduced. This probability of investment cannot be ignored, as it could drive the economic value to zero, either through lack of licence bidding or lack of investment post-licence purchase. For instance, this risk materialised in the US 2008 700MHz auction, when the "D block" was offered and the conditions attached to it led MNOs not to bid for it.

As a practical example, if the economic impacts of exclusive and unrestricted spectrum amount to $100bn, a geographic/time limitation excluding 40% of traffic could reduce the benefits to $60bn. If in the short term other severe uncertainties exist (for example on band harmonisation, handset costs or other coexistence costs), these could lead to a probability of 10% of an operator investing in the spectrum. While the final outcome is binary (if investment occurs the benefits would amount to $60bn, but would amount to $0 if investment does not materialise), the probability weighed benefits amount to $6bn. Given the reported uncertainties, the probability of investment appears lower than under exclusively licensed spectrum, and as such governments and regulators could consider explicitly accounting for it.

In conclusion, this framework provides users with a range for the economic benefits that depends not only on the band characteristics, but also on the sharing conditions and MNO likelihood of investing. Regulators and governments can therefore evaluate whether the conditions that may apply to a specific band (largely dependent upon the features of the incumbent use) generate sufficient benefits.

4.2.3 OTHER COSTS TO THE ECONOMY

While outside the scope of this study, it is important to note that there are at least two cost categories that should be considered when evaluating costs and benefits of spectrum sharing:

- Increased regulatory costs could arise: increasing shared spectrum use would have some direct impact on the administrative costs of regulatory authorities. The scale of the impact depends upon a number of factors, including:
  - The basis for authorisation: a licensed, light-licensed or licence-exempt approach.
  - The basis for sharing, e.g. the requirement for spectrum databases: if sharing was carried out through a spectrum-sharing database for the regulator to administer, this would generate additional costs for the regulator.
- Costs for clearance or extra costs borne by the incumbent user. These costs, however, could be offset by the revenues that the incumbent user would generate by renting out its spectrum.
- Potential additional societal costs associated to the incumbent moving from exclusive to shared conditions. However, in many circumstances, it can be argued that the incumbent is not currently making the most efficient use of its spectrum. Therefore, it is expected that the incentives and compensation that the incumbent will receive from the MNOs would more than compensate the downsides relating to a loss of spectrum availability and flexibility by the incumbent.

5 CASE STUDY ANALYSIS

Applying the framework in the US and EU

This section applies the strategic framework developed in Section 3 and the economic impact framework developed in Section 4 to two bands that are candidates for sharing in the EU and the US: the 3.5GHz band in the US and the 2.3GHz band in the EU.

5.1 CASE STUDIES: KEY FINDINGS

Two bands have been taken as illustrative sharing scenarios in the US and the EU28. The 2.3GHz band has been considered in the European context, while for the US the 3.5GHz band has been considered.

Regulators in the US, and to a certain extent in the EU, are considering the suitability of these bands for mobile services. Currently, these bands are used by different users, which would potentially result in a number of restrictions, ultimately impairing value for MNOs. Efficient regulatory approaches could therefore consider encouraging voluntary negotiations and incentivising incumbents to make the spectrum available. Intrusive regulations, e.g. through the micromanagement of sharing arrangements such as transmitting and power conditions, and obligations on network design and the use of small cells, may lead to suboptimal solutions and thus reduced incentives to invest.

However, the characteristics of these bands make them particularly suitable for supporting traffic in capacity constrained areas and peak hours.

Therefore, the case study evaluated the economic impact of providing spectrum in these bands to support MNOs' operations in capacity constrained areas or hours.

The benefits of spectrum sharing depend on the amount of spectrum made available and on the individual properties of the band.

In Europe, the 2.3GHz band has been considered valuable by MNOs as it complements existing spectrum allocations above 2GHz. An additional 50MHz of shared spectrum in the 2.3GHz band has the potential to unlock network efficiencies while supporting improvements in the quality of service. In addition, the scale economies deriving from successful harmonisation of the band would contribute to reducing the cost that consumers pay for mobile broadband devices. Overall this may lead to an estimated €86bn of incremental value added generated across MNOs, the mobile ecosystem and the wider economy.

In the US, in line with the PCAST recommendation[13], an additional 100MHz of shared spectrum in the 3.5GHz band have been considered. Compared to the EU28 case study, spectrum sharing in the US is estimated to produce a higher economic impact ($260bn). This is primarily due to the fact that the amount of spectrum considered for sharing in the context of the US is double the amount of the EU28 (100MHz versus 50MHz). Also the timing of sharing plays a role in this difference. While sharing is assumed to start in 2016 in the US (and to be fully commercially deployed by 2018), in the EU28 sharing is assumed to become effective in 2020.

At the same time, the lower quality of propagation delivered by the 3.5GHz band compared to the 2.3GHz band makes the incremental advantages of the 3.5GHz lower at the margin compared to the 2.3GHz band.

The absolute amount of economic impact in the US is higher than in the EU also due to the fact that the US mobile broadband market is characterised by higher ARPU, higher willingness to pay for wireless services and higher usage levels per user.

Differences in the incumbent users across the 2.3GHz and the 3.5GHz band also determine a number of different constraints that LSA licensees in these bands would be subject to. These constraints are likely to greatly reduce the economic benefits.

If the economic benefits are to be maximised, population and timing exclusions should be limited. For instance, in the US, if only 70% of the capacity constrained areas and 70% of the peak hours were available to MNOs through sharing in the 3.5GHz band, then the full economic value of spectrum sharing ($260bn) could be halved and the incentives for investment by MNOs would be significantly impacted.

In the EU, the largest barrier to the economic benefits is the risk of a fragmented approach. Implementing spectrum sharing only in the five key markets (UK, Germany, France, Italy and Spain) would reduce the full economic benefits (i.e. those calculated at the EU28 level) from €86bn to €52bn. More importantly, operators reported that absence of coordination amongst these five key markets would not deliver a sufficient scale of operation, potentially leading to limited investment in infrastructure and, consequently, limited economic benefits.

Finally, regulators, besides aiming to incentivise incumbent users to share, should also ensure that the timing of the sharing agreement is long enough to incentivise the key operators to invest in the sharing. A short contract length imposed by the incumbent could rapidly lead to a full loss of economic benefits.

13. President's Council of Advisors on Science and Technology, "Realizing the Full Potential of Government Held Spectrum to Spur Economic Growth," p. ix, July 2012

5.2

US: sharing in the 3.5GHz band

5.2.1 FREQUENCY BAND

The 3.5GHz band is under consideration for spectrum sharing in the United States. PCAST has recommended spectrum sharing as a path to double available spectrum,[14] including the sharing of some 1,000MHz of Federal spectrum via a new Federal Spectrum Access System (SAS) which will act as an information and control clearing house for band-by-band spectrum registration and conditions of use, enabling non-Federal users to access underutilised spectrum in these bands. Access would involve a framework of minimum technical standards for the coexistence of both transmitters and receivers, in contrast to the present system which focuses on transmitters.

The 3.5GHz band was identified as a priority band to establish the principles of sharing both by PCAST and in a 2010 "Fast Track" Report by the National Telecommunications and Information Administration (NTIA).[15] The Federal Communications Commission (FCC) is consulting on the specific sharing and regulatory framework required to make this a reality[16].

The core frequency range under consideration by the FCC is 3550-3650MHz. This range overlaps two standardised 3GPP bands: band 42 which covers 3400-3600MHz and band 43, covering 3600-3800MHz. These frequencies have not previously been available in the US for mobile use although they are in use or planned for use in much of the rest of the world.

Additionally, the FCC proposes applying the same sharing conditions to the range 3650 - 3700MHz, which is already used for commercial broadband services.

Relatively few compact mobile devices are yet available for this frequency band, with many of the available devices being residential fixed wireless broadband routers, but smartphones are expected in greater numbers in the near future. Currently 43 LTE devices support the band (collectively bands 42 and 43) out of 1,064 total[17].

Although there is growing device support for these bands, the combination of bands 42 and 43 spans a wide fractional bandwidth (over 11%) which may create challenges in device design, with some manufacturers likely to support only one of the two 3GPP bands and limiting the spectrum available. However, an industry association comprising mainly operators holding this spectrum has been formed and is lobbying for manufacturers to consider both bands as one in any development planning.

14. President's Council of Advisors on Science and Technology, "Realizing the Full Potential of Government-Held Spectrum to Spur Economic Growth," pg. vi, July 2012
15. National Telecommunications and Information Administration, "An Assessment of the Near-Term Viability of Accommodating Wireless Broadband Systems in the 1675-1710MHz, 1755-1780MHz, 3500-3650MHz, and 4200-4220MHz, 4380-4400MHz Bands," pg. iv, 2010.
16. FCC Notice of Proposed Rulemaking "Enabling Innovative Small Cell Use In 3.5GHz Band NPRM & Order", December 2012
17. Global mobile Suppliers Association (August 2013). "Status of the LTE ecosystem".

5.2.2 INCUMBENT TYPES AND APPLICATION CHARACTERISTICS

The ITU allocations for the 3.5GHz band vary internationally. They are identified for IMT in much of Region 1 (EMEA) and 8 areas within Region 3 (Asia/Oceania). In Region 2 (including the US) the band has a Primary allocation for Fixed, Fixed Satellite and Mobile services and has a Secondary allocation for Radio Location Services (RLS). On a US national basis, the 3.5-3.65GHz band is allocated to RLS and the ground-based Aeronautical Radio Navigation Service (ARNS) on a primary basis for federal use and on a secondary basis to federal non-military RLS usage. The 3.6 – 3.65GHz band is additionally allocated to Fixed Satellite Service (FSS) earth stations.

The 3.5GHz band is currently used in various capacities across the US.

KEY INCUMBENTS AND INCUMBENT USES IN THE 3.5GHZ BAND IN THE US

Department of Defense (DoD) Radars	This is in the 3.5-3.65GHz range and includes shipborne Navy radars, ground based radar and systems for weapons control and for air & surface target detection & tracking. The US Navy uses the band for a major radar system on guided missile cruisers and the US Army for a firefinder system to detect enemy projectiles. The US Air Force uses the band for airborne station keeping equipment throughout the US and to assist in possessions for formation flying and drop-zone training.
Fixed Satellite Services	This is in the in 3.6-3.65GHz range, comprising non-federal fixed satellite earth stations and receive-only space-to-earth operations and feeder links. FSS earth stations are licensed in 32 cities in 3.625-3.65GHz plus two earth stations for mobile satellite near Los Angeles and New York City.
Non-federal Radiolocation	There are three non-federal RLS licences for fixed and mobile RLS in 3.3-3.5GHz and 3.5-3.65GHz.
Other Uses	There are ship stations more than 44 miles from shore and nationwide fixed broadband equipment in 3.65-3.7GHz.
Adjacent Services Which May Require Protection	These include high-powered ground and airborne military radars (3.1-3.5GHz) such as systems used on ships and amateur radio.

Table 3

Source: Deloitte and Real Wireless research

5.2.3 REGULATORY INVOLVEMENT

The FCC is consulting on the potential regulatory framework for making the 3.5GHz band available[18]. They proposed three tiers of access as follows:

Incumbent Access, which would include authorised federal users and grandfathered fixed satellite service licensees. These incumbents would be afforded protection from all other users in the 3.5GHz Band.

Protected Access (also called Priority Access), which would include critical use facilities, such as hospitals, utilities, government facilities, and public safety entities that would be afforded quality-assured access to a portion of the 3.5GHz Band in certain designated locations.

General Authorised Access (GAA), which would include all other users – including the general public – that would have the ability to operate in the 3.5GHz band subject to protections for Incumbent Access and Protected Access users.

The results would be a new Citizens Broadband Service, managed by a Spectrum Access System (SAS) comprising a dynamic database and potentially other interference mitigation techniques. Users would not be permitted within geographically designated Incumbent Use Zones, which would encompass the geographic area where low-powered small cells could cause harmful interference to incumbent operations. These zones would differ between access tiers, with GAA users permitted to operate in areas where some interference from incumbent operations might be expected. This results in four different potential environments for use in this band as illustrated in Figure 11.

FOUR TYPES OF GEOGRAPHICAL AREA ARISING FROM FCC 3.5GHZ SHARING PROPOSALS

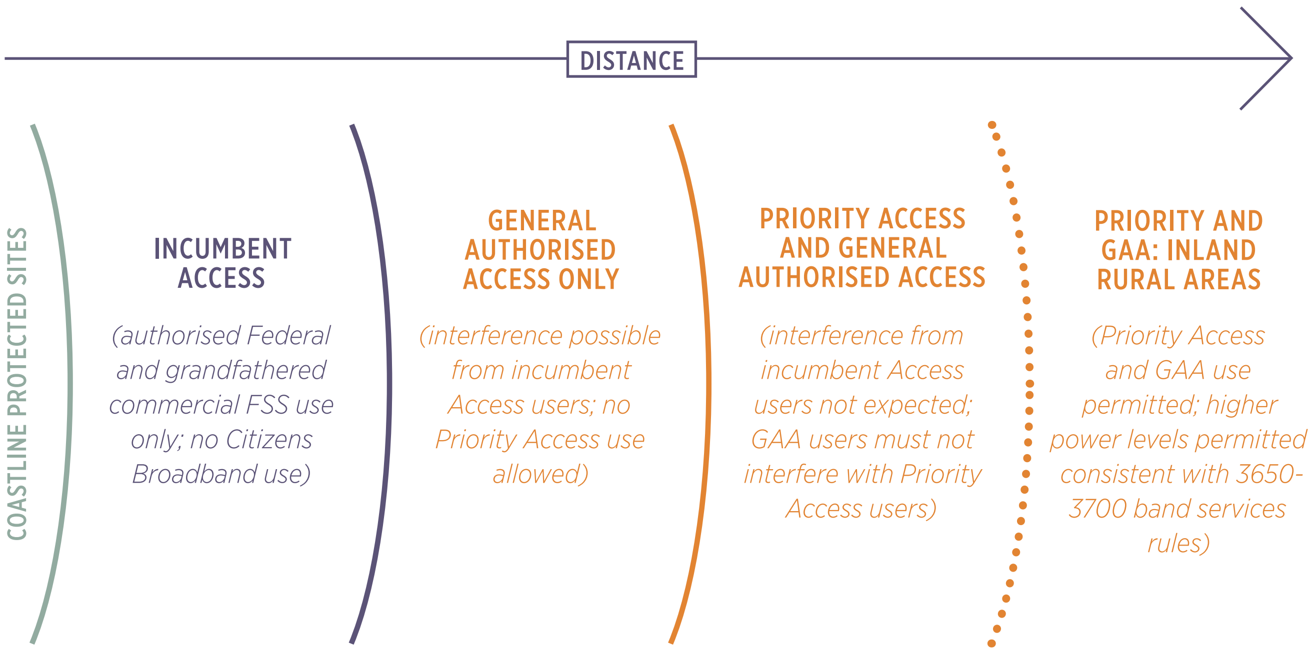


Figure 11

Source: FCC Notice of Proposed Rulemaking "Enabling Innovative Small Cell Use In 3.5GHz Band NPRM & Order", p. 20, December 2012

18. FCC Notice of Proposed Rulemaking "Enabling Innovative Small Cell Use In 3.5GHz Band NPRM & Order", December 2012

The Priority Access and GAA users are considered to be licensed by rule rather than unlicensed. FCC also seeks comment on whether to extend these new rules to the neighbouring 3650-700MHz band, which is already used for commercial broadband services.

FCC estimated that applying an average exclusion zone distance based on macrocells to the shoreline on the East coast, Gulf coast and West coast would exclude 60% of the US population, as illustrated in Figure 12. This does not account for exclusions for ground-based radars. The estimate is based on a coarse approach; a more fine grained approach could substantially reduce the excluded population as could consider the specific frequencies occupied by the incumbent users.

Such improvements may however require the use of a geographical database given the need for detailed location information and to account for the potentially dynamic nature of the incumbents in both frequency and location, increasing the complexity and potential cost of accessing the band.

Overall however the FCC considers that the utility of the band would be enhanced by considering it only for small cell operation which would reduce the potential size of the exclusion zones required. A CTIA report to the FCC indicated that mobile operators had also suggested that 3.5GHz was not very suitable for macrocells.

While the use of small cell technology could enhance the geographical area and population over which the band could be used, it may also limit the utility of the band in locations where incumbent usage is light. Nevertheless it appears from responses to the FCC's NPRM that those with an interest in this band may be prepared to accept such limitations if they enhance the possibility of early access to the band.

EXCLUSION ZONES FOR DIFFERENT SHIPBORNE RADAR SYSTEMS (MACROCELL IMPACT)

ILLUSTRATIVE

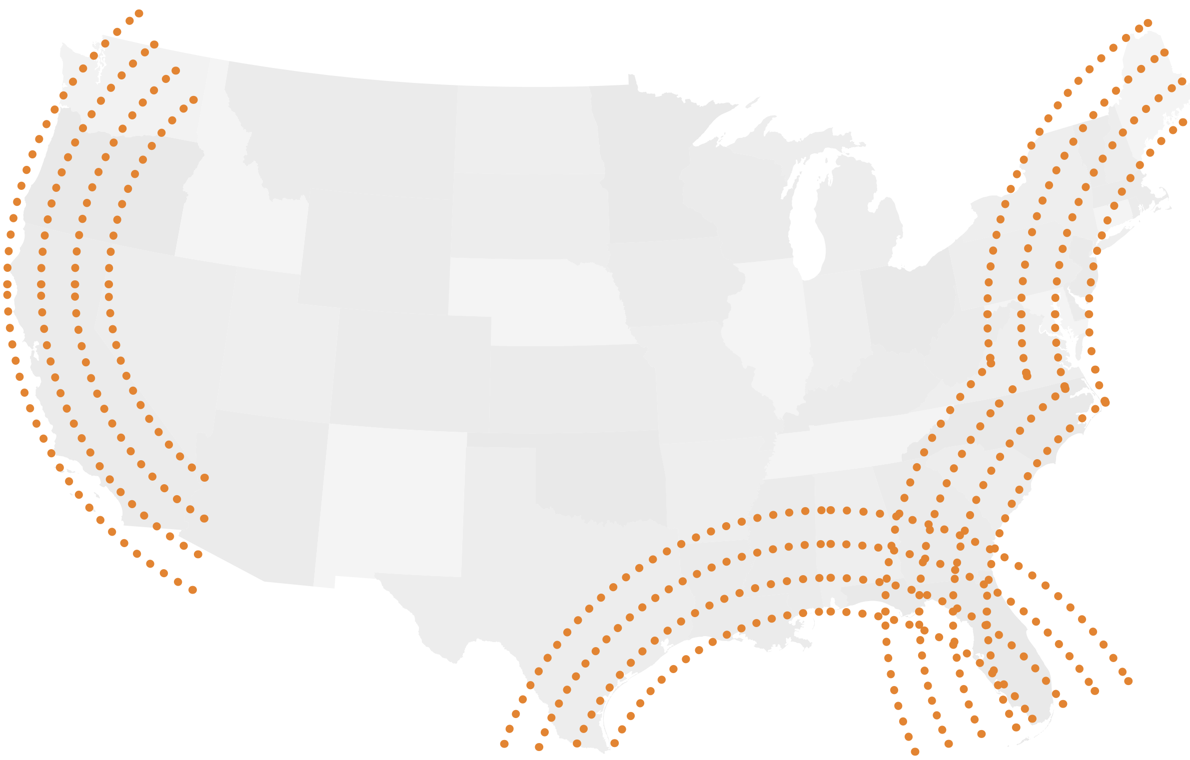


Figure 12

Source: FCC Notice of Proposed Rulemaking "Enabling Innovative Small Cell Use In 3.5GHz Band NPRM & Order", p. 40, December 2012

5.2.4 POTENTIAL MNO BENEFITS

Opening up the 3.5GHz frequency band in the US for shared spectrum could lead to several key benefits for MNOs. Depending on the terms of the sharing agreement, these benefits will be realised to various extents. A primary potential benefit is in providing localised capacity in busy locations, especially in indoor applications such as public buildings, healthcare and leisure environments. A secondary benefit is that the band could be available across all operators, opening up increased opportunities for national roaming between operators which has hitherto been challenging due to complexities in the existing 700MHz band plan.

5.2.5 SHARING SCENARIO

Despite the promise of this band, there are a few considerations specific to the 3.5GHz band that must be taken into account. Though none of these considerations eliminates the value of the 3.5GHz band for shared use, they are key considerations for MNOs. The 3.5GHz band spans two 3GPP bands used for LTE (bands 42 and 43). This forces device manufacturers to implement one or the other, reducing the available spectrum per device and complicating the use of the frequencies. There is an emerging view amongst potential users that while a regulatory restriction to small cells might reduce the utility of the band in locations with little incumbent usage, overall accepting the limitations of such an approach could provide for more rapid access to the band and provide confidence to incumbent users of a reduced interference probability.

US SHARING SCENARIO

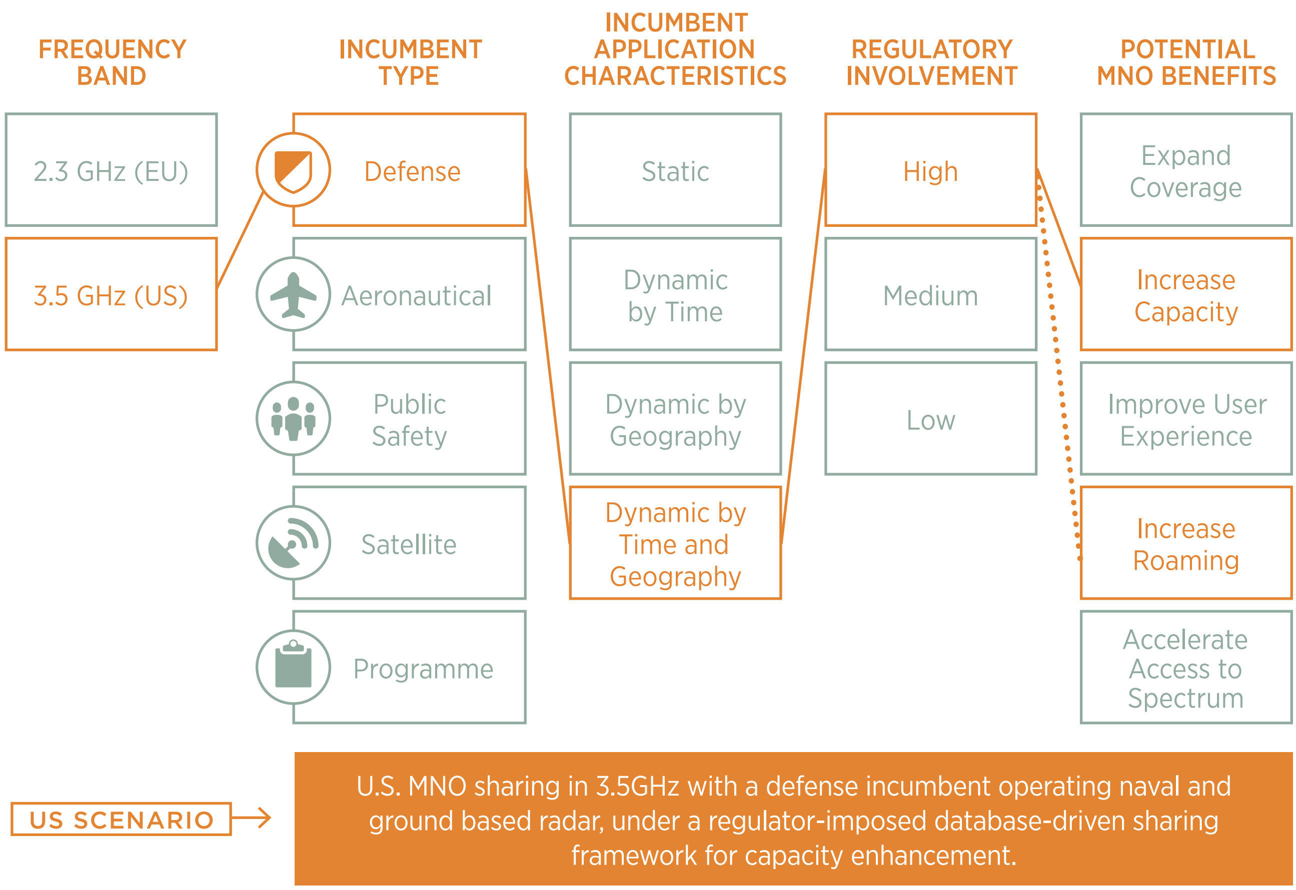


Figure 13

Source: Deloitte and Real Wireless analysis

The value of shared spectrum to MNOs is significantly impacted by the particular sharing arrangement and dynamic nature of the incumbent applications. Figure 14 shows two examples of how an MNO might make use of shared spectrum based on the specific sharing scenario.

SHARING CASE EXAMPLES

	EXAMPLE SHARING CASE 1 HIGHER VALUE BROAD CAPACITY ENHANCEMENT	EXAMPLE SHARING CASE 2 LOWER VALUE INCREMENTAL ROAMING
INCUMBENT PROFILE	Military shares spectrum band on a static basis with known geographic exclusions	Military share spectrum band on a dynamic (time, location) basis
KEY SHARING ARRANGEMENTS	Static geographic exclusion zones Longer term agreement *(minimum of 15 years)*	Dynamic sharing via devices references to a centralised database Shorter term agreement (8 years)
MNO TARGET BENEFITS	High traffic area capacity lift using existing macros and new small cells	Access to wider base of internationally harmonised devices Additional roaming revenue from inbound international roamers
MNO CONSIDERATIONS	Leverage existing macro investment Use and pay on an 'as-required' basis Need two years advance notice of changes to geo-exclusions	Add to existing macros in urban locations favoured by roamers Deploy targeted small cells at key points of increase to attract roamers

Figure 14

Source: Real Wireless analysis

Though these hypothetical examples occur on the same frequency band, the value of the band to an MNO varies substantially between the two scenarios. In the "Broad Capacity Enhancement" example, the static nature of the sharing agreement and the long duration of the agreement allow the MNO to have relative certainty of its access to the spectrum. Conversely, the dynamic nature of the agreement in the "Incremental Roaming" example leaves the MNO with little certainty as to when or where it can use the spectrum. As such the value of the spectrum to the MNO is substantially higher in the "Broad Capacity Enhancement" scenario.

5.2.6 THE ECONOMIC IMPACT OF SHARING THE 3.5GHZ BAND

In line with the economic framework presented in Section 4, the economic benefits associated with sharing spectrum in the 3.5GHz band have been estimated on the basis of these assumptions:

- 100MHz of spectrum in this band are made available on a shared basis, with full commercial deployment realised by 2018.
- The spectrum is used to provide additional capacity for mobile broadband in network congested areas.

To estimate these benefits, the mobile broadband economic impact model described in Appendix A has been applied to the US, first by estimating the economic impact of mobile broadband for the period 2013-2030, then by estimating how these would increase if 100Mhz of spectrum in the 3.5Ghz band is fully deployed on a shared basis from 2018. The model has been calibrated to reflect the features of the US market and the technical characteristics of the 3.5GHz band. Then, a number of sharing-specific factors have been evaluated to determine the impairment discounts that should be applied to capture the conditions attached to spectrum sharing.

The results indicate that, if the spectrum was provided on an exclusive basis, this could generate an additional $366bn of value add across the US economy over the period ($163bn in direct effects, $98bn in indirect effects and $105bn in induced effects), including $220bn of tax revenues to the government. In addition, up to $204bn of incremental consumer surplus would be generated.

The impact on these benefits of the spectrum being provided on a shared basis is then evaluated. Taking into account the increased risk premium required by operators to invest reduces the level of the economic benefits to $260bn of value add ($116bn in direct effects, $70bn in indirect effects and $75bn in induced effects), including $157bn of tax revenues to the government. The estimated incremental consumer surplus would be reduced to $146bn, with an overall 266,000 additional jobs supported through spectrum sharing across the US, in the 2018-2030 period.

Having established the upper bound of the economic benefits, the model also examined how rapidly the economic benefits generated by shared spectrum are impaired as the sharing conditions deteriorate: geographic and timing exclusions, and contracting conditions.

The importance of population and time exclusions has emerged from interviews with US operators. These exclusions could be generated by explicit limitations of spectrum availability for MNOs due to the incumbent's use, or, as discussed in Section 5.2.3, could be an indirect consequence of limitations to the deployment of network infrastructure such as macrocells. If spectrum is available for sharing only for 50% of the mobile networks' peak times or for 50% of the population living in capacity-constrained regions, then the total economic impact may drop from $260bn to $130bn.

Considering the impacts of contract length between the incumbent user and the MNO, a sharing agreement in excess of 15 years is likely to deliver full economic benefits ($260bn). Contracts that do not guarantee that minimum investment period may deter larger operators from investing. If only smaller, spectrum-constrained operators invest, economic benefits could drop to $26bn.

Very short sharing agreements between the incumbent user and the MNO, lack of band harmonisation and dynamic sharing procedures could result in no economic benefits.

SUMMARY OF ECONOMIC BENEFITS OF SHARED SPECTRUM IN THE US, PRESENT VALUE OVER THE PERIOD 2018-2030, $BN

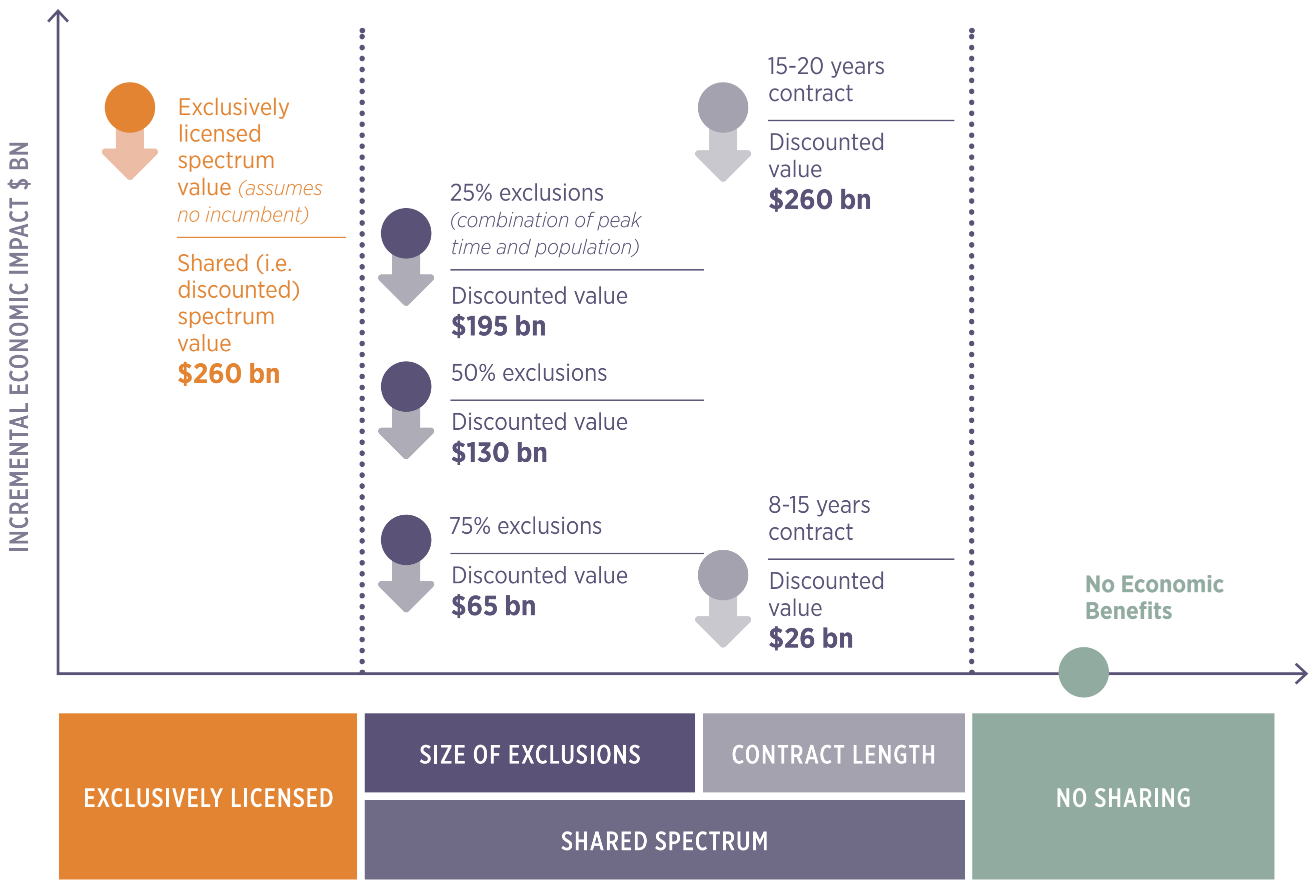


Figure 15

Source: Deloitte analysis

While an additional 100MHz of spectrum in the 3.5GHz band could deliver up to $260bn in economic benefits, population and time exclusions, contract length and scale of operation have the potential to rapidly reduce these benefits to zero. Figure 16 below provides an illustrative example of sharing to show how rapidly the economic benefits in the US can be impaired by poor sharing terms and conditions.

HOW RAPIDLY THE ECONOMIC BENEFITS IN THE US CAN BE IMPAIRED BY POOR SHARING TERMS AND CONDITIONS, PRESENT VALUE OVER THE PERIOD 2018-2030, $BN

US

In the US, up to $260bn of value add could be generated across the US economy over 2016-2030. *This rapidly decreases to zero as geographic and timing exclusions and contracting limitations become more severe.*

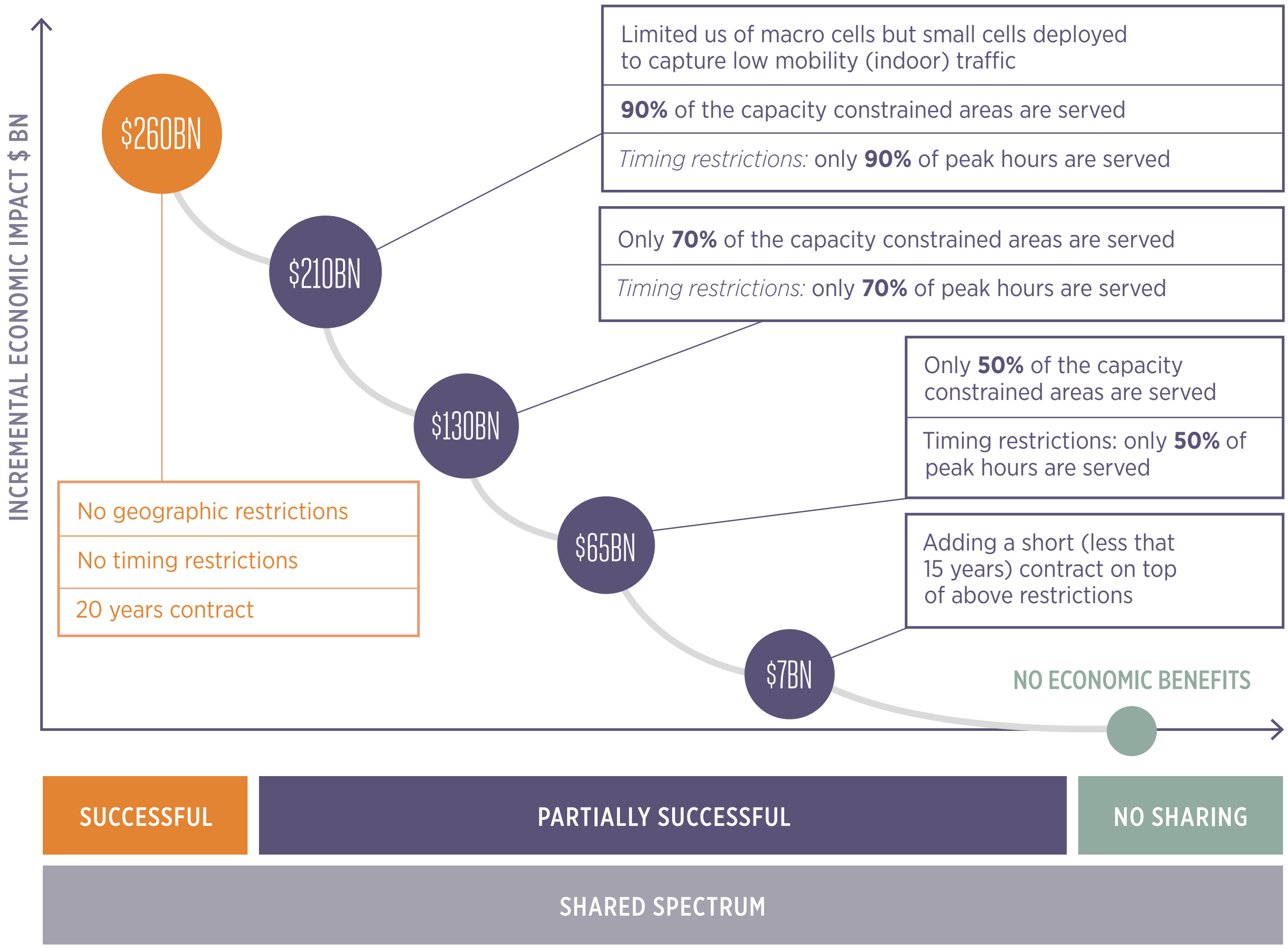


Figure 16

Source: Deloitte analysis

5.3

EU28: sharing in the 2.3GHz band

5.3.1 FREQUENCY BAND

The European Commission (EC) has strongly advocated spectrum sharing as an "essential solution to dealing with the wireless crunch".[19] They have set the development of harmonised spectrum sharing approaches across the EU as an objective of the five-year Radio Spectrum Policy Programme.

The 2.3GHz band from 2300 to 2400 MHz has been identified as the highest priority band for spectrum sharing. This band is a standardised 3GPP band (band 40) with existing LTE equipment availability. The band is also standardised as a TDD band, lending itself naturally to usage of subsets of the band in a shared scenario.

There are existing deployments or commitments on a conventional exclusive basis in Australia, Hong Kong, India, Russia, South Africa and others as well as trials and expectations of wider deployment in China and elsewhere. There are currently 147 LTE devices supporting this band out of a total of 1,064.[20] Together these suggest a large potential mobile equipment market which the EU could benefit from.

5.3.1.1 EU ACTIVITIES ON SPECTRUM SHARING IN 2.3GHZ

To help progress spectrum sharing in 2.3GHz in the EU, several activities are underway:

- The EC and the European Conference of Postal and Telecommunications Administrations (CEPT) formed a dedicated working group (FM52) in January 2013 on shared spectrum approaches, focusing on 2.3GHz, complementing the broader work in FM53 on licensed shared access. A draft ECC Decision (which can be binding on member states) is to be developed to harmonise implementation measures in this band, including regulatory provisions based on Licensed Shared Access.
- The Radio Spectrum Policy Group is developing an approach to Licensed Shared Access following its 2011 report on collective use of spectrum.
- The European Telecommunications Standards Institute (ETSI) has developed a System Reference Document for mobile services under LSA in 2.3GHz[21] which sets out technical principles and potential common architectures for achieving the LSA concept.

5.3.1.2 EXISTING USAGE OF 2.3GHZ ACROSS EUROPE

It is clear that while this band is a prime candidate for spectrum sharing in Europe, the situation is highly variable across Europe. Specific information on incumbent use and plans is difficult to obtain and often obscured by aggregation, sometimes due to military applications. More clarity is required to fully assess its potential value to MNOs.

A number of examples of current usage and plans for 2.3GHz in EU countries are provided in Table 4.

19. European Commission, "Radio Spectrum Policy Programme," March 2012
20. Global mobile Suppliers Association (August 2013). "Status of the LTE ecosystem".
21. ETSI TR 103 113, System Reference Document "Mobile broadband services in the 2300–2400MHz frequency band under Licensed Shared Access Regime", v1.1.1, July 2013.

EXAMPLES OF CURRENT USAGE AND PLANS FOR 2.3GHZ IN THE EU

	CURRENT USAGE / PLANS
GERMANY	In Germany, the range 2300–2320MHz is used for telemetry on a primary basis, including airborne, civil and military usage. The remainder of the band, 2320–2400MHz, is used for cordless cameras on a primary basis and radio amateurs on a secondary basis and is viewed as the primary band for cordless cameras even in the long term.
UK	Within the UK, the Ministry of Defence (MoD) is the incumbent user of the 2.3GHz band. The MoD has been incentivised to release and share spectrum based on Administered Incentive Pricing (AIP), allowing them to save costs by not paying AIP and to retain proceeds of spectrum sold or shared. They plan to sell 40MHz for exclusive access in 2014. The remainder of the band will be retained, so while this is a potential candidate for sharing no such plans have been announced, while other bands have been identified for shared use.
IRELAND	In Ireland, 2.3GHz has some existing licensed usage for rural fixed links (in 2 x 20 MHz of spectrum) at specific locations and some TV usage in the Dublin area in 8MHz of spectrum. Wireless cameras are licensed on a non-interference, non-protected basis. ComReg announced plans to release 2.3GHz with protection for incumbent usage in 2009, potentially including geographically shared licences.
ITALY & SLOVENIA	In Italy and Slovenia the 2.3GHz band is used for wireless cameras.
SWEDEN	Sweden consulted on a planned auction of 2.3GHz for mobile broadband in January 2012. It is understood that the band is current unoccupied, suggesting that any licensing would be on a conventional exclusive basis.
NORWAY	In Norway the band 2301-2323MHz was auctioned on an exclusive national basis in 2006.

Table 4

Source: Deloitte and Real Wireless research

5.3.2 INCUMBENT TYPES AND APPLICATION CHARACTERISTICS

The 2.3GHz band is currently used in various capacities across the EU. Several key incumbent uses are identified below and have distinct characteristics, affecting the options for spectrum sharing.

KEY INCUMBENTS AND INCUMBENT USES IN THE 2.3GHZ BAND IN THE EU

AERONAUTICAL TELEMETRY	This includes telemetry from aircraft and missiles to ground stations and is also used to transmit signals between ground stations.
AMATEUR RADIO	This includes two way ad hoc terrestrial communications with both fixed and mobile usage. While amateur usage typically operates without specific interference protections, the radio characteristics are variable and produce significant uncertainty for an LSA licensee sharer.
PROGRAMME MAKING AND SPECIAL EVENTS	This includes both Services Ancillary to Programme-Making (SAP) and Services Ancillary to Broadcasting (SAB). Deployments may be both urban and rural and include cordless camera links and mobile / portable video links. Depending on the regulatory regime, these services may be treated as an incumbent or as an LSA licensee sharer.
ADJACENT SERVICES	In addition to the incumbent usage in the band, there are several important adjacent services which have to be protected in either exclusive or shared usage. In 2.2-2.3GHz there are defence radio relay links (2200-2245MHz); radio astronomy (at specified locations in Germany, Italy, Norway, Spain); SAP/SAB; space research and space operation (space to earth); satellite payload and space research platform telemetry (deep space). In 2.4-2.5GHz there are Amateur satellite; short range devices; radio determination; railway; RFID; wideband data systems (e.g. Wi-Fi, Bluetooth); IMT satellite component; mobile satellite applications and SAP/SAB.

Table 5

Source: Deloitte and Real Wireless research

5.3.3 POTENTIAL MNO BENEFITS

Opening up the 2.3GHz frequency band in the EU for shared spectrum could lead to several key benefits for MNOs. Depending on the terms of the sharing agreement, these benefits will be realised to various extents. One view of these benefits is identified below, although the specifics will depend on the MNO's existing spectrum portfolio and the regulatory conditions in the relevant nation.

PRIMARY BENEFITS

CAPACITY

The 2.3GHz band could be used to increase the offload potential and performance with harmonised indoor and outdoor small cells, leveraging wide bandwidths (20MHz and above) potentially via LTE-Advanced carrier aggregation in combination with existing bands. The band could also increase the general capacity of existing macrocells.

HARMONISATION

As indicated earlier, harmonisation is both a precondition for spectrum sharing and a potential benefit where it already exists elsewhere. In the case of 2.3GHz, although the band is not currently harmonised in Europe, it has a high degree of harmonisation in other parts of the world. This creates two potential benefits: one to leverage the existing supply chain for 2.3GHz mobile devices, either directly using existing devices or more likely (given the need to support other EU bands) via reuse of chipsets and reference designs. Secondly, this increases the opportunity for EU operators to promote roaming on both an incoming and outgoing basis in this band and to potentially use 2.3GHz as an EU and Asia-wide "common denominator" band across affiliates or partners.

SECONDARY BENEFITS (COVERAGE)

Coverage is not a natural application for 2.3GHz as a shared high frequency band. Geographical limitations arising from sharing, which potentially vary over time, will not allow an MNO to provide consistently national coverage, while the relatively high frequency does not lend itself to economical wide area or deep indoor coverage. Nevertheless, the band could potentially be used via small cells deployed outdoors to increase the depth of urban indoor coverage, enhancing the capacity offload potential. Small cells are also being used to provide rural coverage to isolated communities where conventional macrocells are not economical and here the dependence on frequency is less than for macrocells. The low power nature of small cells could extend the area over which a frequency band could be used, as illustrated in Figure 17. Blue areas are only available to macrocells, while green areas can additionally be accessed by outdoor microcells, yellow additionally by indoor picocells. Red areas are complete exclusion zones.

GEOGRAPHICAL AVAILABILITY OF 2.3GHZ AROUND A TELEMETRY INCUMBENT

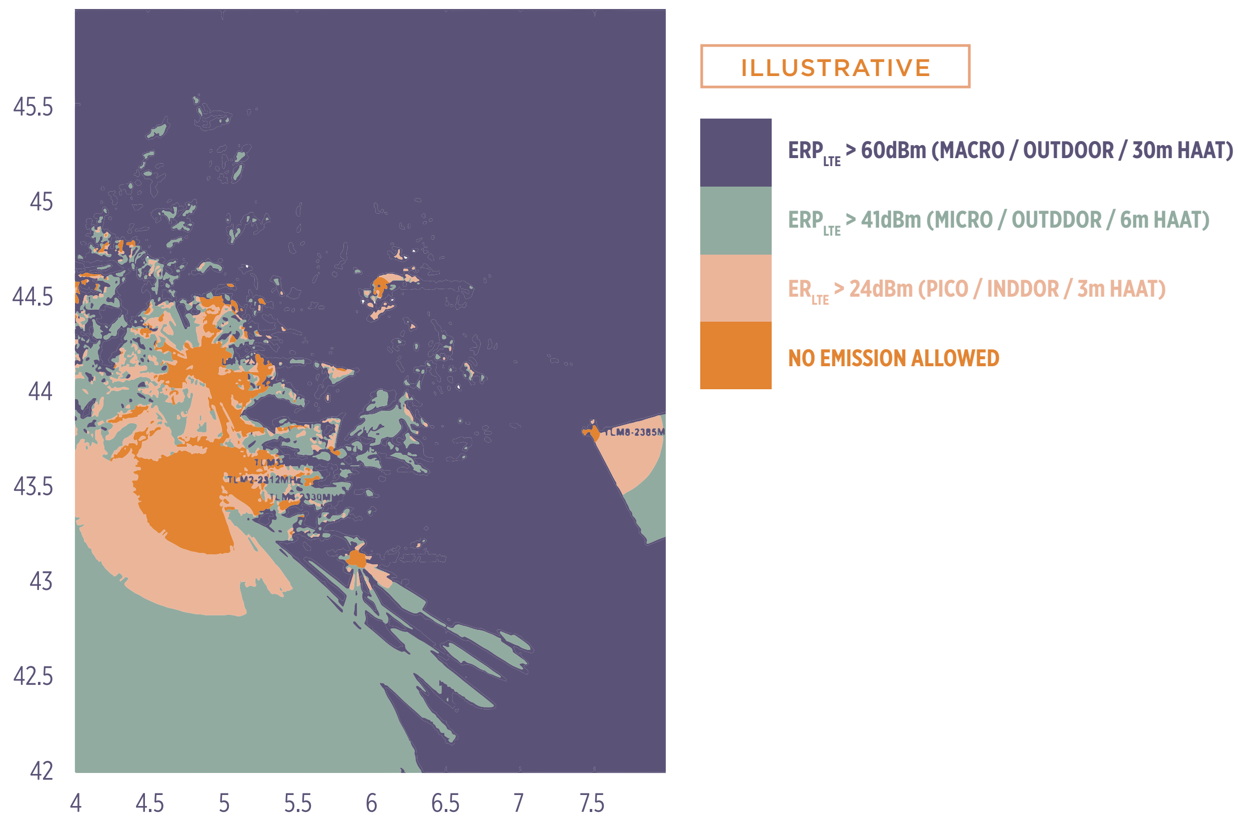


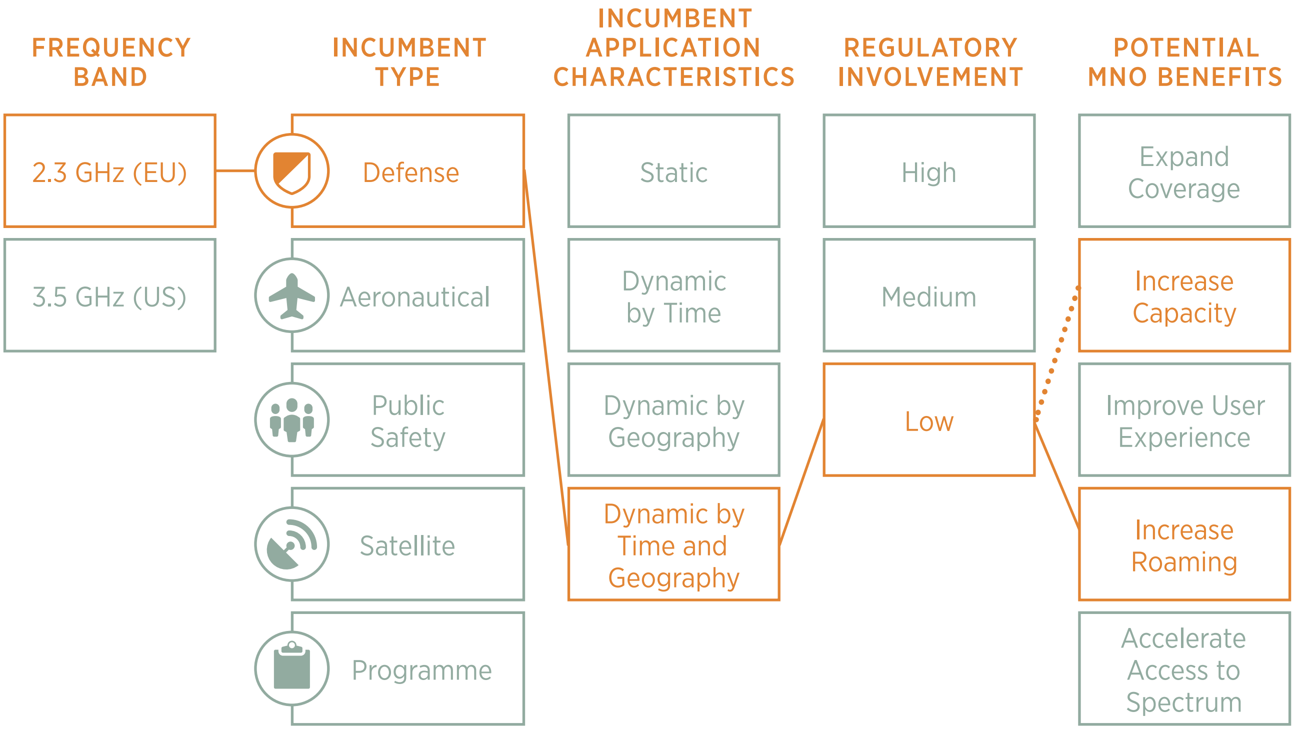
Figure 17

Source: “Optimisation of sharing under LSA with small cells”, ECC FM PT52 FM52(13)19, pg. 4 April 2013

5.3.4 SHARING SCENARIO

Given the considerations above, the likely sharing scenarios for 2.3GHz in the EU can be summarised as follows: an MNO seeking some combination of enhanced capacity and harmonisation in the 2.3GHz band with a military (or potentially PMSE wireless camera) incumbent which is dynamic by geography and time but can be addressed on a bilateral basis with minimal regulatory involvement.

THE EU SHARING SCENARIO



EU SCENARIO →

EU MNO sharing in 2.3GHz with a defense incumbent operating unmanned aerial vehicles, for the purpose of increased roaming (and some capacity benefit) via dynamic sharing; limited regulatory involvement.

Figure 18

Source: Deloitte and Real Wireless analysis

5.3.5 THE ECONOMIC IMPACT OF SHARING THE 2.3GHZ BAND

The economic benefits associated with sharing spectrum in the 2.3GHz band have been estimated on the basis of these following assumptions:

- 50MHz of spectrum in this band are made available on a shared basis, with full commercial deployment realised by 2020.[22]
- The spectrum is used to provide additional capacity for mobile broadband in network congested areas. The characteristics of this band make it particularly suitable for supporting traffic in capacity constrained areas and peak hours.

In Europe, a uniform approach is modelled across the 28 states to allow simple and effective comparison: it is however likely that alternative approaches may be followed in relation to this band and in particular that different timing of release in Europe may occur, as seen recently for the Digital Dividend. The effect of the potential fragmented approach to this band is also examined specifically below, as it could impair a full realisation of the benefits and reduced scale economies.

To estimate these benefits, the mobile broadband economic impact model described in Appendix A has been applied to the EU, first by estimating the economic impact of mobile broadband for the period 2013-2030, then by estimating how these would increase if 50MHz of spectrum in the 2.3GHz band is fully deployed on a shared basis from 2020. The model has been calibrated to reflect the features of the EU market and the technical characteristics of the 2.3GHz band. Then, a number of sharing-specific factors have been evaluated to determine the impairment discounts that should be applied to capture the conditions attached to spectrum sharing.

The results indicate that, if the spectrum was provided on an exclusive basis, this could generate an additional €124bn of value add across the EU28 economies over the period (€55bn in direct effects, €33bn in indirect effects and €35bn in induced effects), including €74bn of tax revenues to the government. In addition, up to €69bn of incremental consumer surplus could also be generated.

The impact on these benefits of the spectrum being provided on a shared basis is then evaluated. Taking into account the uncertainty derived from the increased risk premium required by operators to invest reduces the level of the economic benefits to €86bn of value add (€38bn in direct effects, €23bn in indirect effects and €24bn in induced effects), including €51bn of tax revenues to the government. The estimated incremental consumer surplus would be reduced to €48bn, with an overall 154,000 additional jobs supported through spectrum sharing across the EU, in the 2020-2030 period.

Having established the upper bound of the economic benefits, the model also examined how rapidly the economic benefits generated by shared spectrum are impaired as the sharing conditions deteriorate based on: geographic and timing exclusions, and contracting conditions.

Interviews with European operators have highlighted the key role of reaching a minimum scale of operation in this band for investment incentives. This would require a common approach to spectrum sharing, as a fragmentation in the EU approach to spectrum policy (as for the second extension to the Digital Dividend) risks severely impairing the benefits generated.

22. 50MHz are taken as an illustrative example, as the actual amount of spectrum made available for sharing in each EU country has not been defined to date. While the entire band could be made available for sharing, cross-country variations could derive from government and regulators retaining part of the spectrum for the incumbents' exclusive use. Further, in certain cases spectrum could be released for sharing on a gradual basis, depending on the initial success of sharing.

Operators have identified the five largest markets in the EU (UK, Germany, France, Italy and Spain) as a suitable minimum scale. While the full incremental value of spectrum sharing in the 2.3GHz band across the whole EU28 would be €86bn, sharing in the big 5 only would deliver €52bn of extra economic benefits.

In the absence of a minimum efficient scale, the economic benefits are assumed proportional to the market share of smaller spectrum-constrained operators who would rely on sharing to improve their position. In this case the total economic benefits drop to €5bn.

If population and time exclusions materialise, then benefits are reduced proportionally to the share of capacity constrained population and peak-time covered. For instance, if spectrum is available for sharing only in 50% of the mobile networks' peak times and 50% of the capacity-constrained population, then the total economic impact drops from €86bn to €43bn.

Considering the impacts of contract length between the incumbent user and the MNO, a sharing agreement in excess of 15 years is likely to deliver full economic benefits (€86bn). Contracts that do not guarantee that minimum investment period may deter larger operators from investing. If only smaller, spectrum-constrained operators invest, economic benefits could drop to €9bn.

Very short sharing agreements between the incumbent user and the MNO, lack of band harmonisation and dynamic sharing procedures could result in no economic benefits.

SUMMARY OF THE ECONOMIC BENEFITS OF SHARED SPECTRUM IN THE EU28, PRESENT VALUE OVER THE PERIOD 2018-2030, €BN

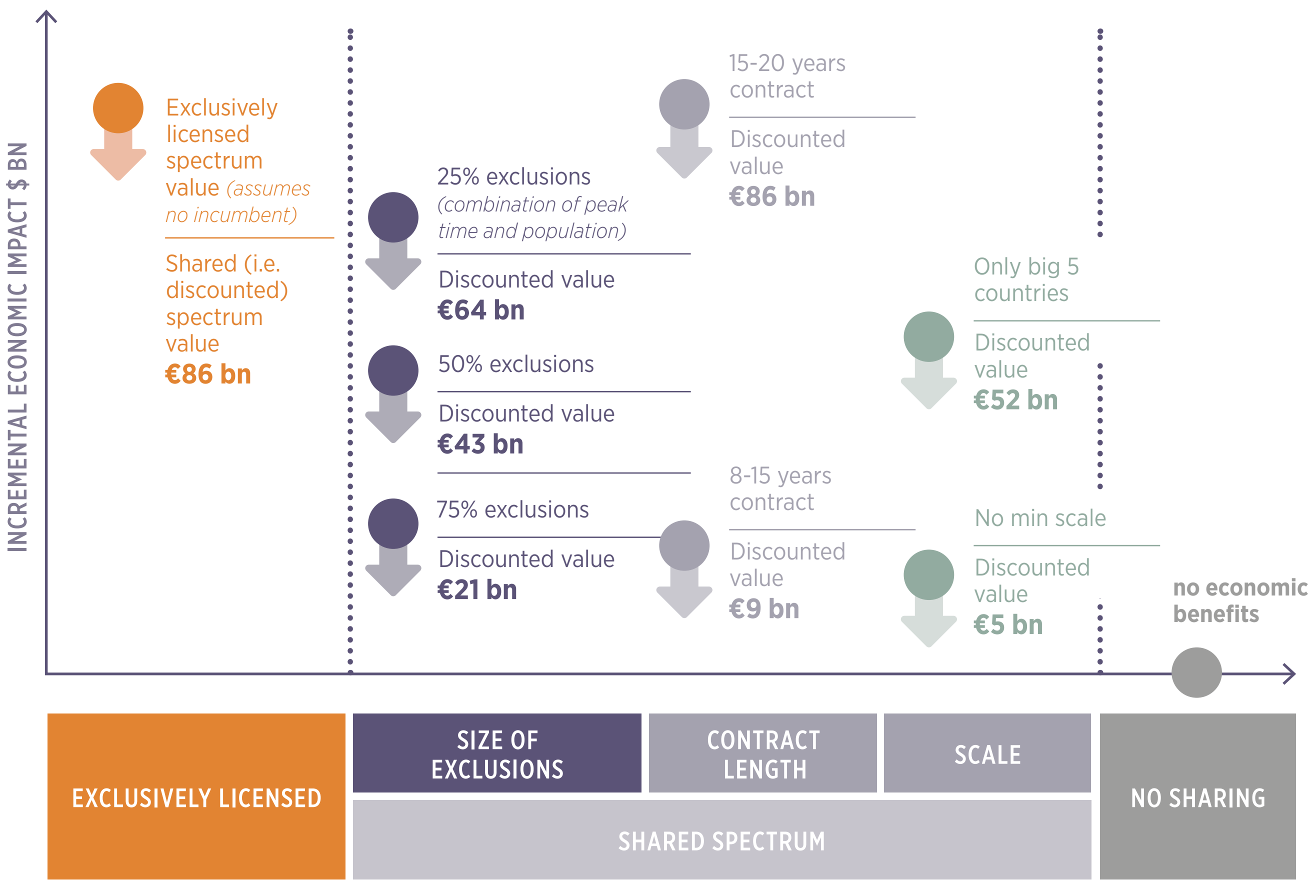


Figure 19

Source: Deloitte analysis

While an additional 50MHz of spectrum in the 2.3GHz band could deliver up to €86bn in economic benefits, population and time exclusions, contract length and scale of operation have the potential to rapidly reduce these benefits to zero. Figure 20 provides an illustrative example of sharing to show how rapidly the economic benefits in the EU28 can be impaired by poor sharing terms and conditions.

HOW RAPIDLY THE ECONOMIC BENEFITS IN THE EU28 CAN BE IMPAIRED BY POOR SHARING TERMS AND CONDITIONS, PRESENT VALUE OVER THE PERIOD 2018-2030, €BN

EU

In the EU, up to €86bn of value add could be generated over the period.
This rapidly decreases if a common approach across states is not implemented, and also as geographic and timing exclusions and contacting limitations become more severe.

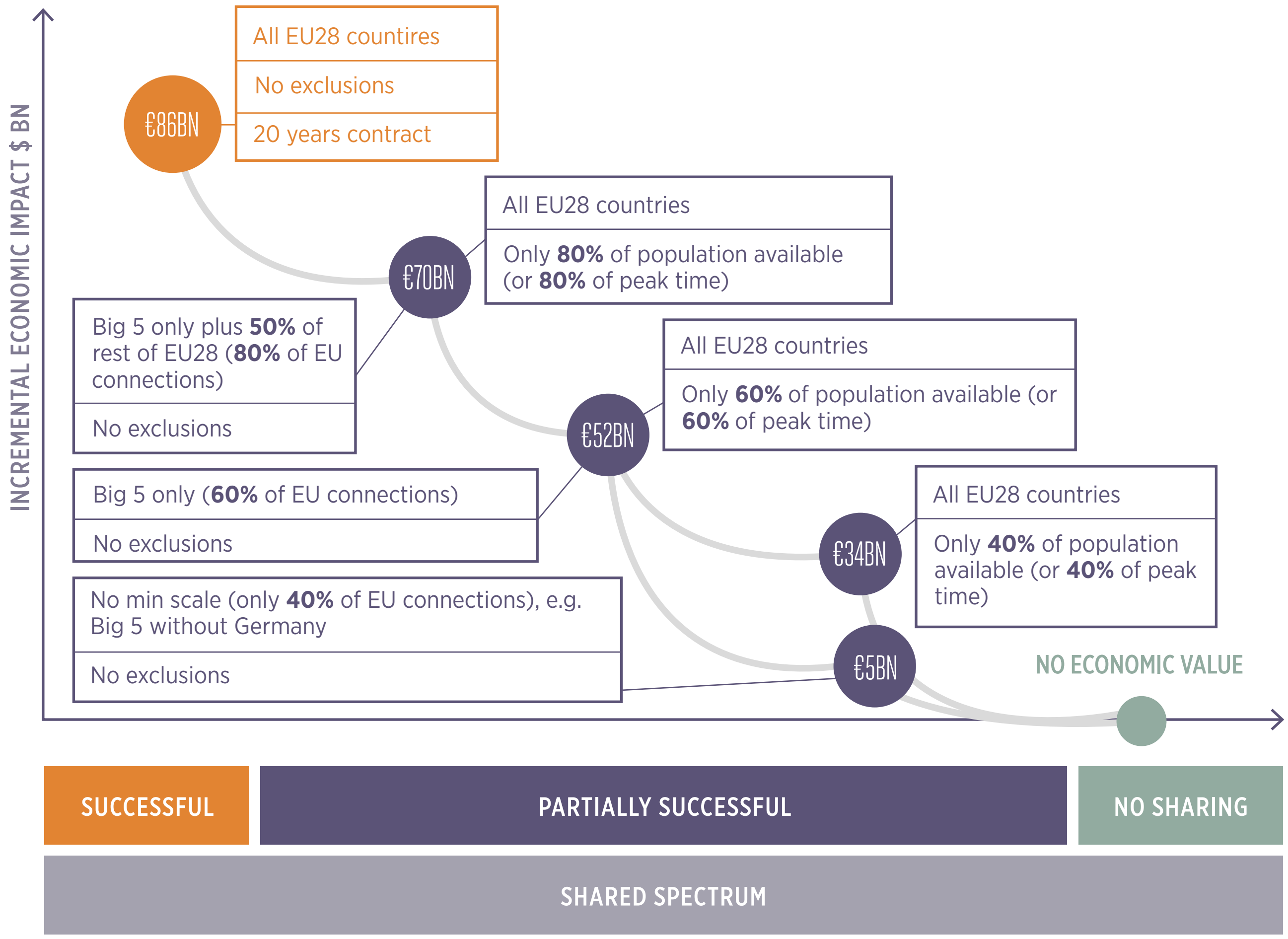


Figure 20

Source: Deloitte analysis

6

Key findings of this report

This section summarises the key findings that have emerged from the analysis of the potential approaches to vertical spectrum sharing and from the economic impact analysis of spectrum sharing.

6.1 KEY CONSIDERATIONS FROM THE STRATEGIC ANALYSIS

Spectrum sharing can deliver targeted benefits to MNOs if favourable agreements are reached with incumbents and if regulators provide a policy framework that enables and facilitates a negotiation process without being overly prescriptive in dictating solutions.

The many variables involved and the additional risks, complexities and uncertainties involved with spectrum sharing necessitate that each sharing opportunity be evaluated on a case by case basis, making no generalised approach possible.

If an appropriate regulatory framework for spectrum sharing is established, all parties will be focussed on maximising the likelihood of investment by MNOs and the generation of the relative benefits. Incumbents will be able to compensate their loss of exclusivity, regulators will reduce mobile spectrum shortfalls and will maximise spectrum utility, while MNOs will maximise the economic return from their assets supporting the sharing.

Due to the inherent limitations in its use, spectrum sharing is likely to be seen by MNOs as a narrower means to achieve incremental capacity in geographic areas facing potential demand peaks. If shared spectrum were to be offered at lower frequency ranges, this could constitute a potentially viable means to fill spectrum portfolio gaps in rural coverage or in select in-building coverage constrained markets.

Considering the uncertainties and complexities illustrated in Section 3 and 4, operators have noted that in general a solution whereby the incumbent migrates into a subset of frequencies which it retains under exclusive usage to allow exclusive licensing of the remaining frequencies for MNOs is likely to be more efficient and potentially produce a better result for the economy than sharing the entire band.

Should this option prove not viable, Figure 21 summarises the key considerations to be actively managed by the incumbents, regulators, MNOs and the mobile ecosystem if spectrum sharing is to become a meaningful reality and contributor to the mobile industry growth.

KEY STRATEGIC CONSIDERATIONS FOR THE DEVELOPMENT OF MNO VERTICAL SPECTRUM SHARING WITH INCUMBENTS

1	Sharing opportunities and value should be defined case-by-case	The many variables involved necessitate terms specific to each sharing opportunity. No generalised approach is possible.
2	Certainty is critical for establishing shared spectrum value	Sharing terms must be comprehensive, unambiguous and wit a multi-year valuation for MNOs to justify investments and manage risk
3	Less dynamic sharing arrangements are more feasible and attractive	Dynamic sharing crates inherent complexities and risks in both spectrum valuation and sharing execution
4	Incumbent must be properly incented to participate	Sharing by its nature creates value loss for incumbents, and proper incentives will be necessary to motivate successful voluntary incumbent participation

Figure 21

Source: Deloitte analysis

6.2 KEY CONSIDERATIONS FROM THE ECONOMIC ANALYSIS

To evaluate the additional economic benefits that spectrum sharing can provide by enhancing mobile broadband provision, the analysis should not just focus on the properties of the band and on the investment generated, but should also consider explicitly the limitations that the incumbent usage of the band and the terms and conditions that can be negotiated between the parties.

To reflect the extra complexities and risks involved with co-existence of more users in a single band, the expected benefits of shared spectrum compared to exclusive spectrum could be measured by applying an impairment discount to the calculation of the present value of these benefits. This maximum value may decrease in line with the size of population and peak time exclusions, together with other contractual elements such as the length of the sharing agreement.

Overall, this analysis reflects the view, expressed by mobile operators, that shared spectrum is not a complete substitute for exclusive spectrum, and that governments and regulators should not fully rely on shared spectrum for the provision of mobile broadband in the future.

Figure 22 summarises the key messages which emerged from the analysis of the economic benefits of spectrum sharing.

ECONOMIC IMPACT ANALYSIS: KEY FINDINGS

1	The economic benefits from adding spectrum for network capacity is unavoidable when spectrum is shared	While sharing will not be the main driver of mobile broadband, it may complement exclusive spectrum to provide capacity in congested areas and potentially deliver significant benefits
2	A discount on the economic impacts is unavoidable when spectrum is shared	• Additional risk and complexities associated with spectrum sharing make investment by mobile operators less certain compared to the case of exclusive spectrum • An impairment discount should be explicitly accounted for when considering the benefits of shared spectrum • After accounting for this discount, the benefits of spectrum sharing are significantly reduced
3	The size of exclusions and contracts length can rapidly impair the economic benefits	As sharing conditions and service exclusions become more severe, the effects of shared spectrum deteriorate and the economic benefits are rapidly reduced
4	Increased sharing dynamism is likely to result in no economic benefit	Sharing is unlikely to occur if unscheduled outages or dynamic conditions are too restrictive, if harmonisation and minimal scale are not present, and if contracts with primary users are too onerous. Additional economic benefits should not be assumed in these circumstances

Figure 22

Source: Deloitte analysis

Appendix A

Modelling the socio-economic benefits of mobile broadband

This Appendix:

- Discusses the socio-economic benefits of mobile broadband.
- Provides details on the model employed in this study to calculate such benefits, the additional impact of shared use of spectrum and the sensitivity of these results to a number of factors and conditions that arise when spectrum is provided on a shared basis.

A.1 THE SOCIO-ECONOMIC BENEFITS OF MOBILE BROADBAND

Spectrum is a vital asset to the EU and US economies and its value relates to the numerous applications for which it is an essential input. The application that in the future is likely to generate the highest value is mobile broadband.

Mobile broadband delivers a number of positive impacts throughout the mobile ecosystem and the wider economy. The mobile ecosystem is formed by providers of services to the mobile operators as well as by other parties, such as OTT players, and the wider economy. The positive effects of mobile broadband are then transmitted, through the ecosystem, to the entire economy. This is illustrated in Figure 23.

THE MOBILE BROADBAND ECOSYSTEM

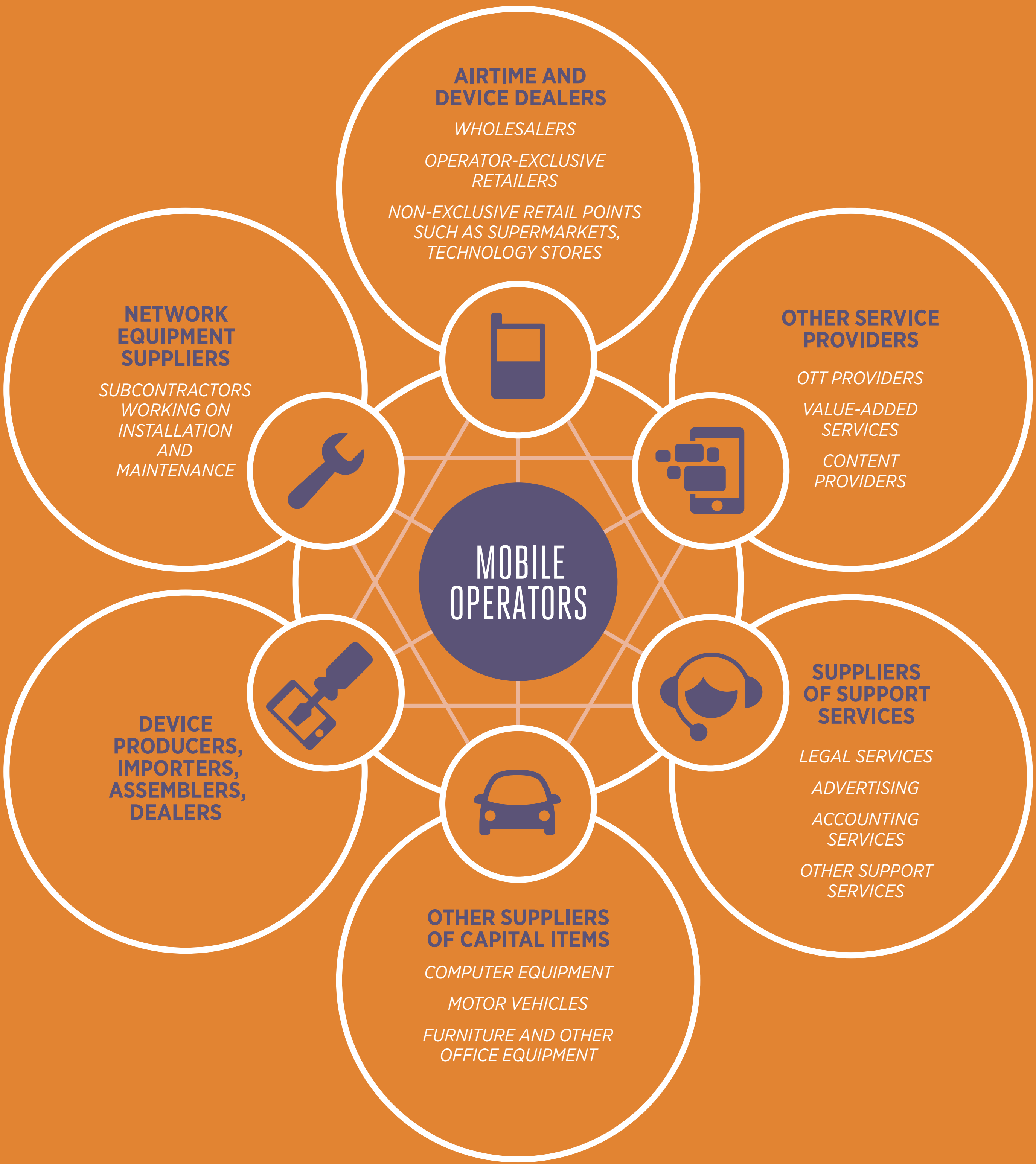


Figure 23

Source: Deloitte analysis

These positive economic impacts can be disaggregated into:

- The direct impacts and narrow effects generated by the investment and day-to-day activity of mobile operators.
- Indirect effects, accruing to third parties in the mobile ecosystem as a result of additional demand enabled by the mobile operators' activities, or additional revenues generated for third parties such as Value Added Services providers and Over The Top (OTT) players.
- The induced effects across the wider economy as result of these direct and indirect activities.
- Job creation, both directly from mobile operators and indirectly in the ecosystem and the economy.
- Revenues that the government collects through taxation.
- Broad effects accruing to third parties in the form of increased productivity and to consumers through consumer surplus generated by growing consumption.

SOCIO-ECONOMIC IMPACT OF MOBILE BROADBAND

Figure 24

Source: Deloitte analysis

Investment is the main driver of economic growth in a market-based economy. It is from investment that an economy expands its capital base, gives a boost to productivity, and increases exports through greater competeiveness. As a result, investment increases employment, income, and government tax revenues by expanding the workforce and the income base. Increased telecom investment expands overall capacity, thereby applying downward pressure on consumer prices.

Mobile broadband (Mbb) is also widely seen as having a key role in increasing economic growth through enhancements to the productivity of both labour and capital. Mobile broadband network investment affects economic competitiveness in two interrelated ways:

- First, the pace and magnitude of the network investment affects the economic activity of MNOs, their suppliers, and the workers they employ.
- Second, the pace and magnitude of the investment influences the economic activity of the organisations, households, and individuals who use the new networks.

PRODUCTIVITY EFFECT ASSOCIATED WITH MOBILE BROADBAND

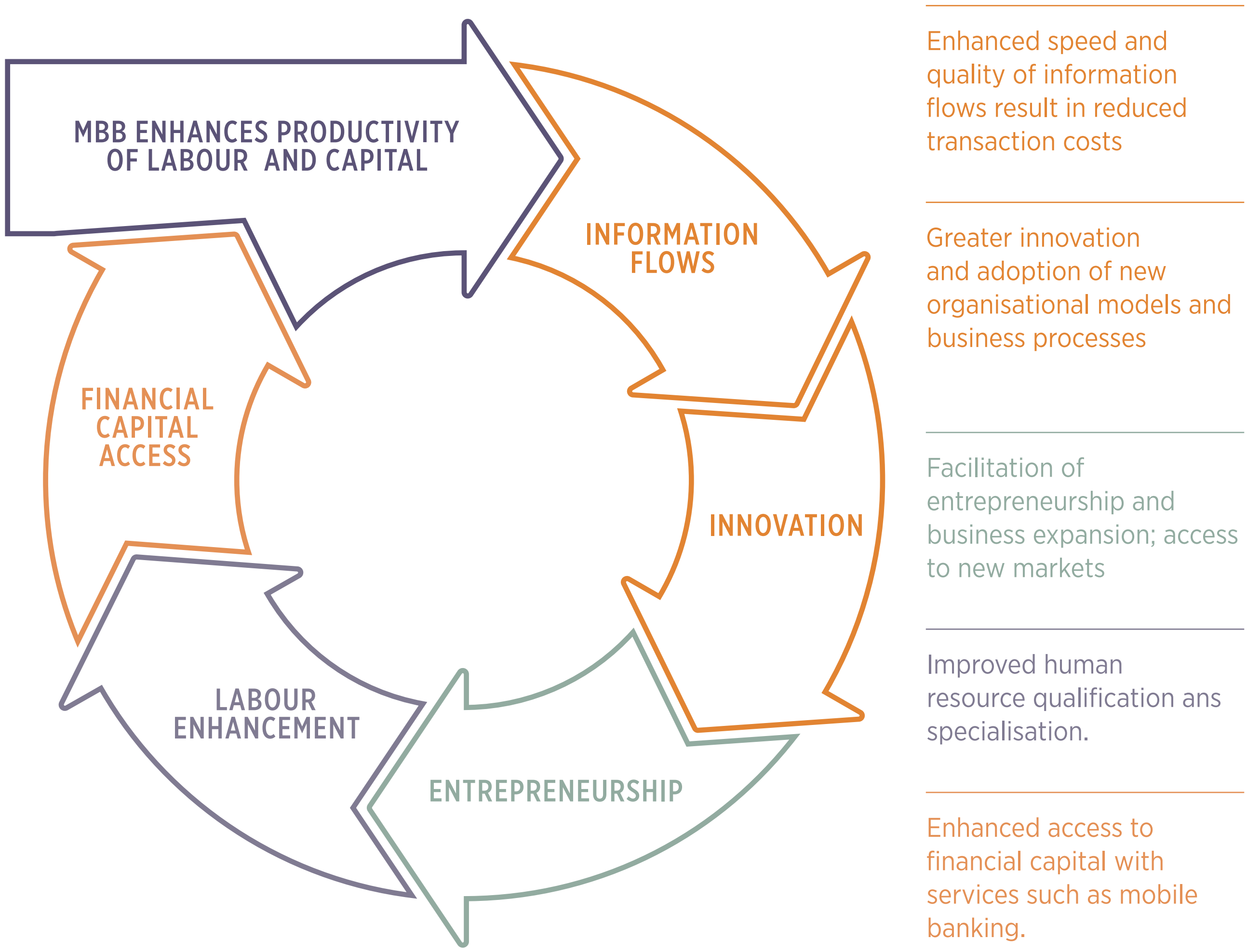


Figure 25

Source: Deloitte analysis

Finally, in addition to the economic benefits of mobile broadband, the sector delivers numerous social benefits, which have grown significantly in recent years. In addition to promoting communications and social cohesion, the increased availability of smartphones and tablets allows services such as m-health and m-education to be provided in rural and remote areas, with significant spillovers to societies and economies. The key social benefits generated by mobile broadband are summarised in Figure 26.

SOCIAL BENEFITS OF MOBILE BROADBAND

IMPROVED POSSIBILITIES FOR EDUCATION

- Enhanced technical literacy
- Improved education possibilities, such as through access to information and resources over the internet, as well as educational software and applications for computers and mobile phones.

DISSEMATION OF USEFUL INFORMATION

- Access to relevant information through communication between individuals or through software and applications that disseminate information. Mbb is used to disseminate health-related information such as vaccine scandals.
- Mbb technologies enable dissemation of locally-generated information and can be valuable in preserving and promoting local cultures.
- Improved quality and reach of public services, and increased goverment efficiency, transparency and accountability.
- Aiding in disaster relief through communication of risks and enabling location of individuals and resources.

SOCIAL COHESION

- Promoting social capital and social cohesion thorugh increased linkages.
- Increased equity and integration of marginalised groups. As Mbb dependence increases globally and within countries, those without access are increasingly marginalised and excluded.

Figure 26

Source: Deloitte analysis

These additional benefits to consumers from using mobile broadband range from promotion of communications and connectivity to social cohesion, are typically measured using a concept known as consumer surplus; this measures the difference between the overall amount that consumers are willing to pay for mobile broadband services and the amount that they actually pay. More details on this are contained in Section A.2.1.2.

A.2 THE MODEL FOR THE CALCULATION OF THE ECONOMIC IMPACT OF MOBILE BROADBAND

This section provides details on:

- The general framework adopted to quantify the benefits of additional spectrum used to provide mobile broadband services.
- The application of the above general framework to a number of illustrative scenarios for the EU and the US.
- The modelling approach adopted to evaluate how the economic benefits of additional shared spectrum differ compared to exclusive spectrum and how these benefits vary depending on a number of terms and conditions of the sharing agreement.

A.2.1 THE GENERAL FRAMEWORK

The socio-economic impacts of mobile broadband are measured by constructing a market demand and supply model which forecast how consumers and companies interact in the mobile broadband market over a period of time. This allows to estimate the size of economic benefits, such as consumer and producer surplus, generated by the mobile broadband ecosystem, as illustrated in Figure 27.

THE FRAMEWORK FOR THE ECONOMIC IMPACT OF MOBILE BROADBAND

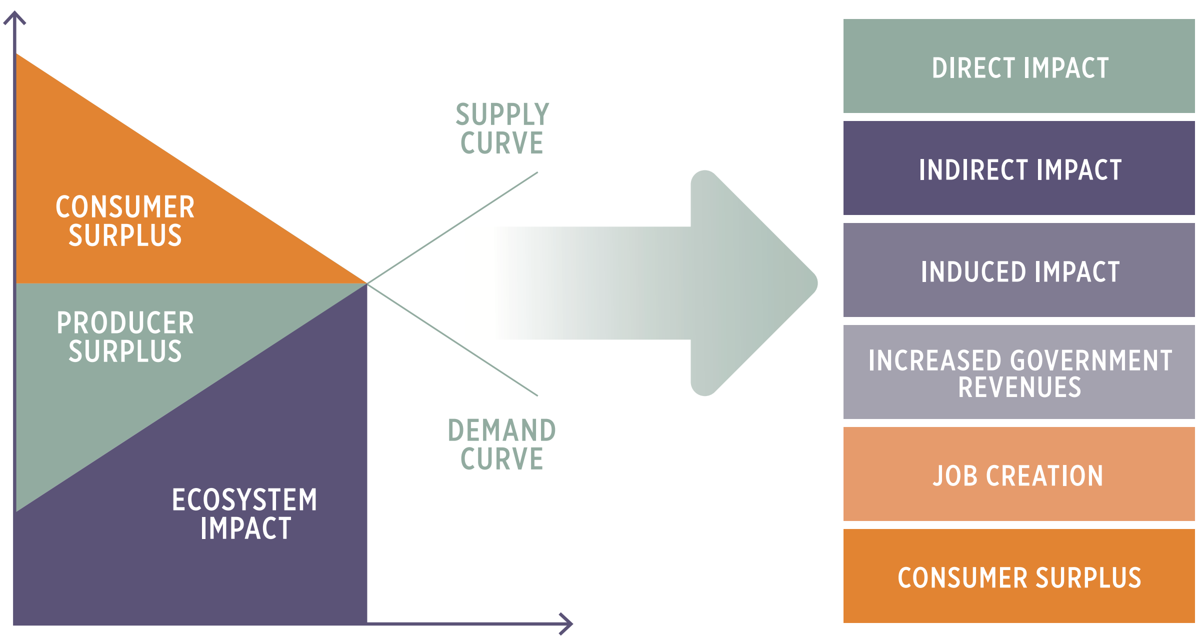


Figure 27

Source: Deloitte analysis

A.2.1.1 PRODUCER SURPLUS AND ECOSYSTEM IMPACTS

This model explicitly links market prices, market volumes such as usage per user and number of connections across mobile services (smartphone, tablets, dongle users and M2M) to the estimation of the producer and consumer surplus generated in the economy. It also estimates how the economic activity generated directly by mobile operators translates into indirect and induced impacts in the ecosystem and the wider economy, respectively, as indicated in Figure 28. In estimating the above impacts, the model provides an analysis at market level, without taking a view on how these impacts are attributed to individual mobile operators.

THE ECONOMIC IMPACT MODEL, PRESENT VALUE OVER THE PERIOD 2013-2030, $BN

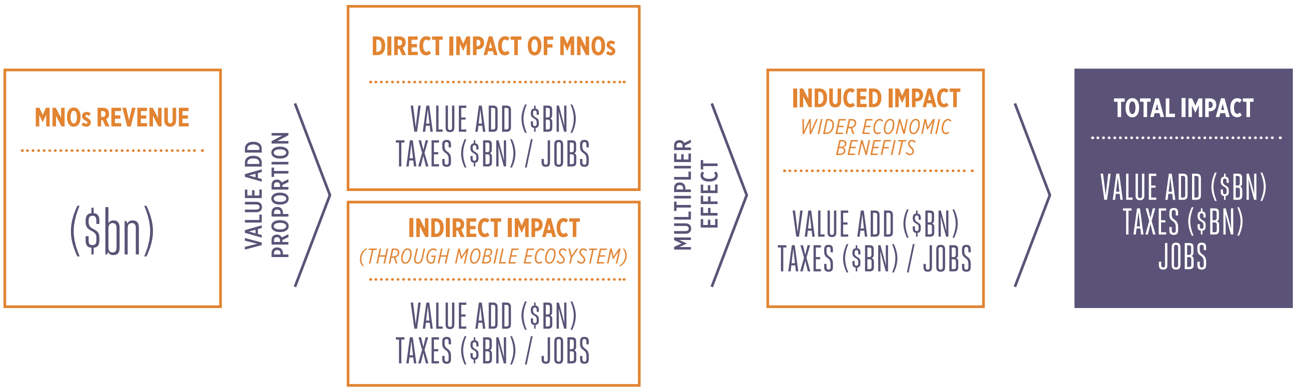


Figure 28

Source: Deloitte analysis

The model calculates market revenues as the product of mobile broadband ARPU and the number of mobile broadband connections. These correspond to the area of the rectangle formed by the two blue triangles in Figure 27. Using a set of benchmarks from numerous economic impact studies[23], these revenues are used to estimate the size of the impact that directly accrues as value added to MNOs and to the ecosystem. Similarly, based on an estimation of the proportion of revenue that is paid as tax deriving from mobile tax studies undertaken for the GSMA[24], the proportion of this value add corresponding to tax payments is also estimated. Based on benchmarks from previous studies, also salary payments and the number of Full Time Employees (FTEs) employed directly by MNOs and by the ecosystem are estimated. Finally, a set of economic multipliers are employed to provide an indication of the induced effects of mobile broadband activities on the wider economy.

A.2.1.2 CONSUMER SURPLUS

Consumer surplus, illustrated by the green triangle in Figure 27, is calculated based on the assumption of a linear, downward-sloping demand curve. The supply curve crosses the demand curve at a point where the quantity is equal to the current number of connections and the price is equal to the current mobile broadband ARPU. The price at which demand becomes zero (i.e. where the demand curve crosses the y-axis) is referred to as the choke price.[25] The consumer surplus is a measure of the difference between the maximum amount that customers would be willing to pay and the total amount that they actually pay. This is calculated as:

0.5×(CHOKE PRICE- ARPU)×CONNECTIONS

23. Deloitte has produced an analysis of economic benefits of mobile broadband and mobile telephony for the GSMA and other mobile operators in the following countries: Brazil, Argentina, Mexico, Chile, Uruguay, Peru, Colombia, Ecuador, Panama, Turkey, Croatia, Serbia, Ukraine, Pakistan, East Africa, and Sudan.
24. See for instance the Deloitte/GSMA "Global Mobile Tax Review 2011".
25. The choke price is defined as the point at which demand for a service would fall to zero.

A.2.1.3 ASSESSING THE BENEFITS SPECTRUM IN THE SCENARIOS CONSIDERED

In summary, the model calculates the present value (in 2013 terms) of the economic benefits of mobile broadband over the period 2013-2030. The main outputs produced are the following:

- MNOs' revenues.
- Direct economic impact from the mobile operators (value added, government tax revenues, jobs).
- Indirect economic impact from the mobile ecosystem (value added, government tax revenues, jobs).
- Induced economic impact (multiplier effect) from the wider economy (value added, government tax revenues, jobs).
- Consumer surplus.

The framework presented above has been applied to a number of scenarios in order to estimate:

- The economic and social impact of mobile broadband from 2013 to 2030 for the US and for EU28, under the assumption that no shared spectrum is made available in this period ("the counterfactual").
- How this impact varies if extra spectrum is added. It has been assumed that that 100MHz of spectrum are added in the US in the 3.5GHz band from 2016, and that 50MHz of spectrum are added in the EU28 in the 2.3GHz band from 2020 (uniformly across all 28 countries).
- How economic benefits change depending on whether additional spectrum is provided on an exclusive basis or on a shared basis.
- How economic benefits are rapidly reduced as the sharing terms and conditions (such as population, time exclusions and contract length) between the incumbent and the MNO deteriorate.

While it is recognised that modelling such a dynamic and innovative market until 2030 will underestimate future innovations and market changes, the purpose of this exercise is to capture at a high level the incremental impacts of sharing in a market that is modelled to develop according to the trends that have emerged in recent years.

A.2.2 THE IMPACT OF MOBILE BROADBAND WITHOUT ADDITIONAL SHARED SPECTRUM

The counterfactual scenario has been constructed as follows:

- The mobile broadband market continues to grow in line with the forecasts available.
- Exclusively licensed spectrum continues to be made available to mobile operators as planned, to allow operators to continue to serve traffic increases driven by the proliferation of smartphones and other mobile broadband-enabled devices such as tablets, data cards and M2M connections.
- Usage per connection increases due to the transformation in the consumer services available for these devices.
- While exclusive spectrum will continue to be made available, this scenario also assumes that network congestion still materialises in the short/medium term, with operators requiring spectrum to fill capacity gaps.

The assumptions made with regards to indicators such as number of connections, usage and mobile broadband ARPU levels are reported below.

A.2.2.1 NUMBER OF MOBILE BROADBAND CONNECTIONS

Connections used in the modelling include smartphones, tablets, dongles, data cards, and M2M connections (feature phones have not been considered given the focus of the study on mobile broadband). Between 2013 and 2017, each of the above connection types has been assumed to grow as indicated by the Cisco Visual Networking Index.[26] For the 2017-2030 period, the following assumptions have been made:

- The total penetration of mobile handsets (smartphones plus feature phones) is assumed to remain constant. The share of smartphones gradually increases up to 100% in 2030, at which point all mobile handsets are constituted by smartphones.
- Tablet penetration increases gradually to become 40% in 2030.
- Dongles penetration increases gradually to become 15-20% in 2030.
- M2M connections reach approximately 45-50% of the total connections in 2030.[27]

CONNECTIONS PENETRATION TRENDS IN EU28 (LEFT) AND US (RIGHT)

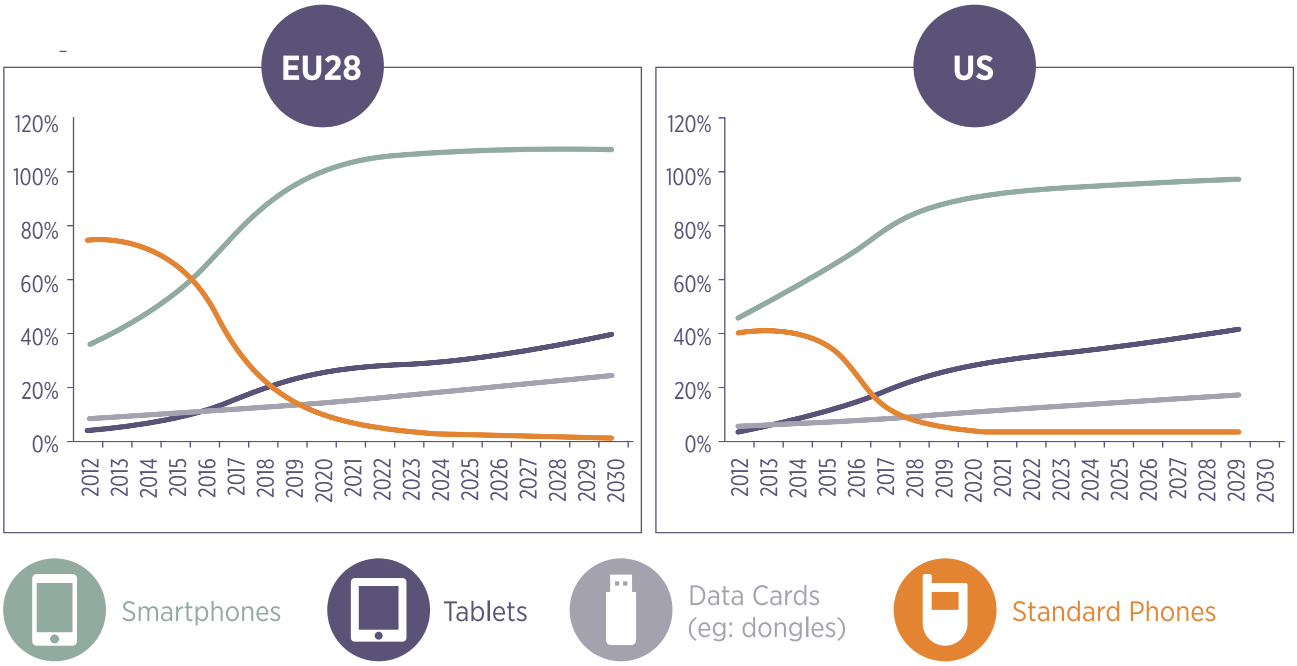


Figure 29

Source: Deloitte analysis based on data from Wireless Intelligence and the Cisco VNI

26. http://www.cisco.com/web/solutions/sp/vni/vni_forecast_highlights/index.html
27. Sources such as Buddecom (Global telecoms. Industry transformation with M2M, cloud computing, big data, Wi-Fi, and new spectrum) suggest that M2M connections could represent up to 45% of total connections already in 2020.

A.2.2.2 TOTAL MOBILE BROADBAND TRAFFIC

Between 2013 and 2017, total mobile broadband traffic has been assumed to grow as indicated by the Cisco Visual Networking Index.[28] After 2017, traffic is driven by the increase in the number of connections, as illustrated above, and by an increase in usage per device.

The total traffic considered in the model has been adjusted account for offloading, and the resulting growth in total traffic (i.e. net of offloading) is shown in Figure 30.

TOTAL MOBILE BROADBAND TRAFFIC NET OF OFF-LOADING (MULTIPLES OF 2012 VALUES) IN EU28 AND US

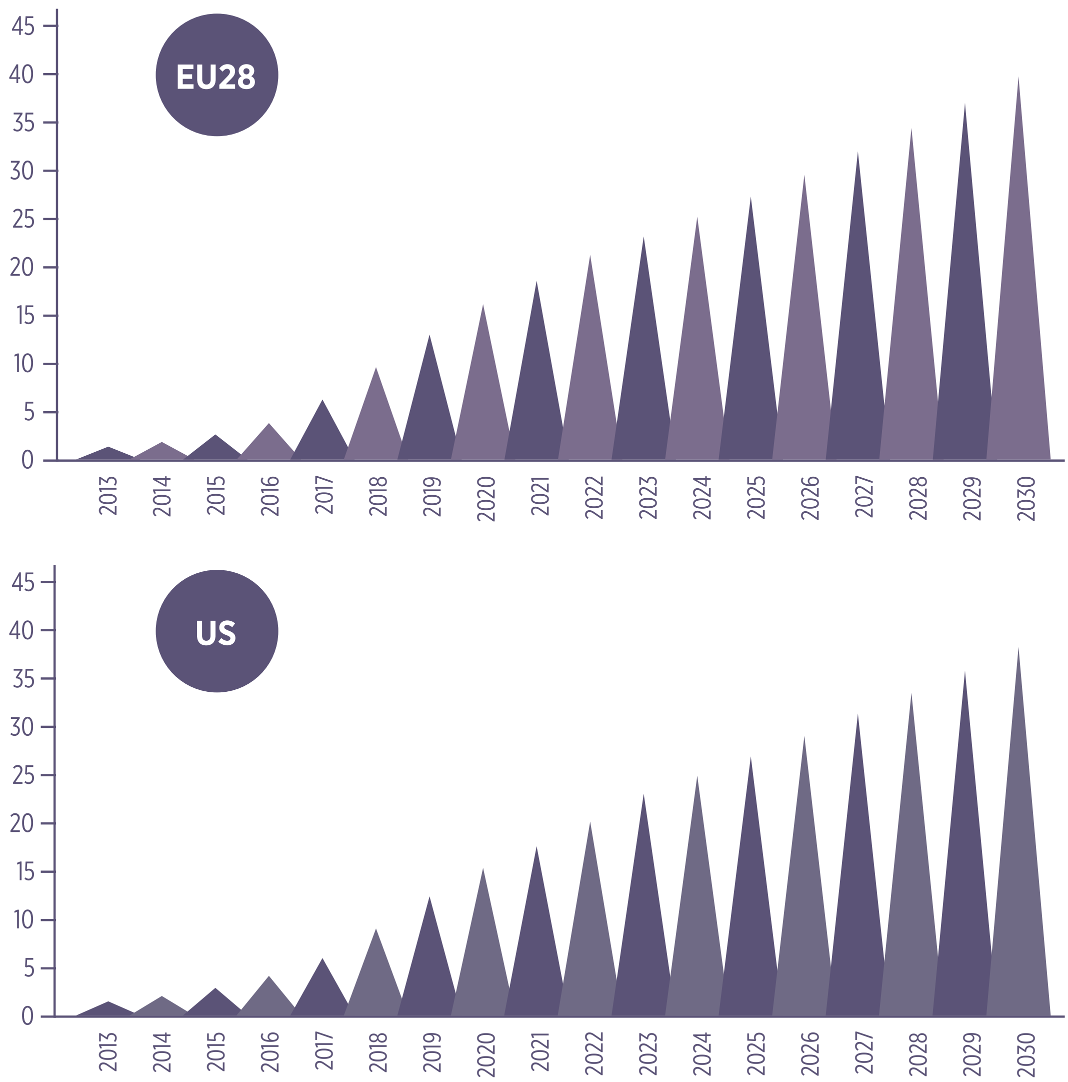


Figure 30

Source: Deloitte analysis based on total traffic projections from Real Wireless

28. http://www.cisco.com/web/solutions/sp/vni/vni_forecast_highlights/index.html

A.2.2.3 ARPU

Between 2013 and 2015, mobile data ARPU has been assumed to move according to forecasts provided by Gartner.[29] After 2015, total ARPU (voice plus non voice, including data) has been assumed to remain constant, while the share of total ARPU attributed to mobile broadband services will represent 100% of total ARPU in 2030.

TOTAL MOBILE BROADBAND ARPU LEVEL TRENDS IN EU28 (TOP) AND US (BOTTOM)

Figure 31

Source: Deloitte analysis based on data from Gartner and Wireless Intelligence

29. Gartner. “Forecast: Mobile Services, Worldwide, 2008-2016, 3Q12 Update”.

A.2.2.4 CHOKE PRICE

While choke prices are best calculated based on consumer surveys of willingness to pay, the value of the choke price in this model has been estimated as follows:

$$P_{choke} = ARPU \times (1 + \frac{1}{\varepsilon}),$$ **where ε represents the price elasticity of demand.**

To estimate choke price in the EU and the US, available existing data on price elasticity of demand estimate has been considered[30] and a final elasticity of -1 has been selected.

A.2.2.5 DATA FOR THE EU28

In relation to data for the EU28 region, the model's inputs are provided at a high degree of granularity for the "big 5" markets in the EU (UK, Germany, France, Italy and Spain). While the big 5 represent approximately 60% of the EU28 connections, an uplift of all modelling inputs has been performed from these five markets in order to obtain the overall economic impact for the EU28:

- The number of connections for each device type (smartphone, tablet, data cards, and M2M) is uplifted based on information on population and total connections.
- The total usage for the other countries was constructed as an uplift based on the number of connections in the other countries compared to the big 5.
- The ARPU for the non-big 5 was assumed to be 50% of the ARPU for the big 5.

This "bottom-up" approach represents an improvement with respect to previous studies which have instead calculated the economic impacts for the main markets and then uplifted this impact to get the relative figures for the entire EU. The implicit assumption of these studies is that the economic impact generated in markets outside the big 5 is the same (after controlling for the size of the market) as the impact generated in the big 5.

30. A number of elasticity measures for mobile services are summarised in Analysys Mason (2012). "Impact of radio spectrum on the UK economy and factors influencing future spectrum demand".

A.2.2.6 THE VALUE ADD PROPORTIONS

The benchmarks employed to estimate value add, indirect impacts, taxation, and wages, as well the multipliers employed, are reported in the table below.

BENCHMARKS FOR THE ECONOMIC IMPACT ANALYSIS

BENCHMARK	VALUE	SOURCE
DIRECT (MNO) VALUE ADDED AS A PROPORTION OF MNO REVENUES	40%	DELOITTE PREVIOUS ECONOMIC IMPACT STUDIES
INDIRECT (ECOSYSTEM) VALUE ADDED AS A PROPORTION OF MNO REVENUES	24%	DELOITTE PREVIOUS ECONOMIC IMPACT STUDIES
WIDER ECONOMY VALUE ADDED (MULTIPLIER EFFECT) AS A PROPORTION OF THE JOINT MNO AND ECOSYSTEM VALUE ADDED	40%	DELOITTE PREVIOUS ECONOMIC IMPACT STUDIES
TAXES AS A PROPORTION OF VALUE ADDED	60%	DELOITTE PREVIOUS ECONOMIC IMPACT STUDIES
TOTAL SALARY PAYMENTS AS A PROPORTION OF VALUE ADDED	25%	DELOITTE PREVIOUS ECONOMIC IMPACT STUDIES

Table 6

Source: Deloitte analysis

A.2.2.7 RESULTS

In summary, following the above methodology, the model calculates the present value (in 2013 terms) of the economic benefits of mobile broadband in the US and the EU28 over the period 2013-2030. For the US, the overall calculated impact consists of an $3,370bn of value add across the economy ($1,500bn in direct effects, $900bn in indirect effects and $960bn in induced effects) could be generated, including $2,000bn of tax revenues to the government. In addition, up to $1,880bn of consumer surplus and an overall 2,100,000 jobs are supported by the US mobile broadband economy across 2013-2030.

US — THE IMPACT OF MOBILE BROADBAND IN THE US, PRESENT VALUE OVER THE PERIOD 2013-2030, $BN

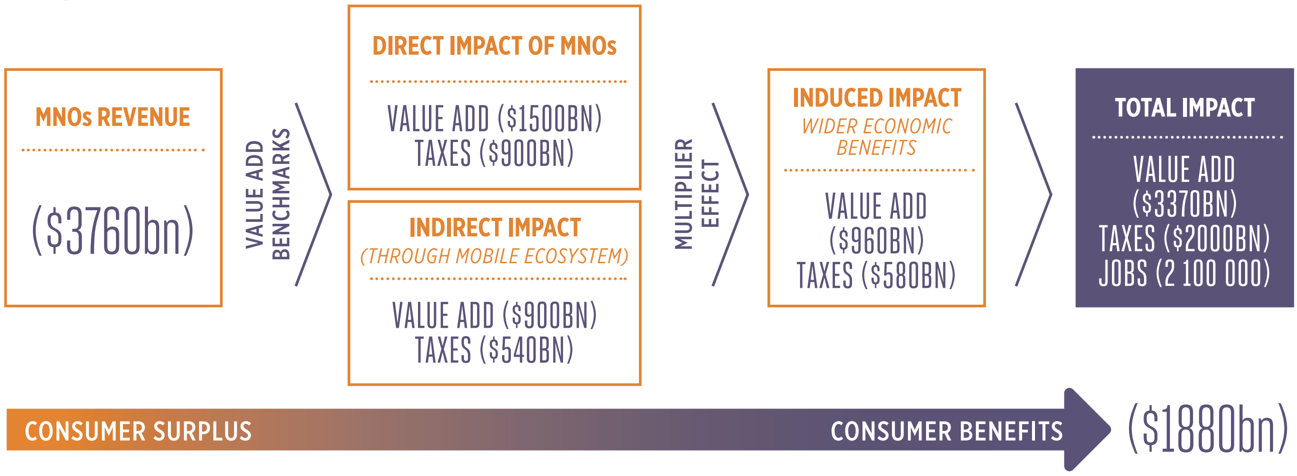


Figure 32
Source: Deloitte analysis; Numbers might not sum up due to rounding.

For the EU, the overall calculated impact consists of €1,640bn of value add across the economy (€730bn in direct effects, €440bn in indirect effects and €470bn in induced effects), including €985bn of tax revenues to the government. In addition, up to €915bn of consumer surplus and an overall 1,550,000 jobs are estimated to be supported by the EU mobile broadband economy across 2013-2030.

EU28 — THE IMPACT OF MOBILE BROADBAND IN THE EU, PRESENT VALUE OVER THE PERIOD 2013-2030, €BN

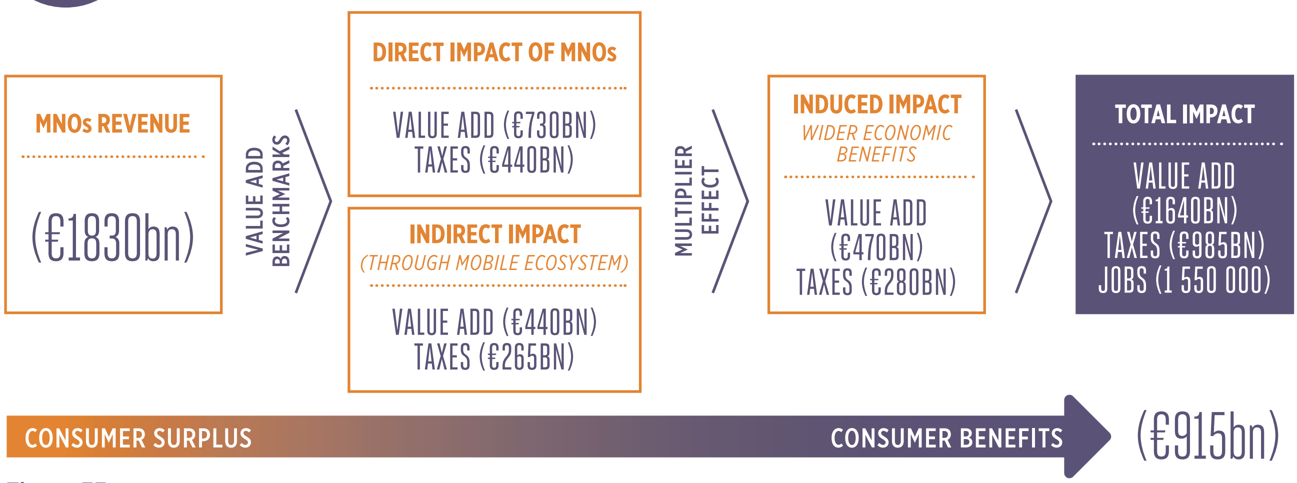


Figure 33
Source: Deloitte analysis; Numbers might not sum up due to rounding.

A.2.3 THE ECONOMIC IMPACT OF ADDITIONAL SPECTRUM

The difference between the counterfactual and the base case scenario is that an additional 100MHz of spectrum are made available in the US in the 3.5GHz band from 2016 (with full commercial deployment assumed from 2018), and that an additional 50MHz of spectrum are made available in the EU28 in the 2.3GHz band from 2020.

This base case scenario assumes that additional spectrum is made available in the US and the EU and that this spectrum is provided exclusively for use of mobile broadband for capacity purposes.

To determine the upper bound of the economic benefits, the model first produces the impact as if the spectrum were made available on an exclusive basis. A series of discount factors is then applied to capture the potential value of the spectrum being provided on a shared basis.

The introduction of extra spectrum leads to the following changes:

1. As a result of the incremental spectrum made available, network efficiencies are generated. This impacts cost per MB and (on an assumption of constant price-cost ratio), price per MB. This relationship is modelled based on studies undertaken by Real Wireless[31] on the cost saving obtained by operators as more spectrum becomes available.

   The contribution of additional spectrum to the generation of network efficiencies has been assumed to be dependent on the following two factors:

   a. The amount of additional spectrum (higher network efficiencies have been assumed for the US case study, to reflect the fact that 100MHz are made available for sharing compared to 50MHz in the EU).

   b. The frequency range of the band itself (comparatively lower network efficiencies have been assumed in the US case study, to reflect the worse quality of propagation delivered by the 3.5GHz band compared to the 2.3GHz band shared in the EU).

2. Harmonisation and scale economies drive device efficiencies, reducing the cost of the devices that consumers require for mobile broadband, which in turn increases the number of new connections. This relationship is modelled based on previous studies undertaken by the GSMA[32] on the impact of harmonisation on device costs.

3. Better, faster and more reliable mobile broadband increase quality of service, impacting usage per user and consumers' willingness to pay. This relationship is modelled by assuming that the improvements in service quality deriving from additional spectrum determine an increase in ARPU. The contribution of additional spectrum to improvements in the quality of service have been made dependent on the following two factors:

   a. The amount of additional spectrum (higher quality improvements have been assumed for the US case study, to reflect the fact that 100MHz are made available for sharing compared to 50MHz in the EU).

   b. The frequency range of the band itself (comparatively lower quality improvements have been assumed in the US case study, to reflect the worse quality of propagation delivered by the 3.5GHz band compared to the 2.3GHz band shared in the EU).

The three dynamics above imply that, once additional shared spectrum is made available to mobile operators, the number of connections, the ARPU and the choke price vary compared to the counterfactual scenario. These changes in market prices and quantities generate variations in producer and consumer surplus. Inputting these revised values into the model provides the total value of mobile broadband under the base case scenario.

31. Real Wireless for Ofcom. Techniques for increasing the capacity of wireless broadband networks: UK, 2012-2030.
32. See for example: http://www.gsma.com/spectrum/wp-content/uploads/2012/04/gsmawhitetechnote.pdf

The difference between the economic impact under the base case scenario and the counterfactual scenario provides the incremental impacts associated with additional spectrum, assuming that this spectrum were provided exclusively for use of mobile broadband for capacity purposes.

THE SCENARIOS MODELLED

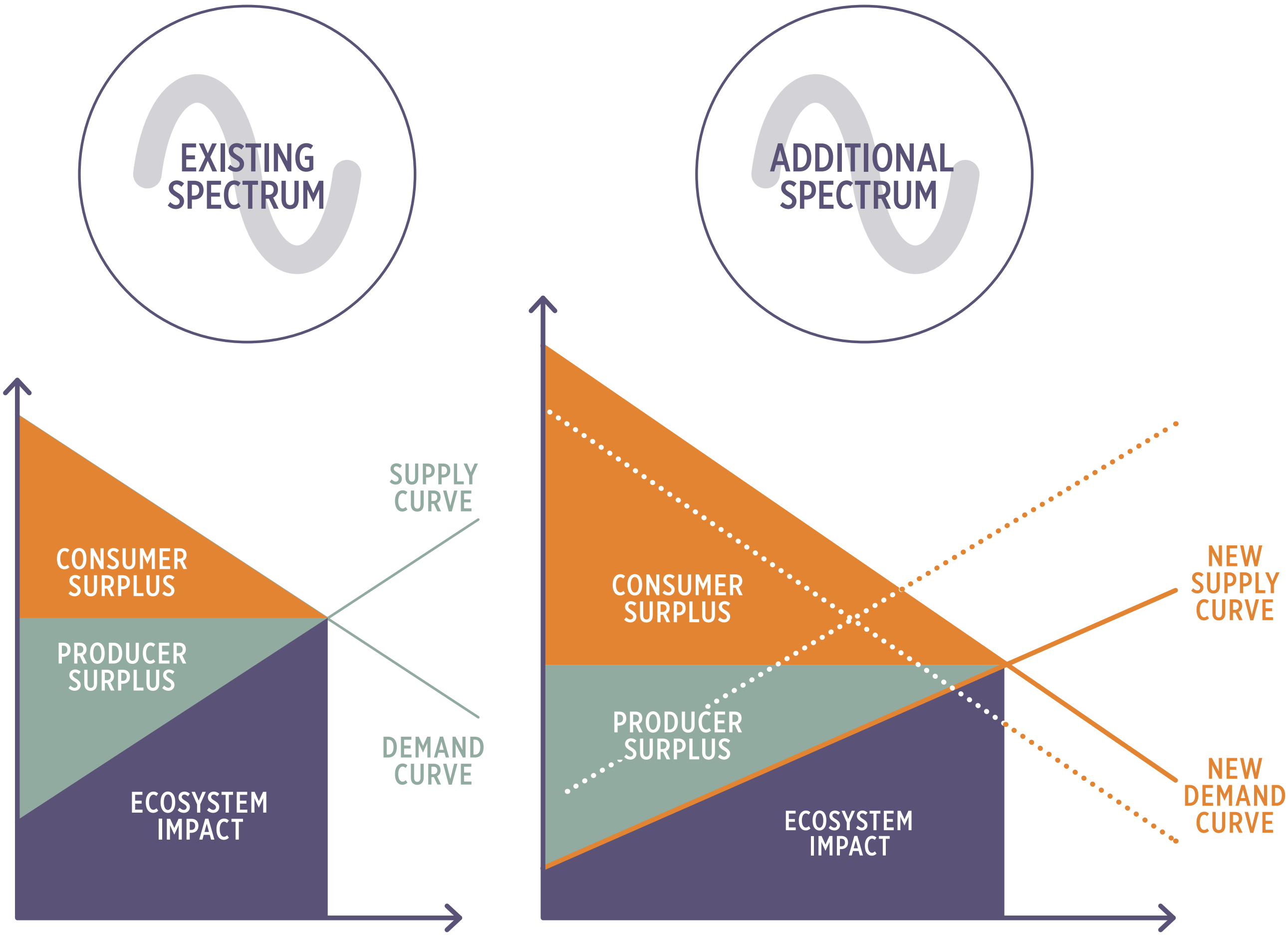


Figure 34

Source: Deloitte analysis

A.2.4 MODELLING HOW IMPACTS VARY IF SPECTRUM IS PROVIDED ON A SHARED BASIS

To capture how economic benefits vary if spectrum is shared, an impairment discount is then applied to the value obtained previously, to capture the additional complexity and uncertainty associated with spectrum being provided on a shared basis. The rationale for this approach is discussed in Section 4.2.

THE UNAVOIDABLE IMPAIRMENT DISCOUNT

<table>
<tr><th>DISCOUNT FACTOR</th><th>HOW IT WAS MODELLED</th></tr>
<tr><td>CO-EXISTENCE</td><td rowspan="3">An unavoidable impairment discount is factored in the modelling by calculating the present value of additional spectrum using a higher discount rate for shared versus exclusively licensed spectrum.

The WACC used by Ofcom for the regulation of mobile termination rates (6.2%) is taken as the discount rate for the calculation of the present value of the incremental benefits from additional exclusive spectrum.[33]

The present value of the incremental benefits from additional shared spectrum is calculated by assuming a 50% premium in the discount rate.</td></tr>
<tr><td>DEALING WITH ADDITIONAL COMPLEXITY</td></tr>
<tr><td>REGULATORY UNCERTAINTIES</td></tr>
</table>

Table 7

Source: Deloitte analysis

Then, to determine the lower bound to the economic benefits, a number of conditions that drive the value of shared use of spectrum to zero are modelled. These factors are summarised in Table 8.

CONDITIONS DRIVING THE VALUE OF SHARED SPECTRUM TO ZERO

<table>
<tr><th>DISCOUNT FACTOR</th><th>HOW IT WAS MODELLED</th></tr>
<tr><td>No Harmonisation (In EU)</td><td rowspan="5">If any of these conditions occurs, the incremental value of additional spectrum is switched to zero in the modelling.</td></tr>
<tr><td>No Minimum Scale (In EU)</td></tr>
<tr><td>Bandwidth Variability</td></tr>
<tr><td>Time Sharing Dynamism</td></tr>
<tr><td>Geographic Dynamism</td></tr>
</table>

Table 8

Source: Deloitte analysis

33. http://stakeholders.ofcom.org.uk/consultations/mtr/statement

THE IMPACT OF EXCLUSIONS

A number of impairment discounts have been included in the model to reflect potential variations on the sharing terms and conditions. This allows to obtain a view on how rapidly the benefits of shared spectrum are reduced as sharing conditions deteriorate. These factors are presented in Table 9.

DISCOUNT FACTORS

DISCOUNT FACTOR	HOW IT WAS MODELLED
TIME EXCLUSIONS	Benefits are reduced proportionally to the availability of spectrum in mobile operators' peak time.
POPULATION EXCLUSIONS	Benefits are reduced proportionally to the availability of spectrum in areas characterised by capacity constrained traffic.
CONTRACT LENGTH	While the optimal sharing contract length should mimic the licence length of exclusive spectrum, i.e. a minimum of 20 years, the modelling assumes that above 15 years full value of shared spectrum is realised. Under a sharing agreement of less than 15 years, only smaller spectrum-constrained operators are assumed to invest. In this case, in the modelling, economic benefits are assumed proportional to the market share of smaller spectrum-constrained operators who would rely on sharing to improve their position. No economic benefits are assumed to be generated for contracts of less than 8 years.
COMMON APPROACH IN THE EU *(MINIMUM SCALE)*	In the EU, in the absence of a common approach to spectrum sharing across the largest countries, economic benefits are assumed proportional to the market share of smaller spectrum-constrained operators who would rely on sharing to improve their position.

Table 9

Source: Deloitte analysis

The above analysis allows the calculation of the following results for the US and the EU28:

- The total impact generated if additional spectrum is made available on an exclusive basis.
- A range (an upper and lower bound) for the total impact generated if additional spectrum is made available on a shared basis.
- An intermediate point within the above range, to capture an intermediate scenario for spectrum sharing in the US and in the EU28.

The results of this analysis are presented in Section 5 of this report.

Appendix B

Abbreviations

ACRONYM	MEANING
3GPP	3rd Generation Partnership Project
AIP	Administered Incentive Pricing
ARNS	Aeronautical Radio Navigation Service
ARPU	Average Revenue Per User
CEPT	European Conference of Postal and Telecommunications Administrations
COMREG	Commission for Communications Regulation
DOD	Department of Defense
EC	European Commission
EMEA	Europe, the Middle East and Africa
ETSI	European Telecommunications Standards Institute
EU	European Union
FCC	Federal Communications Commission
FSS	Fixed Satellite Service
FTE	Full Time Equivalents
GAA	General Authorised Access
GDP	Gross Domestic Product
GHZ	Gigahertz
GSM	Global system for Mobile Communications
GSMA	GSM Association
IMT	International Mobile Telecommunications
ITU	International Telecommunication Union

LSA	Licensed Shared Access
LTE	Long Term Evolution
M2M	Machine to Machine
MB	Megabyte
MHZ	Megahertz
MOD	Ministry of Defence
MNO	Mobile Network Operator
NTIA	National Telecommunications and Information Administration
OTT	Over The Top
PCAST	President's Council of Advisors on Science and Technology
PMSE	Programme Making and Special Events
QOS	Quality of Service
RFID	Radio-Frequency Identification
RLS	Radio Location Services
R&D	Research and Development
SAB	Services Ancillary to Broadcasting
SAP	Services Ancillary to Programme-Making
SAS	Spectrum Access System
TDD	Time-Division Duplexing
US	United States
WACC	Weighted Average Cost of Capital

Appendix C

List of Figures