Socioeconomic Value of Mission Critical Mobile Applications for Public Safety in the UK: 2x10MHz in 700MHz.

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Foreword

Considerable information exists on the use of communications by emergency services. Minimal material exists, however, on the potential contribution that a harmonised utilisation of spectrum for mobile broadband by emergency services can make to the wider economy: the 'socioeconomic impact'. With the impending auction of the 700MHz spectrum in the UK and other European countries, the enclosed research has assessed a number of potential contributing areas that pivot on *intervention benefit*, with a core focus on Police, to forecast a more holistic consolidated benefits figure. This utilisation of an in situ approach within emergency services utilises primary research and interviews to extrapolate estimates to the UK. It will be followed by an EU assessment before the end of 2013.

The methodology utilised to estimate the socioeconomic benefit potentially accruing from intervention-driven changes in policing and other emergency services is multi-pronged. It includes the results from primary and secondary research across a number of areas that are believed to represent major areas of socioeconomic contribution arising from enhanced use of mobile broadband in 2x10MHz in 700MHz. The intervention-driven socioeconomic benefit estimated for Police represents the core contributory block of this research: this is significant on a stand-alone basis and utilises data obtained from primary research within Police. This is complemented by predominantly secondary research in a number of other areas, with recognition that a greater degree of analysis could strengthen results further. It is also recognised that the expansion of results beyond some areas assessed could result in additional socioeconomic benefits that have not been captured, such as the effect of crime reduction on house prices in additional cities beyond London.

The consolidation of estimates on the utilisation of 700MHz for mobile broadband on a more dedicated basis by emergency services indicates that they outweigh the opportunity cost of the 'one-off' sale of spectrum to commercial operators. The degree to which these potential benefits are realised depends on a range of factors including regulatory and licence conditions; the network mode of delivery; the speed of mobile broadband adoption; the nature of the services that are provided, and others. This research is a starting point that amongst other approaches, consolidates existing information; extrapolates methodology from relevant research to additional areas; extends primary research in crime intervention to a UK-wide context. These assess the socioeconomic benefits that potentially can ensue from the enhanced use of mobile broadband by emergency by public protection and disaster agencies.

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Executive Summary

The UK's emergency services have to date primarily relied on TETRA for their communication in the field with mobile data utilised to a significantly lower degree.[1] This has seen a step-change recently as austerity overlapped with a changing social and crime milieu to usher in a new operating paradigm for some public safety agencies such as the Police. Concomitant to, or perhaps as a result of these changes, efficiency-enhancing tools such as mobile broadband have been increasingly used by these agencies to obtain productivity benefits and enhance the performance of fewer resources. They offer significant potential to confer wider socioeconomic benefits that potentially exceed the opportunity cost for the commercial sale of the underlying spectrum by Government in the potential auction of the 700MHz band in the UK.

A lacuna exists in the quantification of these benefits with limited research existing that peels the organisational and social fabric to assess potential benefits. The enclosed bridges this through a four staged process: (1) estimating the socioeconomic benefits of mission critical mobile broadband in public safety in a 2x10MHz portion of the 700MHz spectrum in the UK across the categories of safety, efficiency, macroeconomic growth, and service disruption; (2) estimating the opportunity cost of the alternative use of this portion of spectrum as defined by its potential auction value; (3) comparing the potential auction value with the estimated benefits value; (4) providing the qualitative and quantitative context for PPDR in the UK that frames the analysis in a topical context. This process has estimated an annual consolidated socioeconomic value of around £5 billion from the use of 2x10 MHz in the 700MHz band for public safety in the UK, as depicted in Figure 1. The opportunity cost of the alternative sale of this spectrum at auction could yield a one-off economic gain for the Government ranging from £300 million - £1.1 billion based on a per MHz cost per POP benchmarked from international auctions of 700MHz and 800MHz and from UK auctions to date. The estimated socioeconomic benefit exceeds the potential alternative benefit of this portion of the spectrum: amortised over a 15 year license, the annual socioeconomic benefit equates to £333 million, versus £20milion-£73.3million for the amortised potential alternative sale of the spectrum at auction. These estimates indicate that the socioeconomic benefits of the use of this portion of spectrum by PPDR agencies exceeds the opportunity cost for its alternative sale at auction. In addition to any review of the alternative use of this

[1] Stavroulakis, P. (2007). Terrestrial Trunked Radio - Tetra: A Global Security Tool. Springer.

20MHz block of the 700MHz band, consideration must occur for the appropriate technical and implementation model in order to fulfill key mission critical broadband and voice requirements for public safety whilst maximising the potential that this bandwidth offers. Only by aligning a number of such critical parameters will the maximisation of socioeconomic benefits ensue and continue to occur.

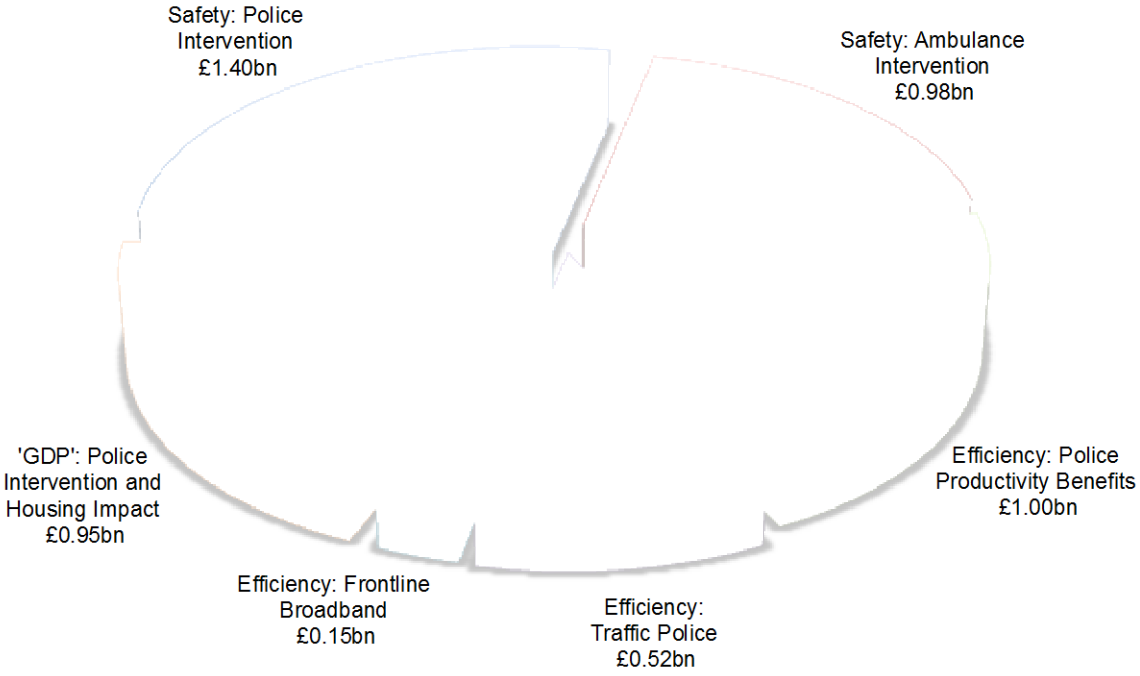

Figure 1: Consolidated socioeconomic benefit in the UK from PPDR use of 2x10MHz in 700MHz

The benefits from Police intervention to reduce crime and its commensurate social costs represent the majority of safety benefits estimated, with the utilisation of technology to assist patrolling police yielding social benefits that are likely to increase over time as adoption of mobile broadband increases. This extends to emergency services, with the potential existing for the Ambulance Service to adopt greater mobile broadband to assist teams reach coronary arrest victims in particular in less than 8 minutes, and save a greater proportion of the 3,000 such fatalities that occur each year. The collective socioeconomic value generated through the utilisation of mission critical mobile applications by Public Safety Agencies for these and other areas can be juxtaposed against the opportunity cost of alternative commercial use of the 2x10MHz spectrum. The estimated socioeconomic benefits for the utilisation of this spectrum by Public Safety Agencies is estimated to be significantly greater than the commercial value of the sale of this segment of spectrum to commercial operators.

The core potential socioeconomic benefits estimated in this study are segmented into a number of categories:

Safety:

- £1.4 billion annual socioeconomic benefit could result from an estimated 12 per cent of current homicide, serious wounding and sexual assault crime costs benefitting from mobile broadband to derive a favourable outcome.[2]

- £0.98 billion annual socioeconomic benefit could result from mobile broadband being utilised to assist ambulance crews reaching out-of-hospital cardiac arrest victims faster and being better informed. For 560 lives saved,[3] a socioeconomic benefit of £980 million could be achieved, as part of a broader social target to reduce 3,000 deaths due to a lack of rapid intervention.[4]

- £1 billion socioeconomic benefit could result from a 10 per cent improvement in productivity by the Police Force as already observed by some Constabularies from the adoption of mobile broadband[5] and the efficiency benefits in policing. An improvement in intervention rates by this driver could result in an additional 350,000 interventions per annum occurring with the final socioeconomic benefit dependent on the mix of crimes that this is applied to.

Efficiency

- £520 million potential socioeconomic benefit per annum could result if UK Traffic Police achieved comparable results as US Highway Patrols in increasing their efficiency by reducing traffic stop times due to the enhanced and integrated use of mobile broadband.[6] The potential socioeconomic benefits are derived from avoiding an estimated total annual 1,415 major serious injuries and some fatalities that could occur otherwise occur if an

[2] Intervention estimates obtained from: Johur, J. (2013). Evaluating the Benefits of Mission-Critical Mobile Broadband to the UK Police Service. MBA Thesis. Henley Business School. Additional primary and secondary research undertaken.
[3] LSE Research.
[4] Price, L. (2006). Treating the clock and not the patient: ambulance response times and risk. Quality and Safety in Health Care; 15: pp127–130.
[5] http://www.straighttalkonline.com/cio-articles/going-mobile-wiltshire
[6] University of Cincinnati Policing Institute. Traffic Stop Data Analysis Study: Year 3 Final Report. November 2009.

officer is engaged on an existing stop, instead of maximising the period of mobility due to enhanced operational efficiency in the field.

- £150 million of efficiency savings could result per annum if the current efficiency benefits being obtained by some UK Police Forces[7] in undertaking some integrated operational duties between the frontline and back-office were realised across all of the UK's Police Forces.

Dedicated versus Sharing Spectrum with the general public

- A socioeconomic cost of £1 billion could result if a 1 per cent reduction in service availability occurred due to spectrum not being available in a dedicated manner for public safety in times of mission critical dependency, particularly for large-scale emergencies.[8] A 5 per cent degradation of service is estimated to potentially result in a socioeconomic cost of over £5 billion.

GDP

- Crime has a significant impact on society, with criminal activity facilitating the consumption of illegal goods and services, whilst concomitantly levying costs through stolen and damaged goods, greater insurance premiums, spending on safety, pain suffering, loss of life and other factors.[9] These impact both the private and public sector with total crime cost accounting for 7.7 per cent of GDP in England and Wales (£124 billion), 11.9 per cent in the US,[10] whilst in Colombia, crime is estimated to hinder economic growth by 2 per cent per annum.[11] Inherent difficulties exist in establishing causality between crime and GDP however. This research briefly reviews limited economic assessments of the relationship between crime and macroeconomic growth.

- £950 million socioeconomic benefit of crime reduction could result from house price growth due to enhanced crime intervention and reduction. Crime has a negative socioeconomic impact on house prices, with UK research in 2004

[7] British APCO Journal. January 31, 2012.
[8] Sampling estimates obtained from: Johur, J. (2013). Evaluating the Benefits of Mission-Critical Mobile Broadband to the UK Police Service. MBA Thesis. Henley Business School. Additional primary and secondary research undertaken.
[9] Detotto, C., and Otranto, E. (2010). Does Crime Affect Economic Growth? KYKLOS, Vol. 63. August; No. 3; pp: 330–345.
[10] Ibid.
[11] Cárdenas , M., and Rozo, S. (2008). Does Crime Lower Growth? Evidence from Colombia. World Bank. Commission on Growth and Development. Working Paper No 30.

indicating that a 0.1 per cent standard deviation increase in crime in London leads to a 0.94 per cent decrease in property values, equating to around £300 million,[12] and around £1 billion in today's housing market. A reduction in crime can reverse negative house prices, with US research estimating that a 10 and 25 per cent reduction in violent crime could increase housing prices in 8 major US cities by 0.83 and 2.1 per cent respectively in the following year.[13] This would equate to US$16 billion and US$41 billion respectively. In London, the significant crime reduction occurring over the past decade could yield a house price increase of over £1 billion, with this figure potentially being higher if other UK cities are included. It is recognised that a more granular degree of analysis could occur in this area, with these estimates being more cursory but believed to be indicative of the potential impact of crime on property values.

If Public Safety Agencies were required to use the spectrum commercial operators have acquired through auctions, a greater degree of risk and operational challenges could ensue through the required fulfillment of communication attributes required including those related to safety; quality of service; network redundancy; security and other areas. Governments and policy makers in some countries are reviewing existing mobile network delivery modes in order to assess the optimal mode for accommodating multiple mobile operators in a 21st Century milieu including public safety and commercial operators to optimise investment and social efficiency. The impending 700MHz auction in the UK represents an opportunity for Government to review spectrum allocation and a delivery model in this band.

[12] Gibbons, S. (2004). The Costs of Urban Property Crime. Economic Journal; v(114); F441–F463.
[13] Shapiro, R. J., and Hassett, K. A. (2012). The Economic Benefits of Reducing Violent Crime: A Case Study of 8 American Cities. Centre for American Progress.

"Technology has transformed the way we live our lives, but it has not yet transformed the way the police do their jobs. In five years time we need to look back and see this was the beginning of a technological revolution in policing. We could see pen and notebook replaced with voice recognition technology or manually sorting paper files replaced by automatic uploading to cloud storage." [14]

UK Home Office Minister, July 8, 2013.

[14] Speech given by Home Office Minister Damian Green on the need for police reform - 8 July 2013. https://www.gov.uk/government/speeches/damian-green-speech-on-police-reform

1. Public Safety and Spectrum

1.1 A close 'Mission Critical' Relationship

> *"Spectrum is a valuable resource that enables growth and innovation. Without it wireless communications such as mobile phones, or Wi-Fi or satellite TV are not possible. It is also a critical input to enable delivery of essential services provided, and supported, by the public sector."* [15]
>
> DCMS, March 2011.

Radio networks continue to be recognised as a fundamental component of public safety operation for professional mobile radio (PMR) which includes emergency services.[16] A key distinction between PMR services and commercial consumer-driven communication is the mission-critical nature of public safety. The TETRA and Critical Communications Association (TCCA) defines the term 'mission critical' as: *"A function whose failure leads to catastrophic degradation of service that places public order or public safety and security at immediate risk. These systems are paramount to the operation of a nation's public safety and critical infrastructure services and are therefore specified to have particular and adequate inbuilt functionality, availability, security and interoperability."* This definition encompasses the wide role of Emergency Services in public protection and disaster relief (PPDR) across a range of activities: protection of the public, property, business, key national infrastructure and government; accident management; crime prevention; natural and man-made disasters, and terrorism.[17] The International Telecommunications Union defines the two terms as:[18]

Public protection (PP) radio communication: Radio communications used by responsible agencies and organisations dealing with maintenance of law and order, protection of life and property, and emergency situations.

Disaster relief (DR) radio communication: Radio communications used by agencies and organisations dealing with a serious disruption of the functioning of society, posing a significant, widespread threat to human life, health, property or the

[15] Department for Culture Sport and Media (DCMS). March 2011. Enabling UK growth – Releasing public spectrum. Making 500 MHz of spectrum available by 2020; p5. https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/77429/Spectrum_Release.pdf

[16] Parliamentary Joint Committee on Law Enforcement. Spectrum for public safety mobile broadband. July, 2013.

[17] TTCA, Public Protection and Disaster Relief (PPDR). TETRA + Critical Communications Association. www.tandcca.com/assoc/page/12329

[18] Report ITU-R M.2033 . Radiocommunication objectives and requirements for public protection and disaster relief: 2003.

environment, whether caused by accident, nature or human activity, and whether developing suddenly or as a result of complex, long-term processes. Over half of the spectrum in the UK is utilised by the public sector, including defence, emergency services and others, [19] with this located below 15 GHz, and with technical characteristics that support a wide variety of applications including mobile communications and increasingly, mobile broadband. [20] Emergency and Safety Services possess 5 per cent of UK spectrum, and account for two per cent of its use.[21]

Mobile broadband growth continues to be fuelled by the consumer and commercial markets, with 92 percent of the UK population owning a mobile phone, and 39 per cent owning a smartphone with internet access. [22] Globally, over 1 billion smartphones are in existence from a total use base of 5 billion mobile phones, with the average data consumption reaching over 500 MB/month.[23] Demand for mobile capacity is estimated to increase by 80 per cent by 2030 in the UK, with auctions of radio spectrum such as 4G in early 2013 focusing on meeting mobile broadband demand.[24] In contrast, the global PMR market has an estimated installed base of around 40 million,[25] and is served by narrowband digital systems that offer limited data capability.[26] In contrast, as commercial consumer-led mobility has increasingly permitted greater data capability, the growth in mobile subscribers has had a complementary impact on applications developed ('apps') across a broad spectrum encompassing entertainment, productivity, music, social networking and others. [27] Over 1.2 billion people were using mobile apps at the end of 2012, with forecasts that by 2017, over 200 billion apps will be downloaded annually globally.[28]

In this increasingly data-centric mobile communication milieu, PPDR organisations are assessing and adopting new technology for data communications from the commercial sector across 2.5G, 3G and 4G, and relying on these mobile network operators for the delivery of those services.[29] The mission critical and safety nature

[19] DCMS, (2011). Op cit.
[20] Ibid
[21] Ibid.
[22] https://www.gov.uk/government/news/speeding-up-mobile-broadband-roll-out
[23] http://www.go-gulf.com/blog/smartphone/
[24] Ibid.
[25] Analysis Mason. DMR Market Report. December 2011.
[26] TCCA. Critical Communications Broadband Group (CCBG). White Paper. *Mission Critical Mobile Broadband: Practical standardisation & roadmap considerations.* February 2013.
[27] http://venturebeat.com/2013/07/10/state-of-the-apposphere/
[28] http://appscend.com/blog/explosive-growth-in-apps-usage/
[29] Ibid.

of PPDR often result in a longer and more 'cautious' process occurring before new technology is adopted, and a high degree of confidence that it is 'fit for purpose' and effective in maintaining or improving safety levels.[30]

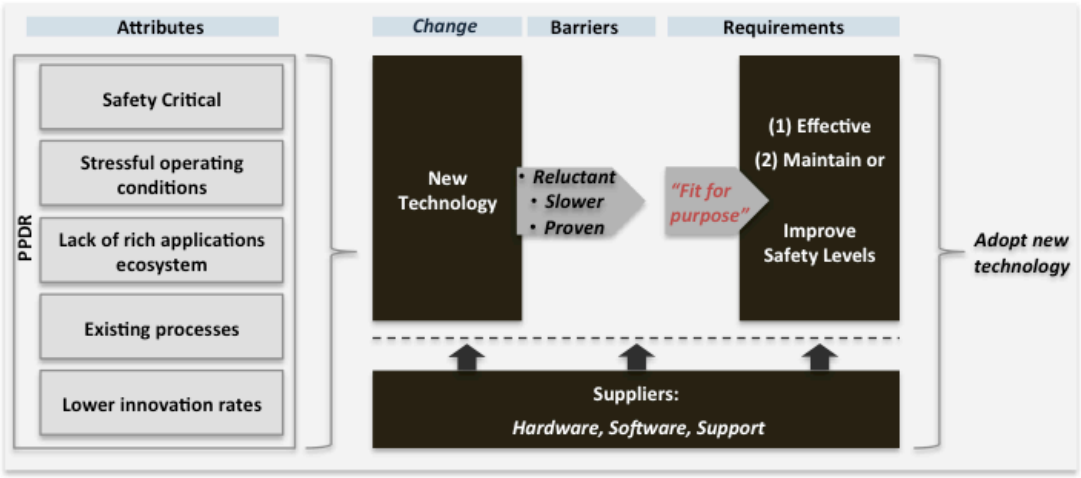

Figure 2: New Technology Adoption by PPDR Organisations

Figure 2 depicts factors influencing new technology adoption in PPDR. Key activities potentially resulting in a lower degree of innovation than the commercial mobile sector include a lower degree of available applications and entrenched processes required due to safety and mission critical requirements. The recent international auctions of 4G and 700MHz represent a potential step change for PPDR however: in addition to private voice and narrowband data networks in use, PPDR organisations are increasingly utilising the public mobile telecommunications networks for broadband services to complement their operations.[31] This represents the commencement of a transition by PPDR agencies from narrowband communication to a more data-rich model. For this to continue successfully, key PPDR-specific network management and security issues need to be addressed to ensure that these are factored by commercial network operators in order to ensure that mission and safety critical communication can occur on an everyday basis and in the event of major disasters. Socioeconomic value could be maximised when control over the activity chain for public safety communications resides with PPDR agencies and these sector-specific attributes are factored. A closer alignment with commercial network operator requirements can potentially dilute this value if critical requirements are not met.

[30] http://www.tandcca.com/Library/Documents/Broadband/Harmonised_dedicated_spectrum_MCC_final.pdf

[31] http://www.telstra.com.au/business-enterprise/download/document/business-public-safety-whitepaper-mbb-4g.pdf

1.2 A Crossroad: Dedicated Spectrum

Secure and reliable wireless communication between PPDR resources and their command posts is vital for the successful management of emergency situations.[32] To date, this has primarily been accomplished through a strategy of dedicated, exclusive-use spectrum: this exclusive allocation for public safety provides agencies with full control over this resource.[33] A greater focus on mobile data by PPDR agencies has shifted the discussion of spectrum allocation for mission and safety critical communications into a more mainstream environment. The opportunity cost of allocating spectrum bands for PPDR networks poses a challenge for spectrum regulatory authorities and Government: the same bands are being sought by commercial operators for the provision of television broadcasting and 3G and 4G mobile communications.[34] Harmonisation of PPDR across Europe appears to be occurring, with this factor recognised as facilitating interoperability and the achievement of economies of scale for public safety communications equipment, technical efficiency and customer convenience.[35]

A review by the European Electronic Communications Commission (ECC) reported that most national security networks were merging into one common network technology, with a trend for greater integration between public safety communication networks and other security related agencies including defence.[36] A minimum of 2 × 10MHz has been identified in Europe for broadband PPDR mobile data networks, without the inclusion of voice.[37] In the UK and Europe, PPDR national agencies have generally invested in dedicated narrowband digital mobile networks for voice and data communications and deployed a wide area network nationally.[38] These organisations require reliable, high availability and secure systems, with the ECC defining a number of essential operational requirements to be fulfilled by public safety radio communication:

- Resilience: Available all the time.
- Coverage: Available in all location.

[32] Ahokas, J et al. (2012). Secure and Redundant Public Safety Communication Network for Public Protection and Disaster Relief (PPDR) Organizations. International Journal of Communications. Issue 3(6); pp:12-127.
[33] ETSI TR 102 970 V1.1.1 (2013-01). Reconfigurable Radio Systems (RRS): Use Cases for spectrum and network usage among Public Safety, Commercial and Military domains; p11.
[34] Ibid.
[35] ECO. Spectrum Harmonisation in Europe: Trends and Topics. 12th September 2012.
[36] ECC Report 102. Public Protection and Disaster Relief. 2005.
[37] Ibid.
[38] Ibid.

- Grade of service: network access instantly available when required that can include flexibility managed by the relevant agency.
- Security and interoperability: secure communications between all parties that need to be involved.
- Radio networks for PPDR should provide high quality end-to-end encryption with key autonomy for each user group.[39]

In contrast, PPDR communication in Europe today is based on narrowband digital dedicated radio networks operated in a harmonised 2 x 5MHz band between 380MHz-400MHz.[40] The capabilities of PPDR agencies in the UK and Europe have been considerably improved as new technologies such as dedicated TETRA networks have been deployed, but major incidents such as the London bombing of 7th July 2005, and the UK floods in 2010 have highlighted the challenges faced. A key difference between commercial systems and dedicated PPDR networks such as TETRA is the latter's requirement for inherent resilience, capacity and security. TETRA networks are designed around these criteria, in contrast to the generally economic considerations faced by commercial network operators.[41] Key variations between PPDR and commercial organisations include:

- *Shareholders*: Commercial operators are generally owned by private shareholders with the majority of operators publicly listed: ownership is distributed amongst a large number of individual and institutional owners. PPDR agencies are Government owned with a single shareholder.
- *Targets*: Operators are profit-driven with commercial targets that include, profit, growth and other metrics designed to maximise the return for shareholders. PPDR agencies most often operate to non-profit targets by Government that are predicated around safety and response, although increasingly, additional austerity targets are being established.
- *Network availability*: Although high network availability is required by both PPDR and commercial operators, it is even higher for PPDR organisations that require ubiquity and are 'always available'. The tolerance for outage is low amongst consumer and business customers, but is even lower for PPDR organisations dealing with potential loss of life, injury, disaster or other emergencies.

[39] Ibid.
[40] Digital Europe. Digital Europe Position on Broadband Public Relief protection and Disaster Relief. Brussels, April 2, 2012.
[41] Europol. Report of the workshop on Interoperable communications for Safety and Security.

- *Coverage obligation*: Commercial operators are required to meet coverage targets as part of their licence agreements but some 'black spots' remain. Although this may be commercially justified, it may not be congruent with the utilisation of commercial networks for PPDR purposes where coverage of emergency and police services are required across the entire population.
- *Security*: In contrast to commercial operators, personnel and data for PPDR often require additional security clearance and protection respectively.

For optimised social benefits to be derived from PPDR activities, a congruent operational delivery mode is required that addresses the unique characteristics of this sector such as the requirement to be 'always available': the inability of safety and mission critical voice traffic to be transmitted due to traffic 'overload' may result in fatal consequences or the impediment of communication at times of emergencies. Equally, as mobile broadband becomes operationalised over time into a more mission critical function, a reduction in service availability can result in the inability of medical, fire, or police teams to utilise situational enhancing information, patient data, intelligence, or other information that can result in loss of life, serious injury, property damage and other negative outcomes, that cause distress and costs to ensue. The socioeconomic cost of a 5 per cent degradation of service availability in the UK in times of mission critical dependency could result in a socioeconomic cost of over £5 billion, whilst a one per cent decrease could yield a socioeconomic cost of £1 billion.[42] Such a reduction in service could occur in a large scale emergency where spectrum is not available in a dedicated manner for public safety. Optimised socioeconomic benefits are more likely to occur when PPDR organisations have greater control over their activity chain and can incorporate and directly manage elements required, such as service availability, security, and other features. Figure 3 depicts four principal network service options in the delivery of PPDR, including a dedicated approach to spectrum allocation that potentially maximises the opportunity to deliver socioeconomic benefits through greater control by providing the highest ability to control activities.

Additional dedicated spectrum options include the use of a carrier's commercial network to provide PPDR. To optimise socioeconomic benefits and ensure service availability, the appropriate hardening and related operational and technical requirements would require implementation. Carriers may be reluctant to undertake

[42] Sampling estimates obtained from Johur, J. (2013). Op cit.

this however, as they seek to balance commercial criteria between the consumer and PPDR segments. This could result in a less effective extraction of socioeconomic benefits than a dedicated approach if PPDR-specific attributes are not implemented. An additional approach is the utilisation of a hybrid model that utilises both a dedicated PPDR and commercial network: a dedicated PPDR network would target higher-risk and populated areas, whilst a commercial network would be utilised to target rural and low-risk areas. The balancing of services between the two presents some operational challenges, but if implemented successfully, this could result in higher socioeconomic benefits ensuing.

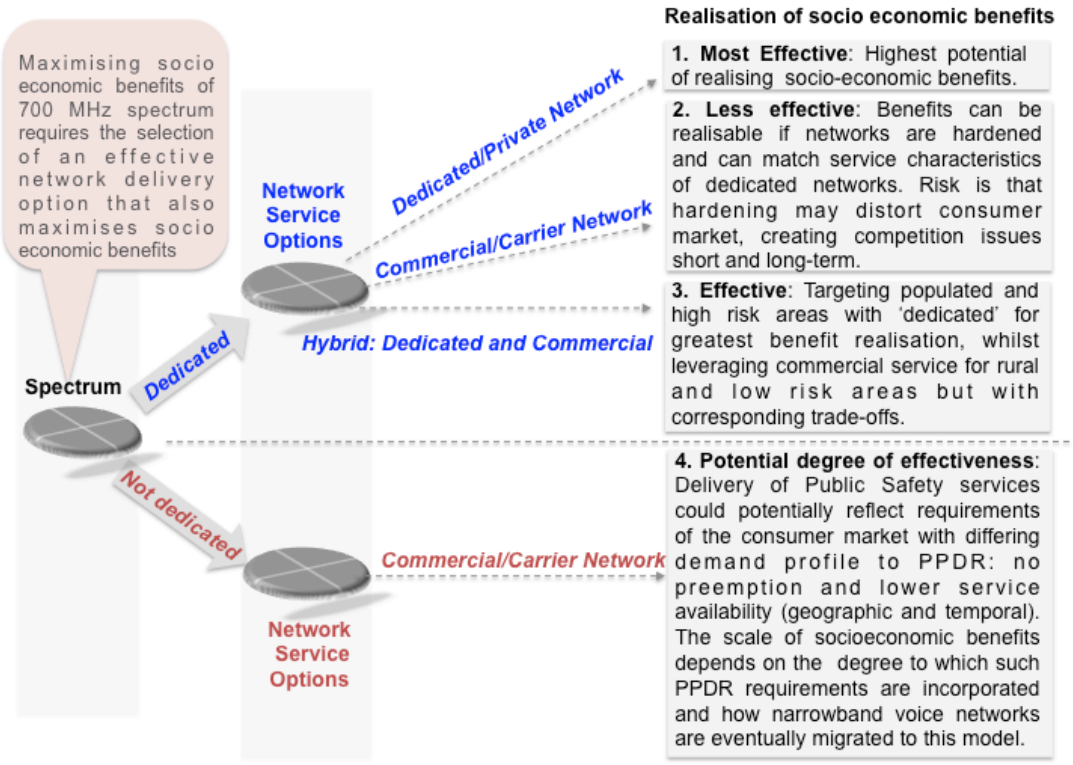

Figure 3: Spectrum implementation options and the maximisation of socioeconomic benefits

These models utilise dedicated spectrum in a variety of modes. A further option reflects the non-dedicated utilisation of spectrum utilising a carrier's commercial network. This could produce lower socioeconomic benefits if the commercial network is utilised to provide PPDR including narrowband voice and mission critical broadband, but without the existence of other PPDR attributes such as *preemption* and *service availability*. Under this scenario, the demand profile of the non-PPDR market is likely to influence the supply-profile and potentially affect the incorporation of PPDR requirements unless they are mandated or a commercial incentive is provided.

These PPDR network service models can be consolidated into three principal options available to Government:[43]

(1) Build, operate and manage their own network utilising exclusive spectrum allocation.
(2) Outsource the build and subsequently manage the contract, utilising exclusive spectrum allocation.
(3) Acquire service from the market on commercial terms utilising spectrum allocated to an operator.

General agreement has been reached amongst the PPDR community internationally that harmonised spectrum is the optimal strategy to maximise broadband services, encapsulated in a resolution by the International Telecommunications Unions' Resolution to formalise this.[44] The focus has shifted to a review of *dedicated* versus *shared spectrum* and the optimal modes by which spectrum can be utilised to achieve both public safety and commercial objectives. Research by the European Union on enhancing PPDR communications concluded that the major challenges faced by PPDR wireless communications systems in emergency and disaster relief scenarios were:[45]

- Lack of broadband.
- Lack of the appropriate technology (high bit/s/Hz).
- Lack of dense network deployment.
- Lack of sufficient spectrum/more efficient utilisation.
- Lack of capacity.

Commercial network operators offer the opportunity to address these issues, but PPDR agencies require the fulfillment of key criteria such as very high network availability. This is a major distinction between commercial and PPDR network utilisation, as depicted in Figure 4, that could act as a deterrent to the participation of commercial operators. Hybrid solutions could leverage commercial mobile broadband network infrastructure to fulfill the requirement from Public Safety users for availability and capacity during routine operation in addition to utilisation during disaster and major events when commercial network could fail due to overloading.[46]

[43] http://www.tandcca.com/Library/Documents/Broadband/Harmonised_dedicated_spectrum_MCC_final.pdf
[44] ITU Resolution: ITU-R 54-1
[45] EU. FP7 Help Project. The evolution of Public Safety Communications in Europe: the results from the FP7 HELP project. 02/2011-07/2012.
[46] ECC Report 199 - ECO DocDB

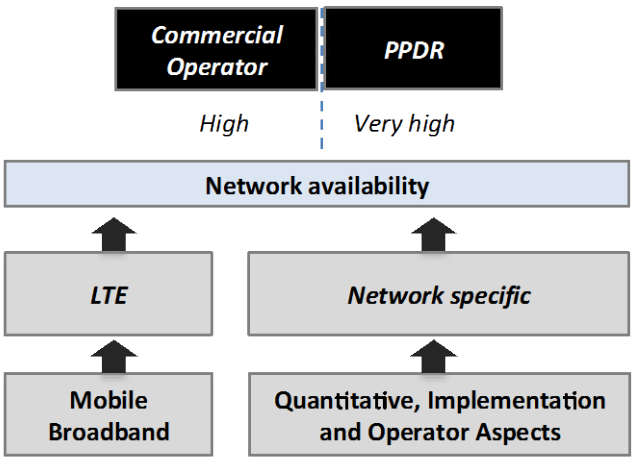

Figure 4: Commercial vs. PPDR network availability

In order to address PPDR challenges, Government can outsource the PPDR network to a third party commercial operator, as has occurred in around one third of European countries.[47] In these scenarios, where control of network design and operations is typically outside of the control of the PPDR agency, the issue of availability becomes more complex. Network operators must also comply with additional stringent provisions with some targeted at the need to maintain quality of service including:[48]

- The absence of 'force majeure': A lack of network availability can have implications for safety and risk lives, with this clause not included.
- Severe non-performance penalties to ensure high network availability and support.
- Operational staff employment contracts that reflect the requirement for high service availability through the 'no right to strike' provision.
- Contractual conditions requiring approval of ownership changes and permitted activities.
- Financial 'health checks' with Government ability to seize control should non-compliance occur.

These and other conditions designed to obviate reduced service availability have to date resulted in outsourced mission critical service provision being undertaken by dedicated operators experienced in meeting the demands of this segment. In

[47] http://www.tandcca.com/Library/Documents/Broadband/Harmonised_dedicated_spectrum_MCC_final.pdf
[48] Ibid.

scenarios where commercial networks are 'shared' to provide a PPDR service, a number of factors need to be considered by operators in order to meet stringent PPDR operational provisions, particularly quality of service. A formal definition for 'network sharing' does not exist by regulatory and standards bodies. The European Telecommunications Standards Institute (ETSI) has defined the term as: *"The shared use of a network, or a part of it, by multiple users. Different types of services for different user organizations may be provided through the shared network by one or several network operators that may have a different degree of control over the resources of the shared network*".[49] Key factors for consideration in the provision of a network sharing model include:

- A hardened network with dedicated (segregated) parallel operations across emergency services (700MHz) spectrum and other commercial spectrum providing the ability to partition PPDR and commercial traffic.
- Priority functions, with PPDR-voice prioritised above broadband data and with both of these prioritised above commercial traffic.
- The ability to utilise the PPDR partitioned spectrum to carry commercial traffic if capacity exists and the reciprocal capability for PPDR traffic to be carried across the commercial spectrum if the need arises, as prioritised traffic.
- A seamless, 'instant' and automated capability to prioritise PPDR traffic and 'spike' capacity when required, such as in times of major emergency incidents when PPDR and other traffic surge and quality of service must be maintained for PPDR use.

Major emergency incidents often exhibit a number of common characteristics: unexpected events with peaks of traffic demand in the first hours after the crisis; impact across a large number of people and assets; concentration in one area; the engagement of multiple public safety organisations; timely communication access requirement. [50] Natural disasters can magnify these both geographically and temporally. Dedicated public safety networks are normally scoped to include a degree of additional capacity to manage demand spikes, but the possibility exists that dedicated network capacity may not be sufficient for such operational scenarios, with additional network or spectrum required. The timely provision of this can present

[49] ETSI TR 102 970 V1.1.1 (2013-01). Reconfigurable Radio Systems (RRS): Use Cases for spectrum and network usage among Public Safety, Commercial and Military domains; p11.
[50] Ibid.

a challenge under more 'rigid structures' where the option of acquiring immediate spectrum is not available.[51]

In addition to existing network hardening and prioritised spectrum options, other sharing options are emerging, such as Licensed Shared Access (LSA) and Authorised Shared Access (ASA). These permit spectrum licensed for international mobile telecommunications to be utilised by more than one entity when the primary licensee is not utilising its designated frequencies.[52] The ITU defines the sharing of spectrum as: "*Spectrum sharing typically involves more than one user sharing the same piece of spectrum for different applications or using different technologies, [and] encompasses several techniques - some administrative, technical and market-based. Sharing can be accomplished through licensing and/or commercial arrangements involving spectrum leases and spectrum trading. Spectrum can also be shared in several dimension, time, space and geography*".[53] This is an emerging area that will increase in focus as 700MHz auctions continue to occur and the use of commercial service providers for mission critical broadband on a shared basis remains a topical issue however, with a view by some PPDR agencies that such services should not be provided by commercial broadband providers, as iterated by New Zealand Police: *"There are serious issues surrounding capacity, redundancy, security and reliability needed for PPDR broadband purposes that result from the different design and provisioning standards that typically apply in commercial networks…There is ample evidence of network congestion being caused by too many call start events for the network to handle, which in turn impacts on the ability of emergency first responders to access the networks in the event that such commercial networks are their primary form of communication."* [54] For the foreseeable future, quality of service, resilience, security, and other features specific to PPDR will continue to drive debate on the optimal mode of spectrum allocation, sharing and use. When these considerations are factored as requirements for PPDR, the acquisition of service from the market on commercial terms utilising spectrum allocated to an operator may offer the lowest opportunity to maximise socioeconomic value and poses a challenge for regulators, Government and both commercial operators and PPDR agencies to successfully address.

[51] Ibid
[52] http://www.gsma.com/spectrum/wp-content/uploads/2013/04/GSMA-Policy-Position-on-LSA-ASA.pdf
[53] International Telecommunications Union. Radio Spectrum Management
[54] New Zealand Police, 6 October 2011. Digital Dividend Submission; p4.

2. Why Broadband?

2.1 Evolution of mobile broadband

European PPDR radio systems are constructed to provide nationwide mobile coverage, with Terrestrial Trunked Radio (TETRA) the dominant standard, but often with lower indoor and rural handheld coverage, with budget constraints defining the degree and extent of coverage. [55] These systems operate in 380MHz–400MHz band with frequencies harmonised for public safety use and only provide voice and narrowband data services. They have been designed around the key criteria of support for group voice communication, availability and security. Limited bandwidth exists, which can only support lower bit rate data services. This limits mobile data to shorter data messages.[56] In addition, the radio network is most often shared among PPDR agencies but this also permits easy and flexible cooperation between agencies in the field. TETRA is an established technology utilised widely internationally for mission critical and business critical organisations. The inherent data capabilities are low however and partly bridged by the wideband data standard, *TETRA Enhanced Data Services* ('TEDS'), also known as 'TETRA 2', that will increase data throughput tenfold from the existing TETRA standard.[57] Greater data carriage however requires additional spectrum. This is not deployed in a harmonised manner however, and wide bandwidth channels (50 kHz and greater) are not generally available. Over time however, increasing demand has occurred from PPDR agencies for access to mobile broadband data applications.[58]

In the UK, as with many other countries, the utilisation of the Long Term Evolution (LTE) standard for 4G is a key catalyst for the convergence of other standards such as TETRA 2, 3G, and WiMAX mobile, with supporting standards such as IEEE 802.16 supporting PPDR through enhanced reliability of resilience, multicast connection based group communications; IP based push-to-talk and nearby direct communications among users. [59] A key requirement of TETRA is to provide interoperable, inter-agency communications during incidents that require a multi-agency response. In the US, LTE has been selected as the standard for broadband data services for public safety, with large network rollouts the primary mode of

[55] Digital Europe, 2012. Op cit.
[56] Ibid.
[57] http://www.tetra-applications.com/item.html&objID=15195
[58] Analysis Mason. 'Exploiting the digital dividend- A European Approach': Final Report. August, 2009.
[59] Chang, S. Broadband Mobile Communication for PPDR Applications - IEEE 802.16 GRIDMAN – 2012.

operation.[60] The adoption of mobile broadband in the UK can enhance everyday functions for UK PPDR agencies, in addition to ensuring that in an increasingly cyber-driven terrorism environment, law enforcement and emergency response agencies do not lag the often sophisticated technical capability of criminals, terrorists and activists. The Civil Contingency Act (2004) created an umbrella under which civil and emergency protection was coordinated to better address the Country's response capability to high impact disasters such as the London Bombings. The UK government faces a variety of challenges for emergency situations that require effective all-hazards response capability.

Radio coverage of the UK's existing PPDR nationwide network is currently in excess of 98 per cent of the UK's landmass.[61] Ubiquitous indoor coverage appears to still be an issue for PPDR agencies.[62] In comparison, at least one commercial 2G operator provides 87.2 per cent coverage but better in-building penetration, whilst for 3G services, this coverage figure drops to 75.7 per cent.[63] Ofcom's aim is to deliver 2G coverage to 99.9 per cent of premises. The government has recently auctioned 4G broadband spectrum licenses in 800/2600MHz bands to commercial operators. One of the licenses being auctioned has a radio coverage obligation that aims to drive indoor coverage of commercial mobile broadband services to 95 per cent of the UK population, and outdoor coverage to 98 per cent. The primary objective of this obligation is to help drive access to broadband services for rural communities. An absence of radio coverage may impede the ability of frontline police officers to perform their role, with inadequate communications potentially delaying or preventing their response to an incident. Mission-critical radio networks target national radio coverage with service availability in excess of 99.9 per cent, whilst commercial networks typically provide radio coverage to densely populated areas with service availability significantly lower than this: this factor however, in addition to security hardening and disaster recovery, assist to underpin a mission-critical network.[64]

In 2013, UK PPDR agencies are poised at the cusp of change, with increasing demand for PPDR users to access broadband data applications whilst mobile access to patient records for ambulance services; criminal records for police services; real

[60] http://www.etsi.org/plugtests/RCS-VOLTE/pres/PSCR%20-%20ETSI%20MSF%20GSMA%20RCS.pdf
[61] Ofcom. Infrastructure Report, December (2012).
[62] Johur, J. (2013). Op cit.
[63] Ofcom. Infrastructure Report, December (2012).
[64] Johur, J. (2013). Op cit.

time video images when responding to major emergency incidents, and others.[65] The bandwidth provided by current wireless PPDR networks is proving to be inadequate in meeting current PPDR demand and forecast future needs. A wireless broadband network offers a range of benefits that include enhanced efficiency; higher intervention rates for Police; faster response times, and other life-saving and asset protection capabilities.[66] The evolution of PPDR mobile broadband services can deliver enhanced services that agencies such as Police, Fire and Ambulance can benefit from when responding: [67]

- *Wideband access for 'video from the scene':* Increased spectrum can provide interactive consultation with specialists from the scene of an incident; reduce collateral damage to property through greater information; provide a video stream for live incidents to other agencies and command posts.
- *Creating local LANs at the scene:* The dissemination and communication with a wider PPDR team on-site for an incident can yield benefits through expedient information, image and other knowledge transfer and for monitoring.
- *Enhancing situational awareness*: Utilisation of smart devices for enhanced situation awareness such as en-route mapping of deployed assets, automated incident reporting from the frontline, and others.

The migration to LTE as an optimal mobile broadband model for PPDR can be maximised further when the two key *operational features* of narrowband public safety networks are factored: *group calling* and *operation outside of the network.* Group Call System Enablers (GCSE_LTE) has been agreed in 3GPP from LTE Release 12, which is planned for freezing in mid-2014.[68] Figure 5 depicts the role that these two critical narrowband features have in shaping a network strategy. If the narrowband feature of PPDR users being able to call other users in a group is incorporated, along with radio-to-radio functionality to permit out-of-coverage communication, mobile broadband LTE networks offer a more seamless migration to mission critical operations that embody some existing network features. In the absence of this,

[65] Analysis Mason, (2009). Op cit.
[66] www.gsma.com/newsroom/gsma-announces-new- global-research-that-highlights-significant-growth-opportunity-for- the-mobile-industry
[67] Spectrum Harmonisation in Europe: Trends and Topics 12th September, 2012.
[68] http://www.3gpp.org/Public-Safety

hybrid solutions may be required that segment the 'alongside operation' of narrowband voice and critical-data networks with broadband data LTE networks.[69]

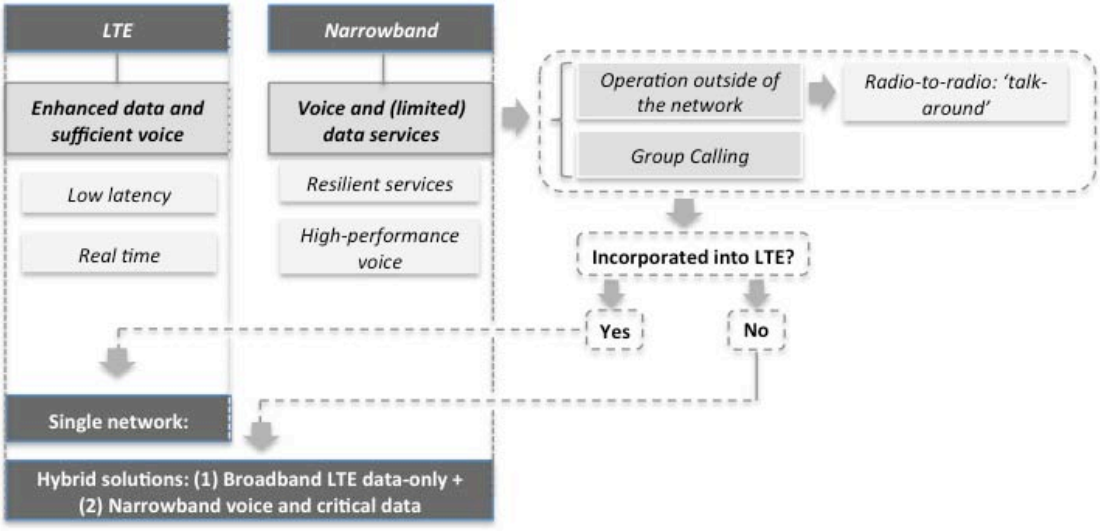

Figure 5: LTE versus narrowband networks and the role of key characteristics

Concomitant to, or perhaps as a result of the success of smartphones in commercial markets, suppliers continue to make billion dollar R&D investments annually to deliver new innovative features and products, as epitomised by leading players such as Apple, Samsung, Google, and others.[70] Today's smartphones possess greater processing power than a 1970s supercomputer,[71] and have spawned a billion dollar applications industry in the process. The emergence of LTE as the global technology standard for mobile broadband has facilitated its increased adoption by government, regulators and the PPDR sector for mission-critical mobile broadband communication services[72] (MCMB). The US Government has recently allocated new radio frequency spectrum and a US$7 billion investment for the implementation of a national, federal communications data network to augment the existing ASTRO P25 mission-critical voice and narrowband data networks that support the US equivalent of PPDR. In Europe, the TETRA and Critical Communications Association (TCCA) also selected LTE as the technology for future MCMB communications.[73] This is occurring against

[69] Source: Drawn from: Analysis Mason, LTE Advances in Public Safety Communication, 03 July, 2012 at http://mason.analysysmason.com/News-and-Events/News/LTE-advances-in-public-safety-communications/
[70] Johur, J. (2013). Op cit.
[71] www.newscientist.com/article/mg21528803.800-harness-unused- smartphone-power-for-a-computing-boost.html
[72] www.fas.org/sgp/crs/homesec/R42543.pdf
[73] TETRA (Terrestrial Trunked Radio) is the accepted digital radio standard for critical communications. TETRA is an open standard where the focus is on meeting the critical communications needs of public safety and security agencies and an increasingly wide range of other market sectors. The technology

a backdrop of austerity with many PPDR agencies being reduced in size and their budgets curtailed,[74] and debate on the appropriate future technology model and standards for PPDR. The TETRA standard is evolving to provide the TETRA Enhanced Data Service (TEDS), which will be an overlay to existing TETRA systems. Other potential solutions include commercially available technologies such as WiMAX and LTE. These technologies may offer economies of scale and the availability of handsets, whilst dedicated commercial networks are most often optimised to meet consumer demand, price pressure and customer service expectations. These commercial objectives are not necessarily congruent with the objectives of PPDR, with such networks not generally hardened or scoped to cater to the stricter requirements of PPDR agencies.[75]

With increased spectrum, PPDR agencies will continue to evolve from a narrowband focus and utilise efficiency enhancing and lifesaving applications and services that generate socioeconomic benefits. Although these are likely to still lag the plethora of applications and terminal choices available to consumers, the evolution of mobile broadband for PPDR will most likely have shifted from its current position. A key consideration for Government, policymakers, and PPDR agencies is the selection of the optimal operating and delivery mode. This is required to maintain current mission critical functionality, in addition to providing access to mobile broadband that widens existing service offerings. Debate continues on this theme, to assess the use of LTE and TETRA to deliver mission critical wireless broadband and voice in a manner that fulfills the objectives of multiple stakeholders. Wireless broadband networks present a unique opportunity to revolutionise how public safety agencies respond to emergencies, with first responders able to utilise new and significant applications that contrast a previous reliance on narrowband voice.[76] The evolution to viable commercial LTE for Public Safety is likely to take the next decade 10 years, with existing solutions utilised during this transition, and an increasingly greater adoption occurring by PPDR organisations as time progresses.

has been standardised by ETSI (The European Telecommunications Standards Institute), at: http://www.tandcca.com/Library/Documents/About_TETRA/TETRA_Fact_sheet_09-12_Final_2.pdf

[74] HMIC (2013). Policing in Austerity: Rising to the Challenge.

[75] Analysis Mason, (2009). Op cit.

[76] Peha, J. M. (2007). How America's fragmented approach to public safety wastes money and spectrum. Telecommunications Policy; 31 (10-11); pp:605-618.

2.2 Adoption by Public Safety Agencies of mission critical mobile applications: A focus on UK Police

Emergency services generally encompass Fire, Ambulance and Police. All three of these services have a critical reliance on mission critical mobile applications.[77] The overwhelming majority of the UK's PPDR resources are in the Police Force, with this group also arguably representing the most diverse use of mobile communication:[78] although sharing point-to-point dispatch with the Ambulance Service and the Fire Brigade, day-to-day Police work includes frontline patrolling in the community on foot, car, motorcycle or bike.[79] A step-change has been occurring following a review by Her Majesty's Inspectorate of Constabulary ('HMIC') in 2011 that defined a spending review period 2011/12-2014/15 during which time key austerity measures were to be met: a 20 per cent cut in the central government police funding grant for all 43 forces in England and Wales by 2014/15 (in real terms); a cash saving of £2.1 billion by 2014/15; a reduction of 34,000 resources balanced almost equally between Police officers and Police staff.[80] These changes are occurring against a backdrop of spending reviews on ICT and strategies for technology change by many forces as they adopt mission critical technology to 'work smarter', with the UK Home Office Minister confirming: *"Exciting work is already underway: apps are being developed to allow forms to be filled in automatically on the street, rather than in time-honoured (and time-consuming) pen and paper fashion at the station. Officers should be able to collect video and picture evidence on the street and download it straight into a digital file.*"[81]

The utilisation of mobile broadband and new applications is a key component of the step-change being evidenced in UK Police forces, with the Metropolitan Police's ('the Met') Assistant Commissioner confirming that mobile technology would play a key role in policing going forward: '*We know that the resolve of victims in domestic violence can fade away very quickly for a whole range of complicated reasons. If [officers] are able then and there to take a statement, and photograph it [using a mobile device] so your evidence capture at the start is much stronger, your chance*

[77] Peha, J. M. (2005). How America's fragmented approach to public safety wastes spectrum and funding. Proceedings of the 33rd Telecommunications Policy Research Conference
[78] Johur, J. (2013). Op cit.
[79] Bowers, K., et al. (2011). Do Geographically Focused Police Initiatives Displace Crime or Diffuse Benefits? A Systematic Review. Journal of Experimental Criminology: v7(4); pp:347-374
[80] HMIC. Adapting to Austerity: A review of police force and authority preparedness for the 2011/12–14/15 CSR period.
[81] Speech given by Home Office Minister Damian Green on the need for police reform - 8 July 2013. https://www.gov.uk/government/speeches/damian-green-speech-on-police-reform

then with the offender of pushing through with that is much greater'.[82] Demand from the Police Force, driven in part by austerity, will continue to be an influencing factor in the evolution of mobile data. During 2005, the Home Office allocated funding to a Mobile Information Programme (MIP) with the objective of increasing the visibility of frontline police officers to the public through the rapid deployment of mobile data devices. In addition to circa 140,000 UK Police officers using TETRA, around 51,000 commercial mobile devices (CMD) had been rolled out as at March 2011, including 10,000 devices deployed outside the Home Office's MIP.[83] These CMD devices are operated using commercial narrowband and wideband data services with tangible benefits including an average increase in time spent out of the station of 18 minutes per officer per shift.[84] South Yorkshire Police also demonstrated savings of 30 minutes per shift per officer and £6m per annum using Blackberry devices, with the benefits attributed to these trials including:[85]

- Extra time spent policing in the community.
- More effective crime fighting such as the ability to perform visual identity checks.
- Photographic and CCTV evidence capture to help secure convictions.

The UK's largest Police Force, the Met, intends to expand its use of mobile technology over the next few years with around 20,000 mobile devices added and a stated intention for officers to 'use their cars as an office' in 2014-15.[86] This is expected to maximise officer visibility, reduce costs and improve community confidence: three key objectives for Police forces.[87] Between 2008-2011, Leicestershire Police utilised enhanced mobile data terminals to streamline its incident report process, yielding an estimated £5.2m saving during this period, increasing visibility by 44 per cent due to greater retention of officers on the front line; reducing crime by 26 per cent and doubling public confidence to 85 per cent.[88]

[82] Assistant Commissioner Mark Rowley, MPS, speaking to the Budget and Performance Committee, 18 June 2013. London Assembly Budget and Performance Committee: Smart policing How the Metropolitan Police Service can make better use of technology. August 2013.
[83] Home Office and National Policing, (2012). *Mobile Technology in Policing.*
[84] Ibid.
[85] http://uk.blackberry.com/content/dam/blackBerry/pdf/a/europeMiddleEastAfrica/english/blackberry-case-study-southyorkspolice-en.pdf
[86] London Assembly. Op cit.
[87] Chief Constable Simon Parr, Association of Chief Police Officers, speaking to the Budget and Performance Committee, 5 March 2013.
[88] London Assembly. Op cit.

In the US, more than 2 million PPDR first responders exist.[89] This encompasses around 630,000 police patrol officers; 300,000 firefighters; other public safety workers and 100,000 Federal Government employees in protective service occupations. Many of these utilise advanced communication infrastructure and devices in their day-to-day functions, including mission critical wireless broadband.

Over 60 per cent of all US law enforcement agencies utilised automated incident report transmission in 2007, versus 38 per cent in 2003, with the current figure expected to be higher still.[90] The trend for 'crossover' applications that augment narrowband technology with mobile broadband is reflected by the Queensland Police Service's rollout in Australia in mid-2013 of 400 iPad minis. These will utilise the Force's intranet and a newly designed in-house app, that will mitigate the need for in-field officers to utilise their two-way radio to speak to an operator, with the State's Minister for Police and Community Safety announcing that: *"With the mobile system, police officers will have [all that] information at their fingertips, saving officers waiting time, and allowing them to move onto other jobs. It is hoped that by reducing the time it takes to perform searches, this Police app will save each police crew around 30 minutes each shift."*[91] A similar strategy to negate radio calls to an operator and empower front-line police with mobile broadband occurred in the Tasmanian Police Force, with 40 3G-capable tablets introduced and the State's Commissioner for Police confirming that: *"One of the main benefits of using this more responsive technology is the amount of time it can save our officers working on the front line. For example, officers using these tablets will be able to submit reports live from the field, rather than having to return to the station to complete their paperwork*."[92] This theme is increasingly emerging across Police forces, with a growing number of municipalities in the US now leveraging wireless broadband networks to enable officers to access real-time information, upload reports, view video and in the process sever the need to be joined to the dispatch center awaiting instructions.[93]

Solutions currently being offered to US Public Safety agencies today and over the next 5-10 years will likely support multi-mode operation that can operate across dedicated MCMB networks, commercial broadband networks and WiFi networks. Multi-mode operation is also expected to be complemented by national roaming

[89] The Benefits of Transitioning to a Nationwide Wireless Broadband Network for Public Safety. The White House. June 2011. http://www.whitehouse.gov/sites/default/files/uploads/publicsafetyreport.pdf
[90] http://www.policechiefmagazine.org/magazine/index.cfm?fuseaction=display&issue_id=12011&category_ID=4
[91] http://www.zdnet.com/qld-police-to-trial-ipad-mini-police-app-7000018640/
[92] Ibid.
[93] http://www.wi-fiplanet.com/columns/article.php/3499546/Wi-Fi-Policing-Comes-to-Georgia.htm

agreements with one or more commercial broadband networks. These capabilities will provide frontline police officers with a greater number of sources of radio coverage, increased service availability compared to today's mobile communication solutions, and in the process, address a number of the requirements inherent in the continued use of dedicated narrowband voice networks today.[94] Debate continues at present however on whether data and video applications are mission critical *today,* or whether this is a future outcome.

The increased utilisation of mission critical mobile broadband presents technical and operational challenges to Government, policy makers and PPDR agencies, but it also offers significant opportunities. In addition to services already defined in this report, enhanced services offered to PPDR resources in the field such as video streaming, body-worn cameras, vehicular cameras, facial recognition, automatic number plate recognition and others, offer the chance to add significant value to the ability of police to operate into the future.[95] The Chief Executive Officer Police Federation of Australia, one of two countries where 700MHz auctions have already occurred, stated*: "This is a generational opportunity for policing to get access to such technology*."[96]

3. The Opportunity Cost of 2x10MHz in 700MHz

The net benefit or cost of the dedicated utilisation by Emergency Services in Public Protection and Disaster Relief of the 2x10MHz 700MHz band can occur when both the socioeconomic benefit is calculated and the opportunity cost of its alternative use. The potential forecast socioeconomic benefit of £5 billion p.a., for PPDR utilisation of this spectrum can be compared the opportunity cost for the alternative use of the spectrum: auction to commercial operators. To date, only two auctions have occurred for 700MHz, which has been earmarked for the provision of public safety communications. Ofcom, the UK Spectrum Regulatory Agency has stated that: *"Ofcom's UHF Strategy Implementation work concerns the future of a part of the radio spectrum which we call the 700MHz band (694-790MHz). Implementing our UHF Strategy is a priority for Ofcom and our objective is to secure the best outcome for citizens and consumers. To do this, we are supporting the international and European work that is underway to harmonise the 700MHz band, which would allow*

[94] Johur, J. (2013). Op cit.
[95] Commonwealth of Australia. Parliamentary Joint Committee on Law Enforcement. *Spectrum for public safety mobile broadband.* July, 2013.
[96] Ibid.

it to be used for mobile broadband. At the same time, we are doing work to ensure that the current users of the 700MHz band (mainly digital terrestrial television and programme-making and special events) will be able to continue to provide services in the event of any future change of use of the 700MHz band."[97] Ofcom's objectives with regard to the use of UHF bands IV and V1, which cover the frequency range 470MHz-862MHz, are two-fold:

- Enable the release of additional low frequency spectrum for mobile broadband use, to help meet the rapidly increasing demand for mobile data capacity, and;
- Secure the ongoing delivery of the benefits provided by Digital Terrestrial Television (DTT).[98]

The 700MHz spectrum was auctioned in the United States in early 2008 across five blocks of frequencies. The fourth block, or D Block, included 10MHz that would be auctioned to one licensee to provide public safety communications throughout the US. The D Block only received one bid of US$472 million, but a license was not awarded as this did not meet the US$1.3 billion reserve price.[99] The Federal Communications Commission (FCC) raised more than US$19.6 billion for the remaining blocks of the 700MHz spectrum, and awarded 1,090 licenses, with AT&T Mobility and Verizon Wireless securing the majority of these for commercial wireless communications. In early, 2012 US Congress passed a law establishing the First Responder Network Authority (FirstNet), an independent authority within the U.S. Department of Commerce that will provide emergency responders with the US' first high-speed, nationwide network dedicated to public safety. This will utilise the 10MHz D Block spectrum. In Australia in May 2013, the Digital Dividend auction that included the 700MHz and 2.5GHz spectrum occurred and raised AU$1.96 billion, but that was below the government's expectations. One-third of the spectrum, with a reserve of AU$1 billion did not sell.[100] The 700MHz auction lasted only one round, with the spectrum selling for its reserve price.

A key consideration in the assessment by Government of the sale of 700MHz spectrum commercially is the alternative socioeconomic benefits that can accrue to the UK from the dedicated utilisation of this by public safety and disaster recovery agencies. Any socioeconomic benefits derived are *recurring* and can yield increasing

[97] http://stakeholders.ofcom.org.uk/spectrum/uhf700mhz/
[98] http://stakeholders.ofcom.org.uk/binaries/consultations/700mhzcfi/summary/UHF_SI_call_for_inputs.pdf
[99] http://wireless.fcc.gov/auctions/default.htm?job=auction_factsheet&id=73
[100] http://engage.acma.gov.au/digitaldividend/

returns over time as public safety resources benefit from the experience of utilising enhanced mobile broadband for mission critical activities. Utilising the common measure for spectrum pricing, per MHz/pop data from 700MHz and 800MHz auctions indicate that the opportunity cost of the commercial sale of 2x10MHz in 700MHz ranges from £300million-£1.2 billion, as depicted in Chart 1.

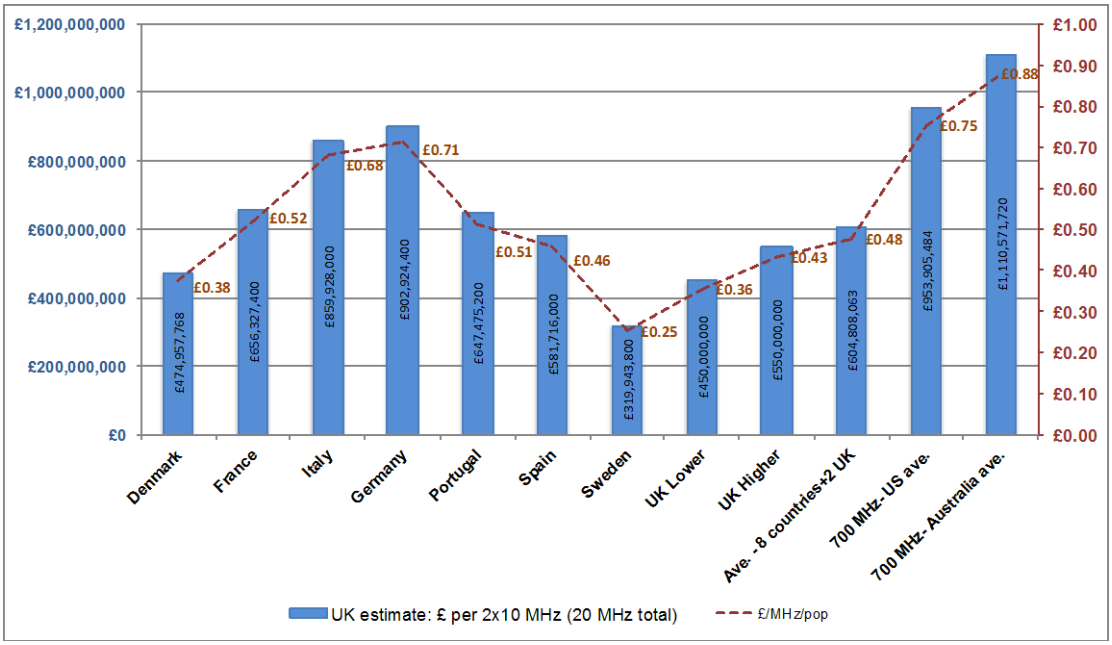

Chart 1: Opportunity cost of the commercial sale of 2x10MHz 700MHz Spectrum in the UK using cost (£) per MHz/pop from auction results

The higher values were obtained from the 700MHz auctions in the US and Australia. This was complemented by the 800MHz auction in the UK included prices of £450 million and £550 million. The sale of this spectrum is a 'one off' income stream for Government, with the opportunity to re-sell the spectrum occurring at the expiration of the 15 year license period. The market conditions at the time will dictate the nature of its utilisation and pricing. Previous UK 800MHz 2x10MHz auction results included two prices: £450 million and £550 million. These contrast the high prices defined by using the per MHz/pop costs from Australia and the US, at £953 million and £1.1 billion respectively. On an annualised basis, this highest (US) potential revenue equates to £73 million p.a., with the lowest potential revenue of £319 million equating to £21 millon p.a. These are significantly lower than the forecast annual socioeconomic benefits forecast from the use of the 2x10MHz in 700MHz of around £5 billion p.a., or when compared to only the forecast benefits from the use of mission critical broadband for Police interventions, of £1.4 billion.

It is envisaged that the existing paradigms for emergency communication and data access will continue over approximately the next 5 years, *augmented* by the utilisation of 2x10MHz in 700MHz spectrum. As the plethora of new services offered become ensconced, operationalised and ubiquitous within and amongst public safety agencies, their return to shareholders, ultimately the Public, will increase. The opportunity cost of seeding this must be considered today, to accurately position the utilisation of mobile broadband spectrum for public safety in the appropriate discussion and decision forums. Any 700MHz spectrum decision at WRC-15 will ultimately be in effect for the next 20 years.

4. Defining the Social Benefits of Mission Critical Mobile Broadband Applications by Public Safety Agencies

4.1 Establishing the benefits ecosystem

A cadre of cost-benefit analysis exists on crime and the value of life in the context of accidents, crime and health.[101] A lacuna exists however on the socioeconomic benefits that mission critical communication can precipitate for public safety.[102] In order to bridge this, an ecosystem of activities has been defined and the socioeconomic benefits estimated and consolidated. It is recognised that this is not inclusive of all relevant applications and services, and that this is an evolving landscape. It should be viewed as a starting point for further discussion on the potential socioeconomic value that can be assigned to spectrum and compared to the opportunity cost of the commercial sale of this scarce resource. The pace of change in the adoption of mission critical mobile broadband by public safety agencies is expected to accelerate as 700MHz, 4G and other enabling factors deliver even faster mobile broadband.[103] This will have implications across an even wider supplier base as devices, applications and operational infrastructure evolve across public and commercial sectors to deliver required end-to-end functionality.

[101] Brandon, C. et al (2001). Costs and Benefits of Preventing Crime. Westview Press. U.S.; ROMAN, J. and FARRELL, G., 2002. Cost-benefit analysis for crime prevention: opportunity costs, routine savings and crime externalities. IN: N. Tilley (Ed.); Evaluation for Crime Prevention, Crime Prevention Studies, 14, pp. 53-92; Michael R. Gottfredson (2013); A Note on the Role of Basic Theory in Thinking About Crime Prevention. European Journal on Criminal Policy and Research. Volume 19, Issue 2, pp 91-97; Blaeij, A.T. de, Florax, R.J.G.M., Rietveld, P., and Verhoef, E. (2003). *The value of statistical life in road safety: A meta-analysis.* In: Accident Analysis and Prevention: vol. 35(6); pp 973-986; Hall, R. E., and Jones, C.I., (2007) The Value of Life and the Rise in Health Spending. The Quarterly Journal of Economics. v122(1): pp: 39-72.

[102] Johur, J. (2013). Op cit.

[103] http://media.ofcom.org.uk/2013/02/20/ofcom-announces-winners-of-the-4g-mobile-auction/

An estimation of the socioeconomic benefits of mobile broadband for PPDR has been undertaken across four areas: *Safety*, *Efficiency*, *Dedicated utilisation (quality of service)* and *GDP impact.*

Figure 6: Socioeconomic PPDR ecosystem assessed[104]

These encompass a number of sub-areas:

Safety: This represents the major area of investigation, focusing principally on Police to assess the use of mobile broadband for crime *intervention* and *productivity improvement in utilisation*. The theme of intervention is extended into ambulance responsiveness and mortality. Some elements of assessment are also applicable in 'Efficiency', but are presented in this section due to their utilisation for intervention

***Efficiency*:** This section focuses on Police, with one element extrapolating the efficiency metrics achieved by a number of UK Police forces to a national level. A further component extends efficiencies being obtained by some US Police Divisions such as Traffic Police to a UK scenario to define efficiencies.

***GDP*:** Significant difficulties exist in attempting to assign causality to an estimated impact on GDP from a reduction in crime or efficiency, with recent research highlighting the cost of crime as a proportion of GDP. This section provides an overview of findings and dovetails into the tangible 'neighbourhood effect' that a reduction in crime can yield, particularly on UK house prices, utilising US data and case studies.

[104] Source: LSE Research. Components are not depicted to scale.

***Innovation from harmonisation*:** With the emphasis on harmonised 700MHz spectrum across Europe, this section reviews the socioeconomic benefits that could accrue from the production in particular of customer equipment for 'one market'. This is in contrast to production for a fragmented market where economies of scale and scope are often obviated.

The potential forecast socioeconomic value is tiered, with greater emphasis placed in the analysis on some of these areas, whilst others complement these, as depicted in Figure 7. The Efficiency and Safety components of the analysis comprise the base estimation for socioeconomic value, enhanced with the addition of the 'neighbourhood effect' of crime reduction. The additional components for innovation and macro GDP impact of crime are provided on an indicative basis but do not form the core component of the socioeconomic value due to the inherent difficulties in their estimation.

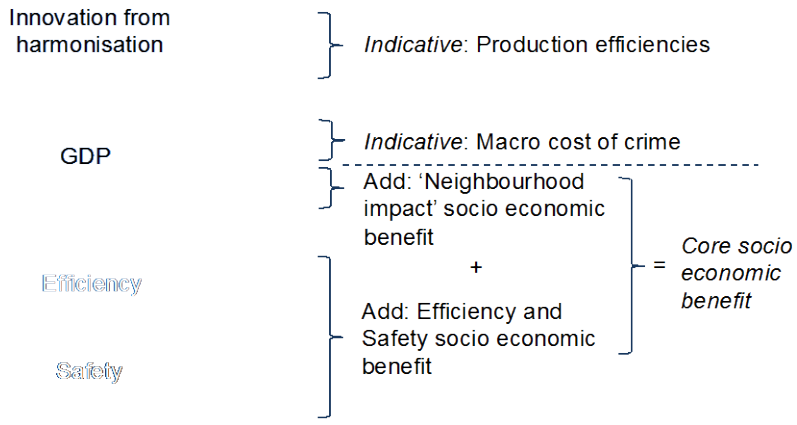

Figure 7: The layering of assessed socioeconomic value

The UK Police Service (UKPS) represents a significant proportion of the mission-critical user base within the UK and indeed Europe, and policing represents the majority PPDR user segment globally. A focus on safety within the context of Police concomitantly provides relevant insight into the market as a whole, including Fire and Ambulance.

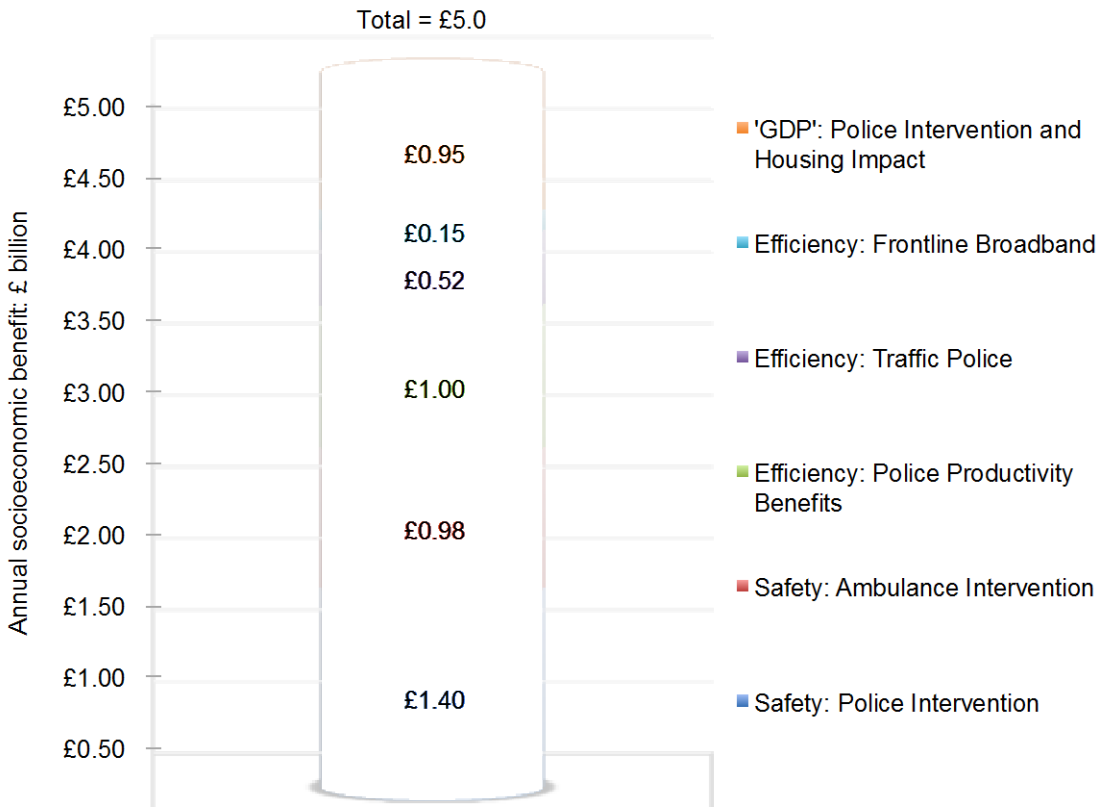

Chart 2: Consolidated socioeconomic benefit in the UK from PPDR use of 2x10MHz in 700MHz

Through interventions, Police and Ambulance provide the largest consolidation of forecast socioeconomic benefits, with a focus on *safety*. This is further complemented by the utilisation of mobile broadband to gain efficiencies on the beat, both on-foot and through the application by Traffic Police.

4.2 Driving Benefits through the Economy

4.2.2 Safety

Three areas were reviewed to forecast safety related socioeconomic value driven by PPDR mobile broadband utilisation: (i) crime reduction; (ii) mortality reduction due to reduced ambulance response times, and; (iii) productivity increases in the UKPS following the initial uptake of mobile broadband, and a learning curve established that re-engineers some processes.[105]

[105] http://www.straighttalkonline.com/cio-articles/going-mobile-wiltshire

4.2.2 Crime Reduction: A Focus on Police

The economic impact of violent crime to the UK was estimated to be £124 billion in 2012, or 7.7 per cent of GDP.[106] This includes expenditure by government for police, justice, prisons, asset damage and destruction. It also includes direct personal lost productivity from crime such as injury and lost earnings, and wider lost productivity in other parts of the economy.[107] The opportunity to assess the nature of any socioeconomic benefits from the utilisation of mission critical broadband is arguably most evident in policing, with the UKPS having a total budget of over £12 billion, a workforce of over 200,000, and around 20 per cent expenditure on goods and services including IT and Facilities.[108] As with other large service-based organisations, the majority of staff cost for the UKPS could result in further reductions in headcount if budget pressure continues beyond the Spending review. Other key attributes contributing to a suitability to adopt enhanced mobile broadband include:[109]

- A reduction in the Police budgets of over 20 per cent by 2015, equating to around £1.5 billion.
- A reduction of around 13 per cent of its workforce, resulting in 32,000 lost posts.
- A reduction in the number of officers in the back office from 7,300 in March 2010 to around 2,500 by 2015.
- A reduction of 14, 22, and 49 per cent respectively in the number of police stations, front counters, and shared locations.
- 22 forces signed up to *Digital Pathfinders* programme encouraging modernisation through digital technology.[110]

The reduction in back office staff roles is designed to concurrently 'protect' frontline police officers and Police Community Support Officers ('PCSO'). The efficiency and effectiveness of frontline staff will need to evolve however, with the above factors creating a milieu congruent with the expanded use of mobile technology to facilitate this, with the UK Police Minister stating: *"This is the way policing will go. It is the next big stage of reform – to make sure police come into the 21st century and the digital world fully...Whether that is using tablets so officers can stay on patrol and not go*

[106] Institute for Economics and Peace. (2013). UK Peace Index.
[107] Ibid.
[108] HMIC (2013). Policing in Austerity: Rising to the Challenge.
[109] Ibid.
[110] https://www.gov.uk/government/news/policing-minister-praises-digital-innovators. August 21, 2013.

back to the police station to file reports, or using body-worn cameras so if any incidents happen they can record them." [111]

Benefits to the end-user drive the estimation of the wider socioeconomic benefits from PPDR adoption of mobile broadband. In the context of policing, the desirable user benefit is *intervention* before harm can occur to the individual.[112] This tenet is at the core of the methodology utilised to assess the socioeconomic benefit of mobile broadband utilisation, having previously been defined and utilised in primary research with the UKPS.[113] A distinction can be made however between *mission critical* and *safety critical* decisions. The term 'safety-critical decision' can be defined as: *"A decision that results in either lives being saved or serious injury being avoided."*[114] 'Mission critical' has already been defined earlier in this paper, and relates to a function whose failure leads to catastrophic degradation of service that places public order or public safety and security at immediate risk.[115] The principal mode by which intervention occurs is through the dispatch of frontline police, or the engagement of frontline officers already at or near an incident. Visible frontline policing is recognised as a key factor in reducing the fear of crime and certain types of crime such as anti-social behaviour, street crime and property,[116] with the mission and measure of Police efficiency defined by the Association of Chief Police Officers ('ACPO') as "the absence of crime and disorder".[117] Any reduction in crime can have significant socioeconomic benefits: a marginal reduction in the estimated £124 billion annual crime cost in the UK of 5 per cent can yield over £6 billion in benefits to the economy. A street crime reduction initiative in early 2000 in England and Wales was estimated to have delivered a net socio-economic benefit of £107million-£130million with incremental policing costs of £24.1million: a return of 4.5-5.4 times the investment.[118] Few studies exist that quantify such activities. Primary research with UKPS has indicated that a number of the activities undertaken by frontline police with the operator can be undertaken with a mobile broadband device, including: accessing information; obtaining evidence; collaborating with other officers, and others.[119]

[111] Ibid.
[112] Johur, J. (2013). Op cit.
[113] Ibid.
[114] Johur, J. (2013). Op cit; additional primary research undertaken to define the term.
[115] TCCA, 2013. Op cit.
[116] Machin, S., and Marie, O. (2005). Crime and Police Resources: the Street Crime Initiative. CEP Discussion Paper No 680. London School of Economics.
[117] www.acpo.police.uk/documents/reports/2012/201210Policinginthe UKFinal.pdf
[118] Machin, S., and Marie, O. (2005). Op Cit.
[119] Johur, J. (2013). Op cit.

The use of mobile broadband by UKPS can provide better information to frontline police officers in real time, and result in higher quality outcomes and improvements efficiency and effectiveness.[120] Primary research indicates that in the near term, over the next 5-10 years, mission critical voice communication will remain the primary mode of communication for safety critical decisions. Mobile data is currently less likely to be utilised for safety critical decisions, but over time, it is anticipated that mobile broadband will be utilised for safety and mission critical scenarios. Figure 8 depicts this and migration and adoption profile.

Figure 8: Safety-critical decision making and future mobile broadband evolution

The considerable data and research on the cost of crime to the UK highlight that the crime category with the greatest socioeconomic impact is 'Violence against the Person', which is comprised of 'Homicide' and 'Wounding' ('Serious' and 'Other').[121] This is followed by 'Sexual Offences'. Data exist on the socioeconomic costs of these crimes, with an intervention having the potential to save a life or avoid serious injury, and result in a 'benefit to the end user'. This research draws on previously undertaken primary research in the UKPS to define the frequency of use of mobile communications by frontline police officers making safety critical decisions to quantify the extent to which interventions are undertaken that can 'save lives or avoid serious injury.' Juxtaposing this on data that defines the cost of each crime category and the frequency of each, it is possible to provide an indicative estimate of the socio-economic benefits that mission critical mobile communications can deliver via frontline police. For the purpose of this assessment, a simplified comparative process will occur as depicted in Figure 9:

[120] Kleijnen, J., P., C. (1982). Quantifying the benefits of information systems. Department of Business and Economics. Tilburg University (Katholieke Hogeschool Tilburg). 5000 LE Tilburg, Netherlands.
[121] Home Office Online Report 30/05. The economic and social costs of crime against individuals and households 2003/04.

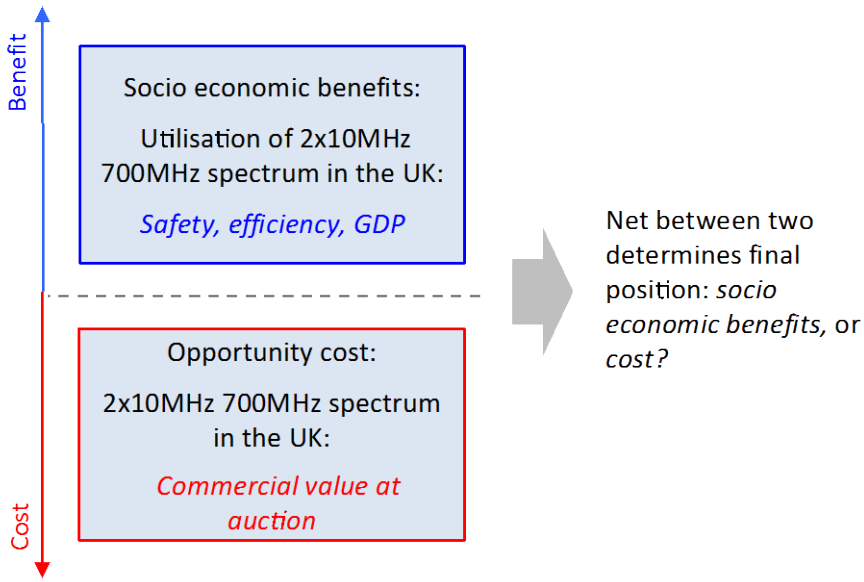

Figure 9: Net socioeconomic benefit or cost of 2x10 700MHz spectrum

The socioeconomic value generated by the use of the 2x10MHz spectrum for public safety can be compared against the potential value from the commercial auction of the spectrum. The net result is either the socioeconomic benefit or cost, as determined by the greater value.

Quantifying Safety Intervention Benefits in Police

Initial primary and secondary research undertaken during early 2013[122] defined the optimal methodology to be utilised to estimate socioeconomic value. A summary of the approach utilised encompasses the following stages:

i. Define the relevant crimes, their economic cost and frequency per annum.
ii. Define the *safety-critical intervention frequency* per annum for frontline officers where lives are saved or serious injury or sexual assault avoided.
iii. Define the proportion of safety critical interventions *likely to benefit from mobile broadband*.
iv. Apply the mobile broadband proportion to interventions.
v. Define socioeconomic value.

The overwhelming majority of research that exists appears to provide estimates of the cost of crime to the UK economy. A key differentiation of this research is the utilisation of primary research within the UKPS to define interventions, their

[122] Johur, J. (2013). Op cit; additional LSE research.

frequency and the relevant crime categories that this is applicable to. This process is ex-ante, occurring *before* crimes have eventuated and represents a 'hidden element' of policing: research in general is focused on the elements of crime occurring *after* the event.

Data for UK crimes have been obtained from the Home Office, with the last comprehensive report published in 2005.[123] The two categories of crime utilised for safety-critical interventions are *homicide and serious wounding,* and *sexual offences*. These are estimated to respectively cost the UK economy £3.6 billion and £8.4 billion annually, with 3.4m combined offences. The costs per offence are £47,000 and £31,000 respectively, as depicted in table 1.

Unit Cost per Crime: Homicide and Serious Wounding

Total homicide and serious wounding:		
Offences		77,000
Cost	£	3,626,000,000
Cost/offence	£	47,091
Sexual Offences		
Offences		269,000
Cost	£	8,464,000,000
Cost/offence	£	31,465

Table 1: Offences, frequency and cost.
(Source: Home Office[124])

The combined cost of £12 billion represents a third of the annual £36 billion cost of crime against individuals and households as depicted in Chart 3.

[123] Home Office Online Report 30/05. Op cit.
[124] Online Report 30/05. Op cit.

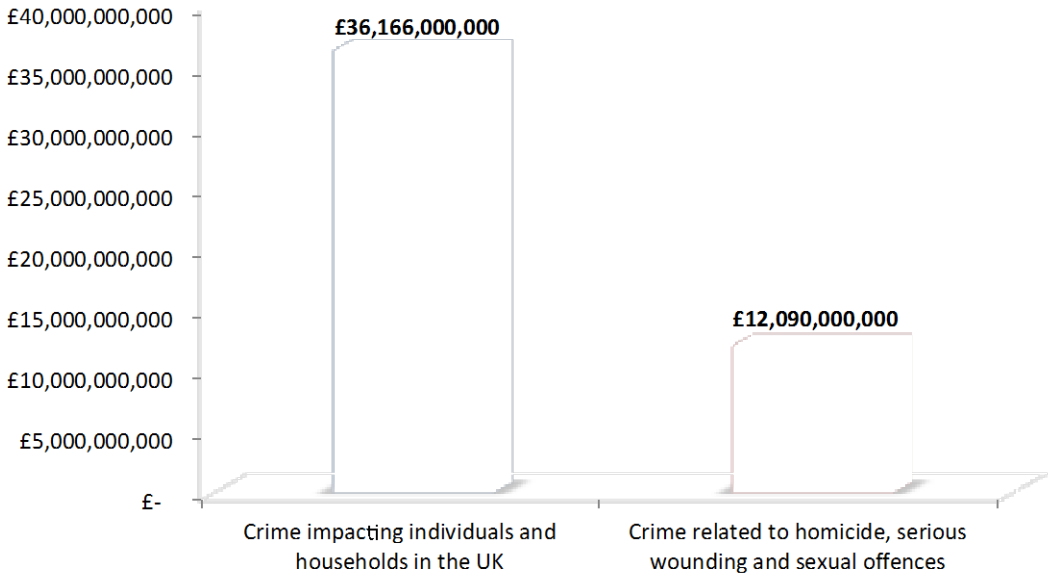

Chart 3: Crimes impacting individuals and households vs. crime related to group for intervention assessment[125]

Primary research forecast that the UKPS' frontline officers make 3.5 million safety related interventions per annum that save a life or result in a serious injury being avoided as depicted in Chart 4:[126]

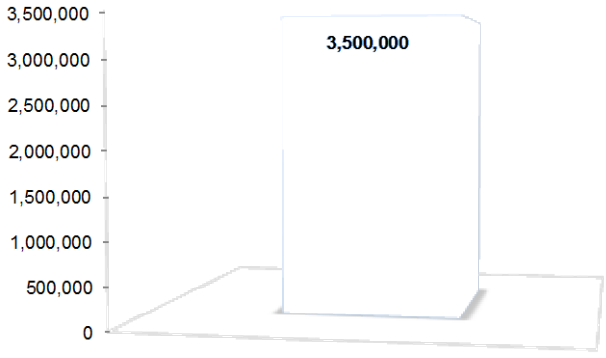

Chart 4: Annual safety-critical interventions by frontline officers: Lives saved or serious injury avoided.[127]

The data and methodology utilised to define this encompassed primary research being undertaken within the UKPS, including exploring the nature of interventions by frontline officers; the communication modes utilised; the nature of safety and mission critical communication today; how voice and data were utilised; trends, preferences, current and future behaviour with respect to both existing voice and data

[125] Source: Ibid.
[126] Johur,J (2013). Op cit.; LSE research.
[127] Source: Ibid.

communication and the proposed rollout plans for higher bandwidth mobile services; other themes. This permits an analysis of socioeconomic benefits to be ensconced within Police and to include operational, frontline, command and other functions.

From the 3.5 million estimated annual safety-critical interventions made by UKPS frontline officers, 83 per cent of interventions are estimated to utilise information from mission critical voice mobile technology. Furthermore, the proportion of interventions that mission critical data and video applications were forecast to utilise mobile broadband technology, which in turn benefit improvements to the efficiency and effectiveness of frontline officers and resulting in better outcomes, was estimated to be 12 per cent.[128] The possibility that future mobile data and video services will provide frontline officers with information in safety critical decisions is expected to increase in the future, along with the probability that these services will be mission critical. [129] Results indicate very high levels of perceived improvements to efficiency and effectiveness associated with the operations of frontline policing through the introduction of mission-critical mobile broadband services. With 12 per cent of interventions forecast to benefit from this new capability, the favourable outcomes possible in these instances yield an estimated socio-economic benefit of £1.4 billion per annum. Table 2 presents this figure for both classes of serious crimes against the individual. If this was segmented, Homicides and Sexual Offences provide £435 million and £1 billion of socioeconomic benefits respectively.

Crime category	Cost	Socio economic benefit p.a.	
	Annual	Annual	15 Years
Total homicide and serious wounding	£ 3,626,000,000	£ 435,120,000	£ 6,526,800,000
Sexual Offences	£ 8,464,000,000	£ 1,015,680,000	£ 15,235,200,000
Total	£ 12,090,000,000	£ 1,450,800,000	£ 21,762,000,000

Table 2: Socioeconomic benefit of interventions

Over life of an equivalent commercial licence, the socioeconomic benefits of the Police-driven interventions are estimated to be almost £22 billion across these serious crime categories. The socioeconomic benefits have not factored any multipliers into the UK economy. Arguably, this could be applied and the corresponding figures increased as a result to reflect the continued ability of the individual to work or be a consumer of goods and services and make a corresponding economic and social contribution.

[128] Johur, J. (2013). Op cit.
[129] Ibid.

A further element of safety is the maintenance of quality of service. This is a key attribute of current Radio communications, with redundancy and the ability to rely on mission critical communications integral to PPDR agencies being able to carry out their functions. If a reduction in service availability occurred, the consequences for PPDR include a risk to life should intervention be hampered or negated. If an inadequate network structure for MCMB were established, the ability to segment, prioritise and 'protect' public safety traffic may suffer. Utilising the forecast rate of interventions of 3.5 million per annum, the derived socioeconomic impact per intervention comprised of a weighted average of the cost of Homicide, Serious Wounding and Sexual Offences of £34k, is applied to the 95 per cent of interventions that are forecast to use information from this technology.[130] A five per cent reduction in service availability can potentially generate a socioeconomic cost of over £5 billion, encompassing 166,000 interventions that could be at risk. Even a one per cent reduction in service quality equates to a socioeconomic cost of £1.1 billion encompassing 33,000 incidents that could be at risk. A key factor for consideration is that any outage or degradation in mission critical voice and data, and video can impact intervention capability; in turn, this can result in a socioeconomic cost where such interventions are not able to result in a safe outcome.

4.2.3 Ambulance Intervention

The UK's ambulance service is divided into 11 NHS Ambulance Trusts[131] with over 1,700 ambulances in operation and 34,000 staff utilised.[132] One in twenty people in the UK annually use the Ambulance Service,[133] with 9 million '999 calls' made in 2012-2013. Of these, 6.98 million (76.9 per cent) resulted in an emergency response arriving at the scene of the incident, with a total of 5 million emergency patient journeys made, and 1.9 million patients treated at the scene, including 681,000 who were classed as Category A (immediately life threatening).[134] The national standard response percentages for Category A calls are for vehicles to arrive on scene within 8 minutes by an emergency response vehicle in 75 per cent of cases and 19 minutes by a fully equipped ambulance in 95 per cent of cases.[135] A total of 2.95 million (32.5 per cent) emergency calls related to Category A patients, with a target for ambulance

[130] Johur, J. (2013). Op cit.; methodology reviewed and utilised in LSE Research.
[131] http://www.nhs.uk/NHSEngland/thenhs/about/Pages/authoritiesandtrusts.aspx
[132] Ambulancezorg, Nederland, January 2010. *Report Ambulance Care in Europe.*
[133] http://www.hscic.gov.uk/catalogue/PUB11062
[134] Ibid.
[135] http://www.hscic.gov.uk/article/2907/Ambulance-services-Rise-in-number-of-patients-treated-entirely-at-the-scene.

arrival at the scene within 8 minutes. From June 2012, this category was further segmented into 'Red 1' (most urgent) and 'Red 2' (serious but less time critical).[136] The percentage of Category A incidents that resulted in an emergency response arriving at the scene of the incident within 8 minutes in 2012-2013 was: (a) 75.5 per cent during April-May; (b) 74.0 per cent for Red 1 during June-March; and (c) 75.6 per cent for Red 2 during June-March.[137] A total of 96 per cent of Category A incidents that required an ambulance arrived at the scene within 19 minutes. In total Red 1 calls account for around 5 per cent of all Category A calls, or 114,000 in total. These figures indicate that 4 per cent of critical calls are not arrived at within 19 minutes, equating to 118,000 calls from the 2.95 million Category A total.

Total expenditure on ambulance services was £1.9 billion in 2009-2010, with £1.5 billion classified as emergency transport services spend, and £0.4 billion on patient transport and other services. Spend on urgent and emergency services increased from around £1.1 billion in 2006-2007.[138] The Government has commenced reform of the NHS, including the transfer of the commissioning of ambulance services from primary care trusts to GP consortia as part of a £20 billion efficiency drive in the NHS by the end of 2014-2015. The ambulance service is required to identify a minimum of 4 per cent efficiency savings within its budget, equating to around £75 million per year.[139] As with the UKPS, staff costs comprise the largest component for the ambulance service, accounting for 68 per cent of expenditure.[140] Continued budgetary pressure by Government is likely to impact resources with ongoing work occurring by the ambulance service to seek savings and optimise operations. As with UKPS, austerity has facilitated a step-change to review efficiency whilst also ushering a review of future data and communication requirements.

Changes to resourcing levels are not by themselves sufficient to transform the ambulance service: in the short term they will merely meet budgetary targets. In recent parliamentary evidence on the UK Ambulance Service, the Chair of the Association of Ambulance Chief Executives tabled that in addition to reforms in staffing levels and improving the skills mix of ambulance crews, paramedics required access to nationally-held patient data in order to make more informed judgements regarding a patient's treatment*: "It would also be enormously helpful for front-line*

[136] HSCIC. Ambulance Services, England 2012-2013. June 19, 2013.
[137] Ibid.
[138] National Audit Office. Department of Health. Transforming NHS Ambulance Service. June, 2011.
[139] Ibid.
[140] Ibid.

paramedics—both those in the control room and responding paramedics—to have access to the national spine, which would enable them to pull down useful and critical information about a particular patient, rather than looking at patients with very limited information, as is very often the case."[141] The issue of accurate and timely data being available to ambulance crews remains topical, both for navigation and clinical purposes: a successful outcome depends on the interplay between multiple factors as depicted in Figure 10.

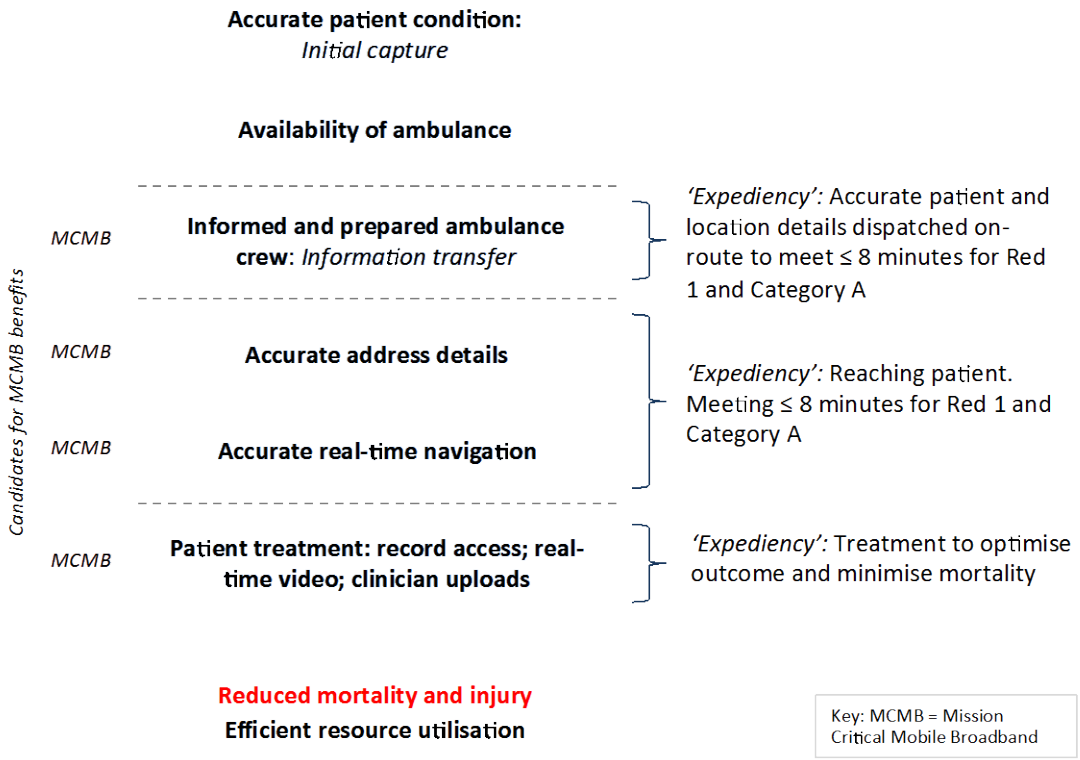

Figure 10: Socioeconomic benefit of expedient and informed ambulance dispatch

A number of the current processes in the ambulance activity chain are candidates for MCMB including an initial transmission process of patient location and details that complements the radio dispatch process. On route, broadband can enhance real-time mapping, traffic and address guidance. Patient records can be transmitted to the ambulance and upon arrival, these and other broadband-enabled services can be utilised such as real-time video (including for consultant interaction) and access to other data, images and files. Collectively, these may contribute to mortality reduction where such factors are currently undertaken at the hospital upon return.

[141] http://www.publications.parliament.uk/pa/cm201314/cmselect/cmhealth/171/17110.htm#n166

The allocation of the 700MHz D Block spectrum signed into law in the US in February 2012 will result in the US$7billion construction of a dedicated broadband network for public safety.[142] Amongst key services touted by Fire and Ambulance Chiefs are LTE apps that will permit them to view situational awareness data including GIS mapping data, building diagrams, hazmat data, video feeds from traffic cameras, and for Ambulance Services to transmit patient information and health metrics to emergency rooms, consultants and others both from the scene and whilst on route. Additional socioeconomic benefits can ensue with Fire and Ambulance teams able to treat patients in their homes, transmit patient information and optimise a path for care. The socioeconomic benefits can be significant with mobile broadband utilised both for mission critical and non-critical situations but with the ultimate common goal of patient care.[143] A key topical issue at present is the expedient dispatch of ambulances to a location, and implications to patient care and ultimately mortality when ambulance diversion occurs. Although a limited resource, London's Air Ambulance management team attends the most serious of the 4,000 daily 999 calls made in the Capital that require an advanced trauma team.[144] In 2013, 4G enabled mobile broadband was introduced, with savings over current solutions from seconds to two minutes, which are significant for trauma intervention. A key benefit has been the replacement of paper maps and slower GPS positioning systems with real-time self-correcting maps, and future plans that include video streaming, consultant access and patient record retrieval in the field.[145]

Recent research has indicated that for out of hospital cardiac arrest ('OHCA') patients in particular, for every 100 diverted ambulances, 3 'avoidable fatalities' occur on route.[146] This can also be extrapolated to encompass ambulance rides that are of a longer than targeted duration. These 'avoidable deaths' represents an opportunity to provide a significant socioeconomic benefit through broadband assistance at multiple points in a journey. At present, this could focus on the ability to provide accurate navigation capability and real-time information on hospital availability for critical care patients. As with homicide victims, the socioeconomic benefit that a saved OHCA victim can yield is significant both economically and socially. Research encompassing 10,554 cardiac arrests in the US indicated that reducing the 90th

[142] http://urgentcomm.com/fireems/fires-case-broadband-related-video
[143] Ibid.
[144] http://www.telegraph.co.uk/sponsored/technology/4g-mobile/10166778/london-air-ambulance-4g.html
[145] Ibid.
[146] Shen, Y.C., and Hsia, R. Y. (2011). Association Between Ambulance Diversion and Survival Among Patients With Acute Myocardial Infarction. *JAMA: The Journal of the American Medical Association*. V305(23): 2440 DOI: 10.1001/jama.2011.811

centile of response time to an ambulance to 8 minutes increased the predicted survival rate to 8 per cent from 6 per cent, and reducing this to 5 minutes almost doubled it to 10-11 per cent.[147] If people are reached before the onset of cardiac arrest, research indicates that the survival rate is 33 per cent.[148] Studies indicate that a 10 per cent increase in the relative risk of death occurred for each 10 km increase in distance and a 7 per cent increase for each 10 minute increase in journey time.[149] Debate continues to occur on the exact number of lives that could be saved annually if a greater proportion of ambulances reached their destinations faster, or were to transport patients faster to emergency care.

Studies indicate that an estimated 60,000 out of hospital cardiac arrests occur in the UK each year,[150] with 30,000 attended by emergency medical services.[151] The proliferation of mobile phones has assisted in the reduction of the time between OHCA collapse and a call being made to emergency services,[152] with mobility now emerging as a mode of further reducing the time to reach patients. With 357 diversions to other hospitals occurring in 2012, equating to an average of one per A&E per day, extra delays increase the risk of a patient's condition deteriorating.[153] Diversions occurred either when the ambulance was already on route to one hospital or in some cases after it had arrived. This delay can contribute to a worsening of a patient's condition, or even to result in avoidable death. The ability to utilise MCMB to provide real time mission critical data to ambulances on route, coupled with accurate alternative route planning early in the return-to-A&E journey can potentially assist to minimise these occurrences when supported with the operational re-engineering of some control room processes. Around 3,000 OHCA victims could potentially be saved in the UK if ambulances were able to achieve the target of reaching 75 per cent of critical Category A patients within 8 minutes.[154]

[147] Pell, P. J. et al (2001). Effect of reducing ambulance response times on deaths from out of hospital cardiac arrest: cohort study. BMJ. June: 322:1385.
[148] Ibid.
[149] Nicholl, J., et al. (2007). The relationship between distance to hospital and patient mortality in emergencies: an observational study. Emergency Medicine Journal. V24; pp: 665–668. doi: 10.1136/emj.2007.047654
[150] Perkins, J. D., and Cooke, M.W, (2012). Variability in cardiac arrest survival: the NHS Ambulance Service Quality Indicators. Emergency Medicine Journal. V(29)1.
[151] http://www.bhf.org.uk/pdf/ELS_policy_statement_June2012.pdf
[152] Iwami, T., Nichol, G., and Hiraide, A. (2009). Continuous improvements in "Chain of Survival" increased survival after out-of-hospital cardiac arrests: a large-scale population-based study. Circulation; V119: pp:728–733.
[153] http://www.dailymail.co.uk/news/article-2333083/Overstretched-A-amp-Es-turning-away-ambulances-Diversions-hospitals-happened-357-times-past-year.html#comments
[154] http://www.dailymail.co.uk/health/article-55521/Thousands-die-ambulance-delays.html

This is an estimate, as currently, little research exists to support estimates of loss of life touted for ambulance delays for OHCA victims. The 3,000 figure represents 10 per cent of the approximate 30,000 OHCA incidents that the Ambulance Service attends to each year. If mobile broadband and enhanced communications were utilised primary research and modeling indicates that around 20 per cent of this figure could be positively assisted and loss of life avoided in 560 cases. The Government has 'kick started' the process before the availability of additional broadband with a £3.4million investment to equip all of England's 3,000 emergency response ambulances with satellite tracking and navigation systems[155]. The 20 per cent estimate represents 1.9 per cent of OHCA's attended to by the Ambulance Service. A value of €2.1 million/£1.7 million for a lost life has been used as defined by Government,[156] with this value also utilised in other studies quantifying loss of life.[157] On this basis, a socioeconomic benefit of around £980 million annually is forecast if an additional 560 OHCA's do not result in a fatality when Ambulance services utilise mobile broadband to a greater degree to reach their patients faster and provide more informed critical care in order to mitigate these fatalities.

4.3 Efficiency Increases in Safety Interventions

4.3.1 Police Productivity

Mission Critical Broadband Communications has the ability to transform Police work across both the back office and the frontline. This is not occurring in isolation however, and is part of a wider system of change that includes procurement centralisation; facilities reduction; headcount reduction; ICT rationalisation and others across constabularies.[158] In some cases, this has resulted in productivity increases of 10 per cent or more, as constabularies utilise outsourced contracts, enhanced mobile technology and apps, and other services to enable frontline officers to stay 'visible' and in the process deliver more interventions.[159] The Met in London has identified data exploitation as a key priority, with investment in this area identified being as integral for the overall effectiveness of the Met as maintaining resources for

[155] Ibid.
[156] UK Department for Transport. Highways Economics Note No. 1. 2003 Valuation of the Benefits of Prevention of Road Accidents and Casualties. London: UK Department for Transport, 2004.
[157] Caro, JUJU., et al. (2007). Cost-Benefit Analysis of Preventing Sudden Cardiac Deaths with an Implantable Cardioverter Defibrillator versus Amiodarone. Value in Health. V(10)1; pp: 13-22.
[158] Serco Institute, (2008). *Making Time: Freeing Up Front-Line Policing*.
[159] http://www.cbi.org.uk/media/1865156/cbi_police_reform_report_embargoed_261112.pdf

officers patrolling local neighbourhoods.[160] This is expected to flow through to efficiencies over time in both the frontline and back office. Police forces overall also recorded £1.509 billion of efficiency savings between 2004 and 2008, with over half of these savings being cashable, and which funded new priorities or reduced budgets.[161] The UKPS must continue to undertake its public safety duties despite being required to achieve £2.4 billion in savings over four years by 2014/2015.[162] On average, forces have been reducing frontline workforce numbers by 6 per cent and non-frontline workforce numbers by 33 per cent between March 2010 and March 2015. During the same period, frontline officer numbers and non-frontline officer numbers are being reduced by 6 per cent and 42 per cent respectively.[163] It is anticipated that by March 2015, over half of the Forces will have 90 per cent of their officers in frontline roles. Primary research indicates that the 20 per cent funding cut is facilitating a culture of 'more with less' with respect to officers and the workforce undertaking duties. The Chairman of Nottinghamshire Police Authority encapsulated the current drive for efficiency savings after the Force achieved £1m in savings and increased its front line officers following the success of an initiative to connect mobile devices with the back office to access data*: "Officers will be doing less paperwork because we are investing in mobile technology which will keep officers out on the beat and is key to creating our financial savings,"* [164]

The UKPS may be able to achieve productivity gains of 5-20 per cent, spurred from reduced headcount; IT replacement; some facilities closure; an increasing adoption of mobile communication for both safety-critical and increasingly mission-critical applications; organisational realignment to direct resources to the front line and support them; and other initiatives. The current restructuring of a £12 billion budget and 200,000 resources will take time to yield potential benefits, but 'hot spots' of activities are emerging, spurred in many cases as 'bottom-up' as frontline police in particular embrace mobile communication to deliver productivity gains. Examples include Wiltshire Police's mobile and remote working solution that is estimated to have resulted in a 10 per cent productivity increase; the equivalent of adding 89

[160] http://www.london.gov.uk/sites/default/files/Police%20technology%20report%20-%20Final%20version.pdf
[161] http://archive.audit-commission.gov.uk/auditcommission/sitecollectiondocuments/Downloads/20100720policevfmreportfull.pdf
[162] HMIC. Policing in Austerity. Op cit
[163] Ibid.
[164] http://www.computerweekly.com/news/2240114611/Nottinghamshire-police-buck-mobile-failure-trend

officers but without the £4 million annual cost.[165] British Transport Police also experienced a similar productivity increase following a similar implementation.[166] In the US, similar austerity challenges have resulted in Police Forces adopting mobile broadband communications as a way to increase the presence of first responders. An example is the City of Altoona in Pennsylvania, which like other many US Police Forces sought to empower officers to work more effectively and faster, with similar Police Forces in neighbouring areas achieving an efficiency improvement from wireless broadband by at least 10 percent.[167] This Police Force exceeded the objective, providing access to critical data across information sources and the ability to upload field reports directly. A common theme evident amongst Police forces that have implemented mobile broadband applications appears to be the ability to increase frontline productivity. A further example of this is the City of Chattanooga in Tennessee, which implemented a city-wide wireless broadband network that resulted in 56 applications being introduced across public safety agencies with Police reporting a reduction in crime rates; productivity increases equivalent to placing 18 new officers in frontline roles; and an increased degree of intervention evidenced by a doubling of the arrest productivity rate.[168]

The wider longer-term adoption of mobile broadband by the UKPS is expected to mirror the initial productivity gains obtained by early-adopting UK Police Forces, and others internationally, with efficiency drivers common across PPDR organisations and initiated in many cases by budget cuts. If a figure of 10 per cent productivity gains due to mission critical mobile broadband is factored into the UKPS' 3.5 million currently estimated annual interventions, an additional 350,000 interventions could ensue. These interventions are *transition-driven* and 'stand-alone'; they are not predicated on the further utilisation of mobile broadband technology. Rather, they represent the adoption by the UKPS of new mission critical broadband technology that augment current solutions, and in the process yield an improvement in productivity. Over time, it is expected that any such incremental productivity gains will become operationalised and the relevant intervention rate at a point will become the new benchmark; if a 10 per cent intervention productivity rise is achieved, the future benchmark would become 3,850,000 interventions per annum. Complexities exist on estimating the exact socioeconomic benefit from additional interventions as this will

[165] http://www.straighttalkonline.com/cio-articles/going-mobile-wiltshire ; and Policing Plan for Wiltshire 2012/13.
[166] http://www.straighttalkonline.com/cio-articles/going-mobile-wiltshire
[167] http://business.motorolasolutions.com/publicsafety/pdfs/Altoona_CS_FINAL.pdf
[168] http://www.motorolasolutions.com/web/Business/BMS_Landing_Pages/Government/Government_Grants/Chattanooga_Case_Study.pdf

be determined by the mix of interventions undertaken. If the interventions made were distributed across all of the major categories for crime defined by the Home Office in the proportion that these have been recorded,[169] the socioeconomic benefit is around £1 billion annually for a 10 per cent productivity improvement. This is derived from 350,000 additional interventions occurring in the UK on an annual basis, with the socioeconomic benefit obtained by individual crime categories including, Homicide (£41m); Serious Wounding (£46m); Other Wounding (£277m); Sexual Offences (£243m); Common Assault (£76m); Robbery (£70m); Burglary in a Dwelling (£82m); Theft (All categories: £120m); Criminal Damage (£64m). If the mix of crimes successfully intervened varies, this figure will vary as well. This is believed to be a conservative estimate with a lower proportion of crime against the individual such as Homicide and Serious Wounding.

A number of key efficiency examples in the application of MCMB in Police have been covered in the previous section. This section reviews the potential efficiency benefits that can accrue in two areas of Police activity that have resulted in positive socioeconomic benefits in the US and which can be applied in the UK: Traffic Police and Mobile Operations. Each represents the commencement of a migration to MCBC, seeded by a mix of safety-critical and mission critical elements at present.

4.3.2 Traffic Police

The highly mobile and visible role that Traffic Police (TP) plays represents both an opportunity and a challenge for MCMB and safety-critical voice communication: Officers are consistently travelling between areas of varying coverage for both Radio and cellular networks and are routinely required to cover considerable distances. An inherent danger exists in the role due to the unpredictable nature of vehicle stops and the requirement to be positioned in traffic except when returning to base intra-shift to complete paperwork and/or bring an individual to the counter. In addition, officers often patrol alone with their communication services representing a key 'lifeline' for safety and for mobile data access. These attributes also make TP an ideal candidate for early-stage MCMB adoption.

[169] Home Office Online Report 30/05: The economic and social costs of crime against individuals and households 2003/04.

The Arizona Department of Public Safety's Highway Patrol employs 780 officers patrolling over 6,000 miles of roadway[170] who make half a million traffic stops per annum, in addition to responding to thousands of traffic collisions, motorist assistance and other calls.[171] All Officers have been equipped with 4G LTE or 3G enabled mobile laptop-style computers with cameras, PC capability and apps that enable mobile reporting across a range of areas including undocking and completing reports with stopped motorists, before uploading these to their network. In addition, productivity gains have been made across the Justice chain, with less input errors and without the requirement for back-office staff to input handwritten notes. These benefits support the previous section's analysis of enhanced productivity accrued by MCMB devices. In addition to these however, the major socioeconomic benefit generated by the adoption of MCMB by TP is potentially, *visibility.* For every minute that a police officer is stopped by the roadside attending to a traffic incident, the probability of a secondary collision occurring has been estimated to increase by 2.8 per cent.[172] This results in a possible roadside collision occurring for 36 minutes that a TP officer is stationary.

The UK employs 4,675 Traffic Police[173] who share many common work and organisational factors with their US counterparts. A range of tasks are undertaken by these officers, including remaining stationary with license plate recognition scanning cars, attending the scene of an accident; undertaking visits to follow-up road accidents, and other tasks. As such, these result in longer 'stops' being undertaken on some days, whilst on others, consistent patrolling may result in higher stops occurring with motorists. Factoring in both US and UK analysis on the working pattern of Traffic Police, metrics have been defined that include an average of around 5 stops per working day, recognising the previous caveat that this may vary considerably between days. A profile was defined to distribute stops across *durations* encompassing six bands ranging from 0-10 minutes to 60 minutes and over. Using UK accident data to define fatal and serious car accidents,[174] the ratio for each of these was calculated and data on the cost to society for each was obtained.[175] Following further data analysis, the socioeconomic benefit of the use of MCMB by TP is estimated to be around £520 million per annum, incorporating approximately 1,400

[170] http://www.azdps.gov/about/Organization/Highway_Patrol/
[171] http://www.panasonic.com/business-solutions/public-sector-case-study-arizona.asp
[172] Ibid.
[173] https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/223836/police-workforce-supptabs-mar13.ods
[174] http://www.apccs.police.uk/fileUploads/APCC_Group_Emails/Road_accident_statistics.pdf
[175] https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/9280/rrcgb2011-complete.pdf

predominantly serious secondary crashes and a smaller proportion of fatal crashes forecast to be avoided. In the rollout stages, a staggered socioeconomic benefit could occur if an increasing proportion of TP were equipped with comparable MCMB.

4.3.2 Operational Productivity from Field Applications

Some Forces in the UK have commenced rolling out mobile broadband and achieved operational savings as defined in earlier sections of this report. This includes Nottinghamshire Police, which has successfully utilised mobile devices and software to connect frontline officers to connect directly to back office systems.[176]Collaboration with an external IT Services organisation resulted in the design and development of solutions delivered via a wireless mobile device, with more than 2,000 smartphones deployed with full mobile data access to police systems. The use of mobile broadband on the frontline has reduced the need for one officer per shift to undertake paperwork utilising overtime, resulting in over £1m in savings in total.[177] Support from senior Officers has assisted such changes to occur and for gains to be realised, with the Chairman of the Nottinghamshire Police Authority stating: *"Officers will be doing less paperwork because we are investing in mobile technology which will keep officers out on the beat and is key to creating our financial savings."* [178] Utilising data on the Force's expenditure; staffing levels; proportion of frontline officers and savings, an extrapolation of the adoption of such MCMB functionality by all of the UKPS could yield a socioeconomic benefit of £156 million annually. Based on a review of the current initiatives across the Police Forces in the UK, this is believed to be representative of the efficiency-enhancing administrative functionality that MCMB can provide to the frontline.

4.4 Intervention, GDP and Local Community

Significant complexities exist in attempting to assess the socioeconomic effects of public safety and crime reduction at the macro level on GDP. It is widely accepted that crime has a significant impact on society,[179] with research indicating the overall costs of crime as a proportion of output and on a stand-alone basis.[180] In the UK, the total cost of crime has been estimated as being 7.7 per cent of GDP, in contrast to

[176] http://www.computerweekly.com/news/2240114611/Nottinghamshire-police-buck-mobile-failure-trend
[177] Ibid
[178] Ibid.
[179] Detotto, C., and Otranto, E. (2010). Does Crime Affect Economic Growth? KYKLOS. v63(3); pp:330–34
[180] Czabanski, J. (2008). Estimates of cost of crime: History, methodologies, and implications. Springer, Berlin.

11.9 per cent in the US.[181] Current research has not adequately addressed the potential benefits that intervention to crime can have on the economy, but it has confirmed that crime negatively impacts economic performance.[182] It is estimated that a 1 per cent rise in crime rates can reduce real economic growth by 0.0004% in a month.[183] Conversely, it can be posited that a reduction in crime rates could contribute to economic growth. Research indicates that the efficiency of a country's criminal justice system may be an explanatory factor influencing crime variations between countries.[184] The ability of the Police to carry out their functions effectively is arguably an extension of this: current research does not however capture the value or benefit in *interventions to crimes*. It can be forecast that if the annual estimated cost of crime was reduced from the current £124 billion, or 7.7 per cent GDP,[185] significant socioeconomic benefits could ensue. Even a marginal reduction in this figure represents a significant impact across events such as loss of life; serious injury; asset damage; theft and others. Although causality between socioeconomic benefits and GDP cannot readily be proven due to the potential influence of a myriad of other variables, it can be posited that a reduction in crime through an enhanced degree of interventions can reduce the downstream impact across a plethora of areas in the economy including, health, property, the judicial system, and others. Collectively, these constitute the cost of crime. A reduction in this cost could arguably impact GDP, but a dependency cannot readily be proven due to the possible influence of other variables. The proportion of GDP accounted for by crime can be defined however, it is utilised as a more appropriate indicator for the macroeconomic cost of this activity.[186] Arguably a reduction in the crime through enhanced intervention and other factors can affect upstream and downstream elements of the crime-related ecosystem. A change in crime could affect these elements, that flow-through to affecting GDP.

Limited research has forecast that crime has a negative socioeconomic impact on house prices.[187] In London, a 0.1 per cent standard deviation increase in crime was estimated to have resulted in a 0.94 per cent decrease in property values, equating to a £0.3 billion decrease in early 2000.[188] Conversely, a reduction in crime has been

[181] Brand, S., and Price, R. (2000). The economic and social costs of crime. Home Office Research Study No. 217; Home Office , London.
[182] Detrott, and Otranto, (2010). Op cit.
[183] Ibid.
[184] Ibid.
[185] Institute for Economics and Peace. (2013). UK Peace Index.
[186] Ibid.
[187] Gibbons, S. (2004). The Costs of Urban Property Crime. Economic Journal; v(114); F441–F463.
[188] Ibid.

posited to increase property values. US research estimated that a 10 and 25 per cent reduction in violent crime in 8 major US cities increased house prices by 0.83 and 2.1 per cent respectively one year later.[189] This equated to a rise in values of $US16 billion and $US41 billion respectively. In London, property crime fell by 40-50% between the late 1990s and the following decade.[190] Although variations exist in crime reduction across the UK, overall, total homicides have reduced by 28 per cent over five years to 2012; violent crime reduced by 21 per cent, weapons crime reduced by 34 per cent, and public disorder reduced by 29 per cent.[191] If a 0.1 per cent standard deviation decrease in crime ensued from this sustained crime reduction, a £0.3 billion increase in house prices could have ensued in early-mid 2000 based on house prices at the time. This figure could be valued at around £1 billion today with continued crime reduction and current house prices.

Enhancing intervention measures through ubiquitous mobile broadband could potentially decrease crime as outlined in this research through the longer utilisation of Police on the frontline as they carry out some tasks such as reporting remotely and utilise enhanced information via broadband. These factors can potentially result in neighbourhoods becoming safer and consequently more 'desirable' places to live. House prices can increase as demand increases. US research has indicated that even higher socioeconomic benefits than those forecast for London are likely if the effect of crime reduction on house prices in other major UK cities is included. It is recognised that at present this is an area that can benefit from more granular analysis, with a more cursory assessment occurring at this time. This area nevertheless reflects the potential wider socioeconomic benefits that could be accrue due to an enhanced intervention strategy in policing, with the belief that the sustained reduction in crime over at least the last decade could have a positive flow-on effect on house prices. Increasing earlier and current intervention rates even further through the use of mobile broadband could potentially increase property values to a greater degree than those observed to date and in the process, raise an area's 'attractiveness' and its property values.

[189] Shapiro, R. J., and Hassett, K. A. (2012). The Economic Benefits of Reducing Violent Crime: A Case Study of 8 American Cities. Centre for American Progress.
[190] http://blogs.lse.ac.uk/politicsandpolicy/archives/33606
[191] Institute for Economics and Peace. (2013). Op cit.