Australian Rail Industry

Submission to the Minister for Broadband, Communications and the Digital Economy

1800 MHz Spectrum Licenses

15 July 2011
1. Executive Summary

Australia is facing a number of challenges including significant population growth, increasing urban congestion, the move towards a carbon constraint economy and ensuring energy security. These challenges must be dealt with in a holistic manner in conjunction with the Governments’ wider policy objective of achieving a sustainable and liveable community.

In addition to meeting the above challenges, Australia also needs to maintain its dynamic domestic economy and international competitiveness. The Australian Government has identified transport policy as key to achieving these goals. The focus on transport policy has in turn highlighted the increasing need to use rail as a solution to transport issues.

In order to respond to the challenges of the Federal Government’s requirements for transport policy and meet Australian Safety Regulators’ requirements, the Australian Rail Industry, over the past five years, has made a significant investment in developing a new telecommunications system that will allow the implementation of next generation train control. Next generation train control will provide benefits including greater utilisation of existing rail infrastructure and improved safety.

The new telecommunication system is based on international standards which rely on either 1800MHz or 900MHz spectrum. The standard being implemented is the European Train Control System (ETCS). This technology has been identified as the most advanced technology for controlling high density operations in Australia. The only telecommunications method authorised for use with the ETCS is GSM-R operating in either the 1800MHz or 900MHz range. The adoption of this international standard will allow a transition to newer technologies, such as LTE, as they become approved as safe for use in rail.

The 900 MHz range, which is commonly used internationally, could not be supported for use in rail telecommunications without major changes to the Australian 900MHz band plan. Instead, the Australian Rail Industry purchased spectrum licenses in the 1800MHz band. These licenses had gone unused for a number of years and were seemingly of low market value.

The Australian Rail Industry is, however, under threat of losing access to its current allocation of 1800MHz spectrum when its licences expire in June 2013 and May 2015. Although we understand that you, the Minister for Broadband Communications and the Digital Economy, could support a determination, by written instrument, that it is in the public interest to re-issue the Australian Rail Industry’s 1800 MHz spectrum licences, we have been informed that it is likely that the licences will not be re-issued and will, instead, go to auction.

Following discussion with the Department of Broadband Communications and the Digital Economy (DBCDE), the Australian Rail Industry has received a set of specific questions to address:

1. Whether or not commercial arrangements can be used to deliver rail safety networks;
2. Whether any alternative spectrum bands are fit for purpose;
3. The exact allocation of spectrum required; and
4. What terms rail authorities would propose for licence reissue, including reissue fees.
Possibility of commercial arrangements

One option to implement widespread rail voice and data communication systems is to use the existing public Carrier networks. On the face of it, this appears to be an option but a detailed examination reveals that safe operations in dense urban systems cannot be guaranteed.

During the due diligence process conducted between 2003 and 2006, the Australian Rail Industry considered the benefits of making use of existing public telecommunications networks, particularly the possibilities of reduced costs. However, following numerous attempts to engage with existing network operators, it became apparent that the public Carriers were not able to provide the Grade of Service or Quality of Service including safe operations required by metropolitan rail operators. The level of service available would have presented significant safety risks for high density passenger rail transport.

Other impediments to using commercial arrangements include:

- **Emergency Calls** - Rail safety requirements also stipulate that Rail Emergency Calls are assigned the highest network priority. This creates a clash of priorities between 000 and rail emergency calls if operating on the same telecommunications network.
- **Coverage** - Rail requires guaranteed, targeted high penetration of signal along the rail corridor including areas with difficult geography. Public telecommunications networks cannot economically provide this guaranteed coverage.
- **Grade of service** - Rail telecommunications are used for time critical voice and data traffic requiring all calls to get through without dropping out or unacceptable delay. Public networks cater for the general populace and do not ordinarily have such a tight grade of service requirement.
- **Quality of service** - Rail requires the ability to prioritise different calls to enable more critical calls with more certainty of getting through during emergency situations in addition to particular call performance criteria. Carriers do not provide a guaranteed quality of service on a public mobile telephone network.
- **Rail specific functionality** - Rail has protocols for special telecommunications needs which are not supported by public networks including fast call setup time, group calls, press to talk and voice broadcast calls.
- **Suitability for train control data** - International standards require high functionality and reliability for train control data transfer and there are very few systems ratified under these standards. Approaches to the market for proposals to meet these performance requirements resulted in responses from the Carriers recommending that a dedicated GSM-R network is the best solution.
- **Spectrum for train control data** - The rail train control data function requires dedicated spectrum to achieve the performance criteria. Whether this is implemented as a private network or outsourced to a Carrier, the spectrum requirements do not change.

Possibility of using alternative bands

GSM-R equipment now supports operation in the 900 MHz and 1800 MHz bands but is not compatible for operation in any other band.

Access to 900 MHz spectrum was explored by the Australian Rail Industry during the selection of the GSM-R technology and was found to be unsupportable in the Australian 900
MHz band plan, without significant replanning and disturbance. This was confirmed again in a recent review by the Australian Communication and Media Authority (ACMA) The 900MHz band-Exploring new opportunities – May 2011 which did not support spectrum for GSM-R.

**Required spectrum allocation**

Five Jurisdictions of the Australian Rail Industry currently hold licences for 15MHz of the 1800MHz spectrum. The Australian Rail Industry seeks to retain the complete 15 MHz until after the initial roll-out of the train control systems. This would allow planning risks to be managed by ensuring adequate spectrum is available until actual system needs can be proven in operation. The Australian Rail Industry recognises the value of the spectrum and would therefore be willing to review its allocation in future if it became apparent that the full 15 MHz was not required once the spectrum needs have been tested and verified in actual operation.

Preliminary planning activities conducted by RailCorp NSW and the Department of Transport (DOT) in Victoria have provided references for the minimum level of spectrum needed for current and anticipated future network configurations. This analysis indicated that up to 12.5 MHz of spectrum will be needed to implement the next generation train control systems.

**The Rail Industry's proposal**

The Australian Rail Industry is adopting new telecommunications and train control systems based on international standards. ETCS supported by GSM-R has been identified as the most advanced, international standards based technology available for the rail industry. Implementation of improved train control will allow current infrastructure to be used more efficiently, increasing capacity on existing lines which will delay the need for physical infrastructure investments and help meet growing demand for public transport. The GSM-R radio system is the only telecommunication technology certified for use with ETCS and, in Australia, the only viable spectrum for GSM-R is the 1800MHz band.

Analysis by Deloitte Access Economics indicates that, even under conservative assumptions of delaying the infrastructure spend by 5 years and when only looking at two potential infrastructure projects, one in Sydney and one in Melbourne, improved rail telecommunications and train control could derive benefits of at least $1.5 billion over that period. This should be of particular interest to the Australian Government and Infrastructure Australia who are looking for cost effective ways to address infrastructure needs to meet the increasing demand for passenger transport. Other benefits, in terms of reduced accidents, congestion and carbon emissions could amount to around $400,000 an hour in both Sydney and Melbourne for every hour the network operates at capacity. Once again this should be of particular interest to the Australian Government as these reductions in costs relate directly to their overall transport policy objectives. The immediate move to GSM-R to support advanced train control is the most cost effective way of addressing impeding capacity issues and allows the implementation of future infrastructure investment to be more strategically staged.

As such, the Australian Rail Industry believes that improving train telecommunications and rail services represents the highest value use of this spectrum and is willing to negotiate and come to an understanding with the ACMA on suitable pricing mechanisms that could be put in place.
Overall, The Australian Rail Industry seeks to secure ongoing access to the 1800 MHz spectrum band through the reissue of spectrum licences under Section 82 of the Radiocommunications Act 1992 supported by a determination from the Minister for Broadband, Communications and the Digital Economy. The Australian Rail Industry considers that this outcome balances the interests of state governments, the Australian government, the Rail Industry and telecommunications providers and, most importantly, provides the Australian public with a service of significant value, public transport.
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2. About this submission

This document forms the Australian Rail Industry’s submission to the Minister for Broadband, Communications and the Digital Economy and supports a determination, by written instrument, that it is in the public interest to re-issue the Australian Rail Industry’s 1800 MHz spectrum licences consistent with the Radiocommunications Act 1992 - Section 82.

Rationale

Over the past five years the Australian Rail Industry has made a significant investment in developing a new telecommunications system that will allow the implementation of next generation train control while significantly improving rail specific voice applications. The implementation of this new telecommunications system and next generation train control will provide benefits including greater utilisation of existing rail infrastructure, improved operations and improved safety. Next generation train control is essential to meet growing demand for passenger transport and to meet the Australian Government’s broader transport policy objectives, which focus on increased use of rail.

The Australian Rail Industry is, however, under threat of losing access to its current allocation of 1800MHz spectrum when its licences expire in June 2013 and May 2015. It seems likely that the licenses will not be re-issued and will, instead, go to auction.

This government position was explained in a press release on 4 March 2010 which announced the Australian Government’s approach to the reissue of current spectrum licences. The Minister for Broadband, Communications and the Digital Economy (DBCDE), Senator the Hon Stephen Conroy stated that:

*Spectrum licence renewal will be offered, to those telecommunications incumbents who are already using their spectrum licences to provide services to significant numbers of Australian consumers, or who have in place networks capable of providing services to significant numbers of consumers, provided they also meet the public interest criteria.*

The Australian Rail Industry has been informed by both the Australian Communication and Media Authority (ACMA) and the DBCDE that they do not consider that the industry has used its licences. As a result, the industry has not been invited into discussions relating to the re-issue of those licences. Further, the Australian Rail Industry has been informed that, if it wishes to retain access to the spectrum, it will need to compete with the telecommunications companies in an open auction.

The Australian Rail Industry has a number of concerns with this policy approach:

- significant planning and implementation has taken place since the purchase of the licences;
- rail telecommunications networks based on the 1800MHz spectrum are being deployed;
- next generation train control will be critical to the smooth functioning of the Australian economy and in meeting Australian Government transport policy objectives; and
- metropolitan rail operators are government owned entities, providing a public good and are ultimately funded by Australian taxpayers. It is therefore not in the fiscal interests of the Australian Government to require the Australian Rail Industry to pay full market rates for spectrum access.
In addition to responding to this general policy approach, the Australian Rail Industry has also received a set of specific questions from DBCDE, which it has been asked to address. These questions are:

1. Whether or not commercial arrangements can be used to deliver rail safety networks;
2. Whether any alternative spectrum bands are fit for purpose;
3. The exact allocation of spectrum required; and
4. What terms rail authorities would propose for licence reissue, including reissue fees.

**Document Structure**

In order to assist the Minister’s, DBCDE’s and the ACMA’s deliberations on the re-issue of current 1800 MHz spectrum licences, the submission is set out as follows:

- Section three provides a background to the rail industry’s use of spectrum, how the current spectrum licenses were acquired, the development of technology for use with the current licences and future plans.
- Section four contains responses to the specific questions posed by DBCDE.
- Section five considers the broader policy goals that should be taken into consideration before making any decision about re-issuing or auctioning the licenses currently held by the rail industry.
- Section six presents the Australian Rail Industry’s proposed approach to handle the re-allocation of the 1800MHz spectrum.

The submission is also accompanied by technical appendices. These provide a technical analysis of the Australian Rail Industry’s spectrum needs and an economic analysis of the potential costs and benefits of continued spectrum access by the Australian Rail Industry.
3. Background of the Australian Rail Industry’s spectrum use

Historical Context
Voice radio telecommunications were introduced into rail operations during the 1970s and have evolved to be an important operational safety function. Today, rail services are not permitted to enter service if the train’s voice telecommunications are inoperative. In the event of voice telecommunications failure during train operation, separate train control systems continue to ensure the safe operation of the train but with reduced efficiency.

In the 400 MHz range rail makes extensive use of the 403-420MHz band. This band is vital to ensure safe rail operations and assist timely responses to emergency situations, but cannot provide data transmission for new generation radio based train control systems. While the usage of 400MHz is expected to reduce over time, the band will continue to be required to support operational narrow band services where it is expected to remain most cost effective. The Australian Rail Industry is in negotiation with the ACMA to establish the Rail Industry allocation to continue to support these ongoing activities.

The Australian Rail Industry is experiencing unprecedented increases in demand, which exceeds current capacity, and this trend is expected to continue. Over the last five years, demand for passenger rail travel in Australia’s cities has grown by 21.5%¹, regional passenger rail demand has grown nationally by more than 50%² and freight rail demand has grown nationally by 18.8%.³

Additionally, there have been a number of past rail accidents, which have resulted in the death of passengers, where the causal factors included telecommunications and signalling issues. These accidents could have been avoided if there were better telecommunications systems available. In the wake of such accidents, there have been Coronial findings requiring the Australian Rail Industry to implement improvements to radio telecommunications and additional signalling technology to improve the safety of the network and prevent similar events in the future.

For example, the Waterfall Inquiry recommended that:

RailCorp should progressively implement, within a reasonable time, level 2 automatic train protection with the features identified in chapter 7 of this report.

There must be compatibility of communications systems throughout the rail network. It is essential that all train drivers, train controllers, signallers, train guards and supervisors of trackside work gangs in New South Wales be able to communicate using the same technology.⁴

Compliance with these recommendations requires the implementation of next generation train control and access to the 1800MHz spectrum band.

Current Environment

Safety is a key focus for the Australian Rail Industry. Railway jurisdictions in Australia are only permitted to operate and maintain railway services and infrastructure upon receiving accreditation from the Rail Safety Regulator. To achieve this, the railway operator or infrastructure owner must demonstrate, to the satisfaction of the Safety Regulator and the industry that the operator or infrastructure owner has the competency and capacity to manage risks associated with railway operations.

As indicated, the findings of past Coronial inquiries have required rail operators to improve train control and telecommunications. To meet the Safety Regulators’ requirements and the unprecedented demand for rail transport services, the Australian Rail Industry has responded by adopting new telecommunications and train control systems.

As such, over the last decade, the Australian Rail Industry has worked to select and implement the necessary systems and strategies to support future operations. A key aspect of this is the transformation of the industry through the adoption of international standards and the introduction of advanced telecommunication technologies. While voice telecommunications will remain important, significantly improved capabilities such as reliable data transfer and train monitoring have been identified as requirements of any replacement telecommunications system.

In the past few years, coordinated industry activity, guided by the ARA, has led to significant progress in transforming the industry’s past disparate approach to telecommunications. Coordination activities have included:

- establishing industry interoperability and standards; and
- development of forums and working groups including:
  - a telecommunications standard development group; and
  - a national rail radio spectrum committee.

The Australian Rail Industry has adopted a standards based strategy for future train control and telecommunications systems. The European Train Control System (ETCS) has been identified as the leading technology for controlling high density operations. The GSM-R radio system is the only telecommunication technology certified for use with this train control system.

The Australian Rail Industry acknowledges the maturity of the GSM-R technology. However, not selecting GSM-R would inhibit any future use of ETCS, which is being adopted across Europe, Asia, the Middle East and North Africa. Consequently, the Australian Rail Industry has selected GSM-R as the national standard for high density rail operations.

Moving to this standards based solution will lead to benefits such as:

- **Use of standardised equipment.** There will be economies of scale available as mass produced rail telecommunications equipment can be purchased.
- **Supporting a competitive environment for vendors.** Multiple vendors (Australian and international suppliers and contractors) will lead to competitive pricing of equipment and services to support the Australian Rail Industry. More competition in the provision of capital equipment will significantly reduce costs for rail operators and consumers.
Fostering technology innovation within Australia. Currently, equipment developed for the Australian market cannot be sold on the international market given lack of compliance to international standards. A move towards international standard equipment, using common spectrum, will create more incentives for local technology development with the ability to export to foreign markets.

GSM-R will address safety improvements, for example to respond to the findings of Coronial inquiries, and benefit other railway functions such as shunting, station operations, crowd management, and worksites. Radio systems would be used to maximise productivity and safety by allowing workers to be in constant communication with centralised control facilities and worksite supervisors.

Current 1800MHz spectrum access
A major consideration when selecting GSM-R technology involved the identification of appropriate spectrum. At the time of making the selection, the GSM-R specification and the European Union identified 900 MHz as the standard spectrum allocation for rail operations.

During the Australian Rail Industry’s technology selection process, it was identified that the European 900 MHz GSM-R assignments could not be supported without major changes to the Australian 900MHz band plan. The high band base transmit segment (921 MHz to 925 MHz) of the European GSM-R allocation falls within the ISM/Radiolocation allocation currently used for predominantly low power devices. The low band base receive segment (876 MHz to 880 MHz) falls within the upper segment of the 850 MHz CMTS base transmit allocation, placing the GSM-R receivers amidst the high power public phone network transmitters and GSM-R transmitters among other sensitive receivers. This anomaly would greatly increase interference for all users and also require additional spectrum to provide appropriate guard bands.

The rail industry was also concerned as to the adequacy of the European allocation of 4MHz\(^5\) (later increased to 7 MHz) in 900 MHz to support the new communication based high capacity train control systems.

As late as 2011, the ACMA, through the consultation paper *The 900 MHz band – Exploring new opportunities*, has confirmed the unacceptability of adopting the European GSM-R allocations for Australia.\(^6\)

During the period of this assessment of the 900 MHz range, the Australian Rail Industry was made aware by the ACMA of spectrum licences held by OneTel, which was in administration. OneTel’s administrator was looking to dispose of its 1800 MHz spectrum licenses which the business had acquired at a cost of $532M. The licences had been on the market for 4 years and, while OneTel’s customer base and mobile network were quickly disposed of, the spectrum received little, if any, interest. This was confirmed by formal market tenders in August of 2004 and 2006 which also resulted in little or no interest.

At the time, GSM-R products were not available in 1800 MHz but investigation by the Australian Rail Industry indicated that, with sufficient investment by the industry and

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\(^5\) 2 x 4 (7) MHz assignment.

suppliers into research, development and implementation, 1800 MHz was a viable option for the implementation of GSM-R in Australia.

The Australian Rail Industry, encouraged by the regulatory framework encouraged by ACMA, therefore purchased its current licences between 2006 and 2008 from the administrator of OneTel. The licences purchased by the industry are set out below:

### Table 1: 1800MHz licences acquired

<table>
<thead>
<tr>
<th>State</th>
<th>Date Acquired</th>
<th>Holding (MHz)</th>
<th>Number of Licenses 1998/2000</th>
<th>Acquisition Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>Victoria</td>
<td>9 Oct 2006</td>
<td>15</td>
<td>2/4</td>
<td>$3m</td>
</tr>
<tr>
<td>New South Wales</td>
<td>27 Oct 2006</td>
<td>15</td>
<td>2/6</td>
<td>$3m</td>
</tr>
<tr>
<td>Western Australia</td>
<td>22 Dec 2006</td>
<td>15</td>
<td>2/2</td>
<td>$120k</td>
</tr>
<tr>
<td>Queensland</td>
<td>17 Jan 2007</td>
<td>15</td>
<td>2/4</td>
<td>$300k</td>
</tr>
<tr>
<td>South Australia</td>
<td>14 Mar 2008</td>
<td>15</td>
<td>4/4</td>
<td>$100k</td>
</tr>
</tbody>
</table>

The Australian Rail Industry has since worked with the International Union of Railways (UIC) to have 1800 MHz included into the GSM-R specification as an alternate band of operation. This has been accepted and is currently being finalised within the standards and specification.

The Australian Rail Industry’s adoption of 1800 MHz was encouraged by the ACMA, in a similar manner as the energy sector has recently been encouraged to consider the 1800 MHz spectrum by the CEO of the ACMA, who stated:

> “I’m advised that some of you believe that 1800 MHz is too high a frequency for your applications. However, I urge you to think about whether you chase spectrum better suited to mobile applications (900MHz) (and thus unattainable and/or expensive spectrum) or whether fixed application spectrum such as 1800 MHz would not be just as good and at a more affordable price.”

### Implementation of GSM-R in the 1800MHz spectrum

Given that the Australian Rail Industry has only had between three and five years to implement its telecommunication strategy, it has achieved significant progress. The Australian Rail Industry has begun implementing this strategy with Victoria and New South Wales deploying GSM-R networks and New South Wales deploying ETCS.

Victoria anticipates its GSM-R network will enter service in 2012, followed by New South Wales in 2013. Victoria and New South Wales are also both working on the planning and deployment of high capacity train control technologies. Western Australian and Queensland are currently working on trials of GSM-R, while South Australia has initiated planning activities to update their metropolitan rail signalling systems. Growing demand for rail services in Queensland is accelerating the move towards implementation of GSM-R and ETCS.

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7 OneTel entered administration in early 2002.
The Oakajee port and rail project has selected GSM-R at 1800 MHz to support their rail operations in Western Australia. QR National, the newly privatised Queensland based freight operator, is currently considering the use of advanced train control systems that require the use of GSM-R, to support coal freight operations between the central Queensland coal fields and the coastal ports.

Over time it is expected that all areas in Australia will transition to the standards based mobile telecommunications systems in line with existing investment cycles and business requirements.

**Future technologies**

As stated above, the Australian Rail Industry recognises the maturity of the GSM-R technology and is working to ensure that Australian implementations of GSM-R support the ability to migrate to newer technologies, such as LTE, once they achieve safety regulatory approval for use in the rail industry. These migration measures will include the ability of

- transceivers to support new certified technologies like LTE air interface; and
- the network and core infrastructure to support migration to IP.

GSM-R is based on a public mobile technology – GSM. This has given the rail industry the ability to leverage off the many developments in technology from public sector systems. GSM has evolved from circuit switched through to packet switched data (known as GPRS\(^9\) and EDGE\(^{10}\)) and more recently IP based core infrastructure. The mobile telecommunications industry has introduced multi technology software defined radio (SDR) base stations, which are becoming more widely available in the GSM-R market.

More specifically, GSM-R is based on the GSM standard (GSM 2+, Released in 99). The GSM Core has evolved from TDM technology to IP consistent with the telecommunications industry, known as GSM R4. The UIC is continuing progress in adopting all these GSM technology improvements, for example R4, Ranflex, Dispatchers SIP interface etcetera.\(^{11}\)

In 2006, studies commenced into the use of more efficient packet switched technologies (GPRS). This technology is planned for use with ETCS. However, due to the complex validation process required for ETCS, this technology is still going through the approval process. The UIC has indicated that studies, specification revisions, validation testing and pilot trials are underway but safety approval and commercial availability will take some time. The first European trial, financed partially by the European Commission, is envisaged to begin in 2012.

Looking further to the future, the GSM-R suppliers represented in the “GSM-R Industry Group”\(^{12}\) have made a public commitment to continue supporting GSM-R until at least 2025. Due to the extensive approval and testing cycles, the UIC has already commenced investigations into next generation mobile telecommunications systems, such as LTE, as a replacement for GSM-R. A commitment to LTE cannot be made at this time due to the immaturity of the voice applications\(^{13}\) and the pending approval for ETCS to operate with

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9 General Packet Radio Service (GPRS)  
10 Enhanced Data rates for GSM Evolution (EDGE)  
11 Based on a statement from the Chairman of the European Radio Implementation Group, UIC  
12 http://www.gsm-rail.com/node/30  
13 Telecommunications systems used in the rail industry, for providing critical train control systems, need to be mature to ensure reliability.
packet switching technologies. However, the UIC have indicated that future pilot studies are likely to occur post 2015. The adoption of the GSM-R standard products will allow the Australian Rail Industry to deploy these successor technologies as they become approved for Rail and not be forced to undertake Australian specific development.

Overall, solutions based on more spectrally efficient technologies are on the horizon, but, for now, circuit switched GSM-R technology is the only approved and proven method of delivering voice and ETCS data for safety critical train control systems.

The timeline below shows a graphical representation of the time relationships for GSM-R implementation, high capacity signalling availability and the introduction of successor technologies for GSM-R.

**Figure 1: Timeline of GSM-R implementation**

![Timeline of GSM-R implementation](image-url)
4. Response to specific questions

Possibility of commercial arrangements

The Australian Rail Industry is committed to providing telecommunications services to meet the demands of the current and future passenger and freight rail task in the most cost effective manner. This includes leveraging off existing technologies and infrastructure wherever possible and appropriate.

One option to implement widespread rail voice and data communication systems is to use the existing public Carrier networks. On the face of it, this appears to be an option but a detailed examination reveals that safe operations in dense urban systems cannot be guaranteed.

In this discussion, it must be recognised that the passenger and freight rail telecommunications requirements vary across Australia according to geography, train density, operational practices, risk, regulatory restrictions, legacy systems, available alternative infrastructure and funding sources. For example, what may be suitable for a regional freight network is not acceptable for a safe high density urban system.

During the due diligence process conducted between 2003 and 2006, the Australian Rail Industry recognised the benefits of making use of existing public telecommunications networks, particularly the possibilities of reduced costs.

However, following numerous attempts to engage with existing network operators, it became apparent that the public carriers were not able to provide the Grade of Service or Quality of Service including safe operations required by metropolitan rail operators. The level of service available would have presented significant safety and operational risks for high density passenger rail transport.

In 2005, RailCorp NSW released a request soliciting responses from the telecommunications industry seeking further evaluation of potential telecommunications options, including public Carriers. As can be seen in the extract at Appendix A, it became apparent that existing public Carriers were unable to meet the requirements of the rail industry. This lead to a decision to use GSM-R as the solution to Sydney’s rail communication needs.

Six years later, in 2011, the public Carriers’ position is still unchanged, that is, they are still unable to meet the requirements of the Australian Rail Industry unless they build a dedicated GSM-R network separate to their existing GSM/3G networks. This is supported in recent correspondence from Vodafone/Hutchison Australia at Appendix B.

The Australian Rail Track Corporation (ARTC) is currently rolling-out a telecommunications solution based on public telecommunication networks. This system is suitable for ARTC’s operations over a wide geographic area but is not suitable in a metropolitan situation. Further, the ARTC has undertaken investment in time and costs to develop unique end user equipment.

The Department of Transport Victoria is also initiating a project to rollout a similar telecommunications system to the ARTC system to support low density regional passenger train services. Future regional rollout of GSM-R in Victoria may only be undertaken to support the rollout of ETCS.
Given the requirements of metropolitan and high density rail networks, public telecommunications networks cannot provide the required performance without investment exceeding that required to rollout a private GSM-R network. That is, public networks can be built, or upgraded to achieve the standard required by rail operations, but the associated costs are assessed as likely to be greater than the establishment of a private network. These costs would have to be paid by rail operators and there would be no saving in the amount of spectrum needed.

**Coverage**

Rail requires guaranteed, targeted high penetration of signal along the rail corridor including open ground, tunnels, cuttings, underground stations, railcar sheds, valleys, mountains and high bridges. The coverage requirement for rail is higher than that required to run a public network.

Public telecommunications networks are primarily designed for general ‘omni directional’ coverage in a mesh network across built up areas to capture a high percentage of the populace. Coverage is not guaranteed.

GSM-R coverage specification calls for a minimum of -93 dBm at 95% confidence for critical data. This means that a design margin must be found to ensure 95% of track receives a minimum signal level of -93 dBm. This figure is based on 9 dB above RX sensitivity which, for GSM 1800, is -102 dBm. This is well above the standard that is typically used for public mobile networks\(^{14}\).

It should be noted that the change from 900MHz to 1800MHz introduces an additional 2dB margin to the figures used for 900 MHz in the GSM-R and ETCS specifications. This margin is being included in the GSM-R specifications for the 1800MHz band. Most railways have implemented GSM-R at much stronger signal levels to provide improved mobility behaviour (handover and call reliability) and greater protection from interference.

**Grade of service (GoS)**

This is the probability that a call will be blocked or delayed in establishment. Rail telecommunications is used for time critical voice and data traffic requiring all calls to get through without drop out or unacceptable delay. Public networks cater for the general populace and do not ordinarily have such a tight GoS requirement.

For public carrier networks the GoS blocking probability is typically 5%, while GSM-R networks are designed using 1%. This requires significantly greater levels of capacity (i.e. channels) which translates in design terms to requiring more spectrum than a typical public network implementation would require. Even if a public carrier was used to provide a GSM-R network, the carrier would require extra spectrum to meet GSM-R GoS requirements. There is also no spectrum saving achieved by using a public carrier for the dedicated data circuits required to support next generation train control for the entire run of a given train.

**Quality of service (QoS)**

QoS relates to the ability of the telecommunications network to prioritise different calls to provide the more critical calls with more certainty of getting through during emergency situations in addition to particular call performance criteria.

Currently, Carriers do not provide a guaranteed QoS on a public mobile telephone network. ARTC has addressed this issue on their public carrier-based solution by the use of an alternative communication path via satellite. While satellite services do not offer QoS guarantees, call set up time, end to end delay and link availability, the low user base means that, in practice, its service availability is usually high. The use of satellite communication paths is not suitable in built-up areas as an alternative for metropolitan networks due to degraded signal quality, call set up time, end to end delay and link availability.

**Rail specific functionality**
GSM-R is implemented by adding features to the basic GSM standard managed by the European Telecommunications Standards Institute (ETSI) and the UIC. The diagram below shows how features were added to the basic GSM standard (grey box), to give the extra functionality needed for rail. The key issue is that the extra features are added in software and hardware, which means that a public Carrier would need to change their GSM network from the standard GSM configuration, to a GSM-R configuration for all users, including the public.

**Figure 2: GSM-R additions to the GSM standard**

As evident in the diagram above, examples of rail specific functionality that are not supported by current public Carrier networks are:

- fast call setup time;
- priority and pre-emption;
- group calls;
- press to talk;
- voice broadcast calls;
- railway emergency calls;
- functional numbering;
- location dependent addressing; and
- fast handover between cells.
When High Speed Rail (HSR) is introduced into Australia, then the extra features offered by GSM-R for high-speed cell handover up to 350km/h will be needed. Currently, the standard for communications in Europe and China for HSR is GSM-R. The current study on the implementation plan for HSR on the Eastern seaboard of Australia will require a continuous dedicated allocation of spectrum. The provision of 1800MHz spectrum will be necessary to allow this to occur. This gives weight to an Australian wide allocation of 1800MHz spectrum.

### Suitable for train control data

International standards require high functionality and reliability for train control data transfer and there are very few systems ratified under these standards. GSM-R is the only system ratified for ETCS.

> [ETCS] “requires a transfer of data that is time critical, so it is important that the data transmitted is received with a predictable error rate and delays that are low enough to be acceptable.”

> “The safety critical nature of the application places unusually high demands on the quality of service required from the data communications system. This translates into a user expectation of:

- A high call success rate
- A low data block error rate
- A low rate of dropped calls (the calls might need to be sustained for hours rather than minutes, depending on train journey time)\(^{15}\)

Approaches to the market for proposals to meet these performance requirements resulted in responses from the Carriers recommending that a dedicated GSM-R network is the best solution\(^{16}\)(Refer Appendix A and Appendix B). This then raises questions as to the viability and cost advantage of sourcing telecommunications from the public Carriers to support high density passenger train services. It should be noted that this issue was investigated by some European administrations, for example Deutsche Bahn, with the national safety authorities, E.B.A., and their conclusion was that not only can a public mobile phone network not be used for the primary telecommunications link for ETCS, but it cannot even be used as a fallback link.\(^{17}\)

### Spectrum for train control data

The rail train control data function requires dedicated spectrum to achieve the performance criteria. Whether this is implemented as a private network or outsourced to a carrier, the spectrum requirements do not change.

Suggestions that a greater efficiency may be obtained by using public networks are not applicable for circuit based train control data as no trunked effect is achieved due to the requirement for dedicated circuits. This means that increasing the number of trains directly increases the number of active circuits and hence the spectrum required. In a typical trunk arrangement, increasing the number of users does not proportionally increase the number of active circuits required.

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\(^{15}\) Institute of Railway Signalling Engineers (IRSE) (2011). ETCS for Engineers., pp152

\(^{16}\) Train Radio in NSW Evolution and a Way Forward, Railcorp Request for Material Information Response. Vodafone/Hutchison correspondence

\(^{17}\) Based on a statement from the Chairman of the European Radio Implementation Group, UIC
Emergency Calls
The Telecommunications (Emergency Call Service) Determination 2009 - F2011C00206 requires that, for emergency call handling,

*The carriage service provider who carries the call must ensure that, in relation to all calls carried by the carriage service provider, the call is transferred to the emergency call person for 000 and 112 with the highest priority.*

Rail safety requirements also stipulate that Rail Emergency Calls are assigned the highest network priority. This creates a clash of priorities between 000 and rail emergency calls if operating on the same telecommunications network.

This clash of priorities can only be resolved by one party conceding a greater level of risk in an emergency. The risk associated with this issue is amplified in metropolitan areas due to the higher probability of emergencies and public network capacity saturation.

In summary, the Australian Rail Industry will continue to monitor and consider the use of public telecommunications networks, with a view to their use in the rail environment. However, even today no public carrier provides the GoS and QoS performance required to safely support high density passenger rail operations. The UIC has advised that public carrier network technology, which incorporate the critical rail functionality and performance, is not anticipated prior to 2020 in the context of a possible migration to LTE. This comes too late for metropolitan rail operators seeking to address rapidly increasing passenger numbers.

In contrast, GSM-R based systems are able to provide functionality that is currently not available on the public telecommunications networks.

The data services that could potentially be provided by the National Broadband Network (NBN) can be considered in the same way as the use of public mobile telephone network services. The network rollout of GSM-R utilises existing rail owned fibre optic resources, which are the same fibre optic resources that may be accessed to deliver parts of the NBN. Given that the wireless access component of the NBN will be geographically and performance limited, it is likely to require significant supplementation by rail to be able to support high capacity train control and safety certification.
Possibility of using alternative bands

GSM-R equipment now supports operation in the 900 MHz and 1800 MHz bands, but is not compatible for operation in any other band.

Access to 900 MHz spectrum, consistent with the European allocation, was explored by the Australian Rail Industry during the selection of the GSM-R technology and was found to be unsupportable in the Australian 900 MHz band plan, without significant replanning and disturbance.

The ACMA released a discussion paper, The 900MHz band-Exploring new opportunities – May 2011 initiating a replanning activity of the 900MHz band. The Australian Rail Industry has examined the consultation paper and noted that alignment with the European GSM-R allocations has not been supported. On further examination of the paper, there appears to be insufficient opportunity for any allocation for GSM-R within the 900MHz band.

Based on this recent analysis the only viable option for GSM-R in Australia is the 1800MHz band.

Required spectrum allocation

Five jurisdictions of the Australian Rail Industry currently hold licenses for 15 MHz of 1800 MHz spectrum. While the upper 2.5 MHz block has a power limitation, the Australian Rail Industry understands that the ACMA will resolve this limitation in the near future.

The Australian Rail Industry seeks to retain the complete 15 MHz until after the initial roll-out of the train control systems. This would allow the accuracy and sensitivity of design assumptions that result in planning risks to be managed by ensuring adequate spectrum is available until actual system needs can be proven in operation.

Preliminary planning activities conducted by the RailCorp NSW and the Department of Transport (DOT) in Victoria have provided some initial references for the minimum level of spectrum that may be needed for the anticipated future network configurations, as shown in table 2 below. It should be noted that this analysis is based on a significant number of assumptions, which will need to be tested and verified during actual operation.

An example of the analysis to support these preliminary estimates is contained in Appendix C and Appendix C.

Table 2: Minimum Spectrum Bandwidth for Australian Networks

<table>
<thead>
<tr>
<th>Network configuration</th>
<th>NSW</th>
<th>Victoria</th>
</tr>
</thead>
<tbody>
<tr>
<td>Capacity expanded build DTRS voice only network</td>
<td>5.4 MHz</td>
<td>7.5 MHz</td>
</tr>
<tr>
<td>Capacity expanded build DTRS voice and Next Generation Train Control</td>
<td>10.6 MHz</td>
<td>12.5 MHz</td>
</tr>
</tbody>
</table>

It should also be noted that the diversity of geography and topography between the two rail networks naturally results in different spectrum needs. The Australian Rail Industry acknowledges that voice-only GSM-R systems can be implemented using less than the currently held 15 MHz of spectrum, with current voice only networks requiring no more than 7.5MHz of spectrum.

However, the main reason for implementing GSM-R, over other voice technologies, is to support high capacity signalling, allowing additional capacity on existing metropolitan rail
networks by increasing the efficiency of existing rail assets. This is a key benefit of improved train telecommunications and, when compared to building more physical track infrastructure, will present savings of billions of dollars to the Australian economy.

As an indication of what is driving these spectrum requirements, the train control system relies on critical data transfer using circuit mode data circuits. This approach requires each active train in the network to be continuously allocated with one of the eight circuits available for traffic in a normal 200 kHz GSM channel in addition to capacity to support voice. At central locations, such as Flinders Street station in Melbourne, this could equate to as many as 32 active trains at any one time.

The design of a rail network must also provide capacity to manage exceptional circumstances, such as railway emergency calls or recovery from a train failure that could result in network congestion and failures of telecommunications equipment that could affect availability. Telecommunications must also be permanently maintained for safety of operation. This means that significant redundancy must be built into the system to ensure safety requirements are met. This necessary system redundancy significantly increases the amount of spectrum required compared to a voice only rail communication network or a typical public mobile phone network.

The Australian Rail Industry recognises the value of the spectrum and would therefore be willing to review its allocation in future if it became apparent that the full 15 MHz was not required once the spectrum needs have been tested and verified in actual operation. The goodwill of the Australian Rail Industry in seeking to make efficient use of spectrum is seen through current negotiations with Vodafone/Hutchison Australia to effect a partial aggregation of the 1800MHz band. This will assist in the efficient use of the available spectrum. It should be noted that this aggregation does not provide immediate benefit to the Australian Rail Industry, but benefits Vodafone/Hutchison Australia by allowing them to implement a LTE technology network. This is a clear demonstration of the Australian Rail Industry’s commitment to use spectrum efficiently.

It is important to understand that the lack of spectrum availability in Europe is impeding the deployment of ETCS in the high density commuter railways. Therefore, the perception that the European allocation of 7MHz is adequate for Europe or Australia is incorrect. The GSM-R application in Australia is for urban high density traffic, where cell size is smaller and number of users higher. This application is constrained in Europe by the lack of spectrum.19

The following extracts provide evidence of this situation:

To date (end 2008), the landscape in Europe reveals a notable level of GSM-R implementation. Investigations on networks with important commercial traffic show that the introduction of new services and mainly the increase in traffic coming from the ETCS will sooner or later lead to congested networks and lack of frequencies20

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18 Of the eight available, a maximum of six are only available for traffic use on the first base transceiver.
19 Based on a statement from the Chairman of the European Radio Implementation Group, UIC
20 EuRail Press. Compendium on ERTMS ECTS Section 6.6.2.2.
It is widely recognised that once all relevant applications are in place, like for instance ETCS level 2/3, there may be a lack of frequencies, especially in big hubs and railway stations.\textsuperscript{21}

The advantage of a packet switched data service in terms of data transport efficiency, optimisation of use of scarce bandwidth and transmission reliability can be seen as important to the widespread use of ETCS. This is especially important in urban areas and it is the long term solution for overcoming the restricted bandwidth available for [circuit switched data] CDS ETCS data transmission.\textsuperscript{22}

The impact of undersupply of spectrum can be seen in Europe. In fact, the European rail industry is now considering the use of 1800 MHz spectrum to supplement the 900MHz allocation.

5. Other policy considerations

Direct economic benefits
Rail makes a substantial direct contribution to the Australian economy:

- Rail accounts for 10% of the transport sector's contribution to GDP, making it larger than water and air transport combined\textsuperscript{23};
- Rail carries more than $180 billion of Australia's exports; and
- Rail directly employs more than 44,000 people with a further 70,000 working in industries supporting rail\textsuperscript{24}.

Having noted this current contribution, the true value of next generation train control is in the increased productivity that can be achieved from the existing rail infrastructure. Transport policy has been identified by the Australian Government as a central plank in attaining the productivity growth needed to maintain Australia's dynamic domestic economy and international competitiveness. The focus on transport policy has, in turn, highlighted the increasing need to use rail as a solution to national transport issues.

A clear way of achieving increased productivity is by running more trains closer together, which allows for an increase in the number of passengers or amount of freight that can be carried.

Increasing capacity for passenger transport in Australia's major cities is currently a key concern of the Australian Rail Industry. This is because, as shown in Table 3, over the last five years, demand for rail travel in Australia's cities has grown by 21.5\%\textsuperscript{25}, regional passenger rail demand has grown nationally by more than 50\%\textsuperscript{26} and freight rail demand has grown nationally by 18.8\%.\textsuperscript{27} The expected increase in Australia's population will

\begin{thebibliography}{99}
\bibitem{21} EuRail Press. Compendium on ERTMS ECTS Section 6.2.3.
\bibitem{22} IRSE (2011). ETCS for Engineers.
\end{thebibliography}
significantly increase the number of passenger and freight journeys within Australia and so similar growth rates are expected to be maintained over the coming years. For example, the land freight task is set to double by 2020 and triple by 2050 from 2007 levels.

Table 3: Yearly rail demand growth

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Total passenger kms</td>
<td>11.36</td>
<td>12.31</td>
<td>13.27</td>
<td>13.95</td>
<td>14.13</td>
</tr>
<tr>
<td>(billion)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total passenger</td>
<td>643.36</td>
<td>677.09</td>
<td>724.70</td>
<td>773.11</td>
<td>769.95</td>
</tr>
<tr>
<td>journeys (million)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Net tonne kms (billion)</td>
<td>189.05</td>
<td>198.65</td>
<td>220.18</td>
<td>238.38</td>
<td>257.45</td>
</tr>
</tbody>
</table>

To accommodate this increase in passengers and freight, investments can be made which increase the capacity of existing infrastructure or new infrastructure can be added. As an indication of the scale of investment in rail infrastructure, the Australian Government is set to increase total expenditure for rail track infrastructure from $2.1 billion dollars in 2007/8 to $3.3 billion dollars in 2009/10. This is an increase of $1.3 billion dollars for track alone. Nationally over $4.8 billion has been committed to the further development of passenger rail transport annually.

An indicator of the public benefit of allocating access to spectrum for rail can therefore be achieved by comparing investments in next generation signalling to investments in conventional infrastructure.

A report from Deloitte Access Economics, at Appendix E considered this issue and found that even when only two major rail infrastructure projects, one in Sydney and one in Melbourne, are considered and even if investment in physical infrastructure is only delayed by around five years then savings to governments could still be in the order of $1.5 billion.

This analysis indicates that the most affordable way to address the on-going increase in demand for rail transport is through the use of this improved telecommunications. The alternative of reacquiring metropolitan land, tunnelling, building additional parallel tracks, constructing new stations and associated infrastructure, including, road crossings, conventional signalling, train control and power distribution is simply uneconomic when compared to the benefits provided by improved telecommunications.

This should be of particular interest to the Federal Government and Infrastructure Australia who are looking for cost effective ways to address infrastructure needs to meet the increasing demand for passenger transport.

Public benefits

The Australian Rail industry provides public benefits through provision of public transportation services. The public benefits created include:

- 727.7 million urban passenger journeys per annum;
- 720 million tonnes of freight per annum;
- reduced road congestion;
- reduced carbon emissions;
- reduced motor vehicle accidents;
- improved energy security; and

• improved social inclusion.

Currently, congested roads cost Australia up to $15 billion a year\(^{29}\). With an increasing population and increasing passenger and freight transport task, these costs will rise significantly without appropriate transport policies. All levels of government have identified rail as a key part of alleviating the growing congestion problem. A single passenger train can remove up to 500 cars from the road during peak times\(^{35}\) and a single freight train can replace up to 150 heavy vehicles\(^{31}\).

Turning to greenhouse gas (GHG) emissions, the transport sector, including private transport, accounts for around 14% of Australia’s total GHG emissions and is likely to account for more than 20% by 2020. Rail is the lowest GHG emitter per passenger kilometre and per ton of freight and only contributes around 2% of all Australian domestic transport emissions\(^{32}\). Rail will therefore be central to reducing the carbon footprint of transportation, especially as electrified rail services have the potential to move close to being emissions free.

Rail is also considerably safer than road travel. Over 1,500 people die on our roads every year, over 30,000 more are seriously injured or permanently disabled\(^{33}\). These road accidents cost the Australian economy up to $35 billion per annum\(^{34}\). With only around 40 deaths per year\(^{36}\), the majority of which are attributed to road vehicles at level crossings, rail transport is significantly safer than road transport.

Considering energy security, freight rail is 10 times, and passenger rail is up to 3 times, more fuel efficient than road transport\(^{36}\). The current transport task in Australia is oil intensive as most of the energy consumed in this industry is by road transport, which is dependent on fossil fuels for its energy. Planning for a less oil-dependent economy and future is a visible concern of the Australian Government. This goes back to 2007 when the Senate Rural and Regional Affairs and Transport Committee Inquiry stated that ‘corridor strategy planning [should] take into account the goal of reducing oil dependence’. The Department of Resources, Energy and Tourism (DRET) is currently working on producing an Energy White Paper in order to set policy directions for Australia’s long term energy security, with the aim of reducing reliance on fossil fuel related greenhouse gas emissions. DRET has also released a report into Australia’s liquid fuel vulnerability and a National Energy Security Assessment, noting that energy security is a priority of the Government. Electrified rail can

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be powered from any electricity source and so increased use of rail presents a perfect opportunity to increase Australia’s energy security.

Deloitte Access Economics has recently conducted an extensive study into the level of public benefits generated by each rail journey in Australia’s. The results of this study are presented below:

**Table 4: Total social cost saving per average commuter trip (2010$)**

<table>
<thead>
<tr>
<th>City</th>
<th>Carbon emissions</th>
<th>Congestion</th>
<th>Accidents</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sydney</td>
<td>0.02</td>
<td>7.01</td>
<td>1.38</td>
<td>8.41</td>
</tr>
<tr>
<td>Melbourne</td>
<td>0.02</td>
<td>5.18</td>
<td>1.46</td>
<td>6.66</td>
</tr>
<tr>
<td>Brisbane</td>
<td>0.02</td>
<td>1.84</td>
<td>1.25</td>
<td>3.11</td>
</tr>
<tr>
<td>Perth</td>
<td>0.02</td>
<td>3.20</td>
<td>1.39</td>
<td>4.61</td>
</tr>
</tbody>
</table>

Applying these public benefit estimates, Deloitte Access Economics estimated that, in Sydney and Melbourne, improved rail telecommunications could generate up to around $400,000 of public benefits for every hour that the rail network and next generation train control operates at capacity.

Once again this should be of particular interest to the Australian Government as these reductions in costs relate directly to their overall transport policy objectives.

6. The Rail Industry’s proposal

Australia is facing a number of challenges including significant population growth, increasing urban congestion, the move towards a carbon constraint economy and ensuring energy security. These challenges must be dealt with in a holistic manner in conjunction with the Governments' wider policy objective of achieving a sustainable and liveable community.

In addition to meeting the above challenges, Australia also needs to maintain its dynamic domestic economy and international competitiveness. The Australian Government has identified transport policy as key to achieving this goal. The focus on transport policy has in turn highlighted the increasing need to use rail as a solution to transport issues.

In order to meet Australian Safety Regulators’ requirements and responding to the challenges of the Federal Government’s requirements for transport policy, the Australian Rail Industry is adopting new standards based telecommunications and train control systems.

ETCS supported by GSM-R has been identified as the most advanced, standards based technology available today. Its implementation will allow current infrastructure to be used more efficiently that is increase capacity on existing lines. The GSM-R radio system is the only telecommunication technology certified for use with ETCS.

In Australia, the only viable spectrum for GSM-R is the 1800MHz band.

Five Jurisdictions of the Australian Rail Industry currently hold licenses for 15 MHz of 1800 MHz spectrum. The Australian Rail Industry’s preference is to retain the complete 15 MHz until after the initial roll-out of the train control systems. This would allow planning risks to be managed by ensuring adequate spectrum is available until actual system needs can be proven in operation.

It is understood that the ACMA is seeking to maximise the value of spectrum as it is a scarce resource and needs to be valued accordingly. The Australian Rail Industry would therefore be willing to review its allocation, once requirements are confirmed, if it became apparent that the full 15 MHz was not required.

The Australian Rail Industry believes that improving train telecommunications and rail services represents the highest value use of this spectrum.

The Australian Rail Industry is seeking the cost of this spectrum to be minimal to its members. This is because the benefits to the Australian economy outweigh the additional funds that could be received should the spectrum be provided to others, such as the Carriers.

The largest user of the rail spectrum is the heavily subsidised passenger rail. Any increased costs associated with the Australian Rail Industry’s access to spectrum will be translated directly into an additional cost imposed on the Australian public through reductions in other government services (or increased taxes) and the loss of externality benefits created by rail transport.
The rail industry is willing to negotiate and come to an understanding with the ACMA on suitable pricing mechanisms that could be put in place.

The criticality of telecommunications to a reliable and efficient rail industry is evident from the information provided in this submission. The rail industry must have access and surety of tenure to the required spectrum to facilitate the necessary planning and development of rail infrastructure and systems to support the future role of rail in the Australian transport sector.

As such, the Australian Rail Industry seeks certainty of tenure over its current allocation of 15 MHz of the 1800 MHz allocation post 2013/2015 for the maximum period allowed under the legislation.

Should the required spectrum not be made available, the “broken gauge”38 problem, which has afflicted the rail industry, will be repeated and the productivity gains from an efficient land transport system for the movement of people and freight will be lost.

The Australian Rail Industry therefore seeks to secure ongoing access to the 1800 MHz spectrum band through the reissue of the existing spectrum licences under Section 82 of the Radiocommunications Act 1992 supported by a determination from the Minister for Broadband, Communications and the Digital Economy.

38 Refers to the lack of National coordination that resulted in Australia having different rail track gauges in different jurisdictions.
### Appendix A: RailCorp Request for Material Information Response

#### Responses Received

The deadline for responses to the RMI was 10am on 15 June 2005. The table below details the responses received and the technology solutions proposed by each Respondent.

<table>
<thead>
<tr>
<th>Technology/systems</th>
<th>Respondent</th>
</tr>
</thead>
<tbody>
<tr>
<td>APCO-25 (ASTRO)</td>
<td>Motorola</td>
</tr>
<tr>
<td></td>
<td>Telstra</td>
</tr>
<tr>
<td></td>
<td>- Telstra (principal)</td>
</tr>
<tr>
<td></td>
<td>- Motorola</td>
</tr>
<tr>
<td></td>
<td>- Dept of Commerce</td>
</tr>
<tr>
<td></td>
<td>Tait</td>
</tr>
<tr>
<td></td>
<td>Aurora Wireless</td>
</tr>
<tr>
<td>GSM-R</td>
<td>Connect Rail</td>
</tr>
<tr>
<td></td>
<td>- Nortel (principal)</td>
</tr>
<tr>
<td></td>
<td>- Leighton Contractors</td>
</tr>
<tr>
<td></td>
<td>- Frequentis Australia</td>
</tr>
<tr>
<td></td>
<td>- Union Switch &amp; Signal</td>
</tr>
<tr>
<td></td>
<td>Huawei</td>
</tr>
<tr>
<td></td>
<td>Siemens</td>
</tr>
<tr>
<td></td>
<td>- Siemens (principal)</td>
</tr>
<tr>
<td></td>
<td>- Telstra</td>
</tr>
<tr>
<td>TETRA</td>
<td>Alcatel</td>
</tr>
<tr>
<td></td>
<td>- Alcatel (principal)</td>
</tr>
<tr>
<td></td>
<td>- Bovis Lend Lease</td>
</tr>
<tr>
<td></td>
<td>Motorola</td>
</tr>
<tr>
<td></td>
<td>NEC</td>
</tr>
<tr>
<td></td>
<td>Ripple Systems</td>
</tr>
<tr>
<td>Open</td>
<td>Frequentis</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Generic interfaces for connection to networks such as EI, ISDN, EIA Tone remote control and others</th>
<th>Zetron</th>
</tr>
</thead>
</table>

<table>
<thead>
<tr>
<th>GRN managed APCO-25/ASTRO</th>
<th>NSW Dept of Commerce</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>- GCIO (principal)</td>
</tr>
<tr>
<td></td>
<td>- Motorola</td>
</tr>
</tbody>
</table>

No respondent offered CDMA as a candidate DTRS solution. It should also be noted, that CDMA does not meet the DTRS Functional Requirements particularly in critical areas of voice communications.
Appendix B: Vodafone/Hutchison correspondence
7 July 2011

Mr Bryan Nye
Australasian Railway Association
Suite 4, level 4
Plaza Offices (East)
Terminal Complex
Canberra Airport
ACT 2609

By email: vbrown@ara.net.au

Dear Mr Nye

Vodafone Hutchison Australia consideration of GSM-R services

Vodafone Hutchison Australia Pty Limited (VHA) has considered the Australian Railway Association’s information request regarding the potential for VHA to provide mission critical voice and data mobile services compliant with GSM-R standards.

While VHA continues to operate a national GSM network our primary focus is the ongoing development of 3G services and establishment of fourth generation networks to support high speed data capabilities.

We understand the GSM-R has stringent standards to ensure a high level of reliability and guaranteed Quality of Service along railway corridors. Network design for railways is substantially different to commercial GSM/GPRS networks. Commercial GSM network design is based on optimising network coverage with the minimum number of base stations whereas GSM-R design for railways operations must take into consideration that railway coverage is a long one dimensional area with challenging terrain, such as cuttings, overhead bridges and tunnels.
Given the unique coverage and Quality of Service requirements that the GSM-R standard demands and the early generation of this technology, VHA has no plans to develop or offer commercial GSM-R services in the Australian environment.

Yours faithfully

[

Brian Currie

General Manager Regulatory
Appendix C: Study of RailCorp GSM-R Spectrum Requirements for DTRS and ETCS
STUDY OF RAILCORP GSM-R SPECTRUM REQUIREMENTS FOR DTRS AND ETCS

Summary

<table>
<thead>
<tr>
<th>Case</th>
<th>Current Required Spectrum (MHz)</th>
<th>Required Spectrum Allowing for 50% Traffic Growth (MHz)</th>
</tr>
</thead>
<tbody>
<tr>
<td>DTRS Voice Calls with Railway Emergency Call</td>
<td>5.4</td>
<td>5.4</td>
</tr>
<tr>
<td>DTRS Voice Calls, Railway Emergency Calls and Train Control System ETCS Circuits</td>
<td>8</td>
<td>10.6</td>
</tr>
</tbody>
</table>

Following a network optimisation process as part of RailCorp's DTRS Project, it is expected that these spectrum requirements should be able to be aligned with current 2.5 MHz license boundaries resulting in a base requirement of 7.5 MHz with a further provision of an additional 2.5 MHz to satisfy future traffic growth.

Key Assumptions:

- Spectrum aggregation at high frequency end of 1800 band. Disaggregated spectrum or spectrum in another part of the band will require additional guard bands and therefore more spectrum.
- Spectrum available in 1800 band.
- GoS is 1%, path loss correlation 10%, slow-fading standard deviation of 5 dB, 2.9 km average site spacing.

This Analysis Includes:

- Spectrum for 3 emergency trailers that can be deployed at any location on the rail corridor.
- Redundant transceivers for REC and ETCS availability only. No specific provision for operational voice traffic redundancy.
- Guard bands for a single adjacent carrier.
- Single guard band to DECT.
- Future voice and data requirements based on 50% traffic increase per track.

This Analysis Excludes:

- Analysis of adjacent GSM/LTE blocking due to near-corridor public carrier sites.
- Non operational and administrative traffic.
- Spectrum used in tunnels.
**Analysis Method**

1. Determine DTRS voice call traffic based on Drivers, Guards, Security Officers and BTS redundancy.
2. Determine path loss exponent.
3. Determine signal strength and margin to 95% certainty to confirm cell radius.
4. Determine CIR for DTRS.
5. Determine CIR margin for 95% certainty.
6. Determine frequency re-use distance assuming an average cell radius.
7. Determine equivalent track distance assuming track distance is 40% longer than LOS and average site spacing is 2.9 km less 250m for worse-case BTS placement.
8. Determine adjacent channel separation for co-located channels and adjacent site channels.
9. Determine guard band based on probable LTE neighbour.
10. Derive frequency plan.
11. Derive required spectrum: guard bands + DTRS channels + ETCS CSD + emergency channels.
12. Redo for ETCS CSD assuming same CIR with full ETCS CSD channel redundancy but removing DTRS redundancy since REC has priority.
# Digital Train Radio System (DTRS) Requirements

<table>
<thead>
<tr>
<th>Requirement</th>
<th>Description</th>
</tr>
</thead>
</table>
| 1           | Coverage RX level = -95 dBm, 95% certainty at a cab radio antenna port.  
   Note that EIRENE requires -95 dBm, 95% certainty for 900 MHz band at a roof-mounted cab antenna which is 9 dB above RX sensitivity of -104 dBm. For 1800 MHz band, RX sensitivity is -102 dBm therefore an adjustment of 2 dB is required for 1800 MHz operation. This is realised by requiring an RX level at a cab radio antenna port instead of at a roof-mounted antenna. |
| 2           | Dual coverage at nominated junctions – this defines a 'worse-case' scenario for RF modelling. |
| 3           | 3 GSM carriers for emergency trailers. |
| 4           | N+1 redundant transceivers |
| 5           | Reliability of Railway Emergency Call (REC) is 99.9%. |
**Assumptions**

<table>
<thead>
<tr>
<th>Assumption</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Slow Fade standard deviation is 5 dB – from ATDI field measurements and model tuning process.</td>
</tr>
<tr>
<td>2</td>
<td>Drivers make 0.227 call per hour; Guards make 1 call per 4 hours; and Security Officers make 1 call per hour.</td>
</tr>
<tr>
<td>3</td>
<td>Driver calls are 65 seconds (95%); Guards and Security Officer calls are 90 seconds (95%) on average (25 mErl).</td>
</tr>
<tr>
<td>4</td>
<td>Track maintenance make 4 calls per hour at 50 mErl.</td>
</tr>
<tr>
<td>5</td>
<td>Shunting/Yard workers make 1 call per hour at 50 mErl.</td>
</tr>
<tr>
<td>6</td>
<td>Station Staff make 1 call per hour per 2 platforms at 50 mErl.</td>
</tr>
<tr>
<td>7</td>
<td>All blocked calls are immediately retried.</td>
</tr>
<tr>
<td>8</td>
<td>A minimum of 2 Security Officers are on 12.5% of rail services.</td>
</tr>
<tr>
<td>9</td>
<td>Freight services and non-service train movements will occur off-peak and therefore can be ignored in capacity calculations.</td>
</tr>
<tr>
<td>10</td>
<td>Track distances are, worse-case, 40% longer than point-to-point distances¹.</td>
</tr>
<tr>
<td>11</td>
<td>Average DTRS cell radius is 2 km – from DTRS contractor preliminary RF design and derived from minimum RX signal level.</td>
</tr>
<tr>
<td>12</td>
<td>Cell handover RX margin is 6 dB – from DTRS contractor preliminary RF design.</td>
</tr>
<tr>
<td>13</td>
<td>Typical GSM-R Grade of Service (GoS) is 1%</td>
</tr>
<tr>
<td>14</td>
<td>Path loss exponent ( \gamma ) is 3.5 – Hata with a 35 m BS antenna height.</td>
</tr>
<tr>
<td>15</td>
<td>Correlation of path fading from co-channel interferers is 10%.</td>
</tr>
<tr>
<td>16</td>
<td>Aggregated rail spectrum at top of 1800 band adjacent to DECT band</td>
</tr>
<tr>
<td>17</td>
<td>Average BTS spacing is 2.9 km (from DTRS contractor preliminary RF design) +/- 250 m.</td>
</tr>
<tr>
<td>18</td>
<td>50% train traffic increase per track.</td>
</tr>
</tbody>
</table>

¹ Based on western and northern lines.
References

- 3GPP TS 45.005 V8.6.0 (2009-09)
- RailCorp DTRS Specification
- EIRENE System Requirements Specification v1.5 May 2006
- CEPT ECC Report 162, May 2011
- CEPT Report 041
- CEPT ECC Report 96, March 2007

Glossary

<table>
<thead>
<tr>
<th>Abbreviation</th>
<th>Meaning</th>
</tr>
</thead>
<tbody>
<tr>
<td>ATDI</td>
<td>Company supporting ICS telecom – an RF modelling and mobile network planning tool used for planning and design of RailCorp's DTRS network.</td>
</tr>
<tr>
<td>BHL</td>
<td>Busy Hour Load – Erlang load in busiest hour at a specified location.</td>
</tr>
<tr>
<td>BTS</td>
<td>Base Transceiver Station</td>
</tr>
<tr>
<td>CEPT</td>
<td>Conference of European Posts and Telegraphs - responsible for radiocommunications and telecommunications matters</td>
</tr>
<tr>
<td>CIR</td>
<td>Carrier Interference Ratio</td>
</tr>
<tr>
<td>CPH</td>
<td>Calls Per Hour</td>
</tr>
<tr>
<td>CSD</td>
<td>Circuit-Switched Data – dedicated data channel between MS and RBC.</td>
</tr>
<tr>
<td>DTRS</td>
<td>Digital Train Radio System – A GSM-R based operational train radio-communications system providing train to signaller/controller operational and emergency voice communication.</td>
</tr>
<tr>
<td>EIRENE</td>
<td>An EIRENE system is a railway telecommunications system based on ETSI GSM standard, which complies with all related mandatory requirements as specified in EIRENE FRS and SRS. An EIRENE system may also include optional features and these shall then be implemented as specified by EIRENE FRS and SRS.</td>
</tr>
<tr>
<td>ETCS</td>
<td>European Train Control System – a signalling, control and train protection system</td>
</tr>
<tr>
<td>Abbreviation</td>
<td>Meaning</td>
</tr>
<tr>
<td>--------------</td>
<td>---------</td>
</tr>
<tr>
<td>FRS</td>
<td>Functional Requirement Specification</td>
</tr>
<tr>
<td>MS</td>
<td>Mobile Station – hand-held or cab radio</td>
</tr>
<tr>
<td>RBC</td>
<td>Radio Block Centre - an ERTMS/ETCS term referring to a centralised safety unit to establish and control train separation using radio for train to ground communication medium</td>
</tr>
<tr>
<td>REC</td>
<td>Railway Emergency Call – an pre-emptive eMLPP group call handled in a GSM-R network which is defined by EIRENE FRS.</td>
</tr>
<tr>
<td>SRS</td>
<td>System Requirement Specification</td>
</tr>
<tr>
<td>TRX</td>
<td>Transceiver</td>
</tr>
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</table>
**Carrier Interference Ratio**

3GPP specification TS 45.005 defines minimum receive levels, performance and interference levels for GMSK and 8-PSK modulated channels.

Relevant performance values for GSM/GSM-R are summarised below.

<table>
<thead>
<tr>
<th>Coding Scheme</th>
<th>Mod</th>
<th>Min C/I TU50</th>
<th>Min C/I RA130</th>
<th>Min C/I A1</th>
<th>Reference Interference Performance TU50 (Table 2)</th>
<th>Reference</th>
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<tr>
<td>Voice</td>
<td>GMSK</td>
<td>9</td>
<td>9</td>
<td>-9</td>
<td>3 – 4.8% BER &lt; 0.001%</td>
<td>6.3</td>
</tr>
<tr>
<td>CSD 2.4</td>
<td>GMSK</td>
<td>9</td>
<td>9</td>
<td>-9</td>
<td>BER &lt; 0.01%</td>
<td>6.3</td>
</tr>
<tr>
<td>CSD 4.8</td>
<td>GMSK</td>
<td>9</td>
<td>9</td>
<td>-9</td>
<td>BER &lt; 0.8%</td>
<td>6.3</td>
</tr>
<tr>
<td>CSD 9.6</td>
<td>GMSK</td>
<td>9</td>
<td>9</td>
<td>-9</td>
<td>BER &lt; 4%</td>
<td>6.3</td>
</tr>
<tr>
<td>CSD 14.4</td>
<td>GMSK</td>
<td>9</td>
<td>9</td>
<td>-9</td>
<td>BLER &lt; 10%</td>
<td>6.2, 6.3, Table 2e</td>
</tr>
<tr>
<td>ECSD 28.8 NT</td>
<td>8-PSK</td>
<td>14</td>
<td>14.5</td>
<td>-1</td>
<td>BLER &lt; 10%</td>
<td>6.2, 6.3, Table 2e</td>
</tr>
<tr>
<td>ECSD 28.8 T</td>
<td>8-PSK</td>
<td>16</td>
<td>17</td>
<td>1.5</td>
<td>BER &lt; 0.1%</td>
<td>6.2, 6.3, Table 2e</td>
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<tr>
<td>CS-1</td>
<td>GMSK</td>
<td>9</td>
<td>9</td>
<td>-9</td>
<td>BLER &lt; 10%</td>
<td>6.3, Table 2a</td>
</tr>
<tr>
<td>CS-2</td>
<td>GMSK</td>
<td>13</td>
<td>13</td>
<td>-5</td>
<td>BLER &lt; 10%</td>
<td>6.3, Table 2a</td>
</tr>
<tr>
<td>CS-3</td>
<td>GMSK</td>
<td>16</td>
<td>16</td>
<td>-2</td>
<td>BLER &lt; 10%</td>
<td>6.3, Table 2a</td>
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<tr>
<td>CS-4</td>
<td>GMSK</td>
<td>27</td>
<td>*</td>
<td>9</td>
<td>BLER &lt; 10%</td>
<td>6.3, Table 2a</td>
</tr>
<tr>
<td>MCS-1</td>
<td>GMSK</td>
<td>10</td>
<td>10</td>
<td>-8</td>
<td>BLER &lt; 10%</td>
<td>6.3, Table 2a</td>
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<tr>
<td>MCS-2</td>
<td>GMSK</td>
<td>12</td>
<td>12</td>
<td>-6</td>
<td>BLER &lt; 10%</td>
<td>6.3, Table 2a</td>
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<tr>
<td>MCS-3</td>
<td>GMSK</td>
<td>17</td>
<td>19</td>
<td>-1</td>
<td>BLER &lt; 10%</td>
<td>6.3, Table 2a</td>
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<tr>
<td>MCS-4</td>
<td>GMSK</td>
<td>23</td>
<td>*</td>
<td>5</td>
<td>BLER &lt; 10%</td>
<td>6.3, Table 2a</td>
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<tr>
<td>MCS-5</td>
<td>8-PSK</td>
<td>15</td>
<td>16.5</td>
<td>-2</td>
<td>BLER &lt; 10%</td>
<td>6.3, Table 2c</td>
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<tr>
<td>MCS-6</td>
<td>8-PSK</td>
<td>18</td>
<td>21</td>
<td>1.5</td>
<td>BLER &lt; 10%</td>
<td>6.3, Table 2c</td>
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<tr>
<td>MCS-7</td>
<td>8-PSK</td>
<td>27.5</td>
<td>*</td>
<td>12.5</td>
<td>BLER &lt; 10%</td>
<td>6.3, Table 2c</td>
</tr>
<tr>
<td>MCS-8</td>
<td>8-PSK</td>
<td>29.5</td>
<td>*</td>
<td>16</td>
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<td>6.3, Table 2c</td>
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<tr>
<td>MCS-9</td>
<td>8-PSK</td>
<td>*</td>
<td>*</td>
<td>*</td>
<td>BLER &lt; 30%</td>
<td>6.3, Table 2c</td>
</tr>
</tbody>
</table>
**Traffic Analysis for DTRS GSM-R Voice Calls**

RailCorp’s current spectrum requirement will limit DTRS to only providing GSM-R voice calls including the Railway Emergency Call (REC). No capacity for ETCS circuit-switched data services is considered.

DTRS must provide a REC function with high reliability [Requirement 5]. To achieve this, a minimum of two transceivers will be deployed at each site [Requirement 4].

<table>
<thead>
<tr>
<th>Call Source</th>
<th>Call Rate</th>
<th>Call Duration</th>
<th>Call Records</th>
</tr>
</thead>
<tbody>
<tr>
<td>Train Driver</td>
<td>0.227 per hour per train</td>
<td>65 s for 95% of calls using a log-normal distribution</td>
<td>Derived from current train radio call records during a period of high demand.</td>
</tr>
<tr>
<td>Security Officers</td>
<td>0.25 per hour per train</td>
<td>90 s for 95% of calls using a log-normal distribution</td>
<td>Derived from current GRN call records.</td>
</tr>
<tr>
<td></td>
<td>based on 1 call per hour; 2 officers per train on 1 in 8 trains</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Guard</td>
<td>0.25 per hour per train</td>
<td>90 s</td>
<td>Guards currently do not use RailCorp's train radio system. This is a change required by the Waterfall recommendations. Call rate and duration based on Security Officer data.</td>
</tr>
<tr>
<td>Station Staff</td>
<td>1 call per hour per 2 platforms</td>
<td>180 s</td>
<td>Station staff currently use one or more UHF channels for operations and emergency management. No call records are available.</td>
</tr>
<tr>
<td>Shunters</td>
<td>1 call per hour</td>
<td>180 s</td>
<td>Shunters typically use one or more UHF channels for shunting and yard movements. No call records are available.</td>
</tr>
<tr>
<td>Work-site</td>
<td>4 calls per hour</td>
<td>180 s</td>
<td>Track-side workers and work-sites use between 2 to 4 UHF channels for Protection Officer and work-site communications. No call records are available.</td>
</tr>
<tr>
<td>Communications</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
DTRS BTS Redundancy

RailCorp DTRS specification requires an additional redundant GSM-R BTS in some critical areas including yards, some stations, tunnels, and junctions [Requirement 2].

In these areas, two independent GSM-R BTSs are to be deployed.

Normally, full redundancy is required which doubles spectrum requirements. However for this minimal DTRS case only redundancy for REC is considered and therefore a single redundant GSM-R BTS TRX is required.

<table>
<thead>
<tr>
<th>Busi Station</th>
<th>Busy Period Trains (on cell)</th>
<th>Platforms</th>
<th>CPH</th>
<th>BHL (Erl)</th>
<th>Signalling Timeslots</th>
<th>GPRS Timeslots</th>
<th>Voice Traffic Timeslots</th>
<th>Redundant TRXs</th>
<th>Total Required TRXs</th>
</tr>
</thead>
<tbody>
<tr>
<td>Central</td>
<td>136</td>
<td>25</td>
<td>116</td>
<td>3.13</td>
<td>2</td>
<td>1</td>
<td>9</td>
<td>1</td>
<td>3</td>
</tr>
<tr>
<td>Strathfield</td>
<td>58</td>
<td>8</td>
<td>51.17</td>
<td>1.41</td>
<td>2</td>
<td>1</td>
<td>6</td>
<td>1</td>
<td>3</td>
</tr>
<tr>
<td>Sydenham</td>
<td>43</td>
<td>6</td>
<td>39.26</td>
<td>1.11</td>
<td>2</td>
<td>1</td>
<td>5</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>Redfern</td>
<td>111</td>
<td>12</td>
<td>91.7</td>
<td>2.39</td>
<td>2</td>
<td>1</td>
<td>7</td>
<td>1</td>
<td>3</td>
</tr>
<tr>
<td>North Sydney</td>
<td>33</td>
<td>4</td>
<td>31</td>
<td>0.90</td>
<td>2</td>
<td>1</td>
<td>5</td>
<td>1</td>
<td>2</td>
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<tr>
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<td>15</td>
<td>3</td>
<td>17.41</td>
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<td>1</td>
<td>4</td>
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<td>2</td>
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<tr>
<td>Springwood</td>
<td>2</td>
<td>2</td>
<td>11.09</td>
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<td>1</td>
<td>3</td>
<td>1</td>
<td>2</td>
</tr>
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<td>27.86</td>
<td>0.84</td>
<td>2</td>
<td>1</td>
<td>4</td>
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<td>Blacktown</td>
<td>24</td>
<td>7</td>
<td>25.95</td>
<td>0.82</td>
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<td>1</td>
<td>4</td>
<td>1</td>
<td>2</td>
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<tr>
<td>Granville</td>
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<td>4</td>
<td>30.26</td>
<td>0.88</td>
<td>2</td>
<td>1</td>
<td>5</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>Parramatta</td>
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<td>4</td>
<td>27.36</td>
<td>0.81</td>
<td>2</td>
<td>1</td>
<td>4</td>
<td>1</td>
<td>2</td>
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<td>1</td>
<td>5</td>
<td>1</td>
<td>2</td>
</tr>
</tbody>
</table>
**Future DTRS Voice Call Capacity**

RailCorp expects to be able to increase train traffic from 20 per hour per track to 30 per hour per track. This represents a peak capacity increase of 50% [Assumption 18].

When this capacity increase of associated DTRS traffic is modelled, an increase in GSM-R TRXs is expected for some sites, however no additional spectrum is required.

<table>
<thead>
<tr>
<th>Busy Station</th>
<th>Busy Period Trains (on cell)</th>
<th>Platforms</th>
<th>CPH</th>
<th>BHL (Erl)</th>
<th>Signalling Timeslots</th>
<th>GPRS Timeslots</th>
<th>Voice Traffic Timeslots</th>
<th>Redundant TRXs</th>
<th>Total Required TRXs</th>
</tr>
</thead>
<tbody>
<tr>
<td>Central</td>
<td>204</td>
<td>25</td>
<td>166</td>
<td>4.26</td>
<td>2</td>
<td>1</td>
<td>10</td>
<td>1</td>
<td>3</td>
</tr>
<tr>
<td>Strathfield</td>
<td>87</td>
<td>8</td>
<td>72.25</td>
<td>1.89</td>
<td>2</td>
<td>1</td>
<td>6</td>
<td>1</td>
<td>3</td>
</tr>
<tr>
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<td>64.5</td>
<td>6</td>
<td>54.89</td>
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<td>2</td>
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<tr>
<td>Redfern</td>
<td>166.5</td>
<td>12</td>
<td>132</td>
<td>3.31</td>
<td>2</td>
<td>1</td>
<td>9</td>
<td>1</td>
<td>3</td>
</tr>
<tr>
<td>North Sydney</td>
<td>49.5</td>
<td>4</td>
<td>43</td>
<td>1.17</td>
<td>2</td>
<td>1</td>
<td>5</td>
<td>1</td>
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<td>4</td>
<td>1</td>
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<td>13.63</td>
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<td>1</td>
<td>4</td>
<td>1</td>
<td>2</td>
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<td>38</td>
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<td>5</td>
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<td>7</td>
<td>34.67</td>
<td>1.02</td>
<td>2</td>
<td>1</td>
<td>5</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>Granville</td>
<td>48</td>
<td>4</td>
<td>41.9</td>
<td>1.15</td>
<td>2</td>
<td>1</td>
<td>5</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>Parramatta</td>
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<td>37.53</td>
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<td>5</td>
<td>1</td>
<td>2</td>
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<td>6</td>
<td>2</td>
<td>10.36</td>
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</tr>
<tr>
<td>Erskineville</td>
<td>18</td>
<td>4</td>
<td>20.09</td>
<td>0.65</td>
<td>2</td>
<td>1</td>
<td>4</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>Hurstville</td>
<td>48</td>
<td>4</td>
<td>41.9</td>
<td>1.15</td>
<td>2</td>
<td>1</td>
<td>5</td>
<td>1</td>
<td>2</td>
</tr>
</tbody>
</table>
**DTRS Coverage Analysis**

For this study, DTRS received signal level is measured at the cab radio antenna connector as per the DTRS specification.

![Graph showing probability distribution](image)

*Illustration 1: Signal Level Margin Example from GSM-R Procurement Guide*

GSM-R specification calls for -98 dBm, 95% certainty for voice and non-critical data. This means that a design margin must be found to ensure 95% of track locations receive a signal level of -98 dBm or greater. This figure is based on 6 dB above RX sensitivity which, for GSM 900, is -104 dBm. However for GSM 1800 MS reference sensitivity is -102 dBm. Therefore, an additional 2 dB shall be added to raise required RX signal level to -96 dBm.

---

**Note:** DTRS specifications mandates -95 dBm [Requirement 1] based on GSM 900 ETCS critical data requirement. A UIC Implementation Report has been raised concerning this issue to amend this requirement for GSM-R 1800. UIC advises that a determination is expected in July 2011.

Assuming normal-distributed slow fading (in the dB domain) with a standard deviation of 5 dB [Assumption 1], DTRS RX margin can be determined as follows:

\[
RX_{\text{margin}} = \sigma \times NORMSINV \left( RX_c \right)
\]

Where,

- Slow fade standard deviation \( \sigma = 5 \)
- RX level certainty \( RX_c = 0.95 \)

Therefore,

\[
RX_{\text{margin}} \approx 5 \times 1.65 = 8.2 \text{ dB}
\]

Therefore, an RX margin of 8.2 dB is required to achieve 95% certainty.
$$RX_{level}(95\%) = RX_{level} + RX_{adj} + RX_{margin} + RX_{loss}$$

Where,

- Received signal level $RX_{level} \geq -98 dBm$
- Received signal level adjustment for GSM 1800 $RX_{adj} = 2 dB$
- Received margin certainty $RX_{margin} = 8.2 dB$
- Cab radio cable and connector losses $RX_{loss} = 3 dB$

Therefore,

$$RX_{level}(95\%) = -98 + 2 + 8.2 + 3 = -84.8 dBm$$

Allowing for 3 dB antenna cable and connector loss, DTRS antenna RX level will be engineered to be greater than -84.8 dBm.
**Carrier Interference**

GSM specification requires CIR of 9 dB for a MS travelling between 50 and 130 km/h. Coverage at this level for voice calls should be 50%. To raise CIR certainty to 95% a margin is required which is dependant on a path loss path loss exponent.

![Illustration 2: CIR Margin Example from Bethel Enterprises GSM Radio Planning](image)

**Hata Path Loss Exponent**

Hata path loss models have a fixed path loss exponent modified by Base Station (BS) antenna height for urban, suburban and open environments.

\[
PL = f \left( 10 \gamma \log d \right)
\]

\[
\gamma = \frac{44.9 - 6.55 \log h_{BS}}{10}
\]

For a likely range of DTRS antenna heights between 15 and 35 m, Hata suggests a worse-case path loss exponent of about 3.5 for a 35 m antenna height.

Therefore a path loss exponent of 3.5 [Assumption 14] is assumed.
**Carrier Interference Margin (CIR)**

A CIR margin is required to meet required minimum CIR with 95% certainty.

To establish a worse-case margin, correlation between the wanted and interfering BTS is assumed to be 10% [Assumption 15].

![Diagram of 3 Interferers](image)

*Drawing 1: Typically 3 Interferers for Rail*

For a rail environment which consists of linear routes and occasional junctions, interferers can be assumed to be fewer than in a commercial GSM network. Rail junctions typically split one route into 2 and therefore 3 interferers will be assumed.

For a wanted signal with 3 adjacent interferers,

\[
\text{CIR}_{\text{margin}} = \sigma_4 \cdot \text{NORMSINV} \left( C \right)
\]

Where,
- CIR certainty \( C = 95\%
- Slow fade standard deviation \( \sigma = 5\)
- Standard deviation of 4 normal-distributed paths \( \sigma_4 \) is 8.96 (see below)
- Path correlation \( \rho = 0.1\)

To determine an approximate standard deviation of the 4 paths (wanted and 3 interferers), the standard deviation of the C/I is derived as follows:

\[
\sigma_2 = \sqrt{\sigma^2 + \sigma^2 - 2 \rho \sigma \sigma}
\]

\[
\sigma_3 = \sqrt{\sigma_2^2 + \sigma^2 - 2 \rho \sigma_2 \sigma}
\]

\[
\sigma_4 = \sqrt{\sigma_3^2 + \sigma^2 - 2 \rho \sigma_3 \sigma}
\]

Substituting in \( \sigma = 5 \) and \( \rho = 0.1 \),

\[
\sigma_4 = 8.96
\]

Therefore,

\[
\text{CIR}_{\text{margin}} \approx 8.96 \times 1.65 = 14.7 \text{ dB}
\]

and,

\[
\text{CIR}_{\text{dB}} \approx 9 \text{ dB} + \text{CIR}_{\text{margin}} = 23.7 \text{ dB}
\]

Therefore, required CIR is 23.7 dB to achieve 9 dB CIR at 95% certainty.
**DTRS Frequency Reuse**

To achieve a CIR of 23.7 dB, a median distance between co-channel BTS sites can be estimated from Lee²:

\[ CIR \approx \frac{1}{i} \left( \frac{D}{R} \right)^\gamma \]

Where,
- \( D \) is median line of sight distance to co-channel site
- \( R \) is cell radius
- \( i \) is number of interferers in rail environment
- \( \gamma \) is propagation factor

Required \( \frac{D}{R} \) ratio is

\[ \frac{D}{R} = \left( \frac{i \cdot CIR}{10^\frac{CIR_{db}}{10}} \right)^\frac{1}{\gamma} \]

For \( \gamma = 3.5 \), \( CIR_{db} = 23.7 \) and \( i = 3 \),

\[ \frac{D}{R} = 6.53 \]

Therefore,

\[ D = 2 \times 6.53 = 13.1 \text{ km} \]

and,

\[ D_{\text{Track}} = D \times 140\% = 18.3 \text{ km} \]

This means that if average cell radius is 2 km [Assumption 11] then a GSM-R frequency can be reused 13.1 km away (line-of-sight) or 18.3 track km without causing excessive interference to voice and emergency calls.

---

DTRS frequency reuse \((k)\) can be estimated by assuming that rail track distances are longer than line-of-sight distances by 40\% [Assumption 10] and that average BTS spacing is 2.9 km +/- 250 m [Assumption 17].

Assuming median DTRS site separation \(d_{\text{BTS}}=2.9\, \text{km}\)
But allowing for non-ideal site compromise of \(\pm\) 250 m
A lesser value of 2.65 km for \(d_{\text{BTS}}\) will be used.

For \(\gamma=3.5\) and \(D_{\text{Track}} \approx 18.3\, \text{km}\),
\[
k_{3.5} = \frac{D_{\text{Track}}}{d_{\text{BTS}}} \approx \frac{18.3}{2.65} = 6.89
\]

Therefore DTRS frequency re-use factor, \(k\), must be 6.9 or more.
**Adjacent Carrier Separation**

Frequency allocation must consider co-located, adjacent and nearby transceivers (TRX).

Handover should occur within a DTRS cell and, therefore, at handover CIR will be at least 23.7 dB. Assuming adjacent carrier emissions are effectively interference then they must also be below 23.7 dB. An additional design margin of 6 dB is added to ensure adjacent carrier interference is insignificant relative to co-channel interference to ensure previous calculations remain valid.

If a handover margin of 6 dB is used, CIR at handover due to adjacent carrier emissions can be determined:

\[ CIR_{HO} = (CIR_{dB} + CIR_{margin}) + HO_{design} + HO_{margin} = 23.7 + 6 + 6 = 35.7 \text{ dB} \]

To meet this CIR a minimum adjacent carrier separation of 600 kHz between adjacent sites can be determined from GSM specification TS 45.005 Figure A.2b. 600 kHz separation provides -65 dB C/I midway (about 1.3 km for this case) between adjacent BTS sites. Therefore at handover a 600 kHz carrier separation will provide an effective CIR at handover of 59 dB.

![Illustration 3: Adjacent BTS CIR Estimation at Midpoint](image1.png)

![Illustration 4: Adjacent BTS CIR Estimation at Hand-over](image2.png)
<table>
<thead>
<tr>
<th>Adjacent Site Carrier Offset</th>
<th>Assumed Interference Due Carrier at Adjacent Site (at midpoint between sites)</th>
<th>Assumed Interference Due Carrier at Adjacent Site (at handover)</th>
<th>Design</th>
<th>Frequency Plan Reuse</th>
</tr>
</thead>
<tbody>
<tr>
<td>200 kHz</td>
<td>0 dBC</td>
<td>+6 dB</td>
<td>Unacceptable</td>
<td></td>
</tr>
<tr>
<td>400 kHz</td>
<td>-42 dBC</td>
<td>-36 dB</td>
<td>Poor</td>
<td>ADBEC 12345</td>
</tr>
<tr>
<td>600 kHz</td>
<td>-65 dBC</td>
<td>-59 dB</td>
<td>Design median</td>
<td>AFDBGEC 1234567</td>
</tr>
<tr>
<td>800 – 1200 kHz</td>
<td>-70 dBC</td>
<td>-64 dB</td>
<td>Preferred</td>
<td>AHFDBIGEC 123456789</td>
</tr>
<tr>
<td>1400 - 1800 kHz</td>
<td>-73 dBC</td>
<td>-67 dB</td>
<td>Ideal</td>
<td>(not investigated)</td>
</tr>
</tbody>
</table>

To achieve 600 kHz adjacent channel separation and linear reuse of 6.9, a minimal set of 3x7 adjacent carriers is required for 3 TRX per site. In addition to this, spectrum needs to be allocated for guard bands and emergency trailers.

**Emergency Trailers**

RailCorp will be adding GSM-R BTS to emergency response trailers to be deployed at any location in RailCorp’s network. To simplify trailer deployment and reduce any risk of interference, a dedicated carrier will be associated to each trailer.

RailCorp will reserve 3 GSM carriers for emergency response trailers [Requirement 3].

These emergency response trailers increase spectrum requirements by 3 GSM channels.
**LTE Guard Band**

Australia’s 1800 band is expected to host initial LTE deployments and therefore it is expected that adjacent LTE carriers will cause some level of interference to a GSM-R DTRS.

Assuming a 5 MHz LTE carrier (worse-case) adjacent to a DTRS carrier, both transmitting 40 W. In band, an LTE system will have an EIRP of 54 dBm/200 kHz. LTE emissions allow up to -7 dBm/100 kHz adjacent to LTE band edge, dropping to -14 dBm at a 5 MHz offset and -25 dBm at 10 MHz offset. These levels become -4, -11 and -22 dBm/200 kHz.

![Diagram showing interference levels](image)

**Illustration 5: Interference from Co-Located or Equi-Distant LTE Interferer**

From this graph, an 5 MHz LTE system (orange) has a similar emissions mask to that of a GSM system (yellow) except that out-of-band emissions are higher.

Midway between a DTRS GSM-R and an interfering LTE site, a CIR of about 40 dB will be met for any adjacent GSM-R system. To ensure CIR at handover, an uncoordinated LTE interferer should not be closer to a Mobile Station (MS) than any DTRS site – roughly 2 km in this case. It is unlikely that potential LTE sites will be more than 2 km away so additional measures need to be taken to reduce the risk of interference.

Establishing a 300 kHz guard band within rail spectrum should offer at least 20 dB additional protection from an LTE interferer. CEPT reports 041 and 096 recommend a minimum of 200 kHz between channel edges. In GSM 1800 band this would be 300 kHz or 500 kHz due to defined GSM carrier frequencies.

Co-location provides another possible mitigation by ensuring an LTE signal has similar propagation characteristics to a co-located DTRS GSM-R transmitter. A minimum 200 kHz guard channel is required and a 300 kHz guard channel offers an additional 20 dB protection.
**DTRS Voice Only Spectrum Requirement**

RailCorp’s proposed spectrum requirement and frequency plan to meet DTRS voice only requirements is presented below.

<table>
<thead>
<tr>
<th>Requirement</th>
<th>Current Requirement</th>
<th>GSM Carriers</th>
<th>50% Capacity Growth Requirement</th>
<th>GSM Carriers</th>
</tr>
</thead>
<tbody>
<tr>
<td>CIR of 23.7 dB</td>
<td>Frequency reuse must be at least 7</td>
<td></td>
<td>Frequency reuse must be at least 7</td>
<td></td>
</tr>
<tr>
<td>DTRS voice call traffic with single redundant TRX</td>
<td>Minimum of 3 carriers per BTS</td>
<td>3x7</td>
<td>Minimum of 3 carriers per BTS</td>
<td>3x7</td>
</tr>
<tr>
<td>Carriers for high traffic areas</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Adjacent LTE separation of 500 kHz</td>
<td>2 guard band channels</td>
<td>2</td>
<td>2 guard band channels</td>
<td>2</td>
</tr>
<tr>
<td>Emergency Trailer BTSs</td>
<td>3 carriers</td>
<td>3</td>
<td>3 carriers</td>
<td>3</td>
</tr>
<tr>
<td>DECT guard channel</td>
<td>1 guard band channel</td>
<td>1</td>
<td>1 guard band channel</td>
<td>1</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>5.4 MHz spectrum</td>
<td>27</td>
<td>5.4 MHz spectrum</td>
<td>27</td>
</tr>
</tbody>
</table>

With specific LTE interference mitigation measures, minimum DTRS GSM-R spectrum requirement is 27 carriers or 5.4 MHz including 1 DECT guard channel, 2 LTE guard channels and 3 emergency trailers.

A possible frequency plan is provided below:

<table>
<thead>
<tr>
<th>LTE Guard Band</th>
<th>Carrier Allocation Order A - G</th>
<th>Emergency Trailer</th>
<th>DECT Guard</th>
</tr>
</thead>
<tbody>
<tr>
<td>2 Guard band carriers</td>
<td>A</td>
<td>F</td>
<td>D</td>
</tr>
<tr>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>9</td>
<td>10</td>
<td>11</td>
<td>12</td>
</tr>
<tr>
<td>17</td>
<td>18</td>
<td>19</td>
<td>20</td>
</tr>
</tbody>
</table>
**Spectrum for DTRS and ETCS**

In addition to voice circuits for DTRS, ETCS requires a dedicated continuous circuit-switched data connection to each train to regularly receive distant signalling state to determine maximum train speed; and to report exact train position. This means that each train will continuously occupy 1 time-slot of a BTS.

**DTRS and ETCS Coverage Analysis**

For this study, ETCS received signal level is measured at the cab radio antenna connector as per the DTRS specification.

GSM-R specification calls for -95 dBm, 95% certainty for critical data. This means that a design margin must be found to ensure 95% of track locations receive a signal level of -95 dBm or greater. This figure is based on 9 dB above RX sensitivity which, for GSM 900, is -104 dBm. However for GSM 1800 MS reference sensitivity is -102 dBm. Therefore, an additional 2 dB shall be added to raise required RX signal level to -93 dBm.

<table>
<thead>
<tr>
<th>Note: DTRS specifications mandates -95 dBm [Requirement 1] based on GSM 900 ETCS critical data requirement. A UIC Implementation Report has been raised concerning this issue to amend this requirement for GSM-R 1800. UIC advises that a determination is expected in July 2011.</th>
</tr>
</thead>
</table>

As for the previous case, an RX margin of 8.2 dB is required to achieve 95% certainty.

\[
RX_{level}(95\%) = RX_{level} + RX_{adj} + RX_{margin} + RX_{loss}
\]

Where,
- Received signal level \(RX_{level}\) ≥ -95 dBm
- Received signal level adjustment for GSM 1800 \(RX_{adj}\) = 2 dB
- Received margin certainty \(RX_{margin}\) = 8.2 dB
- Cab radio cable and connector losses \(RX_{loss}\) = 3 dB

Therefore,

\[
RX_{level}(95\%) = -95 + 2 + 8.2 + 3 = -81.8\ dBm
\]

Allowing for 3 dB antenna cable and connector loss, ETCS antenna RX level will be engineered to be greater than -81.8 dBm.
**DTRS and ETCS Cell Radius**

An average cell radius can be estimated from a required RX level and a Hata suburban environment. In determining an average cell radius a worse-case BTS antenna height of 25 m and a MS height of 1.5 m are assumed.

From a HATA suburban path loss model,

\[ L_{SU} = L_U - 2 \left( \log \frac{f}{28} \right)^2 - 5.4 \]

and,

\[ L_U = 69.55 + 26.16 \log f - 13.82 \log h_B - C_H + (44.9 - 6.55 \log h_B) \log d \]

and to meet required RX signal level,

\[ L_{SU} \leq P_B - P_{RX level} \]

Where

- \( f \) is 1880 MHz
- \( h_B \) is BTS height: 25 m
- \( h_M \) is MS antenna height: 1.5 m
- \( L \) is combiner, splitter, jumper, duplexer and cable losses: 12.3 dB
- \( G \) is Antenna gain: 19 dBi
- \( P_B \) is BTS output power: 46 dBm
- \( P_{RX level} \) is required RX signal level: −81.8 dB (derived above)
- \( C_H \) is antenna height correction for Urban environments

Now,

\[ P_{EIRP} = P_B - L + G \approx 52.72 \text{ dBm EIRP} \]

and,

\[ C_H = 0.8 + (1.1 \log f - 0.7) h_M - 1.56 \log f \approx 0.04 \text{ dB} \]

Also,

\[ L_{SU} \leq P_{EIRP} - P_{RX level} \]

So,

\[ 123.76 + 35.74 \log d \leq 52.72 - (-81.8) \]

Therefore,

\[ d \approx 10^\frac{134.52 - 123.76}{35.74} = 2 \text{ km} \]

Therefore, average GSM-R cell radius is estimated to be 2 km, confirming DTRS preliminary design estimates.

**DTRS and ETCS Carrier Interference**

GSM specification for CSD requires CIR of 9 dB for a MS travelling between 50 and 130 km/h. Coverage at this level for CSD should be 50%. To raise CIR certainty to 95% a margin is required and to determine the margin, a path loss path loss exponent must be assumed.

Therefore, as before a CIR of 23.7 dB is assumed. This defines a minimum frequency re-use of 6.9 for this analysis.

Normally a CIR of 12 to 15 dB (excluding CIR margin) is recommended for GSM-R ETCS. This analysis is assessing the minimum spectrum requirement therefore the minimum CIR required by the GSM-R specification is used.
**DTRS and ETCS Traffic Analysis**

To determine traffic loads an analysis of some representative areas has been performed. For these locations, the following assumptions have been made.

- An average approach and departure speed of 30 km/h;
- DTRS cell diameter of 2.9 km less 250 m worse-case to allow for less than optimal site placement;
- 60 s dwell;
- A train acceleration/de-acceleration of half maximum which is 0.5 m/s²;
- A single continuous CSD connection per train;

Note that during ETCS Radio Block Centre (RBC) handover points, 2 ETCS CSD connections may be required.

- In yards, tunnels, junctions, stations and nominated routes, dual ETCS capacity is required. In these areas, no additional redundancy for DTRS is included;
- 2 signalling timeslots per BTS; and
- 1 GPRS timeslot

Note that RailCorp's DTRS specification requires a minimum of 2 GPRS timeslots. Since these are not required for DTRS nor ETCS at this time, a single GPRS timeslot is used.

<table>
<thead>
<tr>
<th>Busy Station</th>
<th>Busy Period Trains (on cell)</th>
<th>Platforms</th>
<th>CPH (Erl)</th>
<th>BHL Timeslots</th>
<th>Signalling Timeslots</th>
<th>GPRS Timeslots</th>
<th>Voice Traffic Timeslots</th>
<th>ETCS CSD</th>
<th>Redundant ETCS CSD</th>
<th>Total Required TRXs</th>
</tr>
</thead>
<tbody>
<tr>
<td>Central</td>
<td>136</td>
<td>25</td>
<td>116</td>
<td>3.13</td>
<td>2</td>
<td>1</td>
<td>9</td>
<td>21</td>
<td>21</td>
<td>8</td>
</tr>
<tr>
<td>Strathfield</td>
<td>58</td>
<td>8</td>
<td>51.2</td>
<td>1.41</td>
<td>2</td>
<td>1</td>
<td>6</td>
<td>11</td>
<td>11</td>
<td>5</td>
</tr>
<tr>
<td>Sydenham</td>
<td>43</td>
<td>6</td>
<td>39.3</td>
<td>1.11</td>
<td>2</td>
<td>1</td>
<td>5</td>
<td>8</td>
<td>8</td>
<td>4</td>
</tr>
<tr>
<td>Redfern</td>
<td>111</td>
<td>12</td>
<td>91.7</td>
<td>2.39</td>
<td>2</td>
<td>1</td>
<td>7</td>
<td>17</td>
<td>17</td>
<td>7</td>
</tr>
<tr>
<td>North Sydney</td>
<td>33</td>
<td>4</td>
<td>31</td>
<td>0.90</td>
<td>2</td>
<td>1</td>
<td>5</td>
<td>6</td>
<td>6</td>
<td>3</td>
</tr>
<tr>
<td>Penrith</td>
<td>15</td>
<td>3</td>
<td>17.4</td>
<td>0.57</td>
<td>2</td>
<td>1</td>
<td>4</td>
<td>4</td>
<td>4</td>
<td>3</td>
</tr>
<tr>
<td>Springwood</td>
<td>7</td>
<td>2</td>
<td>11.1</td>
<td>0.42</td>
<td>2</td>
<td>1</td>
<td>3</td>
<td>3</td>
<td>3</td>
<td>3</td>
</tr>
<tr>
<td>Hornsby</td>
<td>28</td>
<td>5</td>
<td>27.9</td>
<td>0.84</td>
<td>2</td>
<td>1</td>
<td>4</td>
<td>5</td>
<td>5</td>
<td>3</td>
</tr>
<tr>
<td>Blacktown</td>
<td>24</td>
<td>7</td>
<td>25.9</td>
<td>0.82</td>
<td>2</td>
<td>1</td>
<td>4</td>
<td>6</td>
<td>6</td>
<td>3</td>
</tr>
<tr>
<td>Granville</td>
<td>32</td>
<td>4</td>
<td>30.3</td>
<td>0.88</td>
<td>2</td>
<td>1</td>
<td>5</td>
<td>6</td>
<td>6</td>
<td>3</td>
</tr>
<tr>
<td>Paramatta</td>
<td>28</td>
<td>4</td>
<td>27.4</td>
<td>0.81</td>
<td>2</td>
<td>1</td>
<td>4</td>
<td>6</td>
<td>6</td>
<td>3</td>
</tr>
<tr>
<td>Lithgow</td>
<td>4</td>
<td>2</td>
<td>8.91</td>
<td>0.37</td>
<td>2</td>
<td>1</td>
<td>3</td>
<td>2</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>Erskineville</td>
<td>12</td>
<td>4</td>
<td>15.7</td>
<td>0.55</td>
<td>2</td>
<td>1</td>
<td>4</td>
<td>3</td>
<td>3</td>
<td>3</td>
</tr>
<tr>
<td>Hurstville</td>
<td>32</td>
<td>4</td>
<td>30.3</td>
<td>0.88</td>
<td>2</td>
<td>1</td>
<td>5</td>
<td>7</td>
<td>7</td>
<td>4</td>
</tr>
</tbody>
</table>

Therefore for ETCS, GSM-R capacity at major junctions and stations increases by a factor of 2.

This result suggests that major traffic areas need additional GSM carriers to carry busy hour traffic. If in these cases, busy areas are divided into multiple serving sites then GSM-R carriers can be kept to a maximum of 4 per site. However, due to the proximity of Central, Redfern and Strathfield, 7-8 additional GSM carriers are required.
**Future DTRS and ETCS Capacity**

RailCorp expects to be able to increase train traffic from 20 per hour per track to 30 per hour per track. This represents a peak capacity increase of 50%.

When this capacity increase of associated DTRS and ETCS traffic is modelled, an increase in GSM-R TRXs is observed for all stations. In busy areas additional GSM carriers are required to meet demand.

<table>
<thead>
<tr>
<th>Station</th>
<th>Busy Period Trains (on cell)</th>
<th>Platforms</th>
<th>CPH</th>
<th>BHL (Erl)</th>
<th>Signalling Timeslots per BTS</th>
<th>GPRS Timeslots</th>
<th>Voice Traffic Timeslots</th>
<th>ETCS CSD</th>
<th>Redundant ETCS CSD</th>
<th>Total Required TRXs</th>
</tr>
</thead>
<tbody>
<tr>
<td>Central</td>
<td>204</td>
<td>25</td>
<td>166</td>
<td>4.26</td>
<td>2</td>
<td>1</td>
<td>10</td>
<td>32</td>
<td>32</td>
<td>11</td>
</tr>
<tr>
<td>Strathfield</td>
<td>87</td>
<td>8</td>
<td>72.2</td>
<td>1.89</td>
<td>2</td>
<td>1</td>
<td>6</td>
<td>17</td>
<td>17</td>
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<tr>
<td>Sydenham</td>
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<td>6</td>
<td>54.9</td>
<td>1.47</td>
<td>2</td>
<td>1</td>
<td>6</td>
<td>12</td>
<td>12</td>
<td>5</td>
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<tr>
<td>Redfern</td>
<td>166.5</td>
<td>12</td>
<td>132</td>
<td>3.31</td>
<td>2</td>
<td>1</td>
<td>9</td>
<td>26</td>
<td>26</td>
<td>9</td>
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<tr>
<td>North Sydney</td>
<td>49.5</td>
<td>4</td>
<td>43</td>
<td>1.17</td>
<td>2</td>
<td>1</td>
<td>5</td>
<td>9</td>
<td>9</td>
<td>5</td>
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<td>Penrith</td>
<td>22.5</td>
<td>3</td>
<td>22.9</td>
<td>0.70</td>
<td>2</td>
<td>1</td>
<td>4</td>
<td>6</td>
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<td>Springwood</td>
<td>10.5</td>
<td>2</td>
<td>13.6</td>
<td>0.47</td>
<td>2</td>
<td>1</td>
<td>4</td>
<td>5</td>
<td>5</td>
<td>3</td>
</tr>
<tr>
<td>Hornsby</td>
<td>42</td>
<td>5</td>
<td>38</td>
<td>1.07</td>
<td>2</td>
<td>1</td>
<td>5</td>
<td>8</td>
<td>8</td>
<td>4</td>
</tr>
<tr>
<td>Blacktown</td>
<td>36</td>
<td>7</td>
<td>34.7</td>
<td>1.02</td>
<td>2</td>
<td>1</td>
<td>5</td>
<td>9</td>
<td>9</td>
<td>5</td>
</tr>
<tr>
<td>Granville</td>
<td>48</td>
<td>4</td>
<td>41.9</td>
<td>1.15</td>
<td>2</td>
<td>1</td>
<td>5</td>
<td>9</td>
<td>9</td>
<td>5</td>
</tr>
<tr>
<td>Paramatta</td>
<td>42</td>
<td>4</td>
<td>37.5</td>
<td>1.05</td>
<td>2</td>
<td>1</td>
<td>5</td>
<td>9</td>
<td>9</td>
<td>5</td>
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<tr>
<td>Lithgow</td>
<td>6</td>
<td>2</td>
<td>10.4</td>
<td>0.40</td>
<td>2</td>
<td>1</td>
<td>3</td>
<td>3</td>
<td>3</td>
<td>3</td>
</tr>
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<td>Erskineville</td>
<td>18</td>
<td>4</td>
<td>20.1</td>
<td>0.65</td>
<td>2</td>
<td>1</td>
<td>4</td>
<td>5</td>
<td>5</td>
<td>3</td>
</tr>
<tr>
<td>Hurstville</td>
<td>48</td>
<td>4</td>
<td>41.9</td>
<td>1.15</td>
<td>2</td>
<td>1</td>
<td>5</td>
<td>11</td>
<td>11</td>
<td>5</td>
</tr>
</tbody>
</table>

Most GSM-R sites will require at most 5 TRXs however Redfern, for example, will require 4 extra carriers and Central will require 6 extra carriers to meet future traffic levels. Due to their proximity to Strathfield, a minimum of 12 extra carriers is required.
**DTRS and ETCS Spectrum Requirement**

RailCorp’s proposed spectrum requirement and frequency plan to meet DTRS and ETCS requirements is presented below.

<table>
<thead>
<tr>
<th>Requirement</th>
<th>Current Requirement</th>
<th>GSM Carriers</th>
<th>50% Capacity Growth Requirement</th>
<th>GSM Carriers</th>
</tr>
</thead>
<tbody>
<tr>
<td>CIR of 23.7 dB</td>
<td>Frequency reuse must be at least 7</td>
<td></td>
<td>Frequency reuse must be at least 7</td>
<td></td>
</tr>
<tr>
<td>DTRS voice call traffic with single redundant TRX</td>
<td>Minimum of 4 carriers per BTS</td>
<td>4x7</td>
<td>Minimum of 5 carriers per BTS</td>
<td>5x7</td>
</tr>
<tr>
<td>Carriers for high traffic areas</td>
<td>Minimum of 8 carriers</td>
<td>8</td>
<td>Minimum of 12 carriers</td>
<td>12</td>
</tr>
<tr>
<td>Adjacent LTE separation of 500 kHz</td>
<td>2 guard band channels</td>
<td>2</td>
<td>2 guard band channels</td>
<td>2</td>
</tr>
<tr>
<td>Emergency Trailer BTSs</td>
<td>3 carriers</td>
<td>3</td>
<td>3 carriers</td>
<td>3</td>
</tr>
<tr>
<td>DECT guard channel</td>
<td>1 guard band channel</td>
<td>1</td>
<td>1 guard band channel</td>
<td>1</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>8 MHz spectrum</td>
<td>42</td>
<td>10.6 MHz spectrum</td>
<td>53</td>
</tr>
</tbody>
</table>

With specific LTE interference mitigation measures, minimum DTRS GSM-R spectrum requirement is 53 carriers or 10.6 MHz including 1 DECT guard channel, 2 LTE guard channels, 12 carriers for high traffic areas and 3 emergency trailers.

A possible frequency plan is provided below:
Appendix D: DTRS Spectrum Study Report

Victorian analysis of spectrum requirement

This appendix contains an interim spectrum analysis report from Nokia Siemens Networks on their progress on assessing the level of spectrum required for the current Victorian GSM-R network and future possible configurations. Some of the major points identified in the analysis are:

1. The amount of spectrum is a major contributor to the level of performance that can be derived from the network (noting that rail networks carrying train control data are very high performance networks). For the network planning to be accurate it must include consideration of the signalling network design in addition to the GSM-R network design as there are attributes of the signalling system, such as RBC (signalling controllers that have limited train unit capacity) boundaries, that will significantly affect the planning and spectrum demands of the GSM-R network.

2. A hotspot (an area with a large number of active trains and rail operational staff) such as Flinders Street Station may require as much as 9.6 MHz of spectrum to support the one site (considering separation of frequencies to support the required operational performance).

This preliminary network planning will be refined over the coming years as the current GSM-R network operationally settles and the high capacity signalling and train control network become better defined. At this time there is still a significant level of risk regarding the final amount of spectrum required and a concern that a reduction in the overall spectrum available will significantly limit the ability to address the planning risks that remain.
DTRS Spectrum Study Report
(A Simulation Based approach in Planning Tool – NetAct v6.0)

Nokia Siemens Networks Australia
Table of Content

• Background of the report
• Simulation plan
• Simulation considerations
• Simulation Results
  – C/I for different BWs with increased results compare to current configurations
  – C/A for different BWs with increased results compare to current configurations
  – Coverage
Background of the report

- DoT is assigned 15 MHz BW in 1800 MHz band to operate their GSM-R system. The spectrum allocations are below

<table>
<thead>
<tr>
<th>Expiry</th>
<th>License Number</th>
<th>Lower Frequency (MHz)</th>
<th>Upper Frequency (MHz)</th>
<th>Lower ARFCN</th>
<th>Upper ARFCN</th>
<th>Lower Centre Frequency (MHz)</th>
<th>Upper Centre Frequency (MHz)</th>
<th>Range (MHz)</th>
<th>Quantity</th>
</tr>
</thead>
<tbody>
<tr>
<td>17/06/2013</td>
<td>8100221</td>
<td>1727.5</td>
<td>1730</td>
<td>599</td>
<td>610</td>
<td>1727.6</td>
<td>1729.8</td>
<td>2.5</td>
<td>12</td>
</tr>
<tr>
<td>17/06/2013</td>
<td>8100222</td>
<td>1822.5</td>
<td>1825</td>
<td>599</td>
<td>610</td>
<td>1822.6</td>
<td>1824.8</td>
<td>2.5</td>
<td>12</td>
</tr>
<tr>
<td>1/05/2015</td>
<td>8100223</td>
<td>1877.5</td>
<td>1880</td>
<td>874</td>
<td>885</td>
<td>1877.6</td>
<td>1879.8</td>
<td>2.5</td>
<td>12</td>
</tr>
<tr>
<td>1/05/2015</td>
<td>8100224</td>
<td>1782.5</td>
<td>1785</td>
<td>874</td>
<td>885</td>
<td>1782.6</td>
<td>1784.8</td>
<td>2.5</td>
<td>12</td>
</tr>
<tr>
<td>1/05/2015</td>
<td>8100225</td>
<td>1850</td>
<td>1860</td>
<td>737</td>
<td>785</td>
<td>1850.2</td>
<td>1859.8</td>
<td>10</td>
<td>48</td>
</tr>
<tr>
<td>1/05/2015</td>
<td>8100226</td>
<td>1755</td>
<td>1765</td>
<td>737</td>
<td>785</td>
<td>1755.2</td>
<td>1764.8</td>
<td>10</td>
<td>48</td>
</tr>
</tbody>
</table>

Downlink Frequencies
Uplink Frequencies
Simulation Plan

• There are four scenarios need to simulate for minimum spectrum use plan
  – Current DTRS configuration (5 MHz & 2 TRX)
  – Current DTRS coverage with increased capacity
  – Increased metropolitan coverage and increased capacity
  – Regional Coverage & increased capacity

• For each of the above scenarios there are below items need to get from the simulation
  – Minimum spectrum needed for each of the cases from different BW’s (i.e. 2.5/5/7.5/10/12.5/15 MHz) with keeping the same coverage for 2TRx current configuration.
  – Interference level at each 2.5 MHz increments on C/I & C/A.
  – Increased interference on C/I & C/A over current network configurations.
  – A basic frequency plan for all of the configuration.

• In this first deliverable scenario -1 & 2 is simulated and presented with comments.
Simulation considerations

• For scenario 1 & 2 simulations in NetAct following items are used as same
  – All physical parameters like height, locations, antenna type, pattern, antenna directions etc are kept as same according to current DTRS configurations.
  – Results are taken only in the railway corridor using the below polygon

Figure 1: Railway polygon area used for analysis
Simulation Results – C/I for Different BW (1/5)

- The simulation of C/I is presented in tabular format

<table>
<thead>
<tr>
<th>Criteria</th>
<th>2MHz 2TRX</th>
<th>5MHz 2TRX</th>
<th>5MHz 4TRX</th>
<th>7.5MHz 2TRX</th>
<th>7.5MHz 4TRX</th>
<th>10 MHz 2TRX</th>
<th>10 MHz 4TRX</th>
<th>12.5 MHz 2TRX</th>
<th>12.5 MHz 4TRX</th>
<th>15 MHz 2TRX</th>
<th>15 MHz 4TRX</th>
</tr>
</thead>
<tbody>
<tr>
<td>39.00 ≤ x dB</td>
<td>56.19%</td>
<td>62.61%</td>
<td>58.02%</td>
<td>59.82%</td>
<td>69.28%</td>
<td>42.31%</td>
<td>62.91%</td>
<td>46.11%</td>
<td>60.25%</td>
<td>33.82%</td>
<td>61.59%</td>
</tr>
<tr>
<td>36.00 ≤ x &lt; 39.00 dB</td>
<td>5.92%</td>
<td>2.97%</td>
<td>6.17%</td>
<td>3.11%</td>
<td>4.07%</td>
<td>1.24%</td>
<td>1.91%</td>
<td>1.88%</td>
<td>3.59%</td>
<td>1.49%</td>
<td>3.35%</td>
</tr>
<tr>
<td>33.00 ≤ x &lt; 36.00 dB</td>
<td>5.53%</td>
<td>2.73%</td>
<td>5.68%</td>
<td>2.33%</td>
<td>3.12%</td>
<td>0.94%</td>
<td>2.72%</td>
<td>1.43%</td>
<td>3.53%</td>
<td>1.25%</td>
<td>2.53%</td>
</tr>
<tr>
<td>30.00 ≤ x &lt; 33.00 dB</td>
<td>5.29%</td>
<td>2.24%</td>
<td>5.33%</td>
<td>1.90%</td>
<td>2.95%</td>
<td>0.45%</td>
<td>2.20%</td>
<td>1.05%</td>
<td>3.23%</td>
<td>0.99%</td>
<td>2.05%</td>
</tr>
<tr>
<td>27.00 ≤ x &lt; 30.00 dB</td>
<td>4.74%</td>
<td>1.51%</td>
<td>4.82%</td>
<td>1.72%</td>
<td>2.70%</td>
<td>0.34%</td>
<td>1.51%</td>
<td>0.92%</td>
<td>2.74%</td>
<td>0.63%</td>
<td>1.91%</td>
</tr>
<tr>
<td>24.00 ≤ x &lt; 27.00 dB</td>
<td>9.13%</td>
<td>27.00%</td>
<td>8.33%</td>
<td>30.07%</td>
<td>13.06%</td>
<td>54.58%</td>
<td>26.95%</td>
<td>48.41%</td>
<td>23.83%</td>
<td>61.60%</td>
<td>26.93%</td>
</tr>
<tr>
<td>21.00 ≤ x &lt; 24.00 dB</td>
<td>3.38%</td>
<td>0.59%</td>
<td>3.63%</td>
<td>0.64%</td>
<td>1.81%</td>
<td>0.08%</td>
<td>0.52%</td>
<td>0.09%</td>
<td>1.23%</td>
<td>0.13%</td>
<td>0.81%</td>
</tr>
<tr>
<td>18.00 ≤ x &lt; 21.00 dB</td>
<td>2.81%</td>
<td>0.30%</td>
<td>2.89%</td>
<td>0.28%</td>
<td>1.28%</td>
<td>0.04%</td>
<td>0.28%</td>
<td>0.02%</td>
<td>0.74%</td>
<td>0.06%</td>
<td>0.53%</td>
</tr>
<tr>
<td>15.00 ≤ x &lt; 18.00 dB</td>
<td>1.81%</td>
<td>0.04%</td>
<td>2.01%</td>
<td>0.11%</td>
<td>0.50%</td>
<td>0.01%</td>
<td>0.02%</td>
<td>0.02%</td>
<td>0.42%</td>
<td>0.03%</td>
<td>0.16%</td>
</tr>
<tr>
<td>12.00 ≤ x &lt; 15.00 dB</td>
<td>1.26%</td>
<td>0.01%</td>
<td>1.30%</td>
<td>0.01%</td>
<td>0.31%</td>
<td>0.00%</td>
<td>0.00%</td>
<td>0.02%</td>
<td>0.29%</td>
<td>0.00%</td>
<td>0.11%</td>
</tr>
<tr>
<td>9.00 ≤ x &lt; 12.00 dB</td>
<td>0.64%</td>
<td>0.00%</td>
<td>0.66%</td>
<td>0.00%</td>
<td>0.27%</td>
<td>0.00%</td>
<td>0.00%</td>
<td>0.00%</td>
<td>0.12%</td>
<td>0.00%</td>
<td>0.00%</td>
</tr>
<tr>
<td>6.00 ≤ x &lt; 9.00 dB</td>
<td>0.44%</td>
<td>0.00%</td>
<td>0.44%</td>
<td>0.00%</td>
<td>0.20%</td>
<td>0.00%</td>
<td>0.00%</td>
<td>0.02%</td>
<td>0.02%</td>
<td>0.00%</td>
<td>0.00%</td>
</tr>
<tr>
<td>3.00 ≤ x &lt; 6.00 dB</td>
<td>0.45%</td>
<td>0.00%</td>
<td>0.38%</td>
<td>0.00%</td>
<td>0.25%</td>
<td>0.00%</td>
<td>0.00%</td>
<td>0.01%</td>
<td>0.00%</td>
<td>0.00%</td>
<td>0.00%</td>
</tr>
<tr>
<td>0.00 ≤ x &lt; 3.00 dB</td>
<td>0.40%</td>
<td>0.00%</td>
<td>0.33%</td>
<td>0.00%</td>
<td>0.22%</td>
<td>0.00%</td>
<td>0.00%</td>
<td>0.01%</td>
<td>0.00%</td>
<td>0.00%</td>
<td>0.00%</td>
</tr>
</tbody>
</table>
Hotspot (e.g. FSS) will need 9.6 MHz + Spectrum
(24 TRX * 400 kHz channel spacing)

Outside Hot Spot: 12 TRX
Inside Hot Spot (FSS): 12 + TRX

- ETCS 37 TCH = 6 TRX (based on 32 Trains and 2 RBC and 15% RBC Handover)
- Train Communication = 1 TRX
- Data Traffic (EDGE) = 2 TRX (for GPS application only)
- Voice (Station Personnel 50) 4.2 Erl = 1 TRX
- Redundancy 2 TRX (1 each in 2 BTS)
Simulation Results – C/I for Different BW (4/5)

- The PDF

![C/I results on different BWs (PDF)](image-url)
Simulation Results – C/I for Different BW (5/5)

- The CDF

![CDF Graph](image-url)

- C/I results on different BWs (CDF)

- Axes: C/I (dB) vs. BW (MHz)
- Lines represent different bandwidths and configurations:
  - 2MHz 2TRX
  - 5MHz 2TRX
  - 5MHz 4TRX
  - 7.5MHz 2TRX
  - 7.5MHz 4TRX
  - 10MHz 2TRX
  - 10MHz 4TRX
  - 12.5MHz 2TRX
  - 12.5MHz 4TRX
  - 15MHz 2TRX
  - 15MHz 4TRX

(Refer to page 9 for more details)
Simulation Results – C/I for Different BW variation of current network configurations (5/5)

Delta of C/I variation for different capacity range compare to current configuration

-40.00%  -30.00%  -20.00%  -10.00%  0.00%  10.00%  20.00%  30.00%  40.00%

% of area variation

39 36 33 30 27 24 21 18 15 12 9 6 3 0

C/I (dB)

-40.00% -30.00% -20.00% -10.00% 0.00% 10.00% 20.00% 30.00% 40.00%
Simulation Results – C/A for Different BW (1/4)

- The simulation of C/A is presented in tabular format

<table>
<thead>
<tr>
<th>Criteria</th>
<th>2MHz 2TRX</th>
<th>5MHz 2TRX</th>
<th>5MHz 4TRX</th>
<th>7.5MHz 2TRX</th>
<th>10 MHz 2TRX</th>
<th>10 MHz 4TRX</th>
<th>12.5 MHz 2TRX</th>
<th>12.5 MHz 4TRX</th>
<th>15 MHz 2TRX</th>
<th>15 MHz 4TRX</th>
</tr>
</thead>
<tbody>
<tr>
<td>39.00 &lt;= x dB</td>
<td>64.98%</td>
<td>79.00%</td>
<td>65.93%</td>
<td>68.62%</td>
<td>76.03%</td>
<td>73.53%</td>
<td>79.08%</td>
<td>73.34%</td>
<td>76.26%</td>
<td>70.53%</td>
</tr>
<tr>
<td>36.00 &lt;= x &lt; 39.00 dB</td>
<td>6.53%</td>
<td>5.09%</td>
<td>6.61%</td>
<td>1.75%</td>
<td>4.88%</td>
<td>3.06%</td>
<td>5.07%</td>
<td>2.16%</td>
<td>3.01%</td>
<td>1.59%</td>
</tr>
<tr>
<td>33.00 &lt;= x &lt; 36.00 dB</td>
<td>5.99%</td>
<td>3.74%</td>
<td>6.06%</td>
<td>1.43%</td>
<td>4.00%</td>
<td>2.48%</td>
<td>3.71%</td>
<td>1.68%</td>
<td>2.27%</td>
<td>1.08%</td>
</tr>
<tr>
<td>30.00 &lt;= x &lt; 33.00 dB</td>
<td>5.14%</td>
<td>3.25%</td>
<td>5.10%</td>
<td>1.03%</td>
<td>3.15%</td>
<td>2.38%</td>
<td>3.25%</td>
<td>1.01%</td>
<td>1.82%</td>
<td>0.47%</td>
</tr>
<tr>
<td>27.00 &lt;= x &lt; 30.00 dB</td>
<td>4.34%</td>
<td>1.97%</td>
<td>4.21%</td>
<td>0.69%</td>
<td>2.18%</td>
<td>1.40%</td>
<td>1.95%</td>
<td>0.41%</td>
<td>1.44%</td>
<td>0.21%</td>
</tr>
<tr>
<td>24.00 &lt;= x &lt; 27.00 dB</td>
<td>4.76%</td>
<td>5.43%</td>
<td>4.67%</td>
<td>24.81%</td>
<td>6.82%</td>
<td>15.85%</td>
<td>5.42%</td>
<td>20.71%</td>
<td>13.08%</td>
<td>26.08%</td>
</tr>
<tr>
<td>21.00 &lt;= x &lt; 24.00 dB</td>
<td>2.49%</td>
<td>0.84%</td>
<td>2.59%</td>
<td>0.44%</td>
<td>0.84%</td>
<td>0.85%</td>
<td>0.84%</td>
<td>0.14%</td>
<td>0.63%</td>
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<tr>
<td>18.00 &lt;= x &lt; 21.00 dB</td>
<td>1.83%</td>
<td>0.36%</td>
<td>1.87%</td>
<td>0.42%</td>
<td>0.74%</td>
<td>0.33%</td>
<td>0.36%</td>
<td>0.14%</td>
<td>0.48%</td>
<td>0.02%</td>
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<tr>
<td>15.00 &lt;= x &lt; 18.00 dB</td>
<td>1.68%</td>
<td>0.16%</td>
<td>1.24%</td>
<td>0.30%</td>
<td>0.57%</td>
<td>0.16%</td>
<td>0.16%</td>
<td>0.18%</td>
<td>0.42%</td>
<td>0.01%</td>
</tr>
<tr>
<td>12.00 &lt;= x &lt; 15.00 dB</td>
<td>1.50%</td>
<td>0.11%</td>
<td>1.11%</td>
<td>0.32%</td>
<td>0.52%</td>
<td>0.11%</td>
<td>0.11%</td>
<td>0.16%</td>
<td>0.39%</td>
<td>0.00%</td>
</tr>
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<td>9.00 &lt;= x &lt; 12.00 dB</td>
<td>0.76%</td>
<td>0.05%</td>
<td>0.60%</td>
<td>0.18%</td>
<td>0.28%</td>
<td>0.05%</td>
<td>0.05%</td>
<td>0.07%</td>
<td>0.18%</td>
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<tr>
<td>6.00 &lt;= x &lt; 9.00 dB</td>
<td>0.01%</td>
<td>0.00%</td>
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</tr>
<tr>
<td>3.00 &lt;= x &lt; 6.00 dB</td>
<td>0.00%</td>
<td>0.00%</td>
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<td>0.00%</td>
<td>0.00%</td>
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<td>0.00%</td>
<td>0.00%</td>
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<tr>
<td>0.00 &lt;= x &lt; 3.00 dB</td>
<td>0.00%</td>
<td>0.00%</td>
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<td>0.00%</td>
<td>0.00%</td>
<td>0.00%</td>
<td>0.00%</td>
</tr>
</tbody>
</table>
Simulation Results – C/A for Different BW (2/4)

- The PDF
Simulation Results – C/A for Different BW (3/4)

- The CDF
Simulation Results – C/A for Different BW variation of current network configurations (4/4)

Delta of C/A variation for different capacity range compare to current configuration

CINR (dB)

-20.00% -15.00% -10.00% -5.00% 0.00% 5.00% 10.00% 15.00% 20.00% 25.00%

-20.00% -15.00% -10.00% -5.00% 0.00% 5.00% 10.00% 15.00% 20.00% 25.00%

-20.00% -15.00% -10.00% -5.00% 0.00% 5.00% 10.00% 15.00% 20.00% 25.00%

-20.00% -15.00% -10.00% -5.00% 0.00% 5.00% 10.00% 15.00% 20.00% 25.00%

-20.00% -15.00% -10.00% -5.00% 0.00% 5.00% 10.00% 15.00% 20.00% 25.00%

-20.00% -15.00% -10.00% -5.00% 0.00% 5.00% 10.00% 15.00% 20.00% 25.00%

-20.00% -15.00% -10.00% -5.00% 0.00% 5.00% 10.00% 15.00% 20.00% 25.00%

2MHz 2TRX 5MHz 2TRX 5MHz 4TRX 7.5MHz 2TRX 7.5MHz 4TRX 10 MHz 2TRX 10 MHz 4TRX 12.5 MHz 2TRX 12.5 MHz 4TRX 15 MHz 2TRX 15 MHz 4TRX
Simulation Results – Coverage (1/3)

- Coverage wise there is no change of changing BW’s, the main reason behind this is the simulation region as mentioned earlier i.e. railway corridor.
- The simulation results are presented in tabular format

<table>
<thead>
<tr>
<th>Criteria</th>
<th>2MHz 2TRX</th>
<th>5MHz 2TRX</th>
<th>5MHz 4TRX</th>
<th>7.5MHz 2TRX</th>
<th>7.5MHz 4TRX</th>
<th>10 MHz 2TRX</th>
<th>10 MHz 4TRX</th>
<th>12.5 MHz 2TRX</th>
<th>12.5 MHz 4TRX</th>
</tr>
</thead>
<tbody>
<tr>
<td>Portable indoor (-68.50 ≤ x dBm)</td>
<td>98.49%</td>
<td>98.49%</td>
<td>98.49%</td>
<td>98.49%</td>
<td>98.49%</td>
<td>98.49%</td>
<td>98.49%</td>
<td>98.49%</td>
<td>98.49%</td>
</tr>
<tr>
<td>Portable outdoor (-83.50 ≤ x &lt; -68.50 dBm)</td>
<td>1.36%</td>
<td>1.36%</td>
<td>1.36%</td>
<td>1.36%</td>
<td>1.36%</td>
<td>1.36%</td>
<td>1.36%</td>
<td>1.36%</td>
<td>1.36%</td>
</tr>
<tr>
<td>Incab outdoor (-85.00 ≤ x &lt; -83.50 dBm)</td>
<td>0.01%</td>
<td>0.01%</td>
<td>0.01%</td>
<td>0.01%</td>
<td>0.01%</td>
<td>0.01%</td>
<td>0.01%</td>
<td>0.01%</td>
<td>0.01%</td>
</tr>
</tbody>
</table>
Simulation Results – Coverage (2/3)

Coverage Scenarios on different capacity range (PDF)

- Coverage (%)
- Rx level (dBm)

- 2MHz 2TRX
- 5MHz 2TRX
- 5MHz 4TRX
- 7.5MHz 2TRX
- 7.5MHz 4TRX
- 10 MHz 2TRX
- 10 MHz 4TRX
- 12.5 MHz 2TRX
- 12.5 MHz 4TRX
- 15 MHz 2TRX
- 15 MHz 4TRX
Simulation Results – Coverage (3/3)

Coverage Scenarios on different capacity range (CDF)

Rx Level (dBm)

-68.5  -83.5  -85
Appendix E: Use of Spectrum by the Rail Industry – Deloitte Access Economics Report
Use of spectrum by the rail industry

The Australasian Railway Association

7 July 2011
Thursday, 7 July 2011

Dear Vicki

Use of spectrum by the rail industry

Deloitte Access Economics is pleased to provide this report on the use of spectrum by the rail industry. The report considers current uses of spectrum by the rail industry and the policy framework surrounding spectrum re-allocation as well as giving quantitative examples of the cost savings in terms of infrastructure investment and externality benefits.

We hope that this report will aid the Australasian Railway Association and the Australian Government in their considerations of how best to re-allocate spectrum over the coming years.

Yours sincerely,

Ric Simes
Director
Deloitte Access Economics Pty Ltd
Use of spectrum by the rail industry

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## Glossary

<table>
<thead>
<tr>
<th>Abbreviation</th>
<th>Full Form</th>
</tr>
</thead>
<tbody>
<tr>
<td>ACCC</td>
<td>Australian Competition and Consumer Commission</td>
</tr>
<tr>
<td>ACMA</td>
<td>Australian Communications and Media Authority</td>
</tr>
<tr>
<td>ARA</td>
<td>Australasian Railway Association</td>
</tr>
<tr>
<td>ATP</td>
<td>Automatic Train Protection</td>
</tr>
<tr>
<td>CBD</td>
<td>Central Business District</td>
</tr>
<tr>
<td>DBCDE</td>
<td>Department of Broadband, Communications and the Digital Economy</td>
</tr>
<tr>
<td>ETCS</td>
<td>European Train Control System</td>
</tr>
<tr>
<td>GSM-R</td>
<td>Global System for Mobile Communications - Railway</td>
</tr>
<tr>
<td>LTE</td>
<td>Long Term Evolution</td>
</tr>
<tr>
<td>NGS</td>
<td>Next Generation Signalling</td>
</tr>
<tr>
<td>NPV</td>
<td>Net Present Value</td>
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</table>
Executive Summary

The rail industry in Australia is currently in the process of updating its communication systems to the latest international train communication standards. To do this it acquired spectrum in the 1800 MHz range beginning in late 2006. Since then around $500 million in adapting the international standard to Australian conditions and needs and is on the verge of rolling out services based on this technology, standard and spectrum.

Using this spectrum and this technology would allow for standardisation and improvements in train communications which would result in more reliable performance, more frequent services and less risk of accidents or signal failure.

The 1800 MHz spectrum licences which make these improvements possible are set to expire in 2013 and 2015. Currently it seems as if they will be auctioned instead of being renewed; this will likely result in bids from telecommunications companies and a loss of spectrum access to the rail industry.

Guidelines in development by the Australian Communications and Media Authority (ACMA) allow for consideration of public benefit when deciding on how to re-allocate licences. Specifically, a DBCDE consultation process in 2009 found strong support for public interest criteria in the following five areas:

- the highest value use for spectrum;
- efficient investment and innovation;
- competition;
- consumer convenience; and
- determining an appropriate rate of return to the community.

Considering these factors in the case of rail, it unlikely that, on a strict financial basis, the Australian rail industry will present the highest value option as it does not generate revenue from the spectrum. The value is instead generated by the improved transport services that better communications would facilitate. Risk of losing access to spectrum is likely to lead to inefficient investment over the next 2-4 years as the rail industry is unlikely to invest if it cannot feel secure in a return. Competition and consumer convenience are difficult criteria to apply to rail transport while an appropriate rate of return to the community must take into account the costs of investment in physical infrastructure that could be avoided by improving rail communications.

An analysis of two potential rail infrastructure investments in Sydney and Melbourne where improved communications are used to delay investment in new tunnels near the city centre suggest that even if the need for tunnelling is only delayed by five years then savings could still be in the order of $1.5 billion for these two projects alone.

To these infrastructure benefits must also be added the benefits rail brings by reducing pollution, congestion and accidents. Analysis of potential capacity increases that could come by reducing headways from 3 to 2 minutes in Sydney and Melbourne, an outcome that has been achieved in Switzerland using similar technology, indicates potential
externality benefits in the order of $400,000 for every hour that the train network operates at capacity.

These results give support to the idea that the rail industry should retain access to the 1800 MHz spectrum as:

- The rail industry provides a valuable public good, whose value could increase, by reducing negative transport externalities;
- Spectrum acts as part of rail infrastructure and can be used as a lower cost substitute for physical infrastructure investment, saving state and federal governments considerable investment costs.
- Sale at auction would simply represent a transfer from states to the Australian Government with no real benefit to tax payers.
- Not renewing the rail industry’s licences would result in reduced innovation and investment over the next 2-4 years as the rail industry would be unlikely to invest when there is a low chance of receiving a return on the investment.

Overall, renewing the rail industry’s licences could be seen as an investment by the Australian Government into metropolitan rail which will allow for better use of the existing physical infrastructure and support the development of Australia’s cities and continued growth of public transport. As indicated above, the benefits of this investment could be significant even when compared to what could be raised from an auction.

Deloitte Access Economics
1 Introduction

Following purchase of spectrum in the 1800 MHz range, the Australian rail industry is currently developing and deploying nationally consistent technology to make use of this spectrum. This technology would improve safety for rail transport as well as allowing for an increase in the frequency of service.

The current spectrum licenses are set to expire over the next few years and it is likely that they will be auctioned, attracting bids from telecommunications companies. This outcome could potentially fail to acknowledge the benefits to consumers and governments that are possible from use of the spectrum to improve rail communications.

This report sets out to analyse the arguments for why the rail industry should not pay a full market price for access to spectrum as well as considering the benefits that could be gained by implementing improved train communications, these benefits would be lost if the rail industry could not access the 1800 MHz range of spectrum.

This report does not seek to address the questions put to ARA by DBCDE. These questions will be addressed by ARA in its submission. This report focuses on the economic benefits of improved rail communications.

1.1 Report structure

Section 2 outlines the current spectrum use, investment plans and potential loss of spectrum access for the Australian rail industry. This section also considers some technical issues as to why the rail industry may not be able to rely on other telecommunications companies for provision of communications infrastructure.

Section 3 sets out the reasons for supporting the rail industry’s access to spectrum focussing on the public benefits that arise from rail transport.

Section 4 focuses on quantifying the benefits that could come from implementing improved communications through GSM-R in the 1800 MHz range. This analysis considers the benefits in terms of making efficient use of existing rail infrastructure as well as the societal benefits, such as reduced accidents, pollution and congestion from increased rail travel.

Section 5 concludes and considers possible policy approaches to ensuring the benefits of improved rail communications are secured.
2 Spectrum and the rail industry

2.1 Current use of spectrum by the rail industry

The Australian rail industry currently uses spectrum in both the 400 and 1800 MHz ranges.

In the 400 MHz range rail makes extensive use of the 403-420MHz band. This band has been used for communications between train and ground including command and control, train shunting, train movements and train condition monitoring. This is all aimed at ensuring safe rail operations and preventing accidents. Train to train communication is also used to allow for timely responses in the event of emergency. In addition, the 400MHz range also includes a dedicated emergency channel (450.050 MHz).

Use of spectrum by the rail industry in the 403-420MHz range is not consolidated and the specific frequency used differs by location, there is also no formal agreement between the Australian Communications and Media Authority (ACMA) and the rail industry to ensure access to this spectrum. For example, only around 90% of licence assignments in the band are for railway organisations and there are allocations outside the band due to congestion and insufficient capacity. The patchwork nature of this spectrum access leads to the need for multiple transmitters and receivers when passing through geographic locations and can lead to communication complications. This raises operational costs and complexities as well as increasing the chances of serious accidents.

To overcome the restrictions posed by continued use of the 400 Mhz range and to allow for technological improvements in rail control, the Australian rail industry sought access to new spectrum in the early 2000’s. This resulted in spectrum in the 1800 MHz range being purchased by state rail authorities beginning in late 2006 under the coordination of the Australasian Railway Association. The spectrum licences in this range were originally owned by One.Tel which purchased them at auction in 1998 and 2000. The licences cover Sydney, Melbourne, Brisbane, Adelaide and Perth and are due to expire in 2013 and 2015.

The move to the 1800 MHz spectrum was intended to allow for a nationally coordinated approach to rail communications. The 1800 MHz spectrum allowed for the use of Global System for Mobile Communications – Railway (GSM-R) technology. This technology was developed as part of the European Rail Traffic Management System and is in use, or planned for use by many countries including all European Union members, China, India and nations in the Middle East and North Africa.

The use of GSM-R technology will allow for improved communication between train and ground and could, among other benefits, replace external signalling with direct communications to trains. Improved communications will allow for trains to run closer together and reduce the need for waiting at signals, increasing capacity and decreasing travel times.

Implementation of the new technology has begun and is most advanced in Victoria where it is anticipated that it will enter service in 2012. Overall, a total of around $500 million has been invested by state rail agencies in developing and implementing GSM-R technologies.
2.2 Technical needs of the rail industry

The rail industry has telecommunications needs which are different from an average user. Communications must be highly reliable and available in remote locations, through difficult terrain and in underground stations in central business districts.

Due to its size, the Australian rail industry is also a standards taker, rather than a standards maker. The industry has therefore adopted communications standards which have been developed in Europe. Adopting existing standards has the advantage of it having a proven safety record as well as a range of equipment being already available to implement the standard. Adopting an existing standard does have the downside that the rail industry must use the technology on which the standard is based, in this case that technology is GSM-R, and must accept the technological limitations imposed by that technology (such as the need to operation in certain frequencies).

This report will not consider the technical requirements of spectrum access by the rail industry but will proceed on the assumption that if the network was not provided by the rail industry then the necessary services could not be provided by a telecommunications company.

The role of telecommunications companies will be addressed by ARA in its submission.

2.3 Reallocation of spectrum

The licenses in the 1800 MHz spectrum which are currently controlled by the Australian rail industry are set to expire in 2013 and 2015. These licences were originally auctioned in 1998 and 2000 with a 15 year tenure and were acquired by the Australian rail industry in around 2006-2008.

The general legal framework for managing spectrum is set out in The Radiocommunications Act 1992. A broad aim of the act is to provide for management of spectrum to maximise the overall public benefit from using the spectrum. On expiration of a licence there is a presumption that the licence will be reallocated using a price based method unless it is in the public interest to do otherwise.

As a large number of spectrum licences are set to expire between 2013 and 2017, there has been considerable thought given to how best to reallocate licenses. In a discussion paper, the Department of Broadband, Communications and the Digital Economy (DBCDE) set out that the extent of usage of a licence will be an important factor in considering whether to reallocate or renew a licence (DBCDE 2009). In circumstances where there has been low use of a licence, the discussion paper suggests that there is a stronger argument for price based reallocation, this would likely be achieved using auctioning.

The ARA has been notified by ACMA that it has not used its spectrum and so has not been directly involved in discussions relating to the re-issue of the licences. This suggests that it is likely that the licences currently controlled by the Australian rail industry will be reallocated using an auction. The licenses for the 1800 MHz spectrum, although being disused and seemingly not valued by the market for an extended period in the early 2000s, are currently of great interest to telecommunication companies for use with Long Term
Evolution (LTE) technology and so would be expected to fetch a high price at auction. As an indicator, One.Tel originally secured the licenses for $532 million in the late 1990s.

If the rail industry was to participate and win at auction, this would likely come at a cost in the hundreds of millions of dollars. This cost would be paid for by the state run rail operators and would therefore be largely funded from state government revenue. This would effectively represent a cash transfer from states to the Australian Government.

In the case where the industry loses at auction the investment to date in developing GSM-R technology will be lost. Future potential benefits from better train communications will also be put at risk. This will increase risks of accidents and prevent full utilisation of existing rail infrastructure.
3 Allocating spectrum

As noted above, there have been steps towards establishing criteria on which to make decisions around renewing spectrum licenses. These criteria add to those established in the *Radiocommunications Act*. An overall focus of the criteria is the acknowledgement that overwhelming consumer welfare gains are produced in output markets, not by extracting revenues from the sale of spectrum (Hazlett and Munoz 2010). The criteria, and how they relate to the rail industry are considered below.

3.1 The public interest test

Both the ACMA and the Minister for Broadband, Communications and the Digital Economy have some power in the *Radiocommunications Act* to renew licences to incumbents if it is in the ‘public interest’ to do so. The Act does not specify criteria for determining what conditions may constitute public interest. This lack of a definition has led to considerable uncertainty among incumbent licence holders.

There have however been steps in the direction of establishing what the public interest test may be. A DBCDE consultation process in 2009 found strong support for public interest criteria in the following five areas:

- the highest value use for spectrum;
- efficient investment and innovation;
- competition;
- consumer convenience; and
- determining an appropriate rate of return to the community (Conroy 2010a).

Details about the threshold for satisfying these criteria are not yet available, meaning uncertainty continues. In March 2010 the Minister for Broadband, Communications and the Digital Economy identified a number of spectrum licence holders – namely Telstra, Optus, Vodafone Hutchison Australia, and Unwired – as firms that may meet the ‘public interest’ criteria and “are using their licences to provide services to significant numbers of Australian consumers... or have in place networks capable of providing services to a significant number of consumers” (Conroy 2010b).

This secondary clause is potentially relevant to the case of the ARA as, while its spectrum holdings are not yet in widespread use, investments have been made towards making use of the allocation.

The broad importance of these five criteria is detailed below.

**Highest value use**

Governments work on global, regional and local levels to manage, and where necessary coordinate, the allocation of spectrum for specific purposes such as telecommunications, broadcasting, radio astronomy, satellites, defence, meteorology and others. Total economic welfare is maximised where all spectrum is allocated to its highest value use. The highest economic value use of spectrum is commonly assessed through bidders’
willingness-to-pay for the licence however this does not take into account the value of any externalities involved.

The value of licence renewal to an incumbent is contingent on the future expected value of the spectrum to their business. This differs according to the profitability of services provided through that spectrum, as well as the ‘life cycle’ of the technology in use, in terms of both position on the life cycle curve and its overall length. The government needs to carefully consider whether renewal or re-allocation is likely to result in the highest value use of the spectrum.

**Efficient investment and innovation**

The efficient investment and innovation criterion recognises both the need to provide incumbents with certainty of their future licence holdings, and to provide potential licence holders with certainty about their future holdings.

This certainty is important for two reasons:

- current licence holders are likely to defer investment decisions if they are unsure about whether their spectrum holdings will be renewed; and
- those undertaking innovative developments (whether current licence holders or potential licence holders) that require spectrum to be effective are likely to discontinue innovative activity if they are unsure about their future access to spectrum.

If an incumbent is uncertain about whether they are going to retain their licence beyond the end of the current licence period, they may make decisions with an eye to the short term, reducing overall efficiency. Licence allocation and renewal processes that reduce uncertainty about future spectrum availability will aid in ensuring that the efficiency of investment and innovation is maximised.

The incumbent licence holder’s investment decisions will be more affected as the licence nears expiry because the business case for investments becomes more dependent on returns which occur after the tenure of the licence. Those who expect to regain access to their spectrum are more likely to continue making efficient investment decisions. On the other hand, if the incumbent does not expect to regain access to its spectrum, its investment decisions will be more greatly affected.

However, in the case where an organisation has made investment decisions based on the expectation that they will regain access to their spectrum holdings but ultimately lose these, the costs may be very high. Infrastructure that has been purchased and installed may become essentially worthless, or only usable if potentially costly reconfiguration is undertaken. There is also the cost of lost revenue or other benefits that were generated through use of the spectrum.

**Competition**

Competition issues arise in the distribution of spectrum among market players both within the same industry and across industries. The ACCC has previously supported the application of competition limits for some auctions in order to encourage competition and the entry of new participants in the telecommunications market (ACCC 2002).
Use of spectrum by the rail industry

Competition concerns may arise particularly when there is scope for perverse incentives. This includes the scenario where the highest value use may be for a firm to purchase a licence simply to prevent their rivals from gaining access to it. If a licence holder who is productively using their licence is threatened with loss of access through such anti-competitive measures, there may be scope for licence renewal rather than open auction processes to protect against this.

**Consumer convenience**

Consumer convenience is particularly important in the case of spectrum that has previously been allocated and is due for renewal. If spectrum is being actively used to provide services for consumers, there may be large displacement costs to consumers if that spectrum is then reallocated to a different user. There is an inconvenience cost to these consumers from losing access to their services, and also in lost utility from investments they have made on the basis of receiving these services, as these often cannot readily be transferred for use elsewhere.

However this social value to consumers is not reflected in a licence bidders’ valuation of spectrum. Consequently there is a need to consider the social costs of failing to renew an incumbents’ licence in the decision making process.

**Determining an appropriate value of return to the community**

This relates to the price paid for the licence, as well as the inherent social value that is not captured in the price paid for the spectrum, but which accrues to society as a whole. These social values are dependent on the precise nature of the spectrum use, they may incorporate:
- the benefits of service provision to relatively under-serviced regions;
- improved efficiency in the provision of public goods; or
- use in improving community safety.

Spectrum allocations that provide a high value of return to the community through positive externalities such as these should be provided on a different basis to strict willingness-to-pay, as these benefits do not accrue directly to the spectrum licence holder.

### 3.2 Applying the public interest test to rail spectrum

**Highest value use**

The various rail organisations across Australia have spectrum allocations scattered in a non-contiguous form across the 1800MHz band. The remainder of this spectrum band is held by the three mobile telecommunications carriers in Australia. Vodafone Hutchison Australia Pty Ltd and Singtel Optus Pty Ltd have 1800MHz holdings in most or all capital cities, while Telstra Corporation Ltd also has substantial holdings in regional Australia.
Deloitte Access Economics

Commercial-in-confidence

Use of spectrum by the rail industry

Table 3.1: Current holders of spectrum in 1800MHz bands

<table>
<thead>
<tr>
<th>Licence holder</th>
<th>Holdings</th>
</tr>
</thead>
<tbody>
<tr>
<td>Telstra Corporation Ltd</td>
<td>Substantial holdings across all regions – Adelaide, Albury, Brisbane, Cairns, Canberra, Darwin, Dubbo, Grafton, Mackay, Maryborough, Melbourne, Perth, Regional West, South Australia, Sydney, Tasmania, Victoria.</td>
</tr>
<tr>
<td>Vodafone Hutchison Australia Pty Ltd</td>
<td>Holdings in Adelaide, Brisbane, Canberra, Darwin, Melbourne, Perth, Sydney and Tasmania</td>
</tr>
<tr>
<td>Singtel Optus Pty Ltd</td>
<td>Lower band holdings in Adelaide, Brisbane, Melbourne, Perth and Sydney</td>
</tr>
<tr>
<td>Public Transport Authority of WA</td>
<td>1.725-1.720GHz, 1.775-1.785GHz, 1.820-1.8225GHz, 1.870-1.880GHz in Perth</td>
</tr>
<tr>
<td>Queensland Rail Ltd</td>
<td>1.775-1.785GHz, 1.8225-1.8275GHz, 1.870-1.880GHz in Brisbane</td>
</tr>
<tr>
<td>Rail Corporation NSW</td>
<td>1.7275-1.73GHz, 1.760-1.7675GHz, 1.770-1.7725GHz, 1.7825-1.785GHz, 1.8225-1.825GHz, 1.855-1.8265GHz, 1.865-1.8675GHz, 1.8775-1.880GHz in Sydney</td>
</tr>
<tr>
<td>TransAdelaide</td>
<td>1.7275-1.730GHz, 1.7325-1.735GHz, 1.755-1.7265GHz, 1.7825-1.785GHz, 1.8225-1.825GHz, 1.8725-1.830GHz, 1.850-1.8575GHz, 1.8775-1.880GHz in Adelaide</td>
</tr>
<tr>
<td>Victorian Rail Track</td>
<td>1.7275-1.73GHz, 1.755-1.765GHz, 1.7825-1.785GHz, 1.8225-1.825GHz, 1.850-1.860GHz, 1.8775-1.880GHz in Melbourne</td>
</tr>
</tbody>
</table>

Source: ACMA Register of Radiocommunications Licences

While the initial purpose for which these spectrum licenses were purchased by the carriers was use in second-generation GSM mobile telephony services, the use of this spectrum band for this purpose is in decline, with these services moved into the 850MHz and 900MHz frequency bands. As customers move to third-generation networks on these and the 2100MHz bands, there is some freeing of capacity in the 1800MHz space.

However it remains expected that the carriers will have an interest in retaining and, potentially, expanding their 1800MHz holdings in 2013 and 2015. This is due to the high suitability of the 1800MHz band for LTE fourth-generation mobile communications applications, and the anticipated availability of spectrum.

However for the 1800MHz spectrum band to be suited to this, each carrier would require 20MHz of contiguous spectrum, out of the 2x75MHz band. None of the carriers have such a contiguous allocation, and as a result are likely to seek additional portions of 1800MHz spectrum for this purpose.

Given the potential profitability of LTE services over the next 15-20 years, it is expected that the carriers will have a high willingness-to-pay for this additional spectrum. It is therefore unlikely that, on a strict financial basis, the ARA will present the highest value option.

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1 Includes Vodafone Australia Pty Ltd holdings.
Efficient investment and innovation

The rail organisations across Australia have invested an estimated $500 million in the development of GSM-R technology to be utilised on their current 1800MHz. However at this stage the future value of that investment is uncertain. A failure to see this licence renewed may, in effect, see little to no investment in this spectrum until the licenses are handed over in 2013 and 2015.

The rail industry would face the loss of a large share of this infrastructure investment as it is unclear whether the GSM-R equipment that was intended to be used on the 1800MHz network could be reconfigured for use in another frequency band and if no other band is available then this investment will be entirely lost.

Competition

Competition considerations in this case may revolve around the idea of the adequacy of spectrum allocations to non-telecommunications purposes. While telecommunications operations are among the most profitable uses of radiofrequency spectrum, they are also intense users, and consideration as to whether adequate spectrum remains available for other purposes may be relevant when deciding if alternative measures to open auctions should be adopted for spectrum allocation.

The in-demand nature of the 1800MHz for material use means it is unlikely that any market participant would have plans to squat on a licence in this space.

Consumer convenience

It is difficult to determine the existence and level of a consumer convenience value for spectrum use by the rail industry. While the use of spectrum for communications on trains provides gains in terms of frequency, reliability and safety of rail travel as well as interoperability across state borders through using the same communications services, it is difficult to assess the value that consumers may place on this beyond the fact that there is value.

However, without clearer evidence about the value of time to these individuals, as well as the nature of service quality reductions that result from the loss of this spectrum, it is difficult to assess this value.

Determining an appropriate value of return to the community

The social welfare benefits of rail access to spectrum are key in the consideration of whether rail meets the public interest criteria for spectrum reallocation. Rail use of spectrum generates non-economic benefits in two ways:

- Quality improvements to the provision of public goods; and
- Improvements in public safety.

At its essence, the use of spectrum for rail communications would improve the efficiency of rail networks in Australia, through providing greater better signalling. This leads to a more efficient provision of a public good – public transport.
However, while this creates a benefit in terms of improved delivery of rail services, it is difficult for the rail organisations to extract this value to pay for spectrum access. For example, while there may be some increase in use of public transportation as the reliability of the network improves, there is only limited ability to increase the price charged for the improved network operation and derive a return. Public transport is often viewed as an inferior good, which only retains a market as long as it is cheaper than the ‘normal’ good of personal transport, and an increase in costs may see moves back to private forms of transport, increasing accidents, carbon emissions and congestion. This relationship makes it difficult to establish a fair price for spectrum access by the rail industry, even though the value to consumers may exceed what they would be willing to pay for this benefit.

Through providing more reliable real-time information on network problems such as blockages or faults, use of spectrum for rail communications improves public safety. In particular this may occur through the avoidance of train accidents, which may lead to saving lives of passengers and others and avoiding injuries. Additionally this presents benefits to the owners of the track and rolling stock through physical damage and network interruptions avoided.

The clear existence of these benefits, and the fact that many of these benefits do not accrue to the operators of the rail network but rather to society as a whole, provides a case for providing spectrum access to the rail industry on a basis other than commercial willingness-to-pay through an open auction process in which they may miss out on spectrum altogether. However what this basis should be, and the nature of any pricing discount, is difficult to determine.
4 Economic benefits of spectrum use

4.1 Source of economic benefits

The economic benefits from improved rail communications are derived from two main sources:
- infrastructure expenditure savings; and
- increased use of rail.

Improved rail communications will allow trains to run closer together. This can allow for greater utilisation of existing train tracks, in this sense, investment in rail communications acts as a substitute for investment in physical infrastructure. With increasing population, urban densities and fuel costs there is expected to be growing demand for urban rail services over the coming decades and a need to increase the number of passengers being transported.

If the rail industry is not able to make use of the 1800 MHz spectrum to improve communications and run more trains to meet growing demand then there will have to infrastructure investments made to substitute.

Of course, as communications cannot continually increase capacity, many of these investments would need to be made at some point, regardless of the communications technology that is being used. This means that the true saving that improved communications offers is from delaying the need to invest in new physical infrastructure. Given the cost of the required infrastructure investments, delaying them can result in significant savings.

The changes in cost as a result of changing the timing of a $1bn investment are shown in Table 4.1, below.

<table>
<thead>
<tr>
<th>Planned expenditure year</th>
<th>2011</th>
<th>2016</th>
<th>2021</th>
<th>2026</th>
<th>2031</th>
</tr>
</thead>
<tbody>
<tr>
<td>2011</td>
<td>0</td>
<td>-178</td>
<td>-324</td>
<td>-445</td>
<td>-544</td>
</tr>
<tr>
<td>2016</td>
<td>178</td>
<td>0</td>
<td>-146</td>
<td>-267</td>
<td>-366</td>
</tr>
<tr>
<td>2021</td>
<td>324</td>
<td>146</td>
<td>0</td>
<td>-120</td>
<td>-219</td>
</tr>
<tr>
<td>2026</td>
<td>445</td>
<td>267</td>
<td>120</td>
<td>0</td>
<td>-99</td>
</tr>
<tr>
<td>2031</td>
<td>544</td>
<td>366</td>
<td>219</td>
<td>99</td>
<td>0</td>
</tr>
</tbody>
</table>

Note: assuming a 4% discount rate

Delaying the need to invest in physical infrastructure is particularly important as the physical infrastructure bottlenecks in many capital cities are in built up areas where retrofitting is expensive. This will be considered in further detail below.
The second major source of economic benefits from improved rail communications comes from increased use of rail. By allowing more trains to operate on existing infrastructure, improved communications may lead to more people choosing to travel by rail.

Every additional rail passenger reduces demand for road transport. As rail generates less costs in terms of congestion, carbon emissions and accidents than road transport, this provides benefits to the community.

These benefits were quantified for each major Australian city in a recent report by Deloitte Access Economics:

<table>
<thead>
<tr>
<th>City</th>
<th>Carbon emissions</th>
<th>Congestion</th>
<th>Accidents</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sydney</td>
<td>0.02</td>
<td>7.01</td>
<td>1.38</td>
<td>8.41</td>
</tr>
<tr>
<td>Melbourne</td>
<td>0.02</td>
<td>5.18</td>
<td>1.46</td>
<td>6.66</td>
</tr>
<tr>
<td>Brisbane</td>
<td>0.02</td>
<td>1.84</td>
<td>1.25</td>
<td>3.11</td>
</tr>
<tr>
<td>Perth</td>
<td>0.02</td>
<td>3.20</td>
<td>1.39</td>
<td>4.61</td>
</tr>
</tbody>
</table>

This means that if just one additional train was able to be run during peak hour, carrying around 3500 people, then annual social cost savings (in terms of carbon emissions, congestion and accidents) could be in the order of $5.7m-$15.3m a year.

Both of these economic benefits will be considered for particular investments in the following section.

4.2 Estimating economic benefits

4.2.1 Infrastructure expenditure savings

In preparing this report we have sourced information on likely infrastructure investments and capacities in Sydney and Melbourne networks, similar analysis could be conducted for rail networks in Adelaide, Perth and Brisbane.

Considering Melbourne first, key bottlenecks occur both when separate lines merge into groups near the city and in the city core itself. The Melbourne metropolitan network is shown in Figure 4.1, below. The issue of merging lines can be seen in the north east of the network where the Epping and Hurstbridge lines merge at Clifton Hill to form the Clifton Hill Group. Similar merging occurs to create the Northern Group from lines in the west, the Caulfield Group from lines in the south east and the Burnley Group from lines in the east (Department of Infrastructure 2008).
These groups then converge on the inner core network which is made up of the city loop and the links to North Melbourne, Jolimont and Richmond stations. Under this structure there is therefore increased need for capacity the closer trains are to the inner core network. Trains start off on their own line then merge into a shared group and then into the inner core network.

The department of transport in Victoria is currently considering the benefits of next generation signalling (NGS) on the 1800MHz spectrum in an expansion of capacity on the Clifton Hill Group. Expansion of capacity through NGS is compared to a conventional infrastructure upgrade. The conventional upgrade would involve a tunnel from Clifton Hill to Southern Cross station via Carlton, Parkville and Flagstaff and would create 12 additional peak hour paths.

The two projects have extremely different costs and benefits, as shown in Table 4.3:
Table 4.3: Comparison investments in NGS and conventional infrastructure ($m)

<table>
<thead>
<tr>
<th></th>
<th>NGS</th>
<th>Conventional</th>
</tr>
</thead>
<tbody>
<tr>
<td>Capital costs</td>
<td>456.8</td>
<td>5,328.2</td>
</tr>
<tr>
<td>Operating costs</td>
<td>91.2</td>
<td>199.5</td>
</tr>
<tr>
<td><strong>Total costs</strong></td>
<td>547.9</td>
<td>5,527.7</td>
</tr>
<tr>
<td><strong>Total user benefits</strong></td>
<td>565.2</td>
<td>864.6</td>
</tr>
<tr>
<td><strong>Net present value</strong></td>
<td>17.3</td>
<td>-4,663.1</td>
</tr>
</tbody>
</table>

Source: Department of Transport 2011

In this case, the difference in net present values is in the order of $4.6 billion but this figure does not give a true indication of the savings provided by investment in NGS. This is because the conventional infrastructure investment will likely have to be made regardless of investment in NGS, the investment in NGS simply delays the need to make the conventional investment. The cost savings presented by NGS will therefore vary depending on the amount of time that the need for the conventional investment is delayed, this is shown below in table x.

Table 4.4: Net present value of savings, depending on delay in conventional investment ($m)

<table>
<thead>
<tr>
<th>Delay of conventional investment (years)</th>
<th>NPV of NGS plus delayed conventional</th>
<th>NPV of conventional only</th>
<th>Savings</th>
</tr>
</thead>
<tbody>
<tr>
<td>+5</td>
<td>-4,079.2</td>
<td>-4,663.1</td>
<td>583.9</td>
</tr>
<tr>
<td>+10</td>
<td>-3,192.4</td>
<td>-4,663.1</td>
<td>1,470.7</td>
</tr>
<tr>
<td>+15</td>
<td>-2,497.6</td>
<td>-4,663.1</td>
<td>2,165.5</td>
</tr>
<tr>
<td>+20</td>
<td>-1,953.2</td>
<td>-4,663.1</td>
<td>2,709.9</td>
</tr>
<tr>
<td>+25</td>
<td>-1,526.6</td>
<td>-4,663.1</td>
<td>3,136.5</td>
</tr>
<tr>
<td>+30</td>
<td>-1,192.4</td>
<td>-4,663.1</td>
<td>3,470.7</td>
</tr>
</tbody>
</table>

Note: assumes a 5% real discount rate

This analysis indicates that even if investment in the conventional infrastructure is only delayed 5 years then savings, in net present value terms are still over $500 million. This is a significant saving when it is considered that this is only a single infrastructure investment and when compared to possible funds raised from a spectrum auction.

Sydney has similar rail infrastructure stresses as Melbourne as it, too, has a radial style network, as is shown in Figure 4.2. In the Sydney network there is, however, a stronger focus on capacity in the city circle as the merging into groups that occurs in the Melbourne network does not occur to the same degree in the Sydney network. This means that the key capacity constraint is through Central, Town Hall and Wynyard stations.
Relieving the capacity constraint in the city circle will require a series of investments made over a number of years:

- rail clearways: which seeks to achieve a 20 train per hour capacity on each of six lines that run through the city;
- city relief line: extending a line which currently terminates outside the city circle allowing capacity of up to 24 trains an hour on this line;
- track amplification across Sydney harbour; and
- increased CBD capacity through two additional city lines.

Of these projects, Rail Clearways is currently underway and the city relief line has gone through planning but is currently on hold. The planning conducted for the city relief line, which would allow 24 trains an hour on a single line through the city, is predicated on the availability of Automatic Train Protection (ATP) Level 2, which is essentially an implementation of the European Train Control System (ETCS) Level 2, which relies on GSM-R and the 1800MHz spectrum. This means that, without spectrum access this investment cannot proceed as planned.

Track amplification across Sydney harbour will most likely be achieved through a new cross-harbour tunnel while the two additional city lines will also be tunnelled and will follow the existing city rail tunnels. There are currently no public plans for either of these two projects but some attempts have been made to estimate the cost of the new harbour crossing. A report from SKM estimates costs of around $8 billion (PCC 2011) and it has also been estimated that the second harbour crossing may be required by around 2022 (IPI 2010). This cost and time frame implies the following savings if improved rail communications are able to delay the need to invest in a second harbour crossing:
Table 4.5: Net present value of savings, depending on delay in conventional investment ($m)

<table>
<thead>
<tr>
<th>Delay of conventional investment (years)</th>
<th>Savings</th>
</tr>
</thead>
<tbody>
<tr>
<td>+5</td>
<td>1,012.5</td>
</tr>
<tr>
<td>+10</td>
<td>1,805.9</td>
</tr>
<tr>
<td>+15</td>
<td>2,427.5</td>
</tr>
<tr>
<td>+20</td>
<td>2,914.6</td>
</tr>
<tr>
<td>+25</td>
<td>3,296.2</td>
</tr>
<tr>
<td>+30</td>
<td>3,595.2</td>
</tr>
</tbody>
</table>

Note: assumes a 5% real discount rate

Overall, this analysis indicates that if only two major investments in the Sydney and Melbourne rail networks could be delayed by only five years by using improved communications technology then there would be savings in the order of $1.5 billion.

4.2.2 Increased use of rail

Improved communications will allow for more frequent and reliable train services. This will provide benefits to existing train users in terms of reduced waiting times and less crowding but it will also encourage some existing road users to move to rail. As rail transport creates fewer negative externalities than road transport this generates a gain to society.

Analysis by the Victorian Department of Transport considered this effect for the implementation of NGS on the Clifton Hill Group. Their modelling indicated that NGS would result in 2,164 extra public transport trips by 2021 and 1,126 fewer road trips. This increase in the use of public transport was associated with a reduction in private vehicle travel by around 11,600km by 2021. The effect of this reduction in car travel on congestion, pollution and accidents is then estimated, giving a total externality benefit of $108.4m in the period from 2010 to 2040 (Department of Transport 2011).

This analysis gives a good idea of the externality benefits that could flow from a single project but improved communications can have benefits across the entire rail network. As both Melbourne and Sydney’s rail networks are radial, overall capacity is determined by capacity through the city centre. If improved communications can lead to an overall increase in capacity in the city centre then this will translate to greater capacity and services throughout the entire network.

Considering Melbourne first, the capacity on each line in the inner core network is around 20 trains per hour, and possibly up to 24 trains per hour. With 8 in-bound lines available this gives a theoretical peak hourly capacity of at least 160 trains per hour (Department of Infrastructure 2008 and Mees 2008). Each train can carry around 800 passengers and so this gives a theoretical peak capacity of around 128 thousand passengers an hour.

The Rail Clearways program also gives Sydney’s six city lines a capacity of 20 trains per hour. Information provided by RailCorp suggests that the average train during peak hour has occupancy of around 860 people (RailCorp 2011). This implies a current capacity of around 103 thousand passengers an hour.
In both cities the frequency of service through city stations is constrained by both the headway given between trains and the movement of passengers off platforms. Generally, a three minute headway is allowed in both cities which determines the 20 train per hour capacity on each line.

The movement of passengers off platforms is a serious problem in both Sydney and Melbourne (Department of Transport 2008 and Douglas and Karpouzis 2005). The problem is increased by overcrowding of trains, few and narrow doors on trains, elevator access and speed, sharing of lines by different services and by passenger behaviour. There are a number of strategies which could be used to manage passenger movement from changing the style of trains used to a more metro style with larger and more doors, to reorganising or expanding stations, to controlling and encouraging certain passenger behaviour. The following calculations assume that issues of moving passengers off platforms can be overcome through a mixture of capital and operational investments.

The 1800 MHz spectrum will effectively be used by the rail industry to implement the ETCS Level 2, an international standard for train control and protection. Discussions with RailCorp have indicated current plans to increase services to 22 trains per hour on each line by implementing ATP level 2 on the 1800MHz spectrum, this gives a headway of around 2:43 per train. However ETCS level 2 is already in use throughout Europe and so some estimates of the improved performance that could be expected can be made. Improvements in headway of around 20% have been common with headways being reduced to around 2 minutes on some lines in Switzerland (Lababidi 2008).

If headways were able to be reduced from 3 minutes to 2 minutes in both Sydney and Melbourne then there would be an increase in capacity in the city stations from 20 to 30 trains per hour on each line. The results of this increase are set out in the table below:

<table>
<thead>
<tr>
<th></th>
<th>Sydney</th>
<th>Melbourne</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Current</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Headway (minutes)</td>
<td>3</td>
<td>3</td>
</tr>
<tr>
<td>Trains per hour</td>
<td>20</td>
<td>20</td>
</tr>
<tr>
<td>Lines through city</td>
<td>6</td>
<td>8</td>
</tr>
<tr>
<td>Passengers per train</td>
<td>856</td>
<td>800</td>
</tr>
<tr>
<td>Capacity per hour (passengers)</td>
<td>102,779</td>
<td>128,000</td>
</tr>
<tr>
<td><strong>With improved communications</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Headway (minutes)</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>Trains per hour</td>
<td>30</td>
<td>30</td>
</tr>
<tr>
<td>Lines through city</td>
<td>6</td>
<td>8</td>
</tr>
<tr>
<td>Passengers per train</td>
<td>856</td>
<td>800</td>
</tr>
<tr>
<td>Capacity per hour (passengers)</td>
<td>154,169</td>
<td>192,000</td>
</tr>
<tr>
<td>Increase in passengers</td>
<td>51,390</td>
<td>64,000</td>
</tr>
<tr>
<td>Externality saving per journey</td>
<td>8.41</td>
<td>6.66</td>
</tr>
<tr>
<td>Total externality savings ($ per hour at capacity)</td>
<td>432,188</td>
<td>426,240</td>
</tr>
</tbody>
</table>
These estimates suggest that if peak capacity was improved through better train communications leading to more frequent services, then the potential externality benefit could be up to around $400,000 in both Sydney and Melbourne per hour the system operates at capacity.
5 Conclusion

Spectrum, and the communications it enables, acts as a part of the infrastructure of Australia’s rail industry. Improvements in technology which enhance communications act as substitutes for improvements in the physical infrastructure of Australia’s rail networks. This is important as improvements to communications can be achieved at far lower cost than improvements to physical infrastructure. Analysis in the last section which looked at only two potential physical infrastructure projects indicated that substituting expenditure on communications for expenditure on physical infrastructure, could lead to savings in the order of $1.5 billion and this is if the investment in physical infrastructure is delayed by only 5 years. Also, as the suburban rail agencies are state government owned, this presents a direct saving to the Australian public.

In addition to this infrastructure substitution effect, the rail industry also provides a public good through reducing congestion, pollution and accident externalities. In the previous section an illustration of the potential scale of this was estimated at around $400,000 per hour at capacity in Sydney and Melbourne.

There are therefore strong economic arguments for continued access to spectrum by the rail industry and even for access at a below market rate. From a theoretical point of view, access at a below market rate is a way, although imperfect, to help correct for the positive externalities created by rail travel. From a financial point of view, if the rail industry pays a market price for access to spectrum then this is, effectively, a cash transfer from states to the Australian Government with no net gain to taxpayers.

To this must also be added the investment implications for the rail industry. To date around $500 million has been invested industry wide in development of technology for use with the 1800MHz spectrum. This investment would be lost and further investment between now and 2015 would be discouraged if the rail industry was unsure of its continued access to the spectrum.

Renewing the rail industry’s licences could be seen as an investment by the Federal government into metropolitan rail which will allow for better use of the existing physical infrastructure and support the development of Australia’s cities and continued growth of public transport. As indicated above, the benefits of this investment could be significant even when compared to what could be raised from an auction.
References

Conroy 2010a, Fifteen-year spectrum licence pathway, Media Release, 4 March.

Conroy 2010b, Address to AMTA Member Networking Forum, Sydney, 3 March, emphasis in original.


RailCorp 2011, Information Request.
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