The future of employment and economic activity and its transport and land use implications

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Abbreviations and acronyms

ANZSIC	Australian and New Zealand Standard Industrial Classification
AV	autonomous vehicle
b2b	business to business
b2c	business to consumer
BAU	business as usual
c2c	consumer to consumer
CAA	Civil Aviation Authority
CAU	census area unit
CDV	clean diesel vehicle
CEO	chief executive officer
CEV	clean energy vehicle
DV	diesel vehicle
EFM	economic futures model
EV	electric vehicle
EV	electrical vehicle
FCV	fuel cell vehicles
GV	gasoline vehicle
HCV	heavy commercial vehicle
IoT	internet of things
ITF	International Transport Forum
MaaS	mobility as a service
MEC	modified employment count
MfE	Ministry for the Environment
MOT	Ministry of Transport New Zealand
NGV	natural gas vehicle
PHEV	plug-in hybrid electric vehicle
PT	public transport
SAV	shared autonomous vehicle
UA	urban area
UAV	unmanned aerial vehicles

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Executive summary

Overview

There have been indications that automation and new technologies will have significant impacts on the type, nature and characteristics of employment in the industrial, service and commercial sectors. Little research has been carried out to determine whether such changes will have an impact on the location of employment and land-use patterns, and any consequent transport sector implications.

This research project provides an assessment of these potential effects. The assessment used the findings of a literature review and interviews with key sector stakeholders in New Zealand (conducted in late 2016 and early 2017) to inform a scenario assessment of potential future employment and land-use outcomes.

Literature review

The literature review and sector interviews both indicate that technological change has been relatively gradual in the recent past, although future changes are likely to become more profound as a result of several significant new innovations that are currently in planning stages. The introduction of new technologies in the last century has not tended to result in a net decrease in employment, with any employment losses offset by gains in supporting roles elsewhere. This has varied by sector, and there has been a trend towards more highly skilled roles in many sectors, which is expected to continue as technology improves. There has also been an ongoing increase in lower skilled roles, such as in the service sector. The need to support new technology has led to new roles being created, and a more productive economy, but overall employment levels have not shown any noticeable decrease that can be attributed to the effects of technology.

That may change in the future, and it does not necessarily hold that the past will be a guide to the future in terms of the relationship between technology, employment and land use. Major new innovations such as autonomous vehicles, drones, online retail and the internet of things will potentially have a substantially different effect on employment and land use than have previous innovations, although commentators are notably split about the potential implications of new technology. There is very little consensus on this issue, with approximately half of all experts believing there are unlikely to be any significant effects, and half of a completely contrary opinion.

The literature review found that modelling possible future scenarios and effects is generally accepted to be difficult and highly uncertain. Most studies focus only on individual innovations, and do not attempt to quantify the effects of multiple innovations or across whole economies or large spatial areas.

The respondents interviewed provided feedback which is consistent with the key findings from the literature review. All organisations are currently planning for future changes to affect their business, and recognise that flexibility of corporate structure and business practices will be key to successfully adopting new technology. Respondents are not expecting major changes to current practices in the very near future, with the prevailing view being one of ongoing, incremental change, with even potentially disruptive technologies such as autonomous vehicles not expected to be a significant force in the New Zealand market for several decades yet.

Employment and land use projections and implications

A spatially and sectorally detailed model was developed to enable testing of different technology change scenarios and to show the effects of those changes on employment and land use. The model is structured at a census area unit level (n=1923), and divides economic activity into 48 sectors, providing output for eight future years (every five years from 2016 to 2056).

Total New Zealand employment is currently 2.34M MECs (modified employment count), and is projected to increase to 2.99M MECs by 2056 under a business as usual (BAU) future. The BAU future is the baseline against which are compared projections from the four alternative scenarios, defined as combinations of either lesser or greater automation, and geographic concentration or dispersal. The scenarios are intended to reflect the broad range of possible outcomes indicated, and the absence of consensus presented in the relevant literature. They do not provide predictions of future employment, rather are projections of employment under the assumed combinations of future circumstances.

The BAU future would yield more employment than any of the four scenarios modelled, because all four scenarios assume some increased level of automation over current levels, and therefore a slowing of employment growth compared to the BAU projections (which make no specific assumptions about automation). Under the two lesser automation scenarios, total national employment in 2056 would increase slightly less than under the BAU and be around 97% of the BAU level, whereas under the greater automation scenarios employment would be only 84% of the BAU level. Land use is highly influenced by employment, although increases more slowly consistent with historic productivity improvements and increasing employment density. At a national level, the land occupied by the modelled employment would increase by only 96% as much as under the BAU future given lesser automation, or only 81% as much given greater automation. The table on the following pages summarises the assessment's key modelled outputs and implications.

There will be subnational variations in growth patterns, and to describe these the scenario modelling is summarised to four key urban area types (metropolitan, large city, large town and medium town) and four key sectors (manufacturing, transport, retail and services and offices). Currently more than half of New Zealand employment is located in the three large metropolitan centres of Auckland, Wellington and Christchurch, and it is there that transport issues are most prevalent. Under the two concentration scenarios those metropolitan cities and New Zealand's large cities and towns would attract greater shares of employment, and require larger areas of land to accommodate workers, while rural and smaller urban areas would have a declining share and number of workers.

It is the concentration scenarios therefore that would result in the most challenging transport and land use planning environment in the larger urban areas. While existing metropolitan networks are already congested, a large proportion of the increased employment would involve regular commuter travel typically associated with offices where improved or targeted PT may be able to mitigate the demand increases. However, research indicates that even though mitigation measures may be available, local traffic conditions may worsen as a result of intensification, which is a topic that warrants further investigation. For other sectors that are less conducive to PT use, such as retail and services, education and health, the projected growth would likely manifest as an increase in private vehicle use. For the manufacturing and transport sectors, automation is expected to result in a decrease or only very small increase in employment in larger urban areas from 2016 levels under all but one (greater automation, concentration) scenario, and only under that scenario would there be material implications as a result of increased HCV movements in larger urban areas. One exception to that is ports, where transport movements are likely to continue to increase independent of intensification, although a redistribution of port activity, such as to inland ports, is possible.

Scenario output summary table

Scenario	Employment (million MECs) (2016–2056, change n and %)	Land use (ha) (2016–2056, change n and %)	Modelled output summary	Transport implications
BAU	2.34-2.99 +0.65 (28%)	48,260-49,510 +1250 (103%)	• More employment than the four scenarios, due to assuming less automation • Growth concentrated in largest urban areas	• Ongoing growth in largest urban areas requires continued transport planning, most notably in largest urban areas • Lower mitigation assumed available from autonomous vehicles (AVs)
Greater automation, dispersal	2.34-2.51 +0.17 (7%)	48,260-41,190 -7070 (85%)	• Future national employment 84% of BAU • More growth in smaller urban areas • Likely decline in manufacturing employment and transport requirements in larger urban areas, and small increases in smaller towns • Decline in manufacturing and transport employment and vehicle movements in larger urban areas • Increase in retail and services employment and associated private vehicle movements, albeit lower growth than under business as usual (BAU)	• Modest growth and extant spare capacity in small towns' transport networks means increase in vehicle movements may not be appreciable, and is unlikely to present major challenges for transport planning • Low growth, and therefore less pressure on transport infrastructure in larger urban areas, although there will still be growth in those larger areas • Decrease in heavy commercial vehicle (HCV) movements in larger urban cores, but increased flows between towns, requiring upgrades for rural routes and intersections • Growth in vehicles visiting retail sector, both private and commercial, requires less transport planning than concentration scenarios, because growth is less concentrated
Greater automation, concentration	2.34-2.52 +0.18 (8%)	48,260-40,220 -8040 (83%)	• Future national employment 85% of BAU • More growth in larger urban areas • Transport demand increases significantly from current levels in large cities • Decline in transport employment and vehicle movements in larger urban areas • Increase in retail and services employment and associated private vehicle movements of up to 50%	• Transport demand growth requires significant planning to improve already congested metropolitan networks • Large proportion of increased growth will be in offices and could be accommodated on public transport (PT), but in other sectors growth will result in increased private vehicle use, with additional demand on roads and parking • Growth in vehicles visiting retail sector, both private and commercial, requires additional transport planning • Growth will be mitigated by increased AV use, although not for some time
Lesser automation,	2.34-2.89 +0.55 (23%)	48,260-48,470 +210 (100%)	• Future national employment 97% of BAU • More growth in smaller urban areas	• Modest growth and extant spare capacity in small towns' transport networks means increase in vehicle movements

Scenario	Employment (million MECs) (2016–2056, change n and %)	Land use (ha) (2016–2056, change n and %)	Modelled output summary	Transport implications
dispersal			• Decline in manufacturing and transport employment and vehicle movements in larger urban areas • Increase in retail and services employment and associated private vehicle movements, albeit lower growth than under BAU	may not be appreciable, and is unlikely to present major challenges for transport planning • Low growth, and therefore less pressure on transport infrastructure in larger urban areas, although there will still be growth in those larger areas • Decrease in HCV movements in larger urban cores, but increased flows between towns, requiring upgrades for rural routes and intersections • Growth in vehicles visiting retail sector, both private and commercial, requires less transport planning than concentration scenarios, because growth is less concentrated
Lesser automation, concentration	2.34-2.90 +0.56 (24%)	48,260-47,500 -760 (98%)	• Future national employment 97% of BAU • More growth in larger urban areas • Only scenario with increased manufacturing employment in larger urban areas • Increase in retail and services employment and associated private vehicle movements of up to 50%	• Transport demand growth requires significant planning to improve already congested metropolitan networks • Large proportion of increased growth will be in offices and could be accommodated on PT, but in other sectors growth will result in increased private vehicle use, with additional demand on roads and parking • Growth in vehicles visiting retail sector, both private and commercial, requires additional transport planning • rowth will be mitigated by increased AV use, although not for some time

The projected increase in private vehicle use will place additional demands on the metropolitan road network and on parking facilities. While increased use of AVs may mitigate this, the real benefits of automation will only be evident when some critical mass of AV use is reached, which may be several decades away. The quantum of change in large cities is expected to show similar characteristics, albeit at a reduced scale than in metropolitan areas, and so the impact on transport movements is expected to be correspondingly lower in large cities.

Under the dispersal scenarios a move of economic activity away from larger centres would be facilitated by technological improvements giving business more flexibility with where they locate, and providing workers with more options of where to live. Dispersal scenarios would present fewer planning challenges than the concentration scenarios, although networks may still require some additional capacity to accommodate expanded PT and private vehicle trips.

Smaller urban areas are also likely to present fewer and smaller challenges in planning to accommodate future growth. Employment growth in those areas will be widely distributed around many different locations. In most scenarios growth will be less than the BAU future, and in many a decline in employment is projected. In large towns employment is projected to grow by less than the BAU future under all scenarios, and to decline under greater automaton scenarios. The magnitude of growth is relatively small under all scenarios, and the impact on the operation of the transport network is therefore likely to similarly small. Under the dispersal scenarios employment growth some employment would move from large towns to their hinterland, increasing vehicle flows between the towns and surrounding rural communities. However, the number of movements is likely to be small, and result in a corresponding small change in network operation.

Employment in small towns would increase from current levels under the dispersal scenarios, although that growth would be relatively modest, and less than under the BAU future. That modest growth and extant spare capacity in most small towns' existing networks would mean that an increase in vehicle movements, including HCVs, may not be appreciable, and is unlikely to present major challenges for transport planning.

From a sector perspective, the implications of economic growth for transport and land use planning vary depending on the likely exposure to automation. The greater automation scenarios would result in quite large decreases in manufacturing and transport employment, a corresponding reduction in the number of personal vehicle movements to and from businesses in those sectors, and potentially also a decrease in the HCV movements servicing those businesses. Those scenarios might also result in manufacturing activity moving overseas, exacerbating the changes described. The lesser automation scenarios would yield growth in employment and therefore imply a corresponding increase in HCV movements wherever the activity is located. Only under the lesser automation, concentration scenario would larger urban areas have to deal with additional manufacturing activity, and associated vehicle movements. Under other scenarios larger urban areas would see a decline in transport employment and likely also in vehicle movements. The dispersal scenarios would present different challenges, including the potential need to provide new passing lanes and improve strategic rural routes and intersections to allow for the increased HCV demand outside the main urban areas.

Retail and services and office-based employment would be much more likely to increase. The retail and services sector generates private and both light and heavy commercial vehicle movements, and because few consumers use PT to access retail and services businesses growth in employment indicates likely growth in private vehicle use, which could be as much as 50 percent in larger urban areas under concentration scenarios. Growth of that magnitude would likely present ongoing challenges for transport planning. Under dispersal scenarios the increase would be broadly spread across many locations, in which case few access issues would be foreseeable, unless the movement away from larger cities and towns is focussed into few smaller urban areas, which wold then require a considered approach to facility design in those places.

Even high rates of office-based employment growth are likely to be readily accommodated, because the activity's regular hours and the tendency to agglomerate make the sector readily served by PT. For this reason, irrespective of the size of town or city, a large proportion of the potential increase in vehicle activity associated with this increase could be accommodated by PT movements.

For all sectors and urban areas, the uncertainty associated with new technology will mean that a permissive, flexible planning framework will be required to adequately accommodate changing needs of economic sectors. Appropriate responses might include greater provision for mixed use development and recognition that as employment and land use demand changes over time, changes in zoning and permitted activities should be facilitated and encouraged to promote efficient use of land and economic resources.

Abstract

This report reviewed literature relating to the potential effects that automation and new technologies will have on the type, nature and characteristics of employment in the industrial, service and commercial sectors. The findings of that review were then supplemented with interviews of key sector representatives from large New Zealand companies and organisations. This took place between October 2016 and February 2017.

Together the literature review and stakeholder interviews were used to confirm a methodology and define the parameters and assumptions of scenarios to test possible future employment and land use requirements. Those requirements were assessed for four scenarios and a business as usual baseline to explain the potential effects that automation and new technologies will have on the type, nature and characteristics of employment and land use in the industrial, service and commercial sectors. This work took place between February and July 2017.

1 Introduction

This report assesses the effect that automation and new technologies will have on the type, nature and characteristics of employment and land use in the industrial, service and commercial sectors, and the implications of those characteristics for transport and land use planning.

The first part of this document presents a review of relevant literature and a summary of interviews with some major New Zealand businesses. This work was undertaken to summarise the current nature of innovations and technology, and how these are anticipated to change future employment and land use. The research reviewed New Zealand and international literature, and all sector interviews were conducted with companies or organisations based in New Zealand.

The findings from the first part of the research were used to inform the development of a methodology to quantify the potential magnitude of employment and land use changes. Four scenarios were compared against a business as usual baseline, beginning in 2016 and extending out to 2056. Projections of employment and land use changes in New Zealand were assessed to draw conclusions about the potential implications of the effect of innovations and technology on transport and land use planning, and change was analysed from spatial and sectoral perspectives.

The project was begun in October 2016 and completed in July 2017.

2 Literature review

2.1 Introduction

We reviewed domestic and international literature on the likely impacts of automation and new technologies on the type, nature and characteristics of future employment and economic activity. Given the rapid rate of change of technology, the focus of the review was on recently published articles (since 2012); however, the search was not limited to that period. Many examples found were from overseas, with domestic literature and New Zealand examples being less common. The literature search was conducted using the following databases: Google Scholar, Scopus and Science Direct.

The literature review addresses broad economy-wide trends and topics (section 2.2), before focusing on specific types of technology (sections 2.3.to 2.7) and summarising the implications of these trends.

2.2 Overview of technology, employment and land use

2.2.1 Relationship between technology, employment and land use

Most historic attempts to predict the future of employment have been unsuccessful and have tended to significantly overstate the disruption to employment (Autor 2015a). One reason for this is these theories have not adequately considered the role that any replacement of workers by machines will have on product and factor markets. This was evident with the Industrial Revolution and rapid urbanisation that followed, but was not anticipated. Historic observation indicates that often the introduction of new technologies may decrease employment in one occupation within an industry, but will stimulate employment growth in other occupations in that sector, and in other sectors. Further, an increase in production efficiency reduces the price of products, increasing real income and increasing demand for other goods. That is, there can be several different types of spin-off benefits for employment from automation (Frey and Osborne 2015). These positive effects are often not accounted for in employment projection models.

Modern planning policy uses employment projections to predict land use requirements, as there is a positive relationship between employment and business land use (where business land is land occupied by all non-rural economic uses, including retail, commercial and industrial businesses). However, the relationship is not sufficiently robust to consider employment, when used alone, as a reliable indicator to forecast long-term demand for business land uses (Beckers and Schuur 2015). Forecasting demand for future business land implicitly assumes that historic causal structures will persist in the future, and this assumption may no longer hold. After a post-war period of nearly uninterrupted growth in employment and population, slower growth is possible in the coming decades, leading to structural change in labour and land markets, with unclear effects on demand for business land (Beckers and Schuur 2015).

Some commentators suggest that the labour-displacing effects of innovation and technology are only clearly visible in the manufacturing industry, and that both technological and organisational innovation exert a generally positive impact on employment by improving growth performance (Evangelista and Vezzani 2011). However, the range of that effect may be limited in many sectors to a small number of firms and to creating more jobs in highly skilled roles (Pfeiffer and Rennings 2001).

Job losses in manufacturing occur as increased automation allows technology to replace physical labour. The importance of labour in the production process therefore becomes less important with the introduction of new technology. A potential consequence is that economies where manufacturing has declined significantly in the past (especially western economies) may see a resurgence, as alternative markets with cheaper labour costs become less attractive to companies. Increasingly, manufacturing will become about knowledge and processes, not the capacity of labour, and will require higher skilled workers, such as in computing and design (Sander and Wolfgang 2014). The ability to be close to markets where products are sold and employment markets where there is a large, skilled workforce then assumes a greater importance, and is likely to result in some movement of manufacturing back to locations where the innovation occurs and the firm originates, albeit with lesser employment needed to produce the same output (Spiegel 2013). The extent of this change may be limited as developing economies become more attractive, and retain some of that manufacturing.

Baldwin (2016) addresses these global patterns of wealth and knowledge distribution, and identifies three key changes in the process of globalisation. The first significant change occurred in the early 1800s when the cost of moving physical goods across borders dropped, resulting in industrial agglomeration in some countries and a 'great divergence'. At that time production clusters evolved, sparking innovation and resulting in concentration of economic wealth in a small number of countries. The second change occurred around 1990, when falling communication costs resulted in off-shoring of manufacturing facilities, and rapid growth in some developing nations. That resulted in the off-shore movement of management and administrative functions of many companies, and the rapid industrialisation of a small number of developing countries. That did not necessarily lead to a decrease in employment in developed countries (although it did in some cases) and often freed up labour to complete other tasks and drive economic growth in new directions. Ultimately those changes have led to the 'great convergence', where knowledge and wealth is coming to be more globally distributed.

Future changes may differ from historic changes, and technological advances may result in net employment losses. The nature of innovation and automation is changing, and so is the likelihood that new forms of technology will increase the range of activities able to be undertaken by automated processes. This means that change in businesses practices, employment and land use is highly likely in the future (Hajkowicz et al 2016). The rate of uptake of new technologies is, however, difficult to forecast with confidence, one of the few conclusions that is relatively universal in the literature reviewed.

On one hand the adoption of technology and consequent employment conditions often tend to change slowly for cultural and legal reasons. Adoption of new technologies may be slowed by regulatory and political concerns, such as have slowed the uptake of Uber (which has been banned from operating in some markets) and autonomous cars (through safety concerns) (Fagant and Kockelman 2015).

On the other hand, in the digital age change is occurring very rapidly, and resulting in fundamental changes to how we live and work. Digital platforms will reduce the power of incumbency and act as an agent for change. One significant change is the automation of cognitive tasks involving subtle and non-routine judgment such as legal reasoning or providing medical advice, leading to profound changes to occupations and whole economic sectors, and the dynamics of economic growth. There are likely to be many new businesses and entrants to the labour market, stimulating change faster than previously seen (Frey and Osborne 2015).

One example of how new technology may impact on employment and land use is the emerging technology of 3D printing (or additive manufacturing). 3D printing is capable of producing products in a way that is unachievable by other means, including using composite materials and products with complex geometries. That means that new types of highly customisable products can be manufactured, they can be made relatively quickly and easily and are not constrained to being made in a factory. Because 3D printing lowers the barrier to manufacturing physical products, and introduces new opportunities, it may foster a new wave of innovation (Frey and Osborne 2015). 3D printing can be done at home, and could lead to consumers being able to download plans for items and printing them locally, rather than having them made in a factory, then sent to a warehouse, shop or to the consumer. This will potentially affect many parts of the supply chain and employment across many sectors.

Taking these factors into account, Basu and Fernald (2007) suggest that the lag between investment in digital technologies and productivity gains is between 5 and 15 years. That means that many of the recent and current technological developments are yet to be implemented by businesses, and the productivity gains they might create are yet to arise. The consequence of change as a result of technology is very likely to be significant, as discussed below.

2.2.2 Effects by sector

The advance of technology is expected to have effects on a broader range of occupations than ever before, and it will become harder for human labour to acquire through education new skills to compete with computerisation, as computerisation enters more cognitive domains.

Frey and Osborne (2015) describe the possible outlook for specific sectors. They suggest that retail and sales jobs are susceptible to computerisation, as big data offers the ability of automated systems to make faster, more targeted recommendations for consumers. Legal services jobs such as paralegals and patent attorneys are being substituted for systems that can search legal precedent more comprehensively and faster. Recruitment is increasingly being automated, through the use of functions that can scan, interpret and evaluate resumes. Healthcare diagnosis is being automated, as is finance, where human decision making is being replaced by algorithm-based processes that can process information and make recommendations faster and more accurately than humans. Technology is also affecting the banking sector, where online channels are causing the traditional branch model to come under review, with the possibility of large cost savings in both real estate and wages.

Overall in the United States, 47% of jobs are at high risk due to computerisation, and 52% at low to medium risk, due to improving capabilities for pattern recognition that can substitute for labour in non-routine cognitive tasks (Frey and Osborne 2013). This is expected to lead to automation principally in low-skill and low-wage occupations; however, the introduction of more intelligent, cognitive automation means that even jobs in relatively skilled sectors such as finance, are at risk. The susceptibility to computerisation varies significantly across economic sectors. Frey and Osborne (2013) estimate that as many as 87% of accommodation and food services jobs in the United States are at risk, as are most jobs in transportation and logistics and substantial shares of employment in service occupations. At the other end of the spectrum only 11% of management jobs are at risk, as these are less readily automated.

Demand for industrial robots is increasing strongly, and is expected to grow from around 1.6m units globally in 2015 to more than 2.6m by 2019, representing an increasing rate of adoption (IFR 2016). Adoption of robotics has been relatively low to date, with some estimates being that only around 10% of US companies that would benefit from automated production have installed any robots so far (Frey and Osborne 2013). This is due to a combination of at least two factors: that robots are still relatively expensive and there remain limits to their ability to perform complex tasks. However, with improving technology robots will become cheaper, more adaptable and capable of undertaking a wider range of tasks, including tasks involving more finesse than robots have previously been capable of, and collaborative tasks that involve working alongside people (Hagerty 2015). Robotic automation has to date not had an adverse effect on employment, and the number of employees in affected sectors increased by 2.5% between 2010 and 2015, only slightly less than the 3% growth in the operational stock of robots (IFR 2016). This is consistent with other literature reviewed, indicating that technological advances can result in a net increase in employment in affected sectors (Kammen et al 2006; Salisbury 2013).

Frey and Osborne (2013) do not provide an estimate for New Zealand. In Australia they estimate that 44% of jobs are at high risk of computerisation and automation. As observed by Hajkowicz et al (2016), some sectors have already been largely automated, with remaining jobs at little risk of being automated any time soon, including those in the agriculture, forestry and fishing sectors and many information-based jobs such as call centres and customer services.

A final factor to consider is that a long-term decline in routine occupations is occurring in spurts as these jobs are lost during recessions and not replaced in recovery, often being restructured in favour of automation (Jaimovich and Siu 2012). Economic downturns can therefore be seen as a spur to technology adoption.

2.2.3 Emergence of new occupations

The vulnerability of jobs to automation may, however, be lower than assessed in some studies. A common approach is to assess that vulnerability using an occupation-based approach. However taking into account the diverse range of workers' tasks within occupations, the threat from technological advances is much less pronounced than estimated by an occupation-based approach (Arntz et al 2016). There is the potential for innovation to stimulate economic and employment growth as well as reducing employment in some occupation types, possibly resulting in net employment gains. That is, automation can actually generate new jobs through demand for new technologies, and higher competitiveness, by augmenting the value of human labour, allowing workers to change to different tasks (Arntz et al 2016), subject to skill levels which can be a significant constraint.

Megatrends are a trajectory of change that occurs at the intersection of numerous trends, and develop gradually but eventually reshape the business environment over several decades. There is no statistical modelling technique that can be used to forecast jobs of the future with precision, and so such forecasting relies on understanding some of the background drivers of change (Hajkowicz et al 2016).

New technologies have created entirely new business types in ways that would not likely have been predicted. New businesses such as video and audio streaming, internet publishing, social networking companies and electronic auctions have evolved as technology has made new businesses possible. While the rise of digital photography displaced many jobs in film developing, it has given rise to many other jobs, increasing the number of photographers and also other spin-off businesses such as digital editing, and printing photobooks. Similarly, despite the struggles of the journalism sector, employment in the 'journalism and other writers' category is trending upwards in Australia (Hajkowicz et al 2016).

However, the amount of employment in new sectors is relatively small compared with the existing workforce, with only 0.5% of the United States workforce in 2010 employed in sectors that did not exist a decade previously (Frey and Osborne 2015). Further, there are no guarantees that employment losses will be balanced out by growth of jobs in other parts of the economy, and technological change can be a cause of net decrease in employment, such as occurred in Europe in the 1990s. A negative effect on jobs is found to be most pronounced in larger firms, among low-skilled workers and in capital-intensive sectors (Pianta 2005).

There is little literature specific to New Zealand; however, the case of Australia is a helpful guide. Hajkowicz et al (2016) examine the plausible future for employment in Australia over the next 20 years, and identify six new types of jobs which are emerging or might emerge:

- Big data analysis will continue to grow, leading to more specialisation and flow-on job creation in automation, security, encryption and storage.

- Decision support analysis will draw off improvements in artificial intelligence, shifting this support to complex decision problems and away from rules-based decisions.
- Remote-controlled vehicle operators will include not only small-scale drone operators, but also pilots, drivers and ship captains.
- Customer experience experts will develop as immersion in the virtual world increases the marginal value of the physical world, and consumers demand improved virtual experiences. Physical stores will effectively become showrooms staffed by experts, while purchases are made online and delivered quickly to consumers' homes.
- Personal health helpers will become important, resulting in continued growth in the number of personal trainers and other specialist health advisors, who aim to help clients achieve specific health and fitness targets.
- Online chaperones will help individuals and firms manage their online presence, avoiding identity theft, reputational damage and cybercrime.

A key finding from the work of Hajkowicz et al (2016) is that the full impact of improvements in computing power, connectivity, data volumes and artificial intelligence is yet to be felt, but will be beyond 2020. Change of this type is exponential, and may result in rapid transformation as the curve steepens,beyond 2020. As Hajkowicz et al (2016) observe, although change is inevitable, the implications of this change are far from clear, and there are many possibilities that could eventuate, and many ways that change can be influenced, especially policy responses.

2.2.4 Productivity gains

Gordon (2012), Cowen (2011) and Thiel (2014) observe there has been an extensive type of growth in the 20th century, and at times before, but contend that that sort of growth may have come to an end in many developed economies. They suggest the type of growth that relies on adding more capital or workers in production has now finished, and many of the historic productivity gains are one-offs and cannot be repeated. Productivity gains of this type include those from the declining cost of distance (eg containerisation and improved road and air transport) and rising educational attainment, whereby higher proportions of the workforce have tertiary qualifications.

Wages have not grown at the same rate as productivity in recent decades, and real wages have stagnated in nearly half of all OECD countries since 2000. Technology is a key driver behind this, and while technology can raise productivity and boost wages, it can also take the form of capital that substitutes for labour. The digital age has decreased labour's share of GDP, and at least half of that decrease is explained by advances in computer technology (Frey and Osborne 2015). The digital age is an age of capital, rather than labour, and we are in an era where innovation is likely to make a growing share of workers worse off in the long term (Frey and Osborne 2015).

A countering view suggests there are still plenty of gains to be made. Process automation will drive significant business integration and reorganisation, and allow analytical models to make many of the day-to-day and minute-to-minute decisions that consume employees today (Bassan et al 2008). This ability to integrate intelligence from fields such as environmental sciences, neuroscience, psychology, engineering, information technology and business finance will help to create a network of information that improves productivity and frees up labour for other tasks, without resulting in a net decrease in employment.

2.2.5 Employment structures

Technology has, and will continue to have a strong influence on the type of jobs and the structure of firms. One key change that has occurred is referred to as 'barbell-like' changes in business demography, with an increasing proportion of very small and very large firms and decreasing shares of medium-sized firms. One example of this is brewing, where very large breweries are buying out smaller counterparts, and small craft brewers are increasing in number rapidly (Dellot 2014a). This is not only a function of changing technology, although that is a large influence. Other drivers for this 'barbellisation' include the ability for small firms to innovate quickly and rapidly bring new products to market, and very large firms to seek a global presence, which gives them disproportionate market power.

This barbell-like structural change has also applied to occupation by skill level. Most employment growth since the 1980s has been either in high or low skilled jobs that involve respectively cognitive capacity or manual labour. Middle-skilled manufacturing and clerical occupations have declined, resulting in increased polarisation in the United States and Europe (Frey and Osborne 2015; Autor 2015b; Michaels 2014). This has possible social implications, although these are outside the scope of this review. As data collection and analysis tools improve, less managerial hierarchy is required, and networks will play a greater role in company operation, with significant implications for jobs in middle management (Fjeldstad et al 2012). In Australia the highest skill category jobs have grown significantly more than average since 1991, while less skilled jobs have grown more slowly (Hajkowicz et al 2016).

The growth of microbusinesses (firms of less than 10 workers) and the self-employed is one aspect of this. Self-employment in many sectors is facilitated to a large degree by improved technology, with employees being skilled workers capable of using the technology. Growth in these firms is expected to continue to become more prevalent as a result of ongoing innovation, as the digital economy allows businesses of any size and individuals in most socio-demographic groups to reach global markets, with less capital investment than has previously been needed.

In Britain self-employment has increased more than 30% since 2000 (Dellot 2014a), while in the United States that figure is nearly 50% (Frey and Osborne 2015). There has been a similar increase (31% since 2000) in 'nanobusinesses', those businesses run part time by an individual who devotes some time each week to their business as well as (often) working in paid employment as well. Over a third of those businesses would not be able to function without recent advances in technology, especially the internet (Dellot 2014a). Ongoing technological advances will support ongoing growth in these types of enterprise.

Variable cost structures have become more common in service providers such as advertising (consider the Google model of cost per advert clicked), labour (contractors and freelancers) and telecommunications (cost per unit of data used). These changes have helped to democratise businesses, and allow many small operations to start up when they could not have without the technology (Dellot 2015). Technology can therefore be seen to be enabling entrepreneurial behaviours which have previously been precluded by minimum costs, scale and time factors (Dellot 2014b).

Digital technology is increasingly enabling lean innovation, low-cost and rapidly scalable operations that can compete globally and respond quickly. Entrepreneurs are symptomatic of the rise in the knowledge-based economy, and with the expectations of younger generations entering the workforce (Hajkowicz et al 2016). Entrepreneurs and freelancers are both becoming more viable through the decrease in transaction costs, which have historically been one of the main reasons for firms to exist (Coase 1937).

With decreasing costs, firms will not necessarily be the most efficient entity through which to conduct business, leaving open the potential for new business structures to emerge. One example of this is the peer-to-peer economy. The peer-to-peer or sharing economy enables individuals to reach broad markets and make income from their assets. Companies such as Airbnb, Buzzcar and Uber operate as firms, but allow individuals to operate in markets (such as commercial accommodation) where previously they could not. Freelancing is part of the peer-to-peer market, and is increasing as international job markets become more accessible to sole traders in geographically remote markets (Hajkowicz et al 2016).

Self-employment is attractive not only to workers, who can dictate where and when they work, but also to firms that are increasingly seeking more flexible staffing models (Kitching 2015). Labour-hire companies currently exist to provide short-term workers, which gives firms this sort of flexibility, but even these labour-hire companies may be vulnerable to replacement by digital platforms which cut them out as an intermediary (Hajkowicz et al 2016).

A consequence of this change in employment structure, and the rise of small businesses and the self-employed, is a likely increase in working from home and demand for co-working spaces. Demand for the latter has doubled every year since 2006, with implications for traditional office leases (Deskmag 2012). The peer-to-peer economy may also result in many of the activities conducted in the economy becoming cheaper and more attractive for consumers by introducing new competition to the market (consider the lower cost of Uber compared with taxis in New Zealand), stimulating growth in those sectors.

2.3 The internet of things

The internet of things (IoT) is a network in which everyday objects have internet connectivity, and is described as ‘a dynamic global network infrastructure with self-configuring capabilities based on standard and interoperable communication protocols’ (Vermesan et al 2011). More and more products are internet capable, and when connected offer interesting capabilities and ways to improve productivity and convenience.

The range of applications for IoT technologies is broad, but the transport and logistics industry is likely to be significantly affected. One helpful example of the potential use of the IoT is the connected fridge. It will be able to track expiration dates, detect when supplies are running low and order more automatically. Automatic replenishment and anticipatory shipping have implications for logistics providers, through reducing lead-time and minimising out-of-stock issues (Macaulay et al 2015). IoT technologies will therefore improve the operational efficiency of the supply chain, and support optimal use of roads and parking infrastructure (Miorandi et al 2012). This may however have the effect of increasing the burden on transport infrastructure by creating more, smaller orders, depending on how automated ordering is scheduled.

The IoT will provide the opportunity for firms to monitor the status of their assets and people, track movement through the supply chain, control and change business processes, and inform companies about the strengths and weaknesses of their supply chains (Macaulay et al 2015).

IoT technologies might support the redesign of traditional seaports, resulting in increased use of inland terminals (dry ports) for container pick up and leave (Schiavone 2016). Ports will continue to experience significant improvements in handling capacity and employee productivity as a result of increased automation and improved processes, and the IoT can work on top of those improvements to capitalise on automation, with benefits for the consumer and the port. For example, between 1987 and 2001 container turnover per employee at the port of Singapore quintupled due to automation and organisational changes (Günther and Kim 2006). Further improvements are expected in port-processing capabilities, although a number of design problems cause challenges for future productivity improvements. The need for multi-modal interfaces (links to rail, road and sea) constrains how ports can be laid out, as does the need to accommodate certain types of activities such as hazardous goods, non-standard sized containers, the need to stuff and strip containers and need for access to electricity for cooling.

2.4 Online retail

There is a diverse range of conclusions about the potential impacts of online retailing in international literature, and little consensus. This is influenced in part by the dynamic nature of online retailing, and the trend for rapid changes in the sector, which has resulted in some research on the topic becoming obsolete. Broadly, the literature and theories associated with online retailing have been evolving and changing in an attempt to keep pace with the rapidly changing nature of online retailing. This review seeks to provide a current, relevant review of the current best thinking about online retailing, and so excludes some earlier work that is no longer relevant.

Online retailing is quickly transforming the retail landscape in both the domestic and international markets. Online retailing has grown rapidly in most of the developed world, with average annual growth of up to 20% in some countries, albeit from a small base (Fairgray 2013). Since 2010, online retail sales in New Zealand have grown by over 20% per annum and growth of about this magnitude this has continued into 2016, with the latest data showing growth of 16% compared with the same time last year (BNZ Marketview 2016).

Online retail sales currently make up 7% of all retail sales in both Australia and New Zealand (National Australian Bank 2016 and BNZ Marketview 2016). This rate lags behind many European countries including the United Kingdom, but is similar to North America. European countries were at the levels currently observed in New Zealand and Australia some years ago, and have continued to grow from there. This indicates if the New Zealand market follows similar patterns as observed internationally, then there will continue to be strong growth in online retail in the future, with growth rates considerably higher than those of the total retail sector (Fairgray 2013). The growth potential in online retail is important because traditional bricks-and-mortar retailing and online retailing may have different land use requirements and transport, logistics and employment outcomes. These outcomes could have important implications for urban planning and transportation infrastructure.

Online spend growth rates have tended to broadly correlate with growth in access to internet and mobile devices, indicating that as access in New Zealand continues to increase, online retail will also grow. To date the fastest growth has occurred in the core retail categories of smaller durable and comparison items, with slower growth in consumable, perishable and larger items. The majority of online retail sales in New Zealand are made by domestic retailers (approximately 55%); however, the historic trend shows that international merchants are capturing increasing shares of online retail sales (Fairgray 2013).

Notwithstanding the lack of consensus on some specific aspects of online retail, most studies suggest a key aspect of online retailing is an expected change in consumer shopping behaviour that may result in modified travel patterns. Broadly, there is acceptance that online shopping is likely to result in reduced visits by consumers to retail outlets (Rotem-Mindali and Weltevreden 2013). The conventional hypothesis is that exchange of goods from the business to consumer (b2c) will be reduced, with private trips by the consumer substituted by freight courier trips. That is likely to mean that growth in online retailing will result in many private vehicle trips being exchanged for fewer courier van trips, resulting in fewer vehicle trips overall.

However, it is not clear that the reduction in visits to retail outlets will result in fewer trips overall. Specifically, there is some evidence that many shopping trips are incidental to other household travel patterns (such as trips to work or school), and those trips would still occur with or without a retail component. Further, the social aspect of shopping will remain attractive, indicating that while online shopping may displace some traditional retail, visits to physical stores will remain attractive, and online retail may not impact on household travel patterns as much as theorised (Cullinane 2009). The literature also suggests that there is likely to be a wide range of different consumer behaviours across the various types of retail goods, which means effects on shopping trips, land use and employment is not likely to be uniform across the retail market (Crocco et al 2013).

Another key aspect of growth in online retailing is the likely impact on business logistics and freight requirements. Both business-to-business (b2b) and b2c links could have important implications for business operations and transport (Visser et al 2014). In terms of urban form and employment, there is potential for retailers to change from a traditional retail supply chain (ie supplier to warehouse to store to consumer) to more dynamic supply chains (ie supplier to warehouse to consumer or supplier to consumer). These potential changes in supply chains could have an impact on land use requirements, with decreasing need for retail stores and warehousing, including with direct selling of New Zealand product into overseas markets.

Additionally, the changing business operations could affect the types of jobs and locations of these jobs. Broadly, the traditional brick-and-mortar business operations focus most employment in centres (shop assistants), while online retailing may focus more employment into business and industrial locations (webdesigners, logistic managers, storeroom packers etc) (Terzi 2011).

A separate but important aspect of online retailing is the large and growing consumer-to-consumer (c2c) channel, specifically sellers on platforms such as Trade Me and Etsy. The c2c market is large and growing, and Weltevreden and Rotem-Mindali (2009) found that in the Netherlands, the c2c market is larger than the b2c market in terms of sales volume through online channels (4.6 billion euros compared with 3.9 billion euros). Sellers in the c2c channel are likely to be dispersed across urban areas, which may have important implications for transport and land use. However there is limited literature that focuses on the potential implications of c2c. A quantitative study of consumer behaviour in the Netherlands indicated that c2c led to a net increase in the numbers of trips and distance travelled (Weltevreden and Rotem-Mindali 2009). A driver of this is the purchaser’s desire to check the existence and quality of goods before paying, often requiring a trip to pick up c2c orders to places consumers would not ordinarily travel to. This finding cannot be generalised to other countries because of the likely difference in transport networks, c2c platforms and consumer behaviour. The study did not assess the effects of c2c on land use or employment.

Finally, there is some literature that attempts to understand the potential combined effects of online retailing and other disruptive technologies. The literature suggests that other disruptive technologies, such as drones (and driverless automobiles), might be combined with online retailing and could result in different outcomes in terms of transport (Mangiaracina et al 2015).

2.5 Autonomous vehicles

An important driver of future land use patterns will be how transport is used, and a major influence of transport innovations is likely to be driverless vehicles (also called autonomous or self-driving vehicles). This section reviews literature on autonomous vehicles (AVs), including potential uptake rates, benefits and effects on land use and employment.

2.5.1 Definition of autonomous vehicles

There are different levels of autonomy (Litman 2015, Anderson et al 2016):

- Level 0: No automation, the human driver is in complete control of all functions of the car.

- Level 1: Driver assistance, eg cruise control, lane guidance and automated parallel parking. Drivers are fully engaged and responsible for overall vehicle control.
- Level 2: Partial automation, automation of multiple and integrated control functions, such as adaptive cruise control with lane centreing. Drivers are responsible for monitoring the roadway and are expected to be available for control at all times, but under certain conditions can be disengaged from vehicle operation.
- Level 3: Conditional automation, drivers can cede all safety-critical functions under certain conditions and rely on the vehicle to monitor for changes in those conditions that will require transition back to driver control. Drivers are not expected to constantly monitor the roadway.
- Level 4: High automation, vehicles can perform all driving functions and monitor roadway conditions for an entire trip, and so may operate with occupants who cannot drive and without human occupants.
- Level 5: Full automation, the full-time performance by an automated driving system of all aspects of the dynamic driving task under all roadway and environmental conditions that can be managed by a human driver.

Levels 1 and 2 are already incorporated in most new vehicles, with a selected few providing level 3 autonomy (Tesla model S and X). The Google car is testing level 4 autonomy even though currently there is a test driver aboard at all times. According to Tesla, starting 19 October 2016, all Tesla cars are built with hardware to allow full self-driving capability at level 5 and there are plans to enable level 5 by the end of 2017.

Various types of AVs are possible, including car-like AVs, droids (small AVs slightly larger than a regular parcel which travel at walking speed on footpaths) and drones (autonomous aircraft). In this report droids and drones are referred to specifically, with AVs generally referring to car-like vehicles.

2.5.2 Outlook for AVs

Google's self-driving car project began in 2009, and the testing fleet has since covered over 3 million kilometres, reporting on progress regularly, and significant resources continue to be invested in the project (Harris 2016). Some researchers now claim that AVs could replace human drivers in the next decade (Bunghez 2015). This may be overly optimistic, but every major commercial automaker is conducting research in this area, and full-scale AVs are predicted within 10–15 years (Anderson et al 2016). Murray (2007) is of the view that it will take longer before autonomous cars operate inside cities, but operation on motorways (highways) is likely sooner.

Announcements about research and development progress by major car manufacturers have been frequent recently:

- Starting 19 October 2016, all Tesla cars are built with hardware to allow full self-driving capability at level 5 and there are plans to enable level 5 by the end of 2017 (Tesla 2016).
- In August 2016, Ford's CEO announced that the company plans to offer fully self-driving vehicles by 2021 (Sage and Lienert 2016).
- General Motors announced at a recent conference in Detroit that most industry participants now believe self-driving cars will be on the road by 2020 or sooner (Stoll 2016).
- General Motors announced plans to use the Lyft platform to bring its self-driving cars to the masses in July (Thompson 2016).
- BMW is expected to launch their self-driving electric vehicle (EV) in 2021 (Lambert 2016).

- Toyota plans to bring the first models capable of autonomous highway driving, currently in a testing phase, to the market by 2020 (Caddy 2016).
- Audi has announced that the next generation of their A8 limousine will be able to drive itself with full autonomy (Torr 2014).
- Nissan expects its autonomous models to be consumer ready by 2020, Jaguar and Land Rover by 2024, and Continental and Daimler by 2025 (Driverless-future.com 2016).

Trials of AVs are underway in New Zealand. Christchurch International Airport has started trials on the airport campus of a driverless shuttle, able to carry 15 passengers at a time. The first trial began in January 2017 and is expected to last for two years. Testing began in a controlled environment and with no passengers, but is expected to include the public once the safety case has been made (Hayward 2017; Christchurch Airport 2016).

There is a definite will from manufacturers to make AVs available to the public, and doing so would (eventually) result in a profound change in the nature and safety of transportation. There is also support from the public and those outside the auto industry who recognise the potential to reduce land used for parking, decrease unproductive time spent in cars and decrease crashes. The cost of motor vehicle crashes alone is significant, at nearly $3.5 billion in New Zealand in 2014 (MoT 2016), and 94% of road crashes (United States in 2015) were caused by either human choice or error (NHTSA 2016). AVs have the potential to significantly reduce injuries and other costs, with a reduction in crash and injury rates of 50% expected with only 10% market penetration, and 90% reduction at 90% penetration (Fagnant and Kockelman 2016). Reduction at those levels would provide a significant cost saving, freeing up capital for other uses.

However, most researchers agree that significant barriers to full implementation and mass-market penetration remain. Initial AV technology costs will likely be unaffordable to most people, and there are significant regulatory hurdles to cross. Thierer and Hagemann (2015) address some of the concerns about AVs, and find that while intelligent vehicle technology will create significant economic and social benefits, various technical and policy barriers to widespread adoption remain. They caution against unnecessary constraints such as misguided regulation as might be borne out of fear of worst-case scenarios, which would slow the availability and uptake of AVs.

The outlook for AVs is uncertain, with wide variation in the expected effects of AV introduction and the timing expected. New technological advances have the potential to be game changers, and render current expectations obsolete. In January 2017 Airbus Group announced plans to test an autonomous airborne taxi prototype by the end of 2017, a move which would, if it becomes mainstream, have obvious and profound implications for road-based transport (Reuters 2017).

2.5.3 Impacts on congestion

There is no shortage of predictions about what the future of AVs will look like, and the effects they will have, but there is a noticeable lack of consensus. Predictions range from a scenario where the use of AVs results in no congestion to a future where there will be so many vehicles on the road that our motorways are permanently gridlocked, and everything in between.

An analysis undertaken by the International Transport Forum (ITF) (part of the OECD), found the impact will vary depending on the degree of uptake, as well as the type of driverless vehicle that is adopted. For example, autonomous cars acting as taxis might be either TaxiBots (self-driving vehicles that can be shared simultaneously by several passengers) or AutoVots (which pick-up and drop off single passengers sequentially). These types of AV innovations could lead to mass customisation, where intelligent systems taken into account the needs of millions of individual users and create personalised solutions, yet with the efficiency associated with mass produced solutions (Gruel and Piller 2016).

One school of thought is that there will be much less congestion, due to:

- Increased capacity: AVs can stay within much narrower lanes with greater accuracy and follow each other at much closer distances (Levinson 2015).
- Car and/or ride sharing: currently cars are mostly privately owned, but with vehicles as a service, cars from a pool would be dispatched and the customers taken to their destination, akin to a driverless taxi service (Levinson 2015).
- Fewer delays from crashes: the vast majority of road crashes are caused at least in part by human error related to distracted driving (using phones, eating etc), driving under the influence, fatigue and inexperience. AVs could reduce or even eliminate these (Maheshri and Winston 2016).
- More efficient vehicle operation through smoother, more consistent driving.

That possibility is countered by those who suggest that AVs will result in more congestion, due to:

- Decreased cost of congestion: occupants are able to engage in other activities in their vehicle such as working or sleeping, so the number of trips and overall distance travelled might increase (Anderson et al 2016; Wadud et al 2016).
- Increased number of vehicles on the road: those who were previously unable to drive due to disability, age or being unlicensed, will be able to be the sole occupant in a vehicle (Litman 2015).
- Empty cars on the road: currently the minimum number of occupants in a car is one, but AVs will introduce the possibility that unoccupied cars could use the roads to running errands, repositioning or ‘waiting’ for owners (instead of parking).

Either way it is likely to be some time before significant effects are observed, with any congestion improvement likely to be some time away due to the critical mass of AVs needed to overcome human shortcomings – the system is only as good as its weakest link. The Auckland Technology Alignment Project (ATAP 2017) anticipates it could be at least 10 years before connected AVs start to make a significant difference to road network performance, and that these AVs will not comprise the majority of the fleet in Auckland until after 2036. There is likely to be a lag between adoption of new vehicle technology in New Zealand compared with internationally, given the relatively old age of the New Zealand vehicle fleet (ATAP 2017). Ultimately, the total impact of AVs on congestion is still uncertain. Policies such as road pricing might become more important to control congestion and manage travel demand. Wadud et al (2016) suggest that policy-makers take advantage of vehicles’ built-in navigation and communication systems to apply such policies.

2.5.4 Impacts on land use

The ITF study (2015) found that 9 out of 10 conventional cars could become redundant under certain circumstances, freeing up vast amounts of public space for other uses. Nevertheless, in most scenarios the total volume of travel increases and thus the net benefits depends on the choice of vehicle type, the level of penetration and the availability of high-capacity public transport (PT) to complement the shared self-driving car fleet. There are clearly many variables that influence the possible effect of AVs on congestion, and hence on land use.

In some scenarios modelled by the ITF (2015) car-kilometres nearly doubled. As acceptable trip distances increase (because passengers can undertake other activities in the vehicle), we would expect a greater spread of origins and destinations, for the same reason that commuter trains today enable exurban living or living in a different city. This might mean that more people will live in the suburbs or exurbs, as the pain of travel reduces (Levinson 2015).

Zakharenko (2016) modelled the effects of AVs on urban forms. He focused on the lower cost of travel of AVs relative to traditional vehicles, and the ability to optimise the location of parking and so free up land for higher value economic activity. Currently vehicles need space to park at every location their owner chooses to visit. The use of land for parking crowds out other land uses, eventually leading to reduced density of economic activity. Zakharenko (2016) suggests that when driverless cars dominate, parking space in inner cities will be reduced, and parking is likely to shift to more peripheral locations. He predicts the existence of a parking belt located just outside of the commuter zone that may be hosting as much as 97% of all commuter AVs. He further suggests that as a result of the lower cost of travel, individuals would accept longer travel distances in order to afford larger residences, resulting in urban sprawl. This view is consistent with Levinson's (2015) opinion – the initial effect of AVs would be that people move to places further from their place of work to get more real estate for their dollar.

Shared AVs (SAVs) are like communal cars (rather than buses), and would be available for the use of multiple commuters at different times of the day. Increasing use of these would be likely to have a dramatic downward effect on parking demand. Zhang et al (2015) applied an agent-based model of a 10 x 10 mile hypothetical city laid out in a grid network of 0.5 mile street segments, generating random trips. They developed scenarios with different fleet sizes, levels of willingness to ride-share and empty vehicle cruising strategies. They found that up to 90% of parking demand for that environment could be eliminated if 700 SAVs were put into that particular environment. That finding is transferable to other environments, and indicates that SAVs have the potential to significantly reduce parking requirements.

This has implications for urban planners, because once those urban parking spaces are no longer needed, more sustainable designs, such as more green, open and human-oriented space can be introduced. Planners and local decision makers may seize this opportunity to guide the city to develop in a more sustainable way. This redesigned and potentially more densely occupied urban area could offer more productive working space and greater employee density, contributing to increased challenges of moving workers through the transport network.

2.5.5 Impacts on employment

There is an abundance of literature around the technical aspects and the virtues and vices of AVs, but very little relating to their potential impact on employment. Conventional car manufacturing is changing, but as with other topics, there is little consensus in the literature reviewed on the potential effects of those technological changes on employment.

It is likely that if driverless cars become popular, employment in the auto industry could decrease significantly. For example car sales in the United States could fall by 40% in the next 25 years, which would translate to around 25,000 jobs lost in manufacturing and assembly plants. This has been seen as overly pessimistic, and does not account for the creation of new jobs as a result of AV technology (White and Ingrassia 2016). Replacement of workers as a result of the emergence of AVs, is most likely in countries with higher labour costs (above 10–12€/hour), while in countries where labour is cheaper it will be cheaper for traditional models to remain (Joerss et al 2016).

However, it is not only autoworkers who could be affected. Other occupations that might disappear include truck, bus and taxi drivers and driving instructors. Panelbeaters and traffic police might also be required less over time as there are fewer traffic violations and crashes.

As discussed above in relation to innovations generally, with the disappearance of some occupations, new opportunities and new occupations emerge. For the autonomous driving industry, this could mean more engineers (AV systems, functional safety, motion planning, mapping, etc) designers and software developers (White and Ingrassia 2016).

AVs are likely to be used increasingly in a range of sectors as well as on the roads. In the construction industry autonomous bulldozers already exist, and are used in Japan in conjunction with drones to enable remote control and monitoring or workload and progress. Together with other innovations enabled through the use of technology, these changes are predicted to lead to much faster build times (up to 30%) and cheaper build costs (up to 20%) (Gerbert et al 2016).

Another application for this AV technology is explored by Bellamy and Pravica (2011). They assess the implications of introducing driverless haul trucks in a typical large, remote Australian open-pit mine. Such automation is expected to save employee and associated costs, increase operational productive hours and reduce workforce numbers. They conclude that while there will be fewer jobs per mine, with reduced costs and higher productivity some previously uneconomic mines may again be profitable. Reduced employment would likely result in decreased population in remote mining towns and a decrease in the lower skilled labour requirements. Fly-in fly-out mining operations would increase, and companies would establish remote control centres in larger cities for automated mines. The uptake of this technology would determine the extent of these effects, and the change in employment for the sector as a whole.

2.6 Drones

Drones are unmanned aerial vehicles (UAVs). The military has used drones for many years, for a variety of missions but recently their civilian and commercial ownership has increased substantially (Schaub 2015). E-commerce retailers such as Amazon, are now also evaluating their use and some trials are already underway (Mehra 2015). Widespread use of UAVs in freight delivery and other sectors has the potential to significantly change transport patterns and operational procedures.

The possibilities of what drones will be able to do are broad, although many uses will need to overcome challenges around control autonomy and regulation. Potential uses include transportation of goods, real time aerial photography, remote inspection and monitoring of crop and animal farming, infrastructure and disaster response (Floreano and Wood 2015). UAVs will also be particularly valuable in areas where human safety would be at risk, such as journalism in war zones (Gynnild 2014), and law enforcement organisations have recently employed UAVs as an aid to ground personnel, including successful use in India to control and monitor riots (Sarkar 2016).

The postal and logistics industry is one natural candidate for drones. Joerss et al (2016) estimate that AVs (including drones, droids and ground-based AVs) will deliver 80% of parcels in the future, with only very large customers and special delivery items being delivered by traditional means. In markets with labour costs as high as New Zealand’s, this can result in a 40% decrease in delivery costs, and a 20% increase in profit. Other estimates put the cost of delivering parcels purely by drone at up to 10% if drones are employed, and this saving could increase with ongoing improvements in drone technology (Doskocz et al 2016). Current constraints to drone operation include battery capacity, drone size and the maximum payload it can transport. With improvements in those factors the viability of drones will continue to increase.

DHL Trend Research (DHL 2014) expects UAVs with electrical engines and multicopters to be the most promising choice for applications in the industry, and concludes that they present feasible opportunities for UAV-based deliveries in a real-world setting. The two most promising uses are for urgent deliveries in very large cities and rural deliveries in areas that lack adequate infrastructure. Both cases offer potential to short-cut transit delays caused by non-existent or crowded infrastructure. Widespread use will, however, take some time given refinements of technology and regulatory constraints. Logistics companies might also offer drone-based services for other applications, such as infrastructure monitoring or finding the location of damage in expansive networks such as oil pipelines (DHL 2014). In their report DHL mentions several strategies for the use of UAVs in development of their business, resulting in economic growth.

DHL (2014) and Doskocz et al (2016) both identify regulatory constraints to the application of the technology that exists. Many of these constraints stem from safety and privacy concerns, which appear to be held worldwide. Regulation is possibly the biggest roadblock to a wider use of drones in at least the United States, Europe and New Zealand. Keall (2016) describes attempts made by Domino's Pizza in implementing drone delivery services in New Zealand. Domino's has partnered with a United States technology company to trial a drone delivery service; however, the large no-fly-zones (for drones) over most cities (including Auckland) prevented testing for some time pending Civil Aviation Authority approval, and subject to concerns from the Privacy Commissioner. Eventually Domino's made the first pizza delivery in New Zealand by drone in November 2016, and intends to pursue more widespread use of the technology (Clayton 2016). Transport Minister Simon Bridges has stated that New Zealand's enabling laws and regulation makes New Zealand ideal for trials of all forms of technology (The Beehive 2016).

Similarly in the United States, Amazon revealed plans (in 2013) to launch a delivery service using drones, called 'Amazon Prime Air'. Although Amazon does not currently have Federal Aviation Authority regulatory support, testing is underway to turn this concept into a reality (Amazon.com 2016). This pursuit is influenced by Amazon's recognition of the service's potential, and also by support from consumers, with large proportions of the public supportive of using drones to speed up delivery, and expectant that online merchants will use drones for delivery within the next five years (Mehra 2015). In Britain the government is now allowing the first out-of-sight test flights, indicating a growing movement at various levels to make drone deliveries a reality (Joerss et al 2016).

There is some public opposition to the use of drones for deliveries and other purposes due to perceived risks and privacy concerns. Research indicates that consumers' attitudes towards small UAVs are influenced both by their perception of the related risks and the perceived functional benefits. The higher the alleged performance and quality of service, the more favourable the consumer's attitude towards the use of drones, even if concerns remain. This indicates the public will be prepared to weigh up the costs and benefits of drone use, and ultimately be supportive if the benefits outweigh the costs (Ramadan et al 2016).

These examples indicate there is commercial incentive, and some public desire to see drone deliveries rolled out, although practical and legislative constraints may limit how quickly this can occur. This mirrors the experience with other emerging technologies, such as AVs. While there may be public opposition to some of these new technologies in the near future, it may be overcome through ongoing improvements to mitigate concerns.

As drone use becomes more widespread, there may be some employment loss in affected sectors such as couriers. Given general observations in relation to innovation, those may be offset by increasing employment in UAV operation and maintenance, including pilots, technicians, designers and software developers (Evangelista and Vezzani 2011).

2.7 Electric vehicles

The future of electric vehicles (EVs) is important because EVs can be cheaper to run than vehicles powered by fossil fuels, and offer superior environmental benefits. Improved cost efficiency will have implications for how motorists use their vehicles: cheap fuel will likely increase the degree to which motorists are prepared to use vehicles, potentially increasing vehicle distance travelled per person. It is also important to consider this effect in conjunction with other technology, such as AVs, which combined will make for cars that are cheap to run and able to drive themselves.

As of October 2016, only 1,784 electric vehicles were registered in New Zealand, although the Government has announced an Electric Vehicles Programme in an effort to increase the uptake of electric vehicles in New Zealand, with an aim of doubling that count every year to reach 64,000 EVs on the road, by 2021 (New Zealand Government 2016).

Currently the price of EVs is quite prohibitive to their uptake, although the share of EVs of all vehicles on the road is growing, as battery costs have come down, and vehicle electrification has gone multi-modal. There is growing demand for affordable EVs, as evidenced by the record breaking pre-sales of the Tesla Model 3, with 325,000 pre-ordered in the first week globally (worth over $14 billion). However, the first Model 3 is not expected to be delivered until the end of 2017 (Hull 2016).

There are now 46,000 electric buses and 235 million electric two-wheelers deployed globally, with China, Japan and the United States having large shares of the global EV stock. EVs represented more than 1% of new car sales in 2014 in the Netherlands, Norway, Sweden and the United States (Clean Energy Ministerial 2015).

Analysis by Granovskii et al (2006) shows that EVs and hybrid EVs have advantages over conventional and fuel cell vehicles in terms of economic efficiency and environmental impact. However those advantages depend substantially on the source of the electricity. Because New Zealand has a high proportion of renewable energy, the environmental benefits from EVs are higher here than in markets where electricity is generated from fossil fuels.

Most literature predicts a positive employment effect from the innovation of EVs and the shift to cleaner fuels. The consensus view is that job growth in EV industries will outweigh any reduction of jobs in traditional fuel industries, resulting in net job growth (Kammen et al 2004; Salisbury 2013; Kunapatarawong and Martínez-Ros 2016; Parkinson 2016; Electrification Coalition 2010). Much of the employment losses will be experienced in vehicle assembly and manufacturing, where a move towards EVs is expected to reduce employment (Osawa and Nakano 2016).

Loss of vehicle manufacturing employment is unlikely to have significant effects in New Zealand, because most vehicles in New Zealand are imported. That means that the effect on employment in New Zealand may be generally positive, given sustainable transportation has been found to have net positive impacts on the economy, employment and the environment (Kammen et al 2004). Further, a positive correlation between firms' green innovation and employment is reported (Kunapatarawong and Martínez-Ros 2016). In Spain 'green' strategies and policies in the transport sector have resulted in increased green innovation activities and a positive impact on employment (Kunapatarawong and Martínez-Ros 2016).

Salisbury (2014) proposes that EVs will enable a shift from imported fuel to locally produced electricity sources. This cheaper fuel will create additional disposable income that will be spent mostly in the local economy, creating additional local jobs, rather than requiring fuel to be purchased from overseas. Spending on electricity would remain predominantly inside the country of use (Mattila and Bellew 2011).

A repeated theme in EV literature links in with literature on other innovations. Although the future of EVs is not certain, some change in employment types and locations is likely, and so government policies should strongly promote employment mobility. This is likely to be of less influence in New Zealand than in countries with large automotive manufacturing sectors; however, it is interesting to see the same finding relevant across many sectors.

2.8 Telecommuting

Working from a location other than the conventional work site, known as teleworking or telecommuting, is not new but appears to be getting increasing coverage recently, especially in relation to discussions about technology. Ongoing changes in telecommuting practices have the potential to influence future land use and employment patterns.

Telecommuting has become an increasingly attractive and viable organisational choice, due in large part to technological developments in information and communication technologies (eg broadband internet, mobile devices, social media, cloud computing, and networking tools), media publicity and management awareness, which jointly encourage employees to participate in virtual work (Bentley et al 2013).

The prevalence of teleworking is increasing. Between 1997 and 2010 in the United States there was a 35% increase in the number of people who worked at least one day a week at home, and the number of businesses with a majority of teleworking employees also increased (United States Census Bureau 2015). The value of telecommuting to companies and employees is recognised by the Australian government, which in 2012 announced a target of having 12% of the public sector working from home by 2020 (Greenwood 2012).

No New Zealand targets have been set, but telecommuting is a growing trend here too. Bentley et al (2013) found that 22% of respondents had a written agreement to telework and 47% had an informal arrangement, while 3% teleworked without the knowledge of their manager. Rasmussen and Corbett (2008) reported around 15% of organisations in New Zealand use teleworking (including working from remote offices) for at least a proportion of their staff, although only 3% of the New Zealand workforce was working from home in 2007. The 2012 Survey of Working Life (Statistics New Zealand 2014) showed that almost a third of employed people spent some time working from home over a four-week period.

Fu et al (2012) suggest that land use patterns and thus commute distances influence rates of home working. The potential growth of teleworking is greatest among workers employed in large cities, likely because they face the longest home-to-work commute times (Aguilera et al 2016). Teleworkers tend to be employed in occupations relating to management, business, science and the arts (Larson and Zhao 2017. Around one in four home-based workers are employed in management, business and financial occupations according to the 2010 American Community Survey (United States Census Bureau 2015). Similarly, in New Zealand job roles typically associated with telework include professional knowledge workers, senior managers, project-based staff, IT support staff, field-based operational staff, customer service and sales representatives, and independent consultants and contractors (New Zealand Work Research Institute 2014).

Generally positive findings about the effects of teleworking have led to an increased policy focus on encouraging telework as a part of efforts to improve employee welfare and reduce energy consumption and emissions. Benefits include increased productivity, reduced employee turnover and improved morale. However, despite the welfare and organisational benefits of teleworking, the environmental effects of telework is uncertain because urban sprawl is an unintended consequence of teleworking, which may have implications for teleworking's uptake. A decrease in transportation costs for both teleworkers (due to less commuting) and non-teleworkers (due to reduced congestion), reduces incentives to live near the CBD where housing costs are high. This potentially causes urban sprawl, lowering urban density, and increasing average home and lot size and the distance of the average commute. All of these effects increase energy consumption (Larson and Zhao 2017; Tayyaran and Khan 2007; Rhee 2009). Rhee (2009) suggests policy makers influence land use and prevent urban sprawl through zoning.

There are also shortcomings with teleworking. A number of these are identified by Donovan and Wright (2013). One factor that has prevented a faster increase in teleworking is the benefits of being physically present in a workplace with colleagues. Direct social contact is recognised by many workers as important in their job security (Gajendran and Harrison 2007). Increased permeability between work and home life can create work life conflict (Thatcher and Zhu 2006), and teleworking can weaken personal bonds with co-workers and managers over time (Golden 2006).

2.9 Spatial distribution

The technological changes discussed are likely to manifest differently in different locations. This section summarises the influence of technology on the spatial distribution of economic growth.

2.9.1 Regional effects

There are a number of factors that influence rural and urban prosperity and attractiveness to economic activity. A lack of congestion is an important attractor of innovation and potential spur to decentralisation of economic activity. Zhang and Kockleman (2014) find that congestion in urban areas spurs firms to decentralise and agglomerate away from the urban core, favouring instead either the urban periphery or rural areas. AVs have an important role to play in changing future congestion, and hence urban form, although as discussed earlier the literature reviewed fails to provide any consensus opinion as to whether their effect on congestion in the urban core will be positive or negative. Given that uncertainty, AVs could contribute to either an intensification or decentralisation of economic activity, and result in either more compact or more dispersed cities.

Another way AVs might influence the distribution of economic activity is by changing the cost of movement of economic activity to and from rural areas. Transport costs for people and goods are a significant barrier to rural growth and sustainability. Low-cost AVs, especially non-fossil fuel vehicles, could make peripheral regions financially much more accessible, and could spur urban to rural migration of people and businesses (Cowie 2016). Distance to market will no longer be (as much of) an issue, making locating in smaller urban or rural areas more attractive and viable.

Communications technology will also have a strong role in influencing the geographic distribution of economic activity. In most countries high-speed, satellite and mobile broadband availability currently differs between rural and urban areas, although alternative (slower) internet access is often available as a baseline in most places (Preiger 2013). Nevertheless, difference in service quality has resulted in a widely acknowledged urban-rural digital divide (Philip et al 2017).

The difference in service quality between rural and urban areas is important, because as a general purpose technology, broadband's influence extends across the economy. Access to sufficient quality broadband can therefore constrain or enable various business activities and contribute to economic growth, or at least result in significant productivity differentials (Preiger 2013; Whitacre et al 2014). There is a growing body of research that has found a positive association (although not necessarily causal relationship) between broadband availability and economic growth (Holt and Jamison 2009; Preiger 2013).

These relationships might be applied to emerging forms of technology too, and show how access to technology generally can influence economic growth. Because urban areas are more economically served with new technologies, it is likely to be these areas that gain the early benefits of the technologies (Philip et al 2017). Sociological studies have found that access to technology such as broadband has positive effects for rural communities through improving civic engagement and community participation, so the influence on the future of those communities is not constrained to a business point of view (Stenberg et al 2009).

These positive effects can then make rural areas more attractive to live in compared with if they lacked access to that technology, and therefore the access has indirect effects in improving the attractiveness of rural areas. In some cases a lack of access to technology may make life difficult in rural areas, when residents cannot engage in online activity considered to be 'normal' and increasingly expected of the population by government and commercial entities (Philip et al 2017). A lack of access to technology can then drive a cycle of decline, where unemployment and lack of services leads to depopulation and an ageing population (Paniagua 2013). Indeed there is a statistically significant correlation between inaccessibility and low population density and structural socio-economic weaknesses (Davies and Michie 2011).

Specific efforts to facilitate the development of technology-based ventures have been made in some places, with varying degrees of success. In France, rural 'telecentres' function as drop in destinations for the local workforce or more nomadic teleworkers. They provide a range of services to enable people to work remotely, and can include any type of firms from satellite offices of large firms through to small enterprises (Moriset 2011). These telecentres began as an experimental feature, but are now commonplace in many countries. They are seen as an effective way to anchor the local community in the digital knowledge economy, by providing shared use of high-tech facilities that individual organisations or individuals could not themselves support. They aim to enhance quality of life and business operations in areas which might otherwise prove unattractive to business and the population (Moriset 2011).

In other places policy-based instruments are applied to increase potential for development, either through improving accessibility (virtual or physical), enhancing existing capacities and leveraging off local resources (Davies and Michie 2011).

In summary, areas away from the large urban core often exhibit poorer economic performance, with greater prevalence of structural socio-economic issues than in metropolitan areas. These differences can be exacerbated, or potentially mitigated, by new technology. One key role technology can play is to reduce the effect of distance, through enabling remote working and improving access to markets. The attractive environment in the periphery could attract an increasing share of growth, although that may require specific interventions to assist (Flora and Flora 1990).

2.9.2 Agglomeration

There is a general recognition that cities act to magnify social and commercial interaction, although the details of how this happens are not well understood. Spencer (2015) finds there are quite different dynamics at play that influence where businesses in different sectors locate, and agglomeration patterns vary between sectors. Creative and science industries both tend to establish in high concentrations in the same urban regions; however, the former tend to be heavily concentrated in central areas with vibrant and diverse urban environments, while the latter favour more homogeneous suburban neighbourhoods with little space for human interaction outside the business (Spencer 2015). Agglomeration thus affects sectors differently, and overall is a strong influence on the distribution of economic activity. That influence will continue and possibly become even more pronounced with new technology.

In both developed and less developed countries, a few large cities attract the countries' largest firms, and those firms pay the highest wages and attract the highest skilled workers (Tabuchi et al 2014). At the other end of the scale cities without the 'right' industries and solid base of human capital have less skilled and lower income workers. Krugman (1991) hypothesised that the emergence of sizeable and lasting regional differences began with the Industrial Revolution's reduction in transport costs, enabling manufacturing industries to locate in fewer, centralised locations. Other opinions suggest instead it is technological advances in the manufacturing sector that are the dominant influence driving regional inequalities. This occurred historically because core regions attracted from the periphery the most active and adaptable part of the labour market, and so migration and productivity were strongly linked (Moretti 2011). Further, interregional gaps widen over time, when larger regions can pay higher wages to their workers, attracting the cream of the workforce away from smaller regions, consistently resulting in agglomeration in larger regions.

Scale is important and so is connectivity. Although New Zealand has favourable conditions for a highly productive economy (such as a deregulated and institutionally transparent economy), the country's most productive economy is some 15% less productive than all the major Australian cities (McCann 2009). There is no simple direct relationship between urban scale and productivity; however, all the world's most productive cities are at least twice the size of Auckland. New Zealand's cities are also among the world's most isolated, which means they lack two key ingredients for productive economies. So while economic activity within New Zealand may continue to concentrate in Auckland, Auckland will continue to face challenges competing internationally.

However, new innovations can rapidly lead to larger regions become relatively less attractive, leading to reduced agglomeration (Tabuchi et al 2014). Any increasing attractiveness of peripheral regions will be dependent on their ability to embrace and apply new innovations to a greater degree than the urban core. If the core makes greater use of innovations, existing agglomeration is likely to persist. Transport infrastructure plays a strong role in supporting a decentralised layout of population and manufacturing activity. Improvements in this infrastructure, or transport innovations that lower costs, may lead to more decentralisation (Redding and Turner 2014).

Current theory indicates we are moving towards a knowledge economy, where the generation of ideas is a key driver. Florida (2002) suggests that economic inputs are increasingly reliant on an emerging 'creative class' 'whose economic function is to generate new ideas, new technologies and/or creative output'. That class is strongly influenced by quality of place. Much research has focused on large metropolitan areas as places where creativity thrives (Mcgranahan and Wojan 2007; Sands and Reese 2008; Stam et al 2008), because these large urban cores attract high proportions of talented, highly educated individuals, and creative and high-tech industries. Size is an advantage in this sense, and smaller, peripheral places are left struggling to attract or retain this creative class (Hall and Donald 2009).

This is not to say that peripheral regions do not yield innovations and economic opportunity, and in some cases the remoteness of those regions can spur the development of new ideas and businesses. In fact, peripheral regions often offer untapped development potential that government policy can seek to leverage off, and place-based policies targeting such regions can be effective in meeting national efficiency goals (Dalziel and Saunders 2014). Hall and Donald (2009) provide examples of new businesses in rural Ontario that have been established in remote areas, across a range of sectors (medical research, forestry, mining). Their development is often spurred by proximity to immovable local resources (timber or minerals) or in response to local needs (medical services). Such peripheral innovation is, however, challenged by geographic isolation, given lower accessibility of markets and greater costs. In New Zealand isolation is not as pronounced as in some other places (such as rural Ontario) given the smaller distances involved. However similar issues apply, including: expensive and infrequent transport links (by air or train); few if any complementary businesses; a spatial bias that peripheral areas are economic failures, and a lack of suitably qualified workers (Hall and Donald 2009). Those downsides are countered by the positives offered by the periphery, including: attractive natural landscapes; lack of traffic congestion and cheaper housing.

There are interventions that can influence the spatial distribution of economic activity. Dalziel and Saunders (2014) identify three: investment in physical capital, human capital and new knowledge creation and utilisation. This means that prospects for regional economic growth are not invariable, and responses to the challenges and opportunities presented by technology are possible, and can leverage off new technology.

2.9.3 Conclusions on spatial distribution

Future economic development need not be strongly dominated by the urban core, and there is a role for peripheral regions to play. However it will likely take some time, and possibly deliberate action (such as policy intervention) to overcoming existing entrenched patterns of growth. The increasing flexibility offered by technology may facilitate changed distribution of economic activity, and the emergence of new activities in non-metropolitan areas; however, that is far from certain.

2.10 Social implications of these trends

Many of the implications of technological changes are discussed above; however, some of the social implications are worth discussing as they will contribute to broader effects on urban form and employment.

Places with a skilled workforce have historically benefited most from technological advances. As discussed, while technological progress creates new jobs these are mostly confined to skilled workers (Frey and Osborne 2015). This means that places where there are already a high proportion of skilled workers have been well placed to capitalise on new technologies, where other places have not, and lower-skilled, less mobile workforces have not seen the same benefits. Regional inequalities are thus often exacerbated by technological change, possibly pointing to an on-going and increasing economic dominance of New Zealand's larger cities and high growth areas. However, as with many aspects of technological impacts, there are countering views that indicate the importance of distance will be diminished, providing the opportunity for businesses to establish in less physically inaccessible locations, given improved digital accessibility (Dellot 2015).

Housing constraints are also constraints on growth, and businesses may choose to establish in areas where their workforce can easily find appropriate accommodation. Moretti (2013) estimated that the United States GDP was constrained by 13% due to a lack of housing supply in skilled cities. To capitalise on the potential economic benefits of technology-induced growth, an adequate supply of housing is important, and the absence of adequate housing supply may result in the new-technology firms not establishing in a place (Moretti 2013). This may result in increasing non-Auckland growth until housing affordability in Auckland improves.

The effect of digital disruption on jobs will create a need for targeted labour market re-activation programmes. Historically workers have been relatively immobile, often spending long periods in one occupation. Younger and more skilled workers are often preferred to older and less skilled workers, and those who do not find employment are more likely to shift to cheaper housing nearby (even if employment opportunities are restricted) rather than moving to a region where more employment opportunities exist (Hajkowicz et al 2016).

This suggests that digital disruption, which is likely to be geographically concentrated, has the potential to exacerbate existing regional inequalities, with larger markets with a more skilled workforce better placed to accommodate technologically driven growth, and smaller (often rural) towns less likely to accommodate that growth. That is, technology can be either a threat or an opportunity, depending on one's skill set and place in the market.

2.11 Review of assessment methods and techniques

The final element of the literature review is a review of the methods and techniques employed to assess the impacts of new technologies on the nature of employment and land use.

One key observation from the literature search was that few (if any) models cover the effect of multiple technologies on employment and land use. Most focus on only a single technology, eg AVs or automation. Broader scopes are limited to research examining the general effect on employment of technology in a wider sense rather than looking at a combination of specific innovations. A common observation is that the potential effects of technology are very difficult to predict with any confidence, with many analysts suggesting attempts to make such predictions are speculative. The uncertainty is even more pronounced when attempting to understand future trends as a result of more than one technology, especially when they are acting in combination. Although we can speculate, it is difficult to predict exactly the way in which these new technologies will generate new business opportunities and services that are hard to imagine at present.

2.11.1 Scenario planning

One method of addressing this uncertainty is through the use of scenario planning. Scenario planning is 'that part of strategic planning that relates to the tools and technologies for managing the uncertainties of the future' (Ringland 2006). A scenario is defined as a story that is internally consistent and offers a plausible explanation of how events unfold over time (Gallopin et al 1997; Raskin et al 2002). The strength of scenario planning lies in its ability to consider a wide range of often very complex possible drivers of change, to account for uncertainties, and tie them together in a coherent, plausible, systematic way with the input of a range of stakeholders (Joseph 2000). Scenarios can be predictive (what will happen?), exploratory (what could happen?) or normative (how can a specific future be realised?).

Exploratory scenarios aim to capture a wide range of options, and are not a forecast, but one possible outcome. They deal with different future trajectories that might correspond to distinct future states (Maier et al 2016; Porter 1985). There is an emerging acceptance that having a 'best guess' at future conditions might no longer be appropriate, especially given uncertainty in climate, technology and socio-economics (Maier et al 2016).

Exploratory scenario planning would be valuable for addressing the impact of new technology on employment and land use given the uncertainty inherent in anything to do with technology. Different 'stories' (scenarios) representing divergent future paths could be used to understand a range of possible future outcomes such as that AVs either increase or decrease vehicle congestion significantly, with consequent effects on land use patterns. Exploratory scenario planning has been applied in land use studies, such as the European Environment Agency's Prelude (Prospective Environmental Analysis of Land Use Development in Europe). Prelude simulates five contrasting future environmental scenarios for a Europe affected by changing patterns of land use, climate change, agriculture and demographics (EEA 2008).

Gruel and Stanford (2016) describe the uncertainty of future AV uptake generally, and note the lack of formal research addressing the system-wide and longer-term effects of AVs. They further find that most of the attention devoted to longer-term effects has taken the form of speculative, informal discussion, usually focused on one or two issues in isolation (eg workforce changes and sprawl). They apply a scenario approach and structured qualitative methods to develop conceptual system dynamics models. Their model is based on an established transportation base model which describes known relations between a broad set of variables, and uses qualitative interviews and workshops to produce data for the model. The Gruel and Stanford (2016) model used causal loop diagrams (CLDs) to identify key variables and causal relationships, because CLDs can 'generate valuable insights before the relevant system behaviors can be observed or measured. They shed light on the systemic implications of known or hypothetical relationships by revealing the structure and potential behaviors that they entail'.

Childress et al (2015) developed an activity-based model to measure the impacts of AVs on the Puget Sound region in Washington. They noted there is considerable uncertainty related to AV technology, and attempted to account for this uncertainty through the use of scenarios. The model stretched current model capabilities and depended on highly uncertain inputs, but was concluded to be a useful starting point for discussions with planners and decision makers. The aim of the model was not to accurately predict future AV outcomes, but to develop appropriate ways of evaluating a range of potential impacts on regional transportation.

The high level of uncertainty associated with technology effects means there will be corresponding uncertainties in any work that relies on any projections of future change, such as cost-benefit assessments for major new transport projects. That uncertainty represents a key challenge for planners in assessing the financial implications of transport proposals, especially given the long time horizon for such proposals.

Pianta (2005) reviews a large body of scholarly research, examining the relationship between innovation and employment. In this review he groups literature that examines the effect of innovations on employment with literature that examines effects at a firm, sector and macroeconomic level. Finally, Pianta (2005) reviews the quality of employment, considering the effects on skills and wages, and the impact of organisational innovation. He concludes that this topic is so multifaceted no single approach can account for all the direct and indirect consequences of technological change, or its effects on the quantity and quality of employment.

The theoretical approach of reviewing several economic models and appropriate literature in a meta-study is common (Vivarelli 2013; Malecki 2014; Carnoy 1997; Bunghez 2015; Levinson 2015; Terzi 2011). Using this approach, authors attempt to analyse technology's impact on employment by reviewing existing research and making suggestions, drawing conclusions and identifying gaps.

Additionally, quantitative models have been rigorously used over the past few decades to assist policy makers in planning decision making and urban infrastructure management processes. Models that aid our understanding of population growth, internal migration, as well as the nature of housing and labour markets, all play a crucial role in developing land use strategies which ultimately shape our urban form and economy. Quantitative models such as input-output models are used by Osawa and Nakano (2016) to estimate the effect of emerging clean energy vehicles on employment. This approach assesses employment effects throughout the whole supply chain created by the increase in the usage of CEVs under three scenarios (upside, standard and downside) in an attempt to account for the great uncertainty that exists around the uptake of this technology.

A case study approach is often used to test and calibrate the results of such mathematical models (Alvarez et al 2011). A pure case study approach is used by Bellamy and Pravica (2011) to assess the impact of driverless haul trucks in Australian surface mining and draw conclusions about employment effects. They found that such automation is expected to have an impact on both employment at the mine site as well as at the remote control centres, although the exact impact on employment numbers, as in many of these sort of studies, is not quantified.

Statistical analysis of historic trends is used to draw inferences about possible future changes. Evangelista and Vezzani (2011) employ econometric analysis, using the three-stage least squares model (3SLS) to estimate the effects of firms' innovation strategies on employment. Their study aims to test whether firms that innovate tend to grow faster than firms that do not, and whether this is associated with higher rates of employment growth. Paul and Siegel (2001) also use a 3SLS model to examine the effects of trade, technology and outsourcing on employment and labour composition. Econometric analysis is used by a number of researchers (Harrison et al 2014; Lachenmaier and Rottmann 2011; Alvarez et al 2011; Kunapatarawong and Marinez-Ros 2016).

As previously mentioned, technology or innovation has such a broad scope that it is infeasible to account for all types of technology and accurately predict or estimate the employment effects. Developing a model that would estimate and analyse the impact is likely to be subject to many assumptions and simplifications, and the examples in the literature reviewed have a relatively narrow scope in relation to the range of innovations assessed.

2.12 Conclusions

The literature review found there is very little consensus as to how technology will affect employment in the future. If the past is any guide, an ongoing upskilling of the workforce without any significant net decrease in employment is likely, although increasingly complex and adaptive technologies may mean future employment effects are more significant.

Major new innovations such as AVs, drones, online retail and the internet of things will potentially have a much greater effect on employment and land use than have previous innovations, although commentators are notably split about the potential implications of new technology. Many experts expect few significant effects on future employment and land use patterns, although many others hold a completely contrary opinion and expect future economic structures to be very different from those of today.

One of the few matters on which there is agreement is that modelling possible future scenarios and effects is difficult and subject to much uncertainty. For this reason, most studies focus on individual innovations only, and do not attempt to quantify the effects of multiple innovations or across large spatial areas.

3 Sector interviews

To test the literature review findings about the potential effects of technology on land use and employment, interviews were undertaken with representatives from a range of New Zealand organisations. Organisations were chosen in liaison with the NZ Transport Agency, and were selected to provide coverage from relevant business sectors, in particular those making intensive use of land (warehousing and distribution) or office space (finance sector), having a retail presence and those involved in the transport sector. This section summarises the key themes identified in those interviews. A summary of the interview structure and questions is presented as appendix A.

3.1 Respondents

Some respondents wished to not have their organisation identified in this report, although were happy for their responses to be published. As such several of the respondents are referred to only by the broad sector they represent. If the respondent was happy for the organisation to be identified, only the organisation, not the individual respondent, is identified.

Interviews were conducted with:

- Auckland Transport (provider of PT and planning institute for transport in Auckland)
- Ports of Auckland
- NZ Post
- a large tertiary institution
- a major New Zealand retail chain with a head office, distribution centres and retail stores
- a New Zealand wholesaler with head office, warehouse, and distribution facilities
- a national financial institution with a head office and branch outlets.

3.2 Planning for change

Several interviews discussed horizon planning (although without all referring to it by that label) as a way of prioritising investment in new technology and understanding how change might affect their organisation. Horizon planning discussion arose out of survey questions about rate, timing and extent of change respondent organisations expected to encounter. Horizon planning is a way of thinking about planning for technological change and innovations by connecting what is possible and operative today, with what might become possible in the future. Cooley (2009) summarises the three horizons of growth, which describe how organisations typically plan for change from the prevailing current system to a desirable future state:

- Horizon one represents the operation of the current core business, where the focus is on improving performance and maximising output.
- Horizon two represents the pursuit of new opportunities that are emerging, but which require investment to bring them into the core business and begin to be profitable.
- Horizon three contains ideas for future implementation, such as research projects and pilot programmes that will represent the future of how the organisation will operate.

Horizon three is the furthest in the future, and the progression will be from horizon three to horizon two to horizon one so that opportunities are identified, invested in and eventually become operative and contribute to the organisation's operation. Typically the greatest devotion of resources is to horizon one, with less to horizon two and the least to horizon three, albeit with planning for all three underway simultaneously. That is consistent with the experience of the organisations interviewed where all have an eye to the future, have ideas about how to innovate and embrace new technologies and are investing in innovations to make them operative, but have the greatest focus on the day-to-day operation of the business in the present.

Planning for the future was identified by respondents as involving both developing new business processes and innovations in-house, and monitoring and adopting change identified in other organisations, both domestic and internationally. Respondents exhibited a real awareness of the importance of keeping up with the play in relation to technology, and organisations have structures set up to manage innovation, and attend international conferences to keep up to date with developments.

In general the feedback from respondents is there have not been any recent significant step changes in technology that have affected their organisation, nor are any such changes expected in the next few years. Instead, change arising from technology has been continuous improvements to systems and resources that already exist in order to enhance efficiency, or the slow, on-going adoption of new technologies such as online retail, rather than brand new 'game changing' technology.

There is however an awareness that more profound technological advances and innovations will arrive, and that there is a need to plan for these to ensure businesses remain competitive, and consumer demands are met. Respondents were aware of an increasing rate of technological development and major step changes likely to arise, especially those in the transport sector. 'Game changers' such as AVs, electric (clean energy) vehicles, are anticipated, albeit not expected to see widespread adoption for some time, given constraints such as the cost to purchase new vehicles and regulatory concerns, as identified in the literature review.

Other major technological changes are anticipated, and a minority part of planning for the future relates to long-term (horizon three) innovations which could be described as 'blue sky' changes. One challenge for business is bridging the gap between the blue sky thinking (typically out of universities and research institutes) and the needs of business (which is constrained by commercial practicalities). The opinion of the respondent from Auckland Transport is that the government is best placed to be the intermediary between the two, and that an intermediary role is needed to facilitate the progression of innovations to market.

3.3 Employment change

The literature reviewed identified that increasing automation or other technological advances would not necessarily result in a decrease in total employment, because often new technologies have their own labour requirements, even if labour requirements are decreased in some parts of the business. Technology change may, however, result in a changing structure of the workforce, with some occupation types more susceptible to automation than others. This has generally been the experience of the respondents interviewed, albeit due to different influences.

At Ports of Auckland, cargo volumes have increased over time in line with global freight trends. This would naturally result in additional employment being required to handle the freight; however, automation has led to significant improvements in efficiency in port operations. This efficiency arises because the volume of cargo handled per employee has increased as a result of more efficient equipment and systems. For example new straddle carriers can stack higher and therefore handle more containers per hour, but still each only need one driver. The same employment base is therefore able to handle larger freight volumes, meaning that net employment has remained relatively steady at recent times at Ports of Auckland. It is unclear how this will change in the future, and is largely dependent on growth in freight volumes, as ongoing improvements in efficiency, organisational management and technology are likely to further increase the capacity of each employee.

As business practices change, employment structures change too. Several respondents identified the possibility of moving towards different employment structures, such as greater use of contractors or adopting a crowd-sourced (Uber-type) approach to finding people to provide the service the company offers their clients. While contractors are commonplace in many New Zealand industries now, other structures are less common, although widely anticipated by the literature to provide greater mutual flexibility for companies and individuals.

Technology may result in some types of jobs becoming obsolete, but experience has shown there is usually growth in some other types that broadly balance out. Technological advances in the finance and retail sectors (eg ATMs, online and mobile banking, online shopping etc) have resulted in some types of (especially lower-skilled) employment such as cashiers decreasing, but this also meant the emergence of new roles. This trend was identified by respondents in the retail, finance and ports industries. Workers have adapted and developed new skills and a broader range of skills to remain relevant, and this is expected to continue.

In retail there has been significant increase in employment supporting online retail. The respondent company has established large, specialist teams at head office responsible for web and app design and customer insights, and also supports employment in the courier industry (for deliveries). Net employment has not decreased as a result of online retail, and although in-store employment was decreased at one point to reduce labour costs, recent changes have been to increase that employment again and invest in upskilling staff and training to create a more efficient, effective workforce. The business is still building new physical stores, and devoting energy to improving in-store customer experience, which remains the primary focus of the business.

New technologies have resulted in a significant net decrease in employment in some sectors. In the postal industry the decrease has been driven by increased automation, especially of mail sorting, and further declines are likely as automation innovations begin operating to their full capabilities, although it is expected that once automation is complete (which will be soon) those employment declines are likely to bottom out. The same is true for manufacturing and warehousing, where innovations such as barcode-driven inventory management have already resulted in significant efficiency gains and employment losses.

Automation of other parts of the postal sector such as the physical delivery of items to the destination is likely to take much longer to occur. NZ Post is watching developments in the use of AVs and drones to deliver items, but implementing the technology is some way away, even in European markets (which tend to lead New Zealand in postal innovation).

3.4 Technology trends

As identified above there have been few step changes in technology that have resulted in rapid changes to how the interviewed sectors operate. Instead technological change has occurred as an ongoing, incremental process. All respondents anticipated that their sector is expected to benefit from technological change in the future, and provided an overview of technology and innovation trends in their sector.

3.4.1 Transport

Significant changes are expected in the transport industry; however, the timing of these is a key uncertainty, and challenge for planners. While AVs are expected to be available for public purchase in a few years' time, it is likely to be considerably longer before significant benefits are experienced on the roads. Some of the key results from research and modelling undertaken for Auckland Transport indicate that AVs are unlikely to be a significant portion of fleets worldwide, including in New Zealand, for another 20 to 25 years, and that benefits of AVs only really emerge when 80% to 90% of the fleet is connected and autonomous. Even then, the relationship is not necessarily 1:1, and only about a 40% benefit is felt at this level of penetration. This indicates that while AVs may seem to be a game changer for transport, the long time until they become mainstream and inertia of existing technology will limit how much impact they will have until well beyond 2030.

The rise of AVs will not remove the need for mass rapid transit, because even if all the vehicle fleet is connected and autonomous, and therefore offers much improved cost efficiencies and capacity, there will be insufficient road capacity to move as many people per hour as rapid transit can. This means rapid transit is very much in the long-term thinking of Auckland Transport, even with the expected change in transport technology. Ride-sharing platforms such as Uber, especially when using AVs, will however complement mass transit by providing customised access to and from mass transit nodes. This 'mobility as a service' will be an efficient way of managing the first and last mile of commuter trips.

Not all changes in transport are major game changers, or very visible to the public. Auckland Transport is continually adopting new technology in its traffic monitoring and modelling teams, with the objective of improving traffic flows as much as possible even without any new or upgraded roading. These changes have the benefit of being quick to implement, and very much cheaper than new roads, and so offer good return on investment.

3.4.2 Ports

While the ports industry globally has seen significant growth recently, many ports cannot increase their capacity by expanding their physical footprint. This is largely true for Ports of Auckland, which has instead focused on improved plant and equipment and changed operational practices (layout of the terminal and ground slots, container stacking height, scheduling of ships etc) to increase their capacity. The basic plant and equipment (such as straddle carriers, forklifts, gantries and gantry cranes) is unchanged but has been improved – loading capacities and speed of operation are increased and some cranes and carriers have been fitted with automated technology, but there are no new types of plant or equipment.

Another clear trend emerging across the ports industry is bigger ships, because economy of scale means larger ships carry cargo more cheaply (per unit) than smaller ones, and are becoming cheaper to run and produce less environmental impact than older vessels. The largest container ships now can carry over 18,000 TEU (twenty-foot equivalent unit), and while New Zealand cannot currently accommodate those very large ships because of the small size of our domestic market, as trade grows larger ships are becoming more sustainable. A 9,000 TEU is the largest to have visited New Zealand, which is double the largest size five years ago. This ongoing trend represents a logistical issue for the ports in terms of how to handle large quantities of cargo that must be handled quickly (given dwell-time costs) and require large areas on land for stacking and large berths for the ships.

3.4.3 Finance

The finance sector is also experiencing ongoing incremental rather than rapid step changes. Increased use of mobile technology is to the forefront and is driving a change in how the provision of services in physical stores is managed. Physical stores are still very much a part of future planning, given the respondent's observations about the value of face-to-face contact. Future changes anticipated are ongoing improvements in mobile applications for finance, including micro-personalisation where customer service platforms are more customisable to an individual's needs. In the longer term more significant changes are anticipated, although these are expected to take some time to eventuate and their timing and form are uncertain as they are only in early stage planning at present. The respondent was unable to describe what these were for reasons of commercial sensitivity.

3.4.4 Post and freight

The movement of objects through delivery networks is an interesting example of how technological changes can have significant effects on a business, and present challenges and opportunities. The growth of new forms of communication such as social media, instant messaging and other online platforms has led to significant declines in the volume of letters carried by NZ Post, which has been a challenge for the company. However, alongside that challenge has come a significant opportunity that is expected to be the core of the business going forward: delivering of a large number of items, including parcels and other non-letter items. This has been driven in large part by a more global marketplace, and the ability to purchase goods online. Technology has therefore changed how the NZ Post business model operates, and has required some adjustment to internal processes and delivery mechanisms.

Overall the respondent identified an increasingly 'customer-centric' approach in the business, with a key to future success being diversifying the services offered, with greater flexibility for how, when and where deliveries occur. This will involve greater use of real-time tracking data and transparent information, which will also be useful in optimising delivery practices. This will be increasingly important as parcel deliveries continue to grow, and consumers expect greater immediacy in all elements of their lives. This means there will be a growing provision of same-day deliveries, where previously deliveries tended to have a one to three day window.

The rise of online retail has driven a large growth in the number of parcels handled by NZ Post, both from domestic and international origins. That growth has supported new initiatives such as YouShop (where NZ Post provides a delivery address in other countries for New Zealand consumers to use in their online orders) and Parcel Collect (the use of Countdown supermarkets and Z service stations as parcel collection points) to meet demand for new types of parcel delivery. Consumers have grown used to the immediacy of new communication avenues, and are now increasingly demanding more immediate delivery of parcels, which NZ Post anticipates will continue and is addressing. NZ Post anticipates further partnerships being explored in the future to improve the ability to respond to consumer demands, and also to further improve efficiency.

The need to increase efficiency in postal processing has resulted in increasing automation in postal sorting. NZ Post is well underway with adoption of automated sorting, with some further improvements to come. Increased efficiency is also a driver behind the roll-out of new electric delivery vehicles in New Zealand's larger towns and cities. These EVs are faster and have greater capacity (ie they can carry parcels) than the traditional bicycles, and are much cheaper to buy and operate than petrol vehicles.

3.4.5 Retail

The retail respondent described how there have been few significant changes in retail provision recently, notwithstanding the ongoing emergence of online retail and different ways it can be accessed. The core operation of the retail sector remains the same, with products sourced from manufacturers either domestically or (predominantly) internationally. International stock arrives through seaports and is trucked to distribution centres, for supply to individual stores. This basic model has remained unchanged for most of the company's history.

The respondent's opinion is that New Zealand is a follower, not a leader, in retail innovation. The largest changes that have occurred have been increasing digital integration and adoption of new technologies for internal information sharing and intelligence (including stock and supply chain management, and business intelligence). These new technologies have been integrated into existing systems to make systems more efficient, but represent an expansion and improvement in previous capabilities rather than completely new technology for the business. Increasing automation and use of technology in the retail sector generally has changed how profitable stores are, and adoption of technologies to match competitors is important to match their performance and remain viable. Compression of profit margins has changed the business model and made some stores unprofitable, although overall the respondent's store network is increasing.

Shopping in physical stores is still popular as a leisure activity, although online retail is growing and changing. Retailers are embracing different delivery platforms, including 'click and collect' (order online and pickup from a store or other central location), home delivery, or order in store and have delivered to home. There are no technological constraints to continued growth of online retail, with the business significantly expanding its capabilities and performance in this area. Nevertheless, the expansion of the company's network of physical stores reflects its belief that online retail will not replace in-person shopping in the near future, at least.

The respondent is investigating new ways to service customers in rural areas and smaller markets, with different options of physical and online channels being investigated to maximise market share and find vacant market niches. Technology offers the opportunity to gain access to markets that could not be served within the confines of a traditional store network, which has particular tenancy type, location and size requirements. Those requirements can become more flexible with the assistance of technology, so stores can become viable in places where historically they have not been.

Changing retail trends, including online sales, are not expected to have a significant effect on employment and land use. Innovations such as new ways to pay (eg Apple Pay), digital stock management systems (within the store and linked to suppliers), self-checkouts, increased digital signage, labelling and information in store will focus on improving customer experience, and on improving staff efficiency. Some of these innovations will have negligible effect on employment numbers, others might see some roles disestablished or reduced (such as checkout staff), while others will result in an increase in employment (such as website maintenance).

3.4.6 Manufacturing and warehousing

The manufacturing sector has already experienced significant employment declines as a result of automated technology. However, even that automation has not been sufficient to retain manufacturing in New Zealand in many businesses, despite its ability to lower the high labour costs here. The respondent interviewed noted that while historically one third of their products were manufactured domestically, that is now nearly nil, and most products are instead exclusively imported. Very little manufacturing remains, and that is limited to low level processes such as customisation of products made overseas.

As with other sectors, the respondent noted that much of the automation possible with current technology is already in place, including in the warehouse, and with a voice activated orders system. The business keeps track of international trends in order to make use of all possible efficiencies, notwithstanding a reluctance to be an early adopter of technology, given the cost and risk implications associated with that. Incidentally the business is largely engaged in a sunset industry as a result of changing technology, which has necessitated them expanding their product ranges into new areas.

The responses received here, perhaps even more so than for other sectors, are highly dependent on the type of manufacturing business interviewed. The diverse range of technologies, business models, and corporate attitudes to technology will result in a wide range of responses to technology in the sector. The interview conducted is therefore not necessarily representative of all manufacturing businesses, a factor which was accounted for in defining and applying the scenarios for this report.

3.4.7 Tertiary education

The potential exists for technology to significantly change the employment requirements of tertiary institutions. However the respondent interviewed said this has not yet occurred in their organisation, with broadly the same model of teaching applied now as in the past. Internationally there has been an increase in free, online tertiary courses offered by larger institutions (massive open online courses) where many thousands of students can be taught at once. That is not yet offered by New Zealand institutions, but may be in the future.

Another influence of technology has been the ability to offer training using simulation. This gives flexibility to provide training spaces for activities such as welding or automotive repair in areas where they could not have been located before, such as for reasons of noise and danger. It then gives the institution the ability to reconfigure spaces as training needs change, which is happening ever more rapidly given new technologies that are being used in the tertiary education sector.

As for the manufacturing sector, these responses are representative of the broader industry to a lesser degree than for some other sectors, and their findings were given appropriate weight in the modelled scenarios.

3.5 Impact on land use

Technology has the potential to enable more tasks to be undertaken at distance from other people, whether online shopping, teleworking or socialising. However face-to-face interaction is unanimously still seen to be key by the respondents interviewed, so although the traditional services might be automated or computerised, respondents still value physical interaction rather than an exclusively online presence. This will mean that businesses will continue to require physical space to operate from.

NZ Post described its first-hand experience of a forced loss of office space in Wellington following the Kaikoura earthquake, stating that although the technology to work remotely exists, the lack of social contact following a forced decentralisation of office workers adversely affected productivity and employee engagement.

Respondents in all sectors that have physical outlets or stores are however rethinking the ‘branch’-model. Some organisations in these sectors are rationalising their physical outlets, preferring an online presence for parts of their service. Others retain physical outlets in spite of increasing ability to replace in-person with online services, instead looking to different options for physical presence. Options for this include more flexible leases (such as pop-up stores), co-locating with other businesses under one roof, or changing the focus of physical stores (for example to become showrooms for online purchasing). Retail stores might also increasingly become ground floor tenants with other uses (such as residential, offices or tertiary) above, given increasing land values and the need to make more efficient use of land.

International transport experts are split on the potential implications of AVs for land use. Auckland Transport has access to a Delphi survey of international experts which shows a 50:50 split in opinion, with half thinking that AVs will significantly improve traffic flow, yielding significant potential for land use change, and half thinking that congestion will worsen. There is also no consensus on uptake rates, with some experts anticipating very fast changes as a result of AVs, and others expecting very slow change over a long period. There is also no consensus about the flow on effects for land use, which is consistent with the divided opinion that is put forward in the international literature.

There is an increasing awareness of the need to improve the resilience and efficiency of business networks. NZ Post is well placed to comment on these trends, given its interaction with businesses of all sizes throughout New Zealand. One way this is being addressed in many businesses is through the increasing use of more than one distribution centre nationally. Typically this manifests as one (or more) such centre in the North Island (usually Auckland) and one in the South Island (in Christchurch). That enables faster movement of stock from the distribution centre to stores and consumers (enabling next-day delivery), and also provides resilience in cases of natural disaster or transport infrastructure outages.

There is also an increasing awareness of the need to adopt flexible business practices, including in relation to land use and the occupancy of space. The manufacturing respondent related the recent development of a distribution centre, one of the key requirements of which was being built with an eye to the future, both in terms of size (allowing for expansion) and ability to accommodate technological change. The NZ Post respondent also referred to this 'future proofing' aspect of planning their facilities.

The tertiary respondent described difficulties their organisation is having with existing space, which is requiring in some cases extensive rebuilds to provide spaces that are large enough, and supplied with adequate infrastructure, to support staff and student needs. One key driver of the design is the need for flexible workspaces (generic space typology), both so that current needs can be accommodated, and so that changing future needs can also be met. Students at the institution are predominantly young people (mostly school leavers) and the respondent remarked on an increasing lack of demand for parking, which is taken to be a generational shift in attitudes towards private transport. An increasing proportion of trips to the institution are made by PT, which has implications for how much space is required to be devoted to car parking areas.

3.6 Rate and impediments of change

The literature review indicated that often the rate of change resulting from technological advances can be slow. The experience of the organisations interviewed was generally consistent with that observation. Reasons mentioned that affect technology adoption and the rate of change in sectors are discussed below.

3.6.1 Risk

Companies may be reluctant to expose themselves to risk from adopting new technologies. A lack of proven ability and uncertainty about performance means that adoption of new technology may lag its availability significantly. At Ports of Auckland the use of higher straddles took some time, given concerns about possible safety risks. Financial institutions are very risk averse, and the respondent interviewed noted this as an impediment to rapid uptake of new technology and systems. The retail respondent noted that while it is risky to be the first adopter of new technology, it is also risky to leave adoption too late, and be surpassed by competitors, so it is a balancing act to minimise risk while keeping up with competitors. NZ Post and the warehouse respondent responded similarly, both classifying themselves as a 'fast follower' of innovations (from other countries) rather than a ground breaker.

3.6.2 Regulatory constraints

Respondents indicated a generally supportive regulatory environment in New Zealand, and described successful collaboration with central government in attempting to implement innovations. Government is somewhat risk averse, however, meaning that due process must be followed before some new technologies are able to be rolled out.

One good example of this is in the use of AVs and drones. Currently there is insufficient confidence in the safety and reliability of AVs to allow them to operate autonomously, even though the technology to do so largely exists. Legislation to govern the use of AVs will be needed before they proceed beyond pilot programmes. Drones are subject to Civil Aviation laws, and currently there are restrictions on out of line of sight flying, which restricts their commercial applications.

Ports of Auckland refer to increasing political governance in their operation, which introduces non-corporate (eg social and environmental) objectives into the business's operation. That might be useful at achieving specific goals, but can make it difficult to introduce new innovations, given the extra level of influence on the business.

3.6.3 Cost

New technology comes at a price. Because of small initial demand, purchase prices start off high, and there are additional costs for implementing new technology and incorporating in existing business practices. NZ Post especially refers to this constraint, and its strategic response to consciously be a fast follower rather than ground breaker.

3.6.4 Inertia

Where existing technologies are deeply entrenched, it will take some time for new technologies to replace them, given the cost of upgrading and the stock of consumers using existing products. This is especially true given many existing business structures and systems were not put in place with flexibility or the need to accommodate change in mind. Respondents are aware of the constraint this lack of flexibility represents, and most are pursuing greater flexibility to minimise the adverse effects their organisation might experience by not being able to readily accommodate future changes such as unexpected trends or technology breakthroughs. This has involved in some cases the appointment of dedicated staff to monitor and implement new innovations, and reviews of the practices of key businesses, including supply chains (manufacturing), physical infrastructure (retail, warehousing and post), customer interaction (retail and finance) and product range (retail and tertiary).

The rate of technology change is faster than ever before; however, inertia has the potential to slow commercialisation and implementation of some new technologies. This is especially true for the transport sector, where vehicle costs are very significant, especially before new technologies have reached a level of mass market appeal. There is also an element of corporate inertia in some organisations. Some respondents who wished to not be identified noted that there was level of inertia at board level in their organisation, which was making the pursuit of new technology difficult. One respondent observed this may change as new, younger board members take up positions, given their greater awareness of the potential for technology to be beneficial, and possibly given a deliberate attempt to recruit board members with technology-based backgrounds.

Inertia is also an issue with the ongoing use of paper-based rather than digital information systems. Digital information provides greater opportunities for data mining and continuous improvement, whereas it takes much more effort to gain intelligence from paper-based recording. A move to digital systems was a key response identified by respondents, including the retail, finance, manufacturing and post sectors.

3.6.5 Linkages

NZ Post identified its strategic partnership with other companies and organisations as a key to ensuring future flexibility in its operations. Reliance on services or data offered by external sources can, however, slow the adoption of new technology, or the use of more efficient practices. One particular example noted by NZ Post was the lack of real-time traffic data, which constrained how readily users of the road network could plan optimal routes of their fleets. Traffic congestion, especially in Auckland, was noted as a significant impediment in achieving NZ Post's objectives for rapid parcel delivery. Delays from being stuck in traffic could be mitigated given adequate near real-time data, given technology exists to interpret data and recommend optimal routes. A lack of good public information often results in sub-optimal route selection.

3.6.6 Fine tuning

While most of the technology may exist for a new innovation, having it completely ready for mass application can be more difficult to achieve. For example, while technology for AVs exists, it is still subject to technical difficulties. Auckland Transport noted that the radar and laser technology required has limitations, and, for example, does not work well in hard rain or hilly areas. While these shortcomings can and will be overcome, they will limit how quickly AVs can come to market. This means there needs to be some time allowed for preparations to introduce new technology, which in the case of AVs might involve on-road testing under very controlled circumstances.

3.6.7 Complexity

For most sectors integrating new technology into existing systems is time consuming and complex, and requires a lot of training of staff, software and hardware changes and possibly changes to physical infrastructure. All of these factors are disincentives to adopting new technology, especially until innovations become more mainstream. The retail respondent noted that while historically it has been difficult to implement change quickly, many businesses recognise this and are changing corporate structure to allow for more rapid response to potential innovations. That change has become necessary due to increasing competitiveness between retailers and decreased margins, which require every possible improvement to profitability.

3.6.8 Necessity

Technology may improve efficiency, but is costly to implement, so a business decision will weigh up the net financial benefit of adopting a new innovation. That means adoption may not be worthwhile as soon as an innovation is available, and it could be some time before the company needs to adopt an innovation. Need may be the driver of that timing: the need to compete with other firms who are using the technology; the need to make more efficient use of space (eg Ports of Auckland); or the need to use technology as the only way of providing a core service.

4 Employment and land use model

4.1 Introduction

The first stage of this research project was the literature review and sector interviews, which together provide an indication of informed opinions as to the potential future direction of technological change, and the implications of that change on employment and land use. The learnings from stage one are now applied to inform the development of four scenarios to illustrate a range of potential future outcomes for employment and land use in New Zealand. These scenarios are not forecasts, they are illustrative possible outcomes intended to capture a wide range of options that correspond to distinct future states, as discussed in the literature review (Maier et al 2016; Porter 1985).

This section describes:

- the objectives of the model
- an overview of the model
- modelling methodology, including scenario definition and derivation.

4.2 Objective

The objective of the model was to provide a framework for allocating future economic activity (spatially and by sector) under a range of development scenarios, which were derived from the findings of stage one of this project. The model was to be developed at a detailed resolution to enable testing of different scenarios and to show different effects. For this reason the model is structured at a census area unit (CAU) level (n=1923), and divides economic activity into 48 sectors, providing output for eight future years (every five years from 2016 to 2056).

4.3 Overview

The model provides one indication of possible employment and land use (measured in hectares) under a baseline, ‘business as usual’ (BAU) economic future (described in detail in section 4.4.1). It is this BAU future against which the alternative (scenario-based) economic futures are compared.

A key finding of the literature review was the significant uncertainty as to the timing, magnitude and extent of economic changes that might be caused by technology. To account for that uncertainty, the assessment established four development scenarios to represent diverse future development outcomes (section 4.4.2). The model provided the mechanism for differently allocating economic growth under those scenarios, both spatially and to sectors, consistent with the future scenarios being assessed.

4.4 Methodology

4.4.1 Business as usual

The BAU projections represent a future where there have been no significant technological changes, and therefore the economy remains similarly structured to today’s economy, albeit accounting for potential future changes such as import and export activity. The scenarios for this project assume that import and export volumes will remain at BAU levels. The BAU projections are based on consensus macroeconomic forecasts, from which the economic futures model (EFM) uses econometric models to derive projections.

The BAU projections were calculated using the EFM. This is a multi-regional economic input-output model that captures economic growth feedbacks between regions and the rest of the New Zealand economy. A key feature of the model is that it captures not only the direct economic effects of growth in final consumption, but also the indirect (ie through supply-chain) and induced (ie through consumer spending) economic effects. Only downstream effects are considered, as the EFM is a final demand model. The model is run using scenarios, which map out possible growth paths for all sectors to a 40-year horizon, across all of New Zealand. For this research, the core output of interest from the EFM was employment projections. These were produced to a region level (n=16) and for 48 economic sectors. The most recent sub-regional employment data available (Statistics New Zealand's Business Directory 2016) was then used to spatially distribute employment activity within each region, assuming existing spatial distributions are maintained into the future. Employment data is provided as a modified employment count (MEC), a measure of employment that combines Statistics New Zealand's employment (Statistics New Zealand 2016b) and working proprietor (Statistics New Zealand 2016c) counts to estimate the total workforce, including both paid employees and working proprietors.

The employment projections were then used as the basis for assessing the land area that employment would require to accommodate it. The land use projections were calculated as a two-step process, drawing on empirical data collected for land use studies around New Zealand (including Yeoman et al 2016, Foy and Foy 2016; Akehurst and Foy 2006; Fairgray and Fairgray 2017). First, employment in each sector was multiplied by a workspace ratio (average floor area occupied per employee), to yield an estimate of total floorspace occupied by all employees. Different workspace ratios were applied for each sector and regional variations were accounted for.

The second step was to convert floorspace estimates into estimates of the land area required to accommodate that same employment, using floor area ratios sourced from the same land use studies. The floor area ratios account for varying intensity of use by sector (including buildings' site coverage, vertical development and car parking) and make allowance for roads and other land that is not available for business uses (public space etc). The land area estimates are therefore a measure of the net land area required by that employment.

Output from this process was a set of employment and land use projections for all CAUs (n=1923), sectors (n=48) and for eight future years (every five years from 2016 to 2056). The projections provide a comprehensive picture of employment and land use in the New Zealand economy, and sufficient detail to allow flexible aggregations of the detailed projections to provide useful summary metrics. Projections are grouped to urban areas and 13 sectors, for interpretation and presentation.

4.4.2 Scenario definition

Four scenarios are presented. Together they capture a wide range of economic development options to reflect the uncertainty inherent in outlooks about technology-driven change. The scenarios reflect a general consensus in the literature that technology change will reduce employment, although historically similar projections have proven unfounded. That possibility also exists here, and although the scenarios are intended to represent a broad range of possible future outcomes, they are only possible outcomes, and other possibilities may also occur. This is especially true for potential employment increases, which can occur if new technologies spur previously unforeseen new industries or occupation types. Due to the difficulty of predicting such changes the scenarios applied may understate future employment growth, which is a limitation of the projections presented.

The definition of the scenarios is consistent with the findings of the literature review, which consistently indicated two key employment changes that might occur as a result of new technology: how much employment there will be, and where that employment will be located. These two factors drove the definition of the scenarios for this research:

- The amount of employment will be influenced most strongly by the degree to which automation occurs. From the literature, increasing automation is inevitable (Frey and Osborne 2015; Bungez 2015; Spiegel 2013) but there is no consensus as to its likely degree, timing or effect by industry sector. To account for this, two alternate automation scenarios are presented: lesser and greater.
- Where employment will locate is a complex issue, again with no widespread consensus in the literature. Experts suggest variously that economic activity might become either more concentrated in urban areas (Hajkowicz et al 2016; Paniagua 2013) or more dispersed (Zhang and Kockleman 2013, Cowie 2016). This reflects the possibility that improved technology may make working from remote locations easier, or alternatively historic trends of concentration will continue, driven by cities being focal points for innovation. The literature provides no consensus as to which future outcome is more likely, so both concentration and dispersal scenarios are presented.

Combining the two key change outcomes (automation and location), and two possible alternatives for each, yields four scenarios in total (table 4.1).

Table 4.1 Scenario definition

	Dispersal	**Concentration**
Greater automation	Greater automation, dispersal	Greater automation, concentration
Lesser automation	Lesser automation, dispersal	Lesser automation, concentration

Within each scenario the change to the location and quantum of BAU employment will vary depending on the rate at which new technologies are adopted, and the magnitude of the ultimate effect. As with other aspects of this research there is little consensus about adoption rates and the magnitude of effects. The employment modelling was based on assumptions about both of these factors, using as a guide findings from the literature review and stakeholder interviews. In some cases those findings were quantitative estimates of the scale and timing of potential effects (Frey and Osborne 2013 and Hajkowicz et al 2016 were helpful in this regard), but in many cases no quantitative estimates were provided, and inferences about potential values were adopted.

The rate of change of employment practices was categorised to slow, moderate or fast, corresponding to effects being completely realised by 2046, 2041 and 2031, respectively. Effects were assumed to be experienced linearly. The research project relating to technology diffusion[1] (concurrent with this project and therefore as yet unpublished) would assist in providing a superior understanding of the nature of potential adoption curves; however, the high degree of uncertainty about when new technologies might become mainstream will prove challenging for any similar modelling.

The 48 sectors in the model were categorised independently for both the rate of adoption and magnitude of effects, and for the scale and likelihood that they will either concentrate or disperse. Also taken into account in these categorisations was the location of that activity, with all CAUs categorised to one of seven

[1] The impact on the transport sector of new technology adoption and the rate of technology diffusion (the S curve)

types of urban area, where the existence of an urban area is defined by Statistics New Zealand (2013) and the type of area was determined by population and economic role[2].

Tables 4.2 and 4.3 below summarise the employment growth drivers of the different scenarios, relative to the BAU scenario. The change stated (eg 'Small decrease') was linked to a quantitative measure to describe the ultimate increase or decrease in employment as a result of automation or location-based change, and employment projections were produced for each of the four base scenarios (greater or lesser automation, and concentration or dispersal). The results of those four base scenarios were then combined to produce the four output scenarios (greater automation, dispersal; greater automation, concentration; lesser automation, dispersal; lesser automation, concentration). That combination is achieved by calculating employment projections for the entire country (at the detailed spatial and sectoral level) for the automation scenarios and then adding or subtracting modelled changes from the location scenarios. In some cases that led to the effect of the individual base scenarios amplifying each other (eg a large decrease due to automation and a further large decrease due to dispersal), and in some cases the effect partially cancelled out (eg a large decrease due to automation and a large increase due to concentration). The four key sectors summarised in this assessment were all assumed to experience a moderate rate of change, which results in effects being completely realised by 2041.

Table 4.2 Scenario definition: employment change related to automation (relative to BAU)

Sector	Lesser automation	Greater automation	Rate of change
Agriculture and horticulture	Small decrease	No change	Slow
Mining	Small decrease	No change	Slow
Manufacturing	Very large decrease	Small decrease	Moderate
Infrastructure	Small decrease	No change	Slow
Construction	Moderate decrease	Very small decrease	Slow
Transport	Very large decrease	Moderate decrease	Moderate
Wholesale trade	Moderate decrease	Small decrease	Slow
Retail and services	Moderate decrease	Small decrease	Moderate
Telecommunications	Moderate decrease	Small decrease	Fast
Offices	Large decrease	Small decrease	Moderate
Education	Moderate decrease	Small decrease	Slow
Health	Moderate decrease	Small decrease	Slow
Services	Large decrease	Small decrease	Moderate

A very large decrease is an ultimate change in employment as a result of automation (or location) of more than 30%, a large decrease is 15% to 30%, a moderate decrease is 5% to 15%, a small decrease is 2% to 5%, and a very small decrease is less than 2%. The same scale is applied to increases.

The employment effects of the automation scenarios were assumed to be all neutral or negative, while the concentration and dispersal scenarios result in positive employment growth (in excess of the BAU scenario) in some types of urban areas and negative growth in others.

[2] Metropolitan centres (Auckland, Wellington, Christchurch), large cities (population 100,000+, Hamilton, Tauranga, Dunedin), large towns (eight towns of population 50,000–100,000), medium towns (population 20,000–50,000), small towns (population 5,000–20,000), other urban areas (population 500–5,000) and rural areas.

Table 4.3 Scenario definition: employment change related to location (relative to BAU)

	Concentration	Dispersal
Metropolitan	Large increase	Large decrease
Large city	Moderate increase	Moderate decrease
Large town	Small increase	Small decrease
Medium town	Small decrease	Moderate increase
Small town	Large decrease	Large increase
Other urban areas	Very large decrease	Very large increase
Rural	Very large decrease	Very large increase

4.4.3 Scenario projections

The core model output was employment and land use projections for the four scenarios. Those projections were assessed by applying the different magnitudes and spatial allocation of employment growth to the BAU projections. Output of this stage was five sets (one for each scenario and one for BAU) of employment and land use projections for all CAUs (n=1923), sectors (n=48) and for eight future years (every five years from 2016 to 2056). The detail in those projections allows comparison with the BAU, and between scenarios, from many perspectives, including:

- the geographic distribution of economic activity
- the quantum of employment and land use in each location
- the structure of employment and land use in each location
- changes in each location over time.

The projections are based on the current structure of the economy, and do not assume any major structural shift or evolution of new industries. The changes included are those relating to the relative dominance of existing industries, as driven by consensus macroeconomic projections relating to the outlook for existing sectors.

4.4.4 Key output definitions

Two key perspectives are adopted for interpreting model output. The first is a spatial perspective, which describes how the distribution of economic activity around New Zealand might vary given different scenarios. Four urban areas are presented to provide an indication of a range of different towns and cities. There are relatively few urban areas within each size category, and so there are many differences between their key physical characteristics of each, such as location (coastal or inland, North or South Island, proximity to other urban areas, topography, economic production etc). The four urban areas presented were chosen to be representative of other towns and cities of a similar size, acknowledging the inherent differences between them. The areas chosen were:

- Auckland (one of three large metropolitan cities)
- Hamilton (one of three large cities)
- Nelson (one of eight large towns[3])
- Ashburton (one of 10 medium towns).

[3] Although Nelson is governed by a city council, the label 'town' is applied here to refer to a hierarchy of urban areas, where the group including Nelson also includes urban areas with a smaller population.

Those four areas are distributed throughout New Zealand, including coastal and inland, North and South Islands, etc.

The second perspective is a sector perspective, which describes how the distribution of economic activity might vary throughout the economy. Sectors were chosen that employ large numbers of workers throughout New Zealand, are of interest in relation to technological change and include both land intensive (high density) and land extensive (lower density) activities. Four sectors were chosen for analysis:

1 Manufacturing

2 Transport

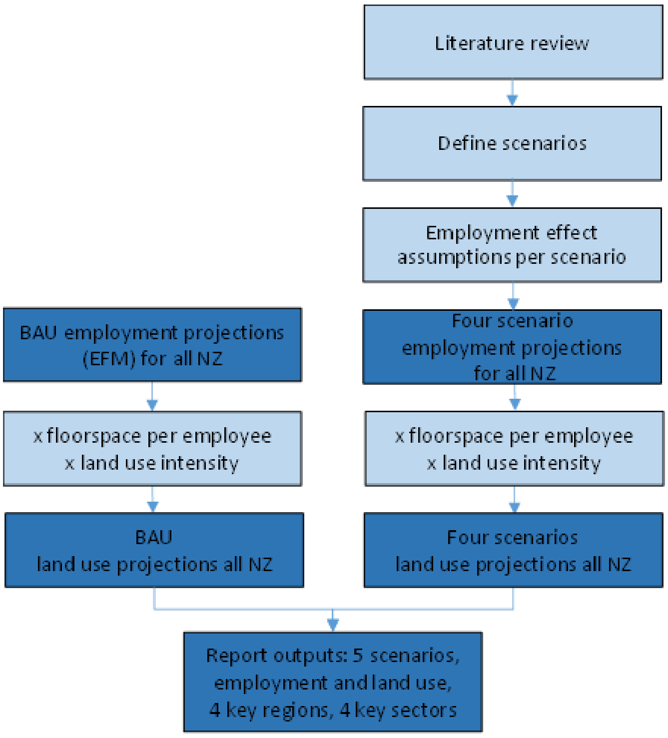
3 Retail and services

4 Offices.

Sectors were defined with reference to the Australian and New Zealand Standard Industrial Classification (ANZSIC). Level 1 of that classification was used, so that manufacturing in the model is the ANZSIC division C Manufacturing, transport is division I Transport, and retail and services are divisions G Retail Trade and H Accommodation and Food Services. The offices sector includes five divisions which all have office-based activity as their core land use.[4] Note that land use is not projected for primary industries (agriculture and horticulture, and mining) although employment is projected for those sectors.

An overview of the methodology is shown in figure 4.1.

Figure 4.1 Methodology overview



[4] K Financial and Insurance Services, L Rental, Hiring and Real Estate Services, M Professional, Scientific and Technical Services, N Administrative and Support Services, O Public Administration and Safety

5 Employment and land use projections

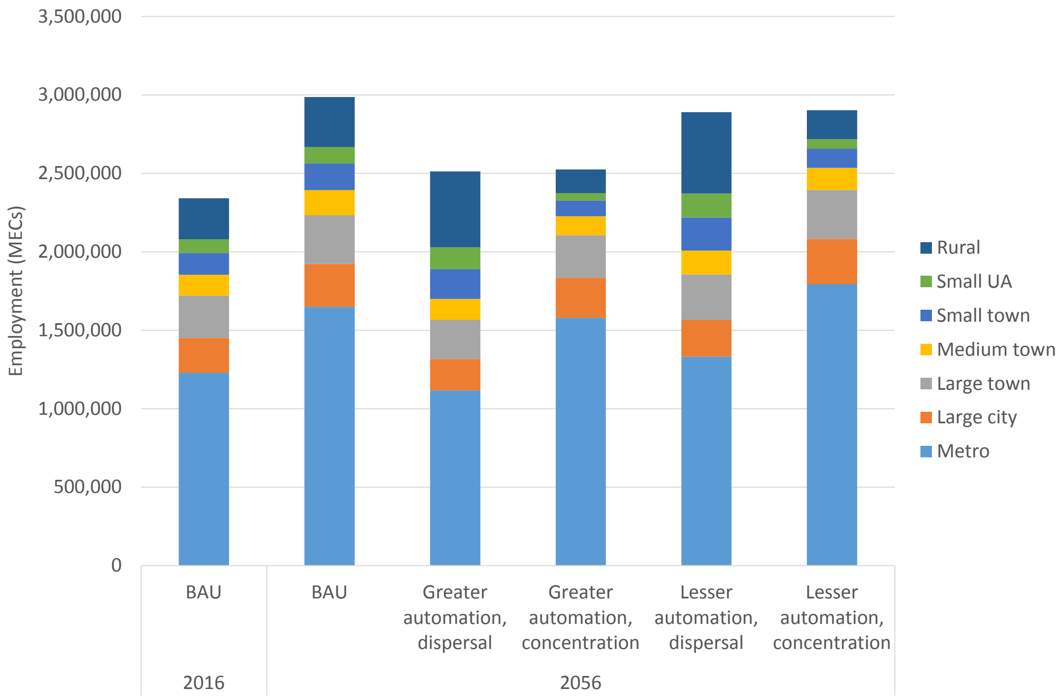
This section summarises the output from the model's projections, first at a national level (section 5.1) for both geographic and sectoral distributions, then gives summaries of key observations from a spatial perspective for the four sample urban areas (section 5.2), and from a sector perspective for the four sample economic sectors. Data underlying the figures in this section is provided in appendix B.

5.1 Overview

5.1.1 Spatial perspective

Total New Zealand employment is currently 2.34M MECs, of which 1.23M (52%) is in the three large metropolitan centres of Auckland, Wellington and Christchurch. Of the balance, large cities employ 222,000 (9%), large towns 270,000 (12%), smaller urban areas 360,000 (15%) and rural areas (11%). By 2056 total national employment would increase to 2.99M under a BAU future, or 4% to 16% less (2.51M to 2.90M) as a result of automation (figure 5.1). It is worth noting at this point that these are not predictions of future employment; they are projections of employment under the assumed combination of future circumstances and are based on Statistics New Zealand's (2016d) medium growth population projections that the current national population of 4.69M will increase to 5.92M by 2043. The same population projections are used in all scenarios.

Figure 5.1 New Zealand employment by urban area and scenario

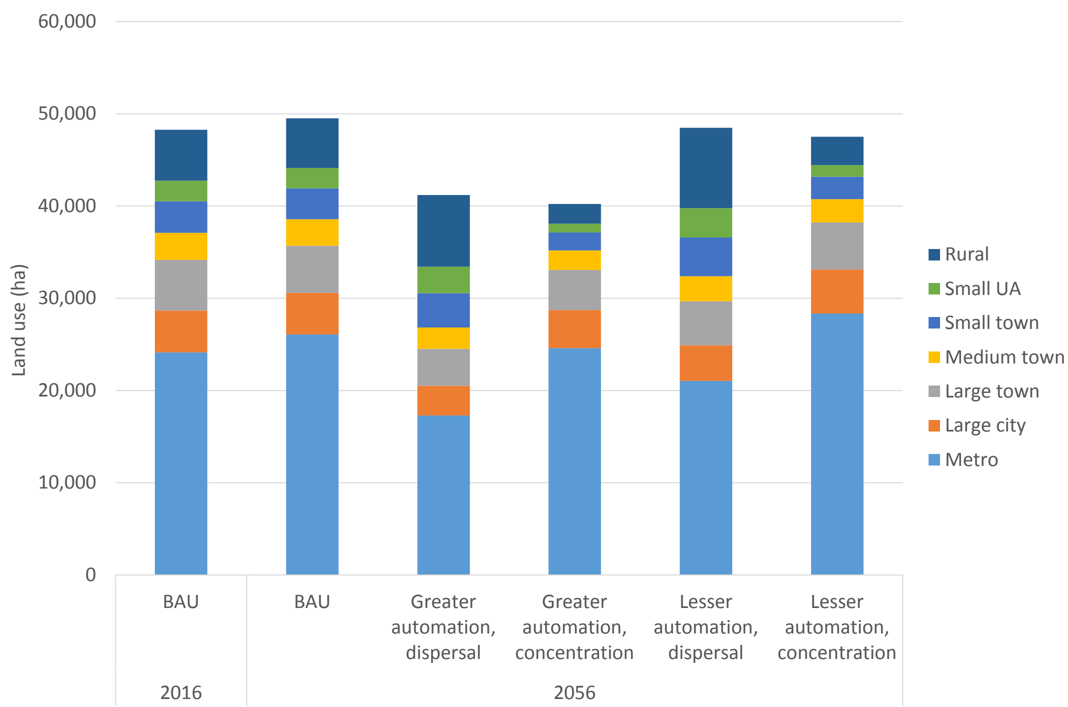


Metropolitan centres would by 2056 vary between 44% and 63% of total national employment (greater automation, dispersal and greater automation, concentration scenarios respectively) while rural areas would be between 19% and 6%. Larger population centres would attract greater shares of employment and require larger areas of land to accommodate workers, under the two concentration scenarios. Rural and smaller urban areas would have a declining share and number of workers under these scenarios, which are consistent with a significant body of opinion in literature that expects concentration to continue, given the intangible benefits of face-to-face contact in the workplace (sector interviews, Gajendran and Harrison 2007; Thatcher and Zhu 2006; Golden 2006).

Under the dispersal scenarios the situation would be reversed, with a move away from larger centres facilitated by technological improvements allowing workers to have more options with where they live. Dispersal scenarios would be contrary to long-term trends in New Zealand, although there is the possibility that imminent technological advances might result in changes to long-established patterns, and recent small increases in telecommuting (Statistics New Zealand 2014), might gather speed (Greenwood 2012).

The scenarios used are based on the literature's indication as to potential employment effects in each sector. The general consensus is that future technology change will be likely to reduce employment, and while similar expectations have existed historically, such as during the industrial revolution, widespread employment declines do not always come to pass, and historic attempts to predict the future of employment have tended to significantly overstate the disruption to employment (Autor 2015a). As discussed in the literature review, theories relating to employment change have not adequately considered the role of new technologies in stimulating new employment. One reason for this inadequate consideration is that it is very difficult to foresee how new technology creates new types of activity and stimulates employment growth in other occupations in affected sectors. That is, there can be spin-off benefits for employment from automation (Frey and Osborne 2015), and these positive effects are often not accounted for in employment projection models. The model developed for this study is possibly subject to the same conservatism, and may understate future employment growth, which is a limitation of the projections presented.

Figure 5.2 New Zealand land use by urban area and scenario



Total land area required to accommodate the workforce shows similar trends, and under the most pessimistic scenario (greater automation, concentration) land area required would be 19% less than a BAU projection in 2056, or 2% to 4% less under lesser automation scenarios (figure 5.2). The model includes an assumption that recent labour and multifactor productivity gains and how efficiently space is used will continue (Statistics New Zealand 2016a). That means that growth in land demand will be slower than employment growth under all scenarios.

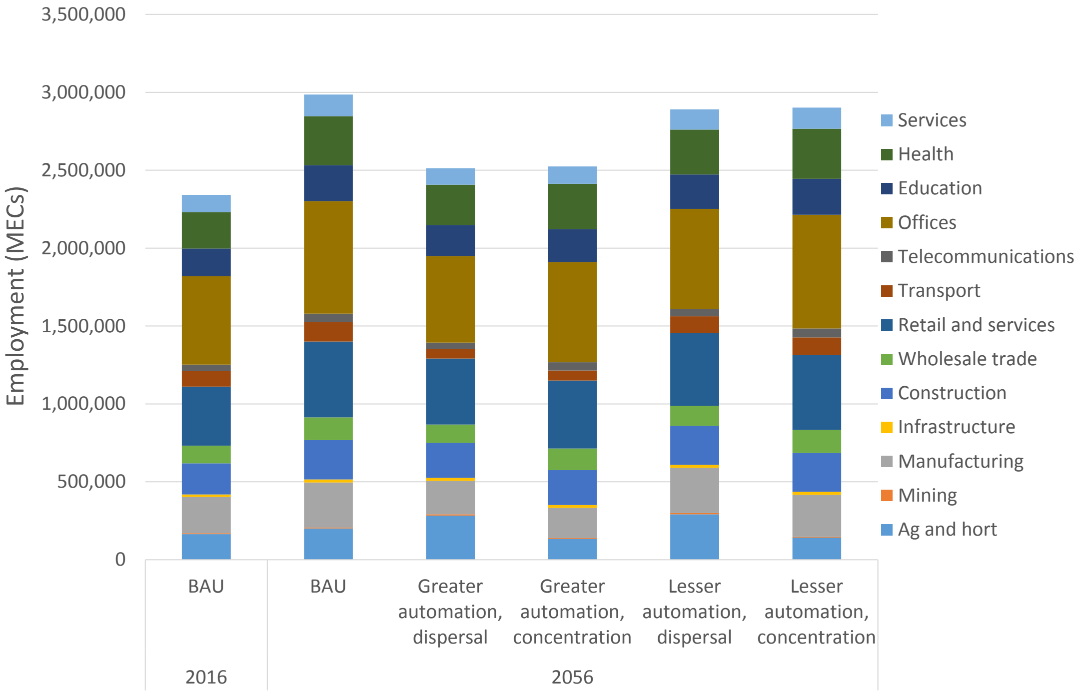
5.1.2 Sector perspective

The largest employment sectors are offices (566,000 MECs, 24% of national employees), retail and services (380,000, 16%), health (234,000, 10%) and manufacturing (233,000, 10%). Under a BAU future total national employment in those sectors is projected to increase by 24% to 34%, although under the scenarios growth would be significantly less, and in some instances there would be a decline in employment relative to current (2016) levels (figure 5.3).

Office employment is projected under a BAU to increase to 722,000 MECs, although that could have decreased below the 2016 level to 555,000 (greater automation, dispersal) or alternatively might have increased by nearly 30% to 730,000 (less automation, concentration). The possible decline in employment reflects literature findings that the rise of artificial intelligence may have profound impacts across a number of office-based activities, replacing human workers with machines in ways never previously seen (Frey and Osborne 2015; Hajkowicz et al 2016).

Retail and services employment is projected to have a narrower range of growth, and to be slightly less vulnerable to effects of automation than office-based employment. The scenarios indicate an increase of retail and services employment of between 12% (to 423,000 MECs, greater automation, dispersal) and 27% (to 481,000 MECs, less automation, concentration).

Figure 5.3 New Zealand employment by sector and scenario



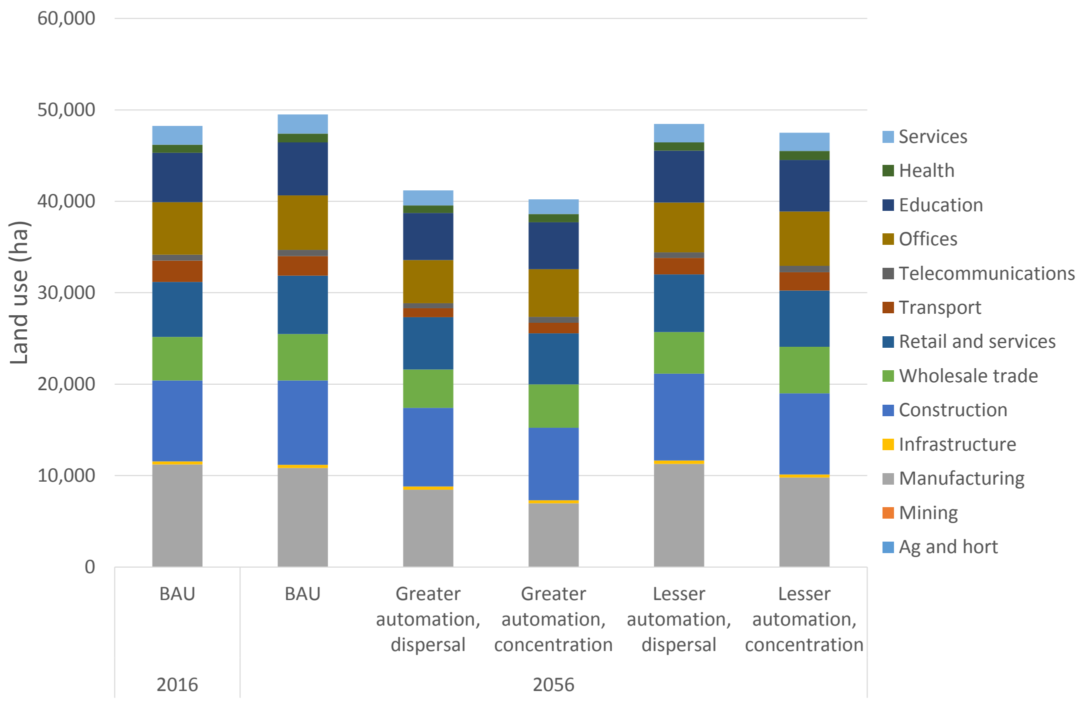
The heath sector has a similar growth outlook to retail and services, given that both are strongly influenced by population growth. The health sector is currently one of the fastest growing parts of the economy, and this is expected to continue to grow due to an increasing and ageing population and the provision of new treatment options. However technological change is likely to slow this rate of employment growth as artificial intelligence begins to replace some roles in the sector (Hajkowicz et al 2016). There is a greater likelihood that employment in the manufacturing sector will decrease from current levels, with both the greater automation scenarios showing that decline, and a most optimistic scenario that yields growth only of the same scale as the BAU future.

Transport is the other large sector that is projected to experience employment declines from current levels, influenced by the very high likelihood that AVs will replace large numbers of employees, so that by 2056 sector employment might be as low as 60% of current levels, even accounting for the fact that there are likely to be more vehicles on the road. It is noted that the transport sector contains many more types of occupations than just drivers, however, and employment decreases among other occupation types (mechanics, administration etc) are likely to be more modest and parts of the sector may even show some employment growth. The sector also includes air and sea transport, which may be affected by automation, although likely to a lesser extent than road transport.

The combination of background productivity improvements facilitating more efficient use of land and technologically induced employment decreases will yield much reduced demand for employment land in the many sectors. Land occupied by the transport sector might be as little as 40% of current levels by 2056, while in manufacturing that figure would be just over 60%. Increasingly efficient use of office space would see a decline in demand across three of the four scenarios, with an increase only under the lesser automation, dispersal scenario (figure 5.4).

These results indicate the potential for future land requirements to be lower than current requirements in many instances, especially taken in the context of many of New Zealand's regions where population declines are projected. Higher growth areas are likely to still see an increase in land demand, although the spatial distribution of that growth around the country is likely to be relatively uneven, raising the possibility of increasing social inequity (Paniagua 2013 and Davies and Michie 2011).

Figure 5.4 New Zealand land use by sector and scenario



5.2 Spatial perspective

This section summarises scenario projections from a spatial perspective, for four key urban areas of interest.

5.2.1 Large metropolitan city: Auckland

Auckland is the country's largest urban area, and strong demographic and economic growth is projected. The Auckland urban area's population is projected to grow from 1.50M in 2016 to 2.14M in 2043 (under a medium growth scenario). The urban area's employment count is projected to increase from 767,500 MECs in 2016 to 1.08M by 2056, under the BAU scenario (table 5.1). Under these scenarios the projected future employment ranges from a low of 729,000 (greater automation, dispersal) to a high of 1.17M (lesser automation, concentration). Again, these are not predictions of future employment, but are rather projections of employment under the assumed combination of future circumstances.

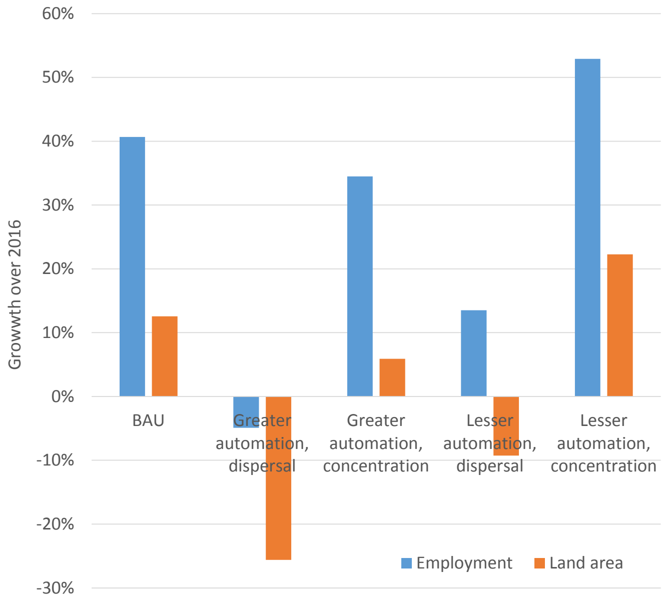
Table 5.1 Auckland urban area employment projections by scenario

Scenario	2016	2056
BAU	766,500	1,078,300
Greater automation, dispersal	766,500	729,000
Greater automation, concentration	766,500	1,030,900
Lesser automation, dispersal	766,500	870,200
Lesser automation, concentration	766,500	1,172,100

As the country's largest urban area, Auckland will have strongest growth in employment and land use under the concentration scenarios. Auckland's employment, and its share of total New Zealand employment, have both increased significantly since 2000. Auckland region's total employment has increased from 615,000 MECs in 2000 to 764,000 in 2016, growth of nearly 150,000 MECs, or 24%. Employment in the rest of the country has grown by only 13% (168,000 MECs). This faster growth has seen Auckland's share of New Zealand employment increase from 31.9% to 34.1%. If these trends continue, the two concentration scenarios, where economic activity concentrates in the larger centres, are more likely for Auckland than the dispersal scenarios.

The scenarios indicate a large potential variation in employment numbers in Auckland. The concentration scenarios indicate 20% to 30% faster growth (2016–2056) than the dispersal scenarios, and the lesser automation scenarios would have 15% to 20% more employment than the greater automation scenarios (figure 5.5). The highest employment scenario (lesser automation, concentration) would be more than 50% higher than both the lowest (greater automation, dispersal) and the current (2016) by 2056.

Figure 5.5 Auckland employment and land demand change 2016–2056



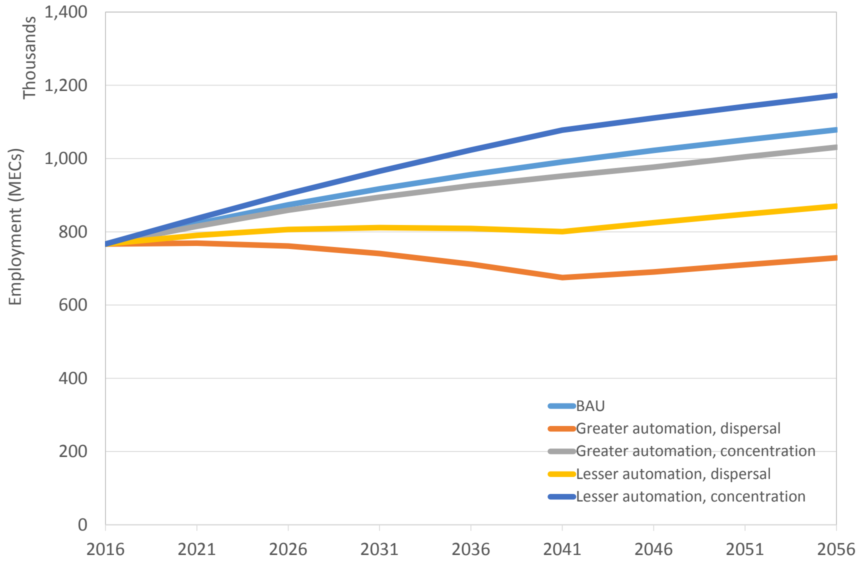
The change in Auckland's employment numbers over time under the scenarios is shown in figure 5.6. Only the lesser automation, concentration scenario would result in more employment in Auckland than the BAU future, and under that scenario employment would be 10% more than BAU employment. This relatively modest increase over the BAU is because the increase in employment due to a concentration effect will be reduced somewhat by increased automation. Although only one scenario is more than the 2056 BAU employment projection, all but the greater automation, dispersal scenario would yield growth in employment over the 2016 base. The strong effect of the concentration assumption is apparent in the projections, with the two concentration scenarios notably more optimistic about employment counts than the dispersal scenarios.

Employment growth modelled is influenced by the uptake horizon for technological change, which is set at 2041 for many key industries and scenarios. That timing is why employment count (and land use) have notable inflection points at that time (figure 5.6). This reflects that sectors will be largely as automated as they can be by that time, so ongoing population growth post-2041 will result in employment (and land use) growth. The post-2041 shape of the projections also indicates what the pre-2041 shape would be in the absence of the assumed technology effects.

In addition to the total quantum of change projected in Auckland, the model also yields sub-regional spatial projections. For Auckland these projections indicate that there is unlikely to be significant change in the spatial distribution of employment in Auckland. This is due to the potentially broad reaching effects of automation across sectors, including offices, warehousing, transport etc and also to the relatively large inertia of the established employment base in each area. For these reasons the CBD will remain the dominant employment area, and other parts of urban Auckland will continue to play a similar role in the regional economy. The ability for employment numbers to continue to increase, either in any single location or across the urban area generally, will be dependent on the provision of adequate infrastructure to support that growth. Infrastructure provision therefore has the potential to influence the scale and location of growth. This indicates that to achieve the local government development objectives, cost-benefit assessments will need to adequately recognise benefits to urban form.

Under the two concentration scenarios significant employment growth would occur in the CBD and fringe with 2016 employment (191,000) increasing by 36% to 52% (70–100,000 workers) by 2056. Other central areas would grow by similar proportions, with slightly weaker growth in more peripheral areas such as the urban parts of the former Waitakere and Rodney Districts, and much weaker growth of less than 20% in Auckland's rural areas.

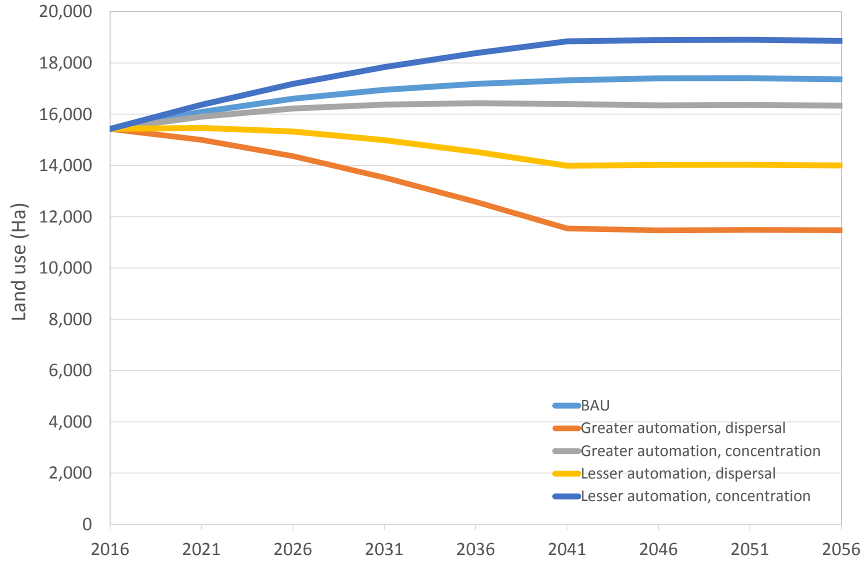
Figure 5.6 Auckland employment 2016–2056 (MECs)



None of the scenarios indicate any significant change in role for current major port infrastructure (sea or airports) in Auckland, especially given the large inertia that exists, and would act against changing their location, and because geographic changes in the distribution of activity are relatively small compared with the current quantum of economic activity. Auckland would under all scenarios remain easily the largest economy in the country, which would also act against any major infrastructure changes being expected. The transport movements associated with ports may change independent of concentration scenario, because the movement of freight will be driven by consumer demand, and is not linked to employment. A more fundamental influence on port transport movements will be the location of ports, with the possibility for inland ports to be developed away from ports' existing locations, as a result of corporate or political strategy. Such changes are difficult to predict, and transport and land use planning should aim to be responsive to those one-off location changes.

The land area required to accommodate economic activity follows similar trends to employment, although given the assumed increasingly productive use of space over time the increase in land use will be lower than employment growth (figure 5.7). For the dispersal scenarios a decline in land use is projected in Auckland because employment, and the land it occupies, would be more widely dispersed around the country, especially into regional areas. The concentration scenario is not concentration in the sense of a more compact urban form, instead it reflects a preference for activity to locate in Auckland (and other larger urban areas) than in smaller urban areas. By 2056 under the dispersal scenarios between 9% and 26% less land will be required. Under the concentration scenarios it would instead be an increase between 6% and 22%.

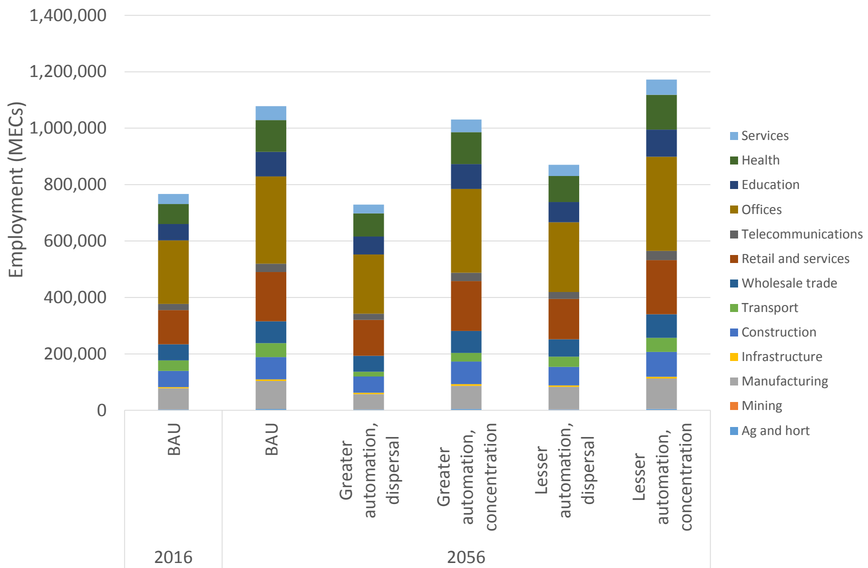
Figure 5.7 Auckland land use 2016–2056 (ha)



Note that post the 2041 point of inflection in the data, the projections for Auckland indicate that ongoing growth in demand for land is broadly balanced out by the assumed increase in productivity, and therefore land demand is relatively stable.

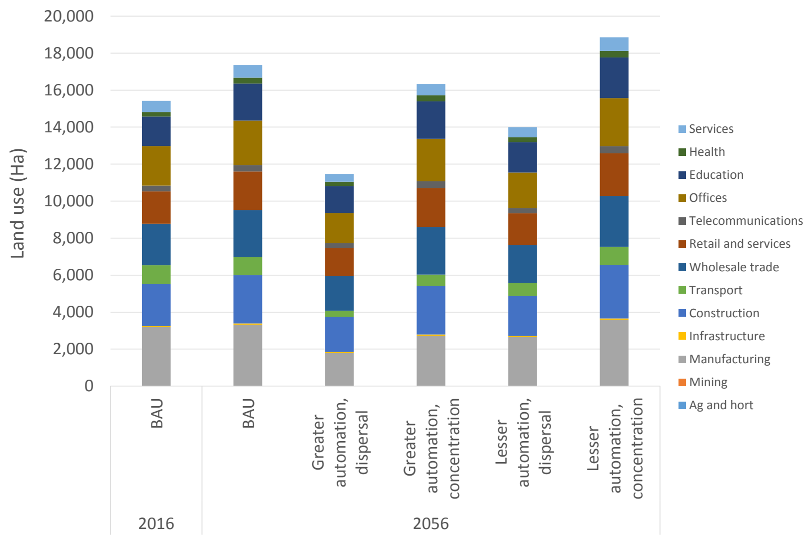
Currently offices are the largest employment sector in Auckland, with 24% of the workforce, followed by retail and services (16%), manufacturing and health (both 10%). That structure is not projected to change significantly, although under the greater automation scenarios manufacturing employment would drop from 10% to be only 8% of urban area employment by 2056, and health, offices and retail employment would all make up slightly larger shares (figure 5.8).

Figure 5.8 Auckland employment 2016 and 2056 (MECs)



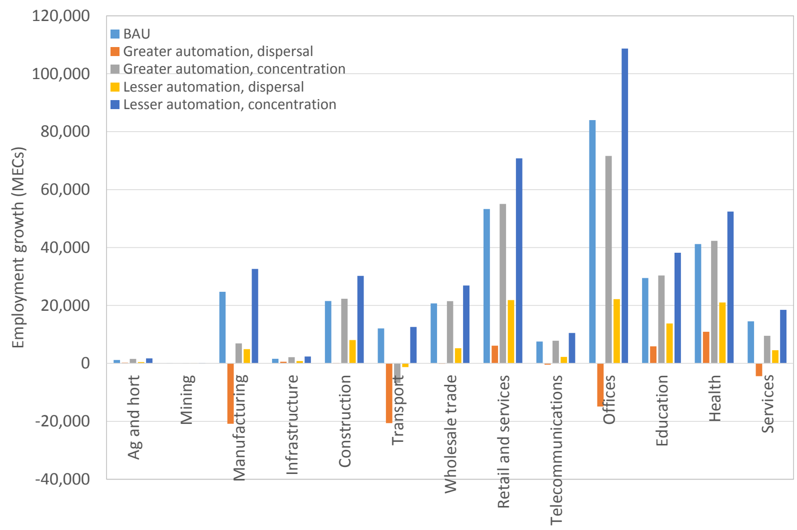
These patterns are more pronounced for land use. Manufacturing represents extensive land use, occupying an estimated 21% of Auckland urban area employment land in 2016. With high levels of automation that share may drop to 16% by 2056, as a result of a decline in employment and increasingly efficient land use (figure 5.9). The decrease would be significant in nominal terms, from 3,200ha to 1,800ha. The largest increase in land would be education (600ha), retail and services (550ha) and offices (450ha). The possibility exists that these activities may be increasingly accommodated in higher rise buildings, especially in the CBD, and especially for offices, although alternatively a dispersal future may eventuate where telecommuting and decentralisation becomes more prevalent.

Figure 5.9 Auckland land use 2016 and 2056 (ha)



Significant employment declines are possible under the greater automation, dispersal scenario, with a decline (2016–2056) of 10,000 to 20,000 workers in manufacturing, transport and offices (figure 5.10). Other scenarios would all result in employment growth across all sectors, albeit in some cases modest, although assumptions relating to dispersal or concentration have a large effect on projections. Office employment and retail are especially variable in this regard, with literature indicating no consensus about the likely future direction of growth, and thus providing little assistance to understanding where within a relatively broad range future employment might fall. Office employment may increase significantly in line with population growth, or the ability to work remotely (ie from home) might alternatively result in a move of office activity away from Auckland.

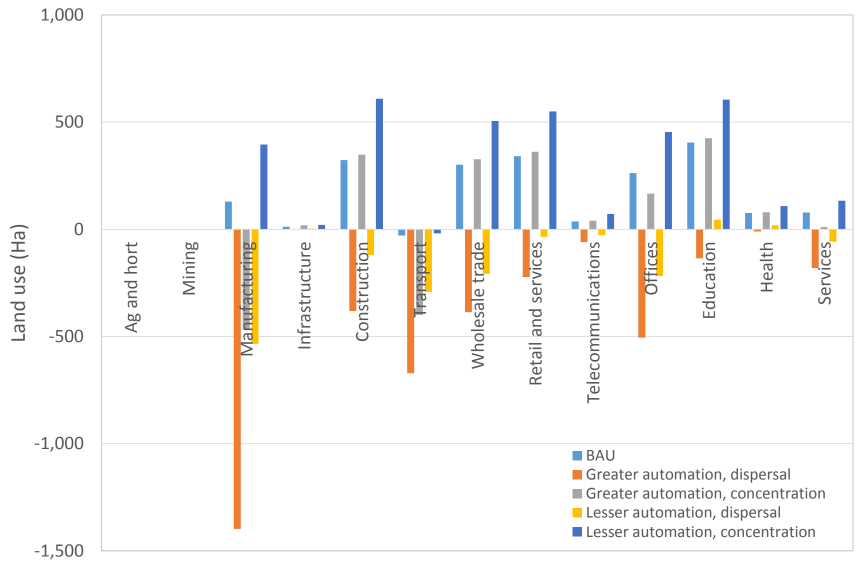
Figure 5.10 Auckland employment change 2016–2056 (MECs)



Other strong growth sectors include education, health and retail and services, while manufacturing, transport and services are all projected to experience lower increases in employment.

The increasingly efficient use of space that underlies all projections in this assessment shows through clearly in projections of land use change. The sectors which are projected to experience the weakest employment growth are projected to experience declining demand for land. This is especially apparent in the manufacturing and transport sectors, as well as other sectors under some scenarios (figure 5.11). Certain types of technology, such as 3D printing, have the potential to significantly alter how some sectors operate, and if they are widely adopted might result in a much lower need for business land. Other sectors such as education, retail and wholesale trade are less likely to experience employment declines, and an increase in land demand will occur under more of the scenarios for those sectors.

Figure 5.11 Auckland land use change 2016–2056 (ha)



5.2.2 Large city: Hamilton

Hamilton is the country's fourth largest urban area, with a 2016 population of 196,400, projected to grow to 278,000 in 2043 (under a medium growth scenario). The urban area's employment count is projected to increase from 99,900 MECs in 2016 to 126,500 by 2056, under the BAU scenario (table 5.2). Under the scenarios the projected future employment ranges from a low of 93,000 (greater automation, dispersal) to a high of 134,200 (lesser automation, concentration).

Table 5.2 Hamilton urban area employment projections by scenario

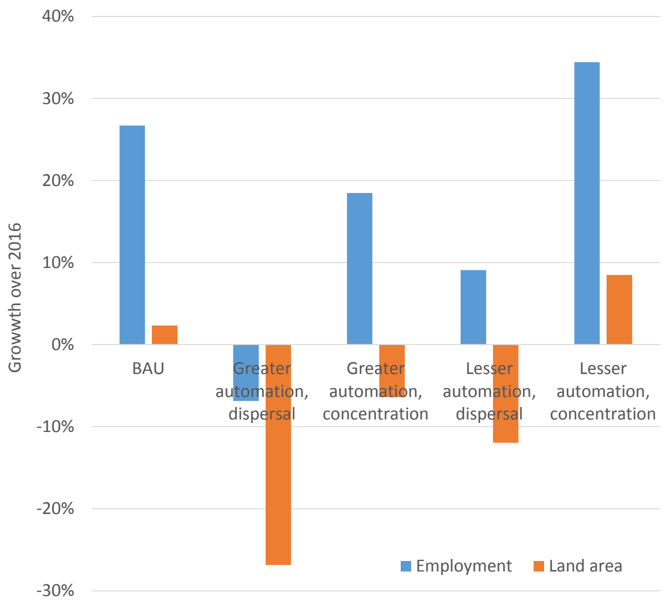
Scenario	2016	2056
BAU	99,900	126,500
Greater automation, dispersal	99,900	93,000
Greater automation, concentration	99,900	118,300
Lesser automation, dispersal	99,900	108,900
Lesser automation, concentration	99,900	134,200

Hamilton currently has just under 100,000 MECs, which will change to anywhere between 93,000 (greater automation, dispersal) and 134,000 (lesser automation, concentration). The other scenarios indicate

109,000 and 118,000 MECs by 2056. The employment numbers translate to an employment decrease in 2056 (over 2016 levels) of 7% (greater automation, dispersal) at one end of the spectrum, through to an increase of 34% (lesser automation, concentration) at the other. The other scenarios would yield an increase over that time of 9% (lesser automation, dispersal) and 18% (greater automation, concentration) (figure 5.12).

The land area required for that employment would drop under three of the four scenarios, with only the concentration, lower automation scenario resulting in an increase (of 8%) in land area required in Hamilton. Under the least optimistic scenario that land area decrease would be 27% (greater automation, dispersal), while the moderate scenarios between those extremes would have a decrease in land use of 12% and 6%.

Figure 5.12 Hamilton employment and land demand change 2016–2056



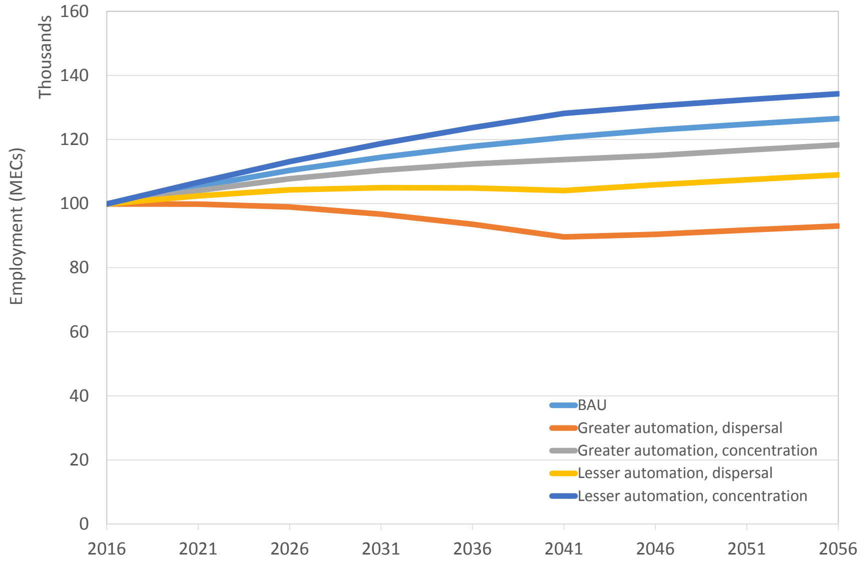
As for Auckland, the existing urban structure is likely to remain under all scenarios. Hamilton would remain as the dominant economic centre in Waikato, with the next largest centre being Taupo, at roughly 10% the size of Hamilton. Outside of Hamilton other urban areas in Waikato would see a significant decrease in employment under the concentration scenarios, but gains under the dispersal scenarios as those smaller centres would become more attractive to residents and businesses. Rural areas would experience the greatest growth if economic activity disperses away from Hamilton in which case employment could double by 2056. Alternatively those areas would face the greatest declines (in percentage terms) within the region if that activity concentrates in Hamilton, in which case the employment in rural areas could be 40% than current levels. An increasing share of employment in Hamilton future would be consistent with recent changes in Waikato.

Although the modelling indicates that the change in employment and land use in Auckland and Hamilton would be comparable, Venables (2017) examines the effects of transport improvements on the economy of urban areas, and finds that the benefits of improvements will accrue to both larger and smaller cities, but disproportionately more to the smaller city, because transport improvements can move cities to a point at which specialisation is triggered. That suggests that the concentration scenarios, and the transport improvements these would trigger, might provide real economic impetus to Hamilton's economy, and for the modelled results to understate how beneficial technology may be to Hamilton.

The change in Hamilton's employment numbers over time under the scenarios is shown in figure 5.13. Only the lesser automation, concentration scenario would result in more employment in Hamilton than the BAU future, and under that scenario employment would be 6% (7,700) more than BAU employment by 2056. This relatively modest increase over the BAU is because the increase in employment due to a concentration effect will be reduced somewhat by increased automation.

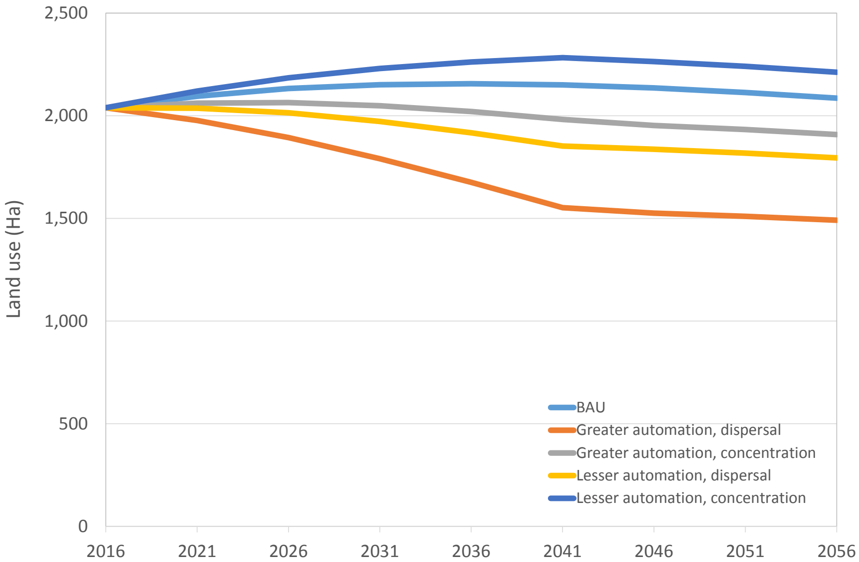
There are strong parallels between Hamilton and Auckland, indicating that the size and variety of both economies is sufficiently comparable to drive similar future development paths. In Hamilton, as in Auckland, by 2056 employment would be less than 2016 levels in only one scenario (greater automation, dispersal). Again, the strong effect of the concentration assumption is apparent in the projections, with the two concentration scenarios notably more optimistic about employment counts than the dispersal scenarios, so that for comparable automation levels the concentration/dispersal effect is around 15,000 MECs different by 2056.

Figure 5.13 Hamilton employment 2016–2056 (MECs)



The land area required to accommodate economic activity follows similar trends to employment, although given the assumed increasingly productive use of space over time an increase in employment might result in a decrease in land use. In fact, three of the four scenarios would result in lower land use by 2056 than 2016 levels (figure 5.14). Only the lesser automation, dispersal scenario would result in an increase of land use by 2056, and that a relatively modest 173ha. Under the other scenarios land use would decrease from 2016 levels by between 130ha (greater automation, concentration) and 550ha (greater automation, dispersal), equivalent to a decrease of between 6% and 27%.

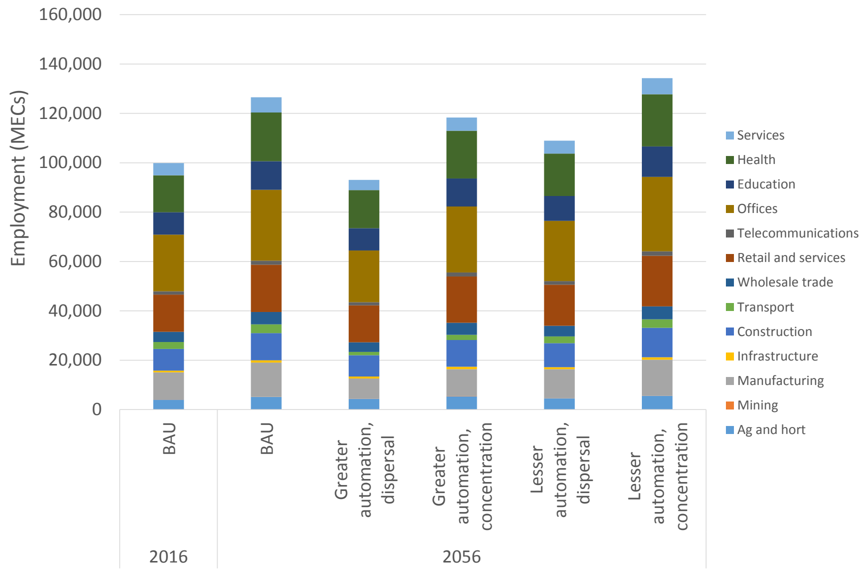
Figure 5.14 Hamilton land use 2016–2056 (ha)



Similar growth patterns (by sector) in employment are projected in Hamilton as in Auckland. The weaker employment futures under the two dispersal scenarios would be driven by slow growth (the lesser automation variant) or a decline (the greater automation variant) in manufacturing, transport and offices. Under the greater automation, dispersal scenario there would be a decline (2016–2056) of 1,500 to 3,000 workers in manufacturing, transport and offices, for an overall decline of 6,800 workers (7%) (figure 5.15). Other sectors would have a less subdued outlook, although a decrease in employment would be common across all but the primary sectors and health.

Other scenarios would result in employment growth over 2016, although assumptions relating to dispersal or concentration have a large effect on projections. Employment in offices and retail are especially variable in this regard, with literature indicating no consensus about the likely future direction of growth. Office employment may increase significantly in line with population growth (up to 7,200 MECs under less automation, concentration), or the ability to work remotely (ie from home) might alternatively result in a move of office activity away from Hamilton (as much as 2,000 workers under the greater automation, dispersal scenario). Any move of office employment away from the Hamilton urban area would not necessarily concentrate in any single alternative destination, rather a more likely outcome would be for that activity to disperse across multiple other towns and the rural area, including residential areas.

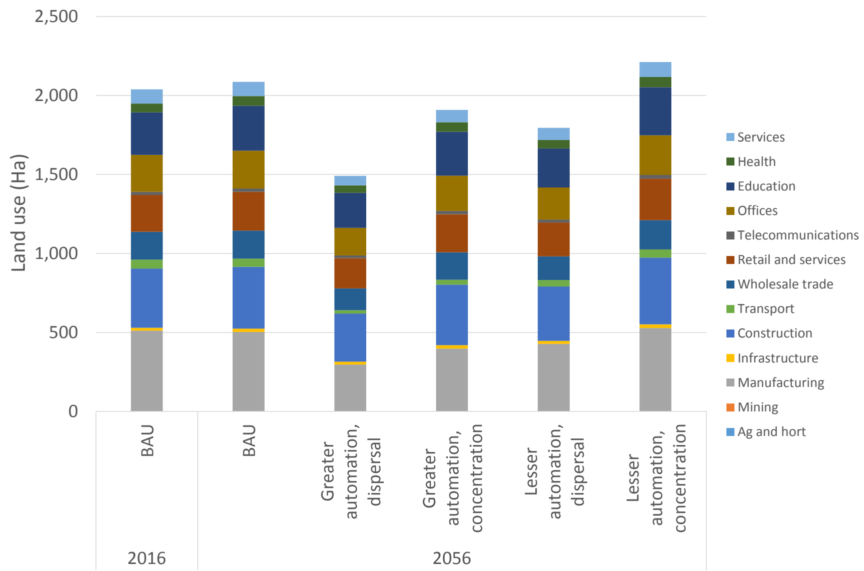
Figure 5.15 Hamilton employment 2016 and 2056 (MECs)



Again, as for Auckland, land area required shows greater variation than employment, due to underlying uncertainty about how much space sectors would require in the event of automation (figure 5.16). Likely effects are for automation to result in more efficient use of space, and a decrease in total space needed for manufacturing and transport in particular, but also potentially a number of other sectors. Total land required varies between 27% below (greater automation, dispersal) and 8% above (lesser automation, concentration) current levels, compared with 2% above under a BAU future. These growth expectations are more modest (in percentage terms) than for Auckland, indicating some outflow of potential growth from Hamilton to the larger Auckland market under the concentration scenarios.

As for Auckland, none of the scenarios indicate any significant change in role for current major infrastructure (eg possibility of inland ports) in Hamilton. Hamilton's role in the national economy is unlikely to change significantly, and not enough to either open up obvious new opportunities for inland ports, nor to cause them to become uneconomic.

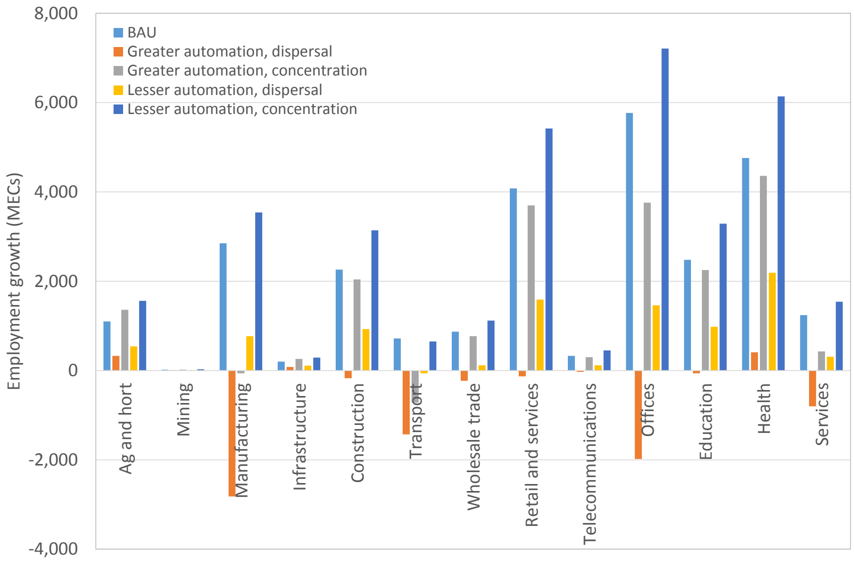
Figure 5.16 Hamilton land use 2016 and 2056 (ha)



The strong growth sectors include education, health and retail and services, each of which would employ well over 5,000 more workers by 2056 under the most optimistic scenario (lesser automation, dispersal). Under that scenario manufacturing and construction would also increase significantly (3,500 and 3,100 MECs respectively), yielding total employment growth in the urban area of over 34,000 MECs (figure 5.17).

Under the other concentration scenario (greater automation) the total growth would be 18,000, supported by increases in health, retail and services and office employment (all 3,700 to 4,400 MECs' growth). Manufacturing employment would, in contrast to the most optimistic scenario, decline, as would transport.

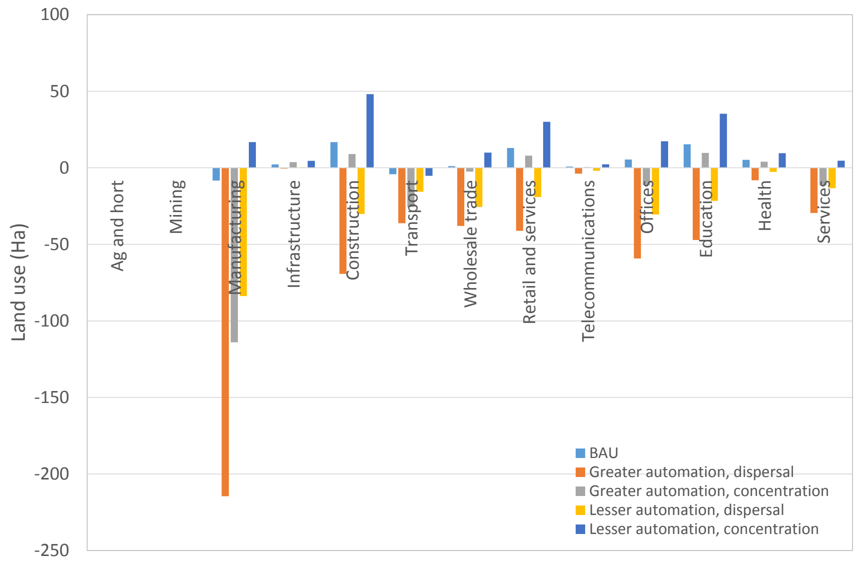
Figure 5.17 Hamilton employment change 2016–2056 (MECs)



Under the most pessimistic employment scenario (greater automation, dispersal) manufacturing, transport, offices and services are all projected to experience large declines in employment, of between 800 (services) and 2,800 (manufacturing). Declines would be widespread across most industries, with only health (increase of 400) and primary sectors increasing under this scenario by 2056.

The increasingly efficient use of space that underlies all projections in this assessment shows through clearly in projections of land use change. While employment growth is projected under many sector/scenario combinations, the outlook for land use is considerably less optimistic. Under the two dispersal scenarios, all sectors would experience a decrease in demand for land, while under the greater automation, concentration scenario growth is negative in most sectors (figure 5.18), and very low (less than 10ha) in the others. Under the most optimistic scenario there would be an increase in demand across most sectors, including 35ha in health and 50ha for construction. Construction employment would predominantly be accommodated on building sites, and therefore not require dedicated business land.

Figure 5.18 Hamilton land use change 2016–2056 (ha)



5.2.3 Large town: Nelson

The Nelson urban area is the country's 15th largest urban area, with a 2016 population of 65,700, projected to grow to 75,500 in 2043 (under a medium growth scenario). The urban area's employment count is projected to increase from 35,900 MECs in 2016 to 40,900 by 2056, under the BAU scenario (table 5.3). Under the scenarios the projected future employment ranges from a low of 32,800 (greater automation, dispersal) to a high of 41,000 (lesser automation, concentration).

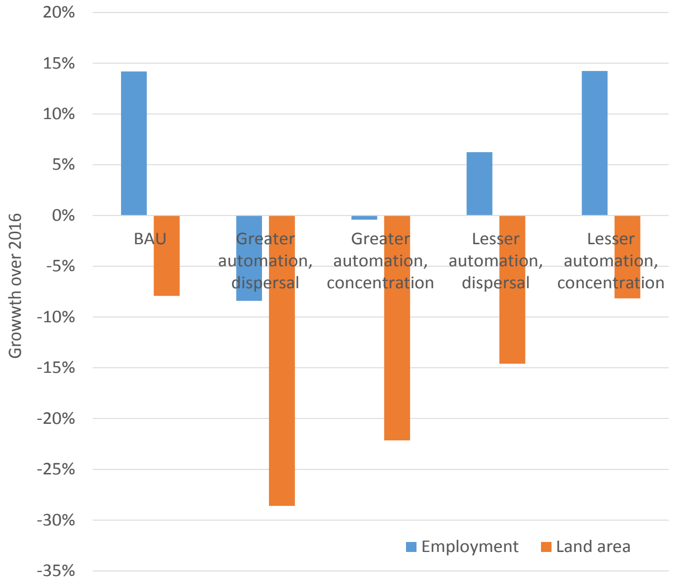
Table 5.3 Nelson urban area employment projections by scenario

Scenario	2016	2056
BAU	35,900	40,900
Greater automation, dispersal	35,900	32,800
Greater automation, concentration	35,900	35,700
Lesser automation, dispersal	35,900	38,100
Lesser automation, concentration	35,900	41,000

There are currently nearly 36,000 MECs employed in the Nelson urban area (including Richmond and Stoke). As a smaller urban area than Hamilton, Nelson would be benefited to a lesser extent than larger cities under the concentration scenarios, although the effect of those scenarios would still be positive on Nelson's employment growth. Nelson would not, however, benefit by a corresponding amount under the dispersal scenarios, as it is large enough to attract only a small amount of growth away from larger centres but not large enough to draw from the smaller areas under dispersal scenarios.

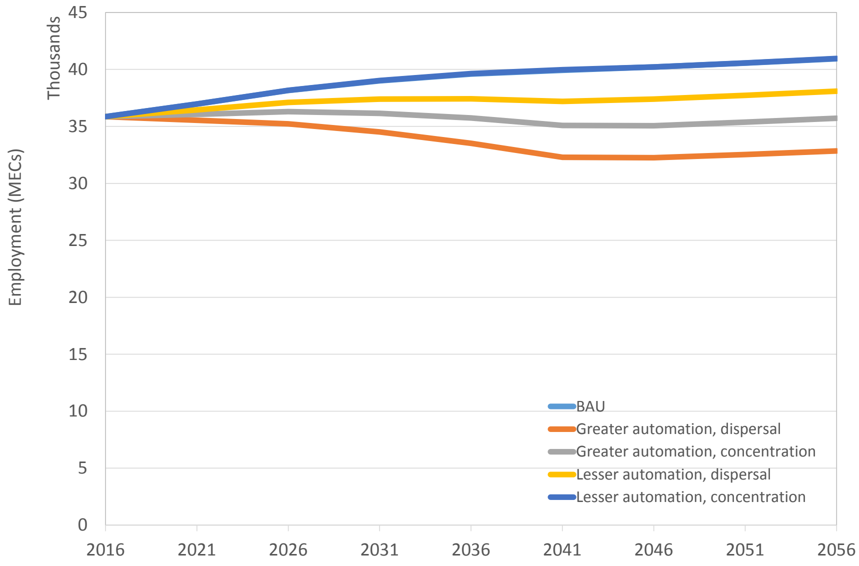
Nelson's current workforce would increase to nearly 41,000 MECs (14%) under both the BAU and lesser automation, concentration scenario, 38,000 (6%) under the dispersal variant, no change under greater automation, concentration and a decline of 8% to 33,000 MECs under the greater automation, dispersal scenario (figures 5.19 and 5.20). Those growth amounts translate to an increase of between 2,200 and 5,100 MECs under the lesser automation scenarios, and a decline of 3,000 under the greater automation, dispersal scenario.

Figure 5.19 Nelson employment and land demand change 2016–2056



Other urban areas in the Nelson-Tasman region would see a significant decrease (40% to 50%) in employment under the concentration scenarios but gains of a similar magnitude under the two dispersal scenarios. This outcome is similar to Hamilton in terms of the larger centre in the region attracting from or feeding to the hinterland, depending on assumptions about technologically facilitated economic mobility. However, even though there is significant variance indicated between scenarios, under all of them the existing urban structure is likely to remain, albeit with varying degrees of growth by scenario. As is the case in Auckland and Hamilton, Nelson would remain the dominant economic centre in its region, with 70% of regional employment. The next largest centre is Motueka, which has around one eighth the employment of Nelson.

Figure 5.20 Nelson employment 2016–2056 (MECs)



The land area required would drop under all scenarios, with slower declines in the first decade, before these declines accelerate thereafter, reaching as much as 22% to 29% below current levels under the greater automation scenarios or 8% to 15% lower under the dispersal scenarios (figure 5.21). This indicates that the main effect on employment change is the effect of automation assumed in the scenarios, with concentration/dispersal making a smaller influence on employment outcomes. That is consistent with Nelson's role as a medium-sized urban area, meaning it would have higher growth under the concentration scenarios than the dispersal scenarios. Ashburton is the only urban area of the four modelled that would have more employment under the dispersal scenarios than the concentration scenarios, because it is the smallest of the four urban areas modelled. Ashburton is relatively representative of other towns of its size, in terms of the expected change in employment and land use.

Figure 5.21 Nelson land use 2016–2056 (ha)

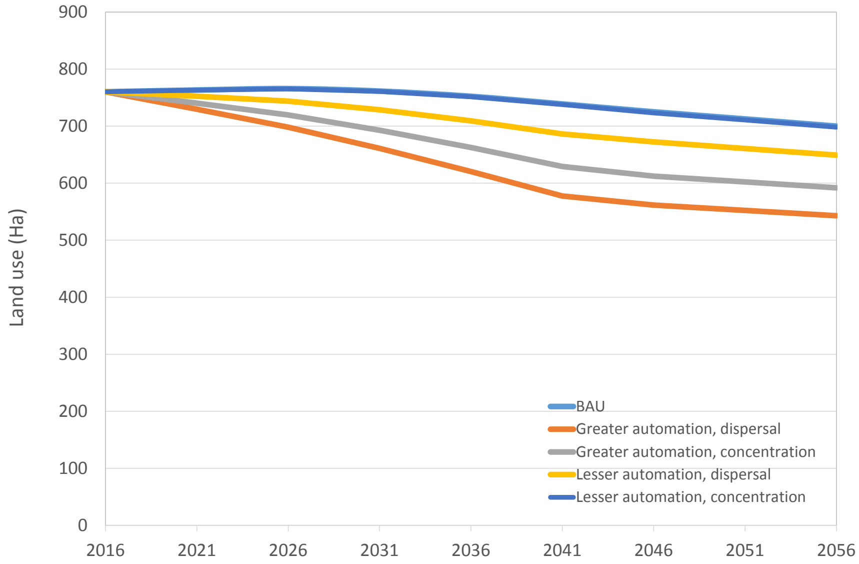
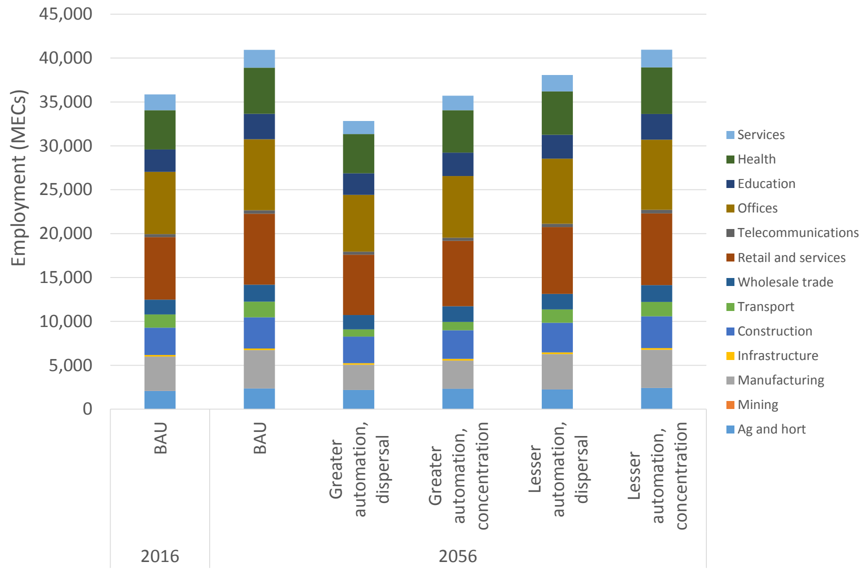


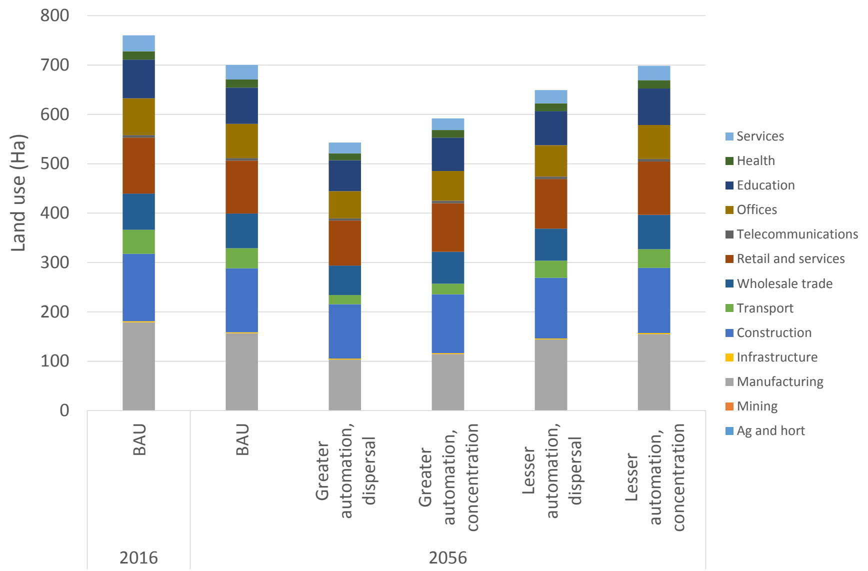
Figure 5.22 shows the decrease in employment to 2056 under the greater automation, dispersal scenario, and the nearly nil aggregate change under the greater automation, concentration scenario. Under the latter, declines in offices, services, transport and manufacturing employment would be balanced out by growth in other sectors.

Figure 5.22 Nelson employment 2016 and 2056 (MECs)



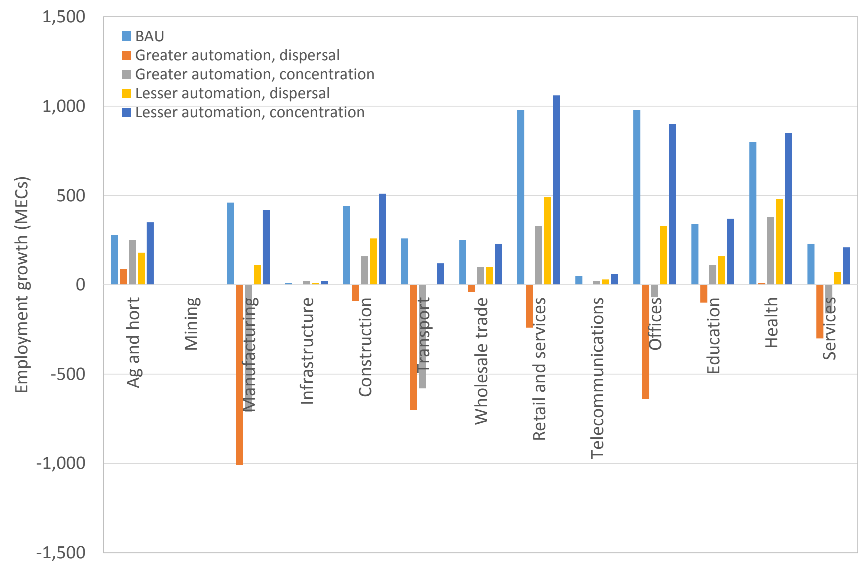
The potential for future land use to be more efficient in Nelson, and the increasing influence of remote access (online shopping, working online etc) means that land area required to support future economic activity will decline, even for scenarios where modest employment growth is projected (figure 5.23).

Figure 5.23 Nelson land use 2016 and 2056 (ha)



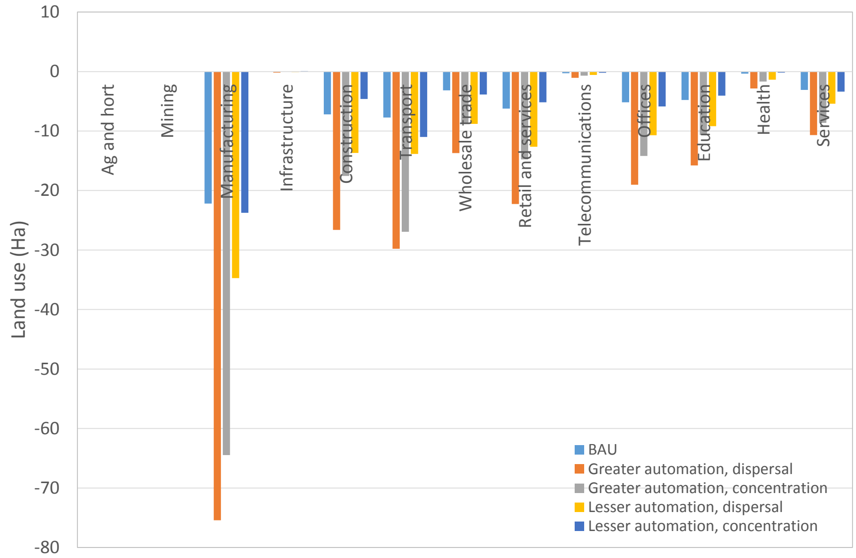
Large employment declines are possible under the greater automation, dispersal scenario in some sectors, with a decline (2016–2056) of 600 to 1,000 workers in manufacturing, transport and offices (figure 5.24), for an overall decline of 3,000 workers (8%). Under that scenario the only sector projected to experience positive employment growth would be agriculture and horticulture. Under the greater automation, dispersal scenario there would also be large declines in manufacturing (-700 MECs) and transport (-580 MECs) employment below 2016 levels, although other sectors would experience growth, including notably health (+380 MECs) and retail and services (+330 MECs).

Figure 5.24 Nelson employment change 2016-2056 (MECs)



The outlook for land use is considerably less positive, with universal declines in all sector/scenario combinations, some significant (figure 5.25).

Figure 5.25 Nelson land use change 2016–2056 (ha)



5.2.4 Medium town: Ashburton

The Ashburton urban area is the country's 33rd largest urban area, and the third largest in Canterbury, with a 2016 population of 19,600, projected to grow to 23,500 in 2043 (under a medium growth scenario). The urban area's employment count is projected to increase from 11,200 MECs in 2016 to 14,300 by 2056, under the BAU scenario (table 5.4). Under the scenarios the projected future employment ranges from a low of 10,800 (greater automation, concentration) to a high of 13,600 (lesser automation, dispersal).

Table 5.4 Ashburton urban area employment projections by scenario

Scenario	2016	2056
BAU	11,200	14,300
Greater automation, dispersal	11,200	11,800
Greater automation, concentration	11,200	10,800
Lesser automation, dispersal	11,200	13,600
Lesser automation, concentration	11,200	12,600

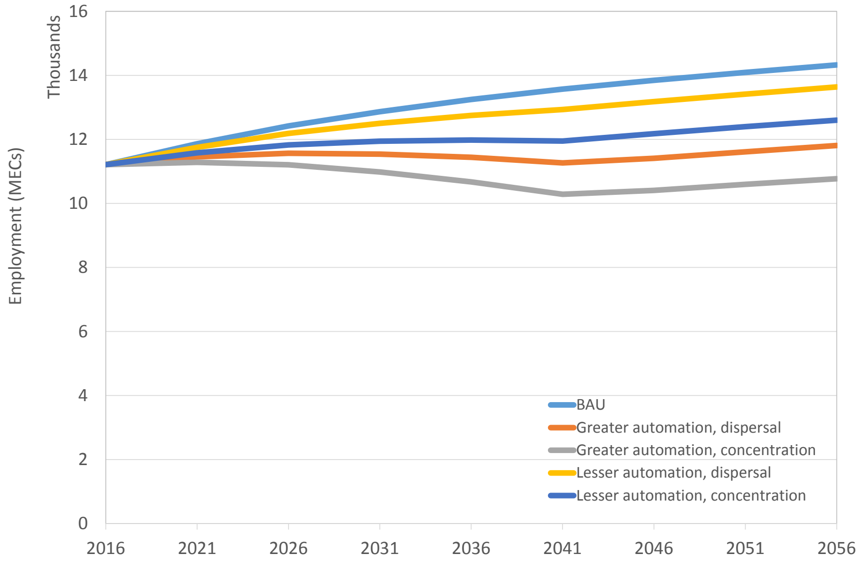
There are currently some 11,200 MECs employed in Ashburton, 21% of which are in retail and services, 17% in the office sector and 13% in manufacturing. Ashburton is the third largest urban area (by employment) in Canterbury, behind Christchurch (over 220,000 MECs) and Timaru (over 16,000), but significantly larger than Rangiora. As for the other urban areas assessed, the existing urban structure is likely to remain across Canterbury under all scenarios, although with varying degrees of growth by scenario. Christchurch would remain by far the dominant economic centre, more than 10 times larger than Timaru.

Figure 5.26 Ashburton employment and land demand change 2016–2056

Ashburton's current workforce would increase under all but the greater automation, concentration scenario, with the largest increase under the lesser automation, dispersal scenario, where growth of 2,400 (22%) is projected. All four scenarios would experience much smaller increases in employment than the BAU scenario (27% increase), indicating that even if a dispersal future eventuates and some activity relocates away from larger urban areas, it will not be enough to offset the projected declines driven by increased automation. Nevertheless, only one scenario would result in a decline in employment from 2016 levels, with a 4% decline (nearly 500 MECs) projected under the greater automation, concentration scenario (figure 5.27).

Under the other two scenarios (greater automation, dispersal and lesser automation, concentration) employment would increase by 5% and 12% respectively by 2056, somewhat slower than BAU growth.

Figure 5.27 Ashburton employment 2016–2056 (MECs)



The modelled increase in land use efficiency, and the increasing influence of remote access (online shopping, working online etc) means that land area required to support future economic activity will decline, even for scenarios where modest employment growth is projected (figure 5.28). This decline will see land required reaching 16% to 23% below current levels under the greater automation scenarios, or 1% to 9% below under the dispersal scenarios. This indicates that the main effect on employment change in Ashburton is the effect of automation assumed in the scenarios, with concentration/dispersal making a smaller influence on employment outcomes.

Figure 5.28 Ashburton land use 2016–2056 (ha)

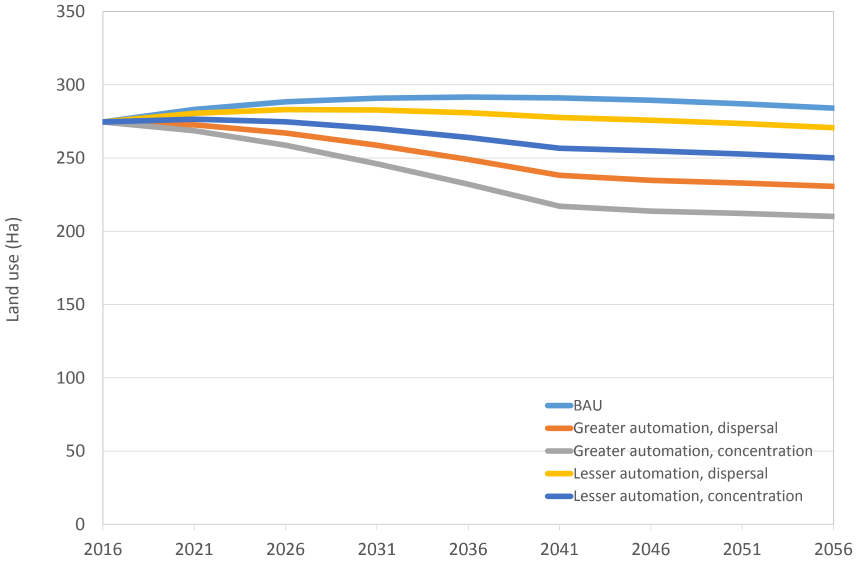
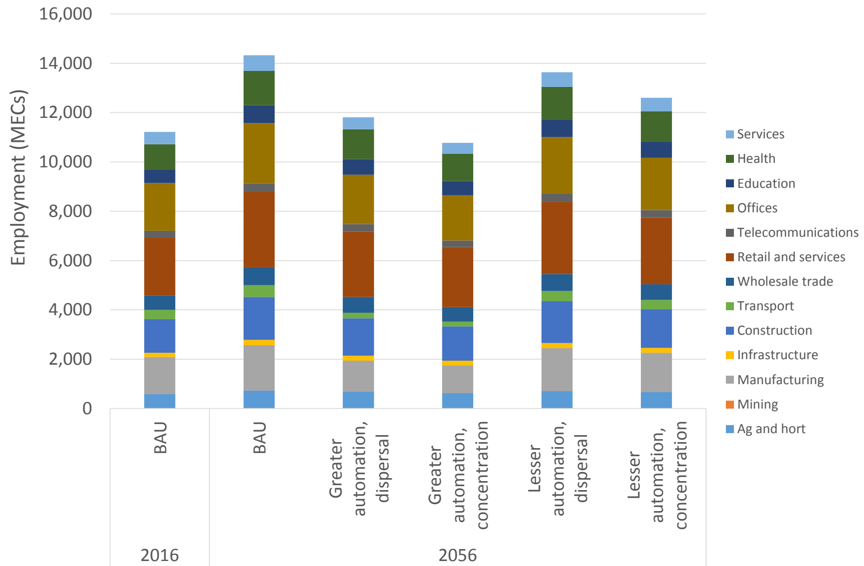


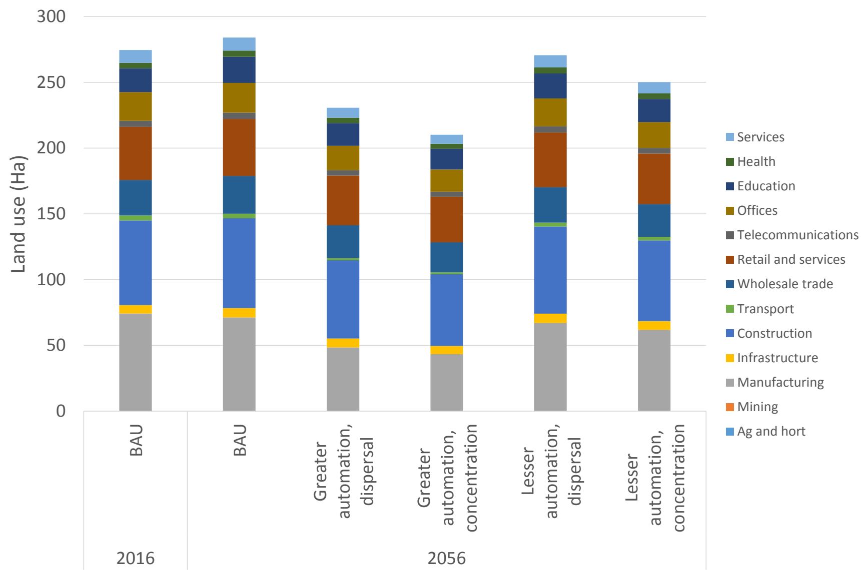
Figure 5.29 shows the decrease in employment to 2056 under the greater automation, concentration scenario, and the increase under the other scenarios. No significant structural change is projected in the Ashburton economy, with declines in manufacturing and transport more than offset by increase in employment in retail and services, health and offices in all scenarios.

Figure 5.29 Ashburton employment 2016 and 2056 (MECs)



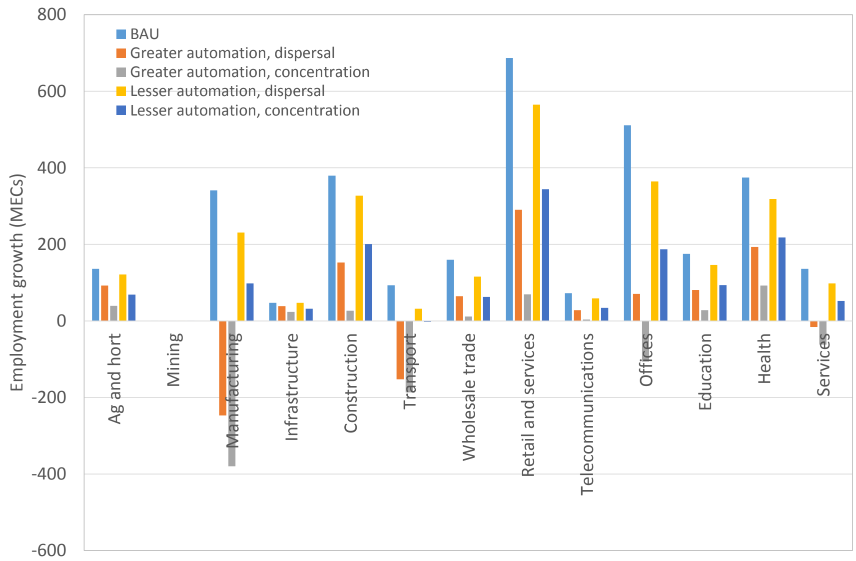
As described above, and consistent with observations in the other urban areas summarised, the land area required to support future economic activity will decline, even for scenarios where modest employment growth is projected. The smallest decline will be the lesser automation, dispersal scenario, where 2056 land use is projected to be only four hectares less than 2016 levels. The greater effect of automation on the land hungry manufacturing sector will result in significant decreases in land required, of 25–30ha under the greater automation scenarios, a drop of 35% to 42%. That would result in manufacturing occupying a materially lower proportion of Ashburton land in the future, down from 27% in 2016 to as low as 21% under the greater automation scenarios (figure 5.30).

Figure 5.30 Ashburton land use 2016 and 2056 (ha)



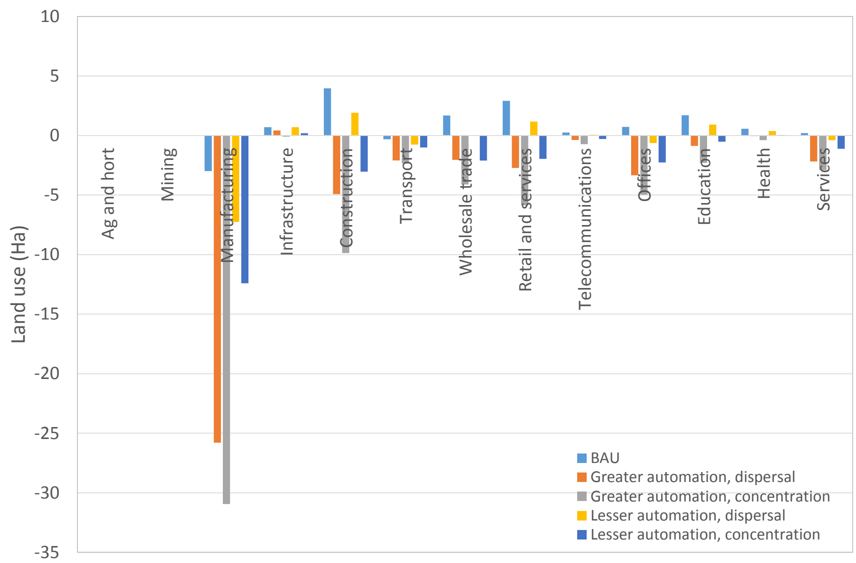
As for other areas, the manufacturing and transport sectors are projected to experience the largest employment decline, with manufacturing employment decreasing up to 25% under the highest impact scenario (greater automation, concentration) and transport employment falling 40% to 50% below current levels under both the greater automation scenarios. However most scenario/sector pairs are projected to experience employment growth out to 2056 (figure 5.31). The largest growth is projected to be in the retail and services, offices, health and construction sectors.

Figure 5.31 Ashburton employment change 2016–2056 (MECs)



As for Nelson, the outlook for land use is considerably less positive, with a large decline in many sector/scenario combinations projected, and only relatively modest growth in pairs where declines are not projected (figure 5.32).

Figure 5.32 Ashburton land use change 2016–2056 (ha)



5.3 Sector perspective

This section summarises the scenario projections from a sectoral perspective, for four key sectors of interest, and urban areas. The definition of these sectors is provided in section 4.4.4. Again, these are not predictions of future employment, but are rather projections of employment under the assumed combination of future circumstances.

5.3.1 Manufacturing

Total national manufacturing employment is currently 234,000 MECs, a number which is projected to increase steadily in the next four decades to reach nearly 290,000 by 2056. Currently 47% of manufacturing employment (110,000 MECs) is in metropolitan centres (Auckland, Wellington, Christchurch), and that share is projected to increase even further, to 49%, under the BAU future. The next largest employment locations are rural areas (37,000 MECs) and large towns (26,000 MECs). Rural areas have many small manufacturing businesses, but also few very large businesses, such as sawmill, dairy factories and quarries.

Under the greater automation scenarios total national manufacturing employment would decrease to between 194,000 and 215,000 MECs by 2056, a significant decrease, and one which reflects the vulnerability of jobs in the sector to being replaced by automation. Under the lesser automation scenarios manufacturing employment would still increase, to between 270,000 and 290,000 MECs.

The effect of the concentration/dispersal assumptions is apparent from the right-hand chart in each of the figures (5.33 to 5.37) below. They show that rural and smaller urban areas will increase their shares of total national employment under dispersal scenarios, while larger urban areas have greater shares under concentration scenarios. Under the BAU future the current urban structure is maintained. Under the dispersal scenarios, the share of manufacturing employment in metropolitan areas could drop from 47% to around 36% to 39%, whereas under the concentration scenarios a movement towards larger urban areas would see that share increase to 57% to 60%. The smallest urban area types (small town, small urban area, rural) would change from 62,000 in 2016, to 95,000–110,000 under the dispersal scenarios or 25,000–45,000 under the concentration scenarios. The charts show the assumption that most technological change currently envisaged will have been implemented by 2041, hence the point of inflection post-2041 in some scenarios.

These divergent outcomes reflect different development paths for the manufacturing sector. BAU economic growth is projected to lead to an increase in manufacturing employment, notwithstanding international trends such as a movement of some New Zealand manufacturing activity offshore. However, under the scenarios different future prospects exist. Automation in the sector is expected to continue, for example through the use of robotics and automated production line processes, with some estimates being that current robotics use in the USA is as low as 10% of those who could benefit from their use (Frey and Osborne 2013).

Other changes, such as 3D printing from home, might become a big part of manufacturing, reducing the need for large factory-based businesses and facilitating dispersal of manufacturing activity into places where it is not currently feasible (Frey and Osborne 2015). Alternatively, under a concentration future highly automated and efficient manufacturing would still occur in businesses in industrial areas, and these would be increasingly located in larger urban areas (Stam et al 2008).

There is significant variation in these futures, which is useful as it describes a broad range of possible future outcomes, and reflects the inherent uncertainty in trying to understand the effects technology may have. The variation between the scenarios, for example an employment decline under the greater automation, concentration scenario but employment growth under the lesser automation dispersal scenario reflects the degree to which the BAU growth might be affected. Scenarios with higher automation would see greater loss of current jobs as new technology comes online, and a lower rate of job creation, while lower automation scenarios erode both employment categories less, resulting in net employment growth.

Figure 5.33 Spatial distribution of manufacturing employment (BAU)

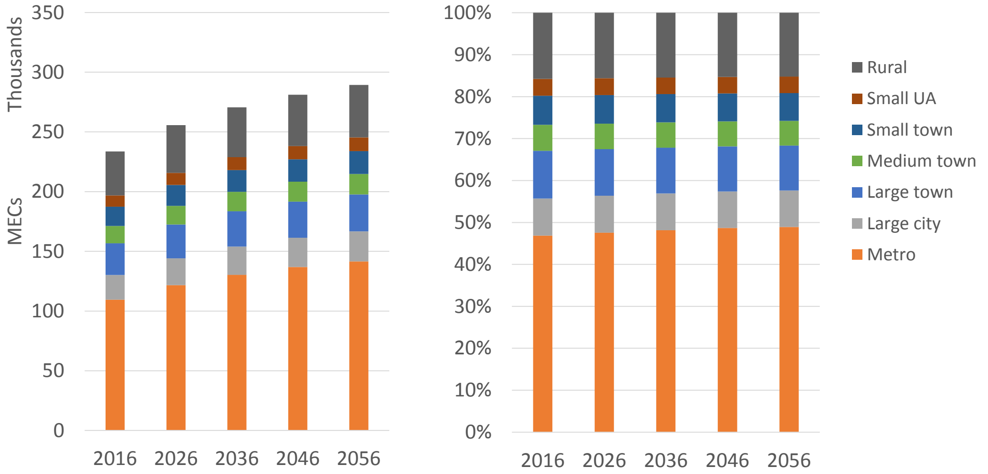


Figure 5.34 Spatial distribution of manufacturing employment (greater automation, dispersal)

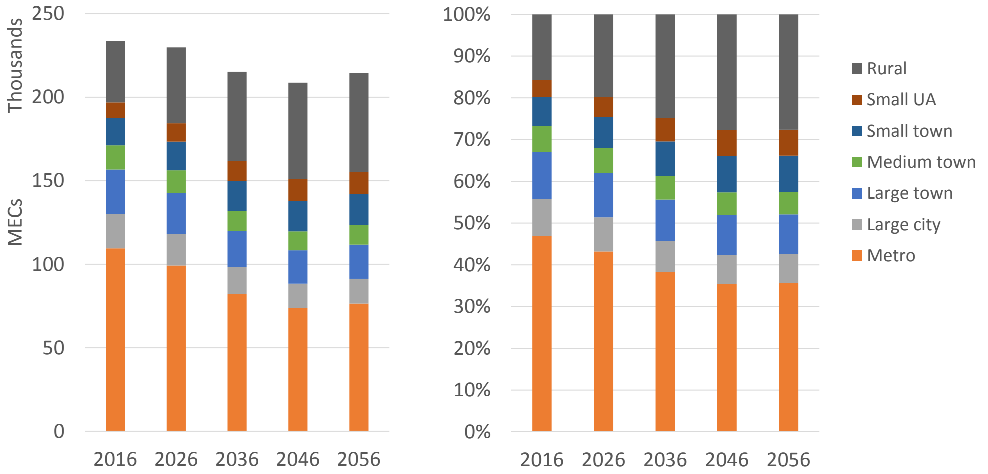


Figure 5.35 Spatial distribution of manufacturing employment (greater automation, concentration)

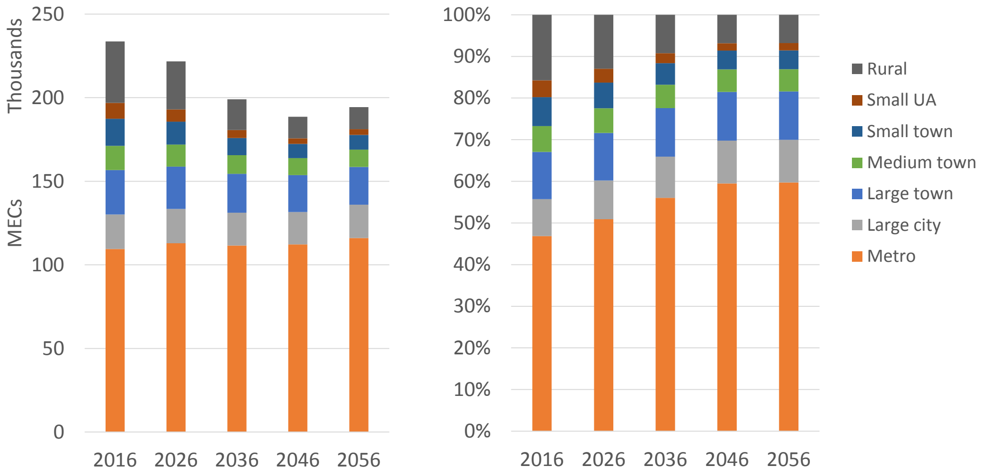


Figure 5.36 Spatial distribution of manufacturing employment (lesser automation, dispersal)

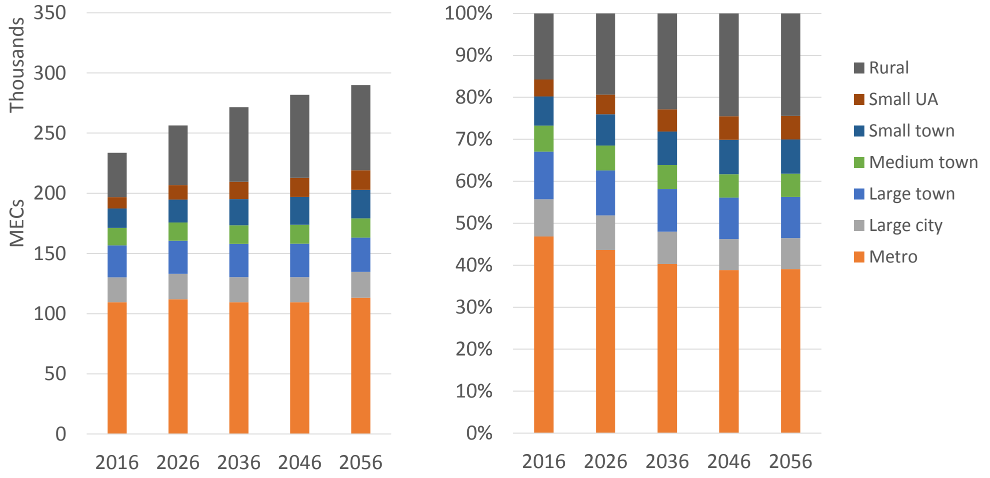
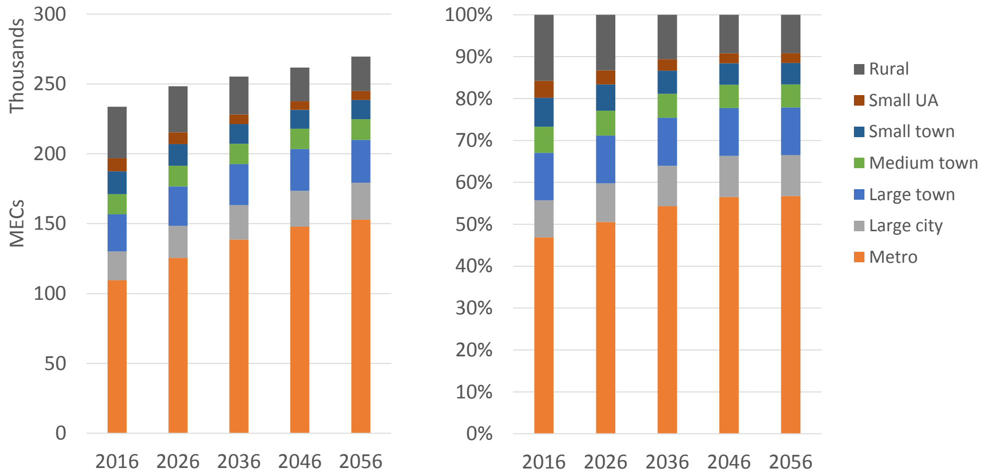


Figure 5.37 Spatial distribution of manufacturing employment (lesser automation, concentration)



5.3.2 Transport

Total national transport employment is currently 99,000 MECs, a number which is projected to increase steadily in the next four decades to reach nearly 124,000 by 2056 under a BAU future. Currently 57% of transport employment (57,000 MECs) is in metropolitan centres (Auckland, Wellington, Christchurch) and that share is projected to increase slightly to 59% under the BAU future. The concentration in the largest cities is due to the presence of large transport facilities (sea and airports) in the main centres, as well as a large number of transport-based businesses that rely on close proximity to those ports and the population base they serve. The next largest employment locations are rural areas (9,000 MECs) and large cities (8,600 MECs). There are some 30 large (50+ MECs) road freight businesses located outside urban areas, as well as some airports (Dunedin) and seaports (Marsden Point) that account for one third of the employment in rural areas, with the balance being spread across many locations in smaller businesses.

Under the greater automation scenarios total national transport employment would decrease to between 59,000 and 64,000 MECs by 2056, a significant decrease, and one which reflects the vulnerability of jobs in the sector to replacement by automation. The increased automation comes notably through AVs, but also at ports and airports involving freight movement and handling. Under the lesser automation scenarios transport employment would still increase over 2016 levels, to between 108,000 and 112,000 MECs, which is lower than the BAU future.

The effect of the concentration/dispersal assumptions is apparent from the right-hand chart in each of figures 5.38 to 5.42 below. They show that rural and smaller urban areas will increase their shares of total national employment under dispersal scenarios, while larger urban areas have greater shares under concentration scenarios. Under the BAU future the current urban structure is maintained. Under the dispersal scenarios, the share of transport employment in metropolitan areas could drop from 57% percent to around 42% to 49%, whereas under the concentration scenarios a movement towards larger urban areas would see that share increase to 66% to 71%. The smallest urban area types (small town, small urban area, rural) would change from 15,000 in 2016, to 19,000 to 27,000 under the dispersal scenarios or 2,000 to 9,000 under the concentration scenarios.

These divergent outcomes reflect different development paths for the transport sector. For example, automated freight handling could improve the efficiency of existing ports (eg Ports of Auckland), reducing the effect of capacity constraints that currently exist, and allowing these operations to prosper and grow in their current location. Within the scenarios, this potential shows through more strongly in the greater automation variants and less strongly in the lesser automation variants. Alternatively, a reduced need for labour might spur a dispersal of many transport activities, especially road related, around the country. A decreased reliance on labour and potentially lower fuel costs (for electric vehicles) would equate to flexibility for transport operators to be based in a broad range of locations, and might result in the relatively small number of rural-based transport operators existing today increasing in size and number.

As for the manufacturing sector, the broad variation in these futures is helpful to describe a range of possible future outcomes, and reflects the inherent uncertainty in trying to understand the effects technology may have.

Figure 5.38 Spatial distribution of transport employment (BAU)

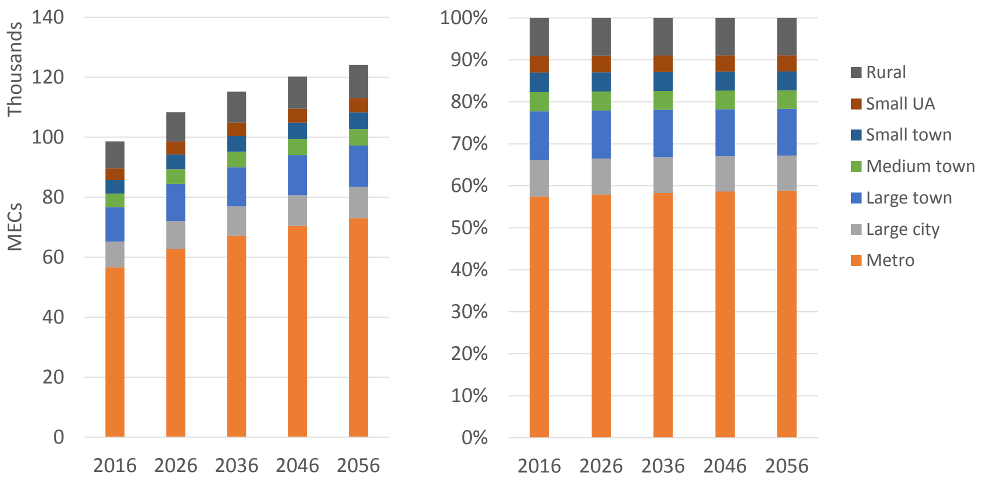


Figure 5.39 Spatial distribution of transport employment (greater automation, dispersal)

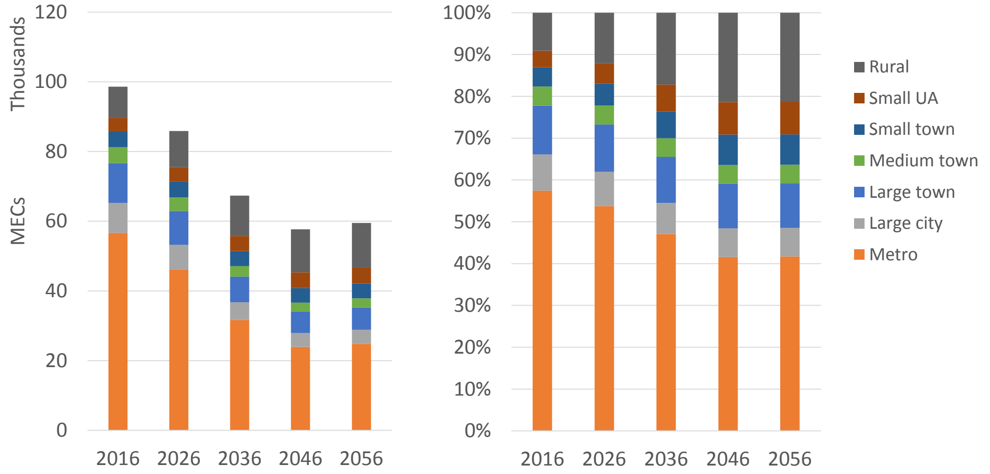


Figure 5.40 Spatial distribution of transport employment (greater automation, concentration)

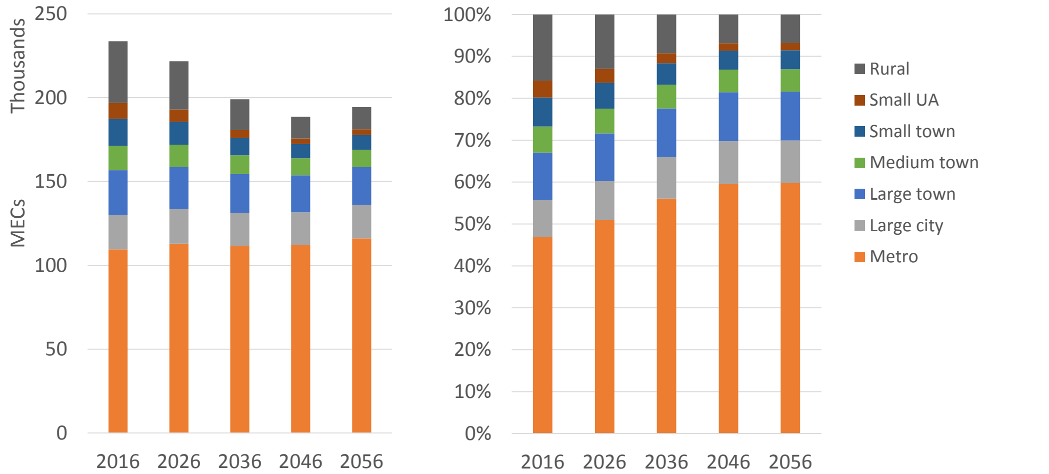


Figure 5.41 Spatial distribution of transport employment (lesser automation, dispersal)

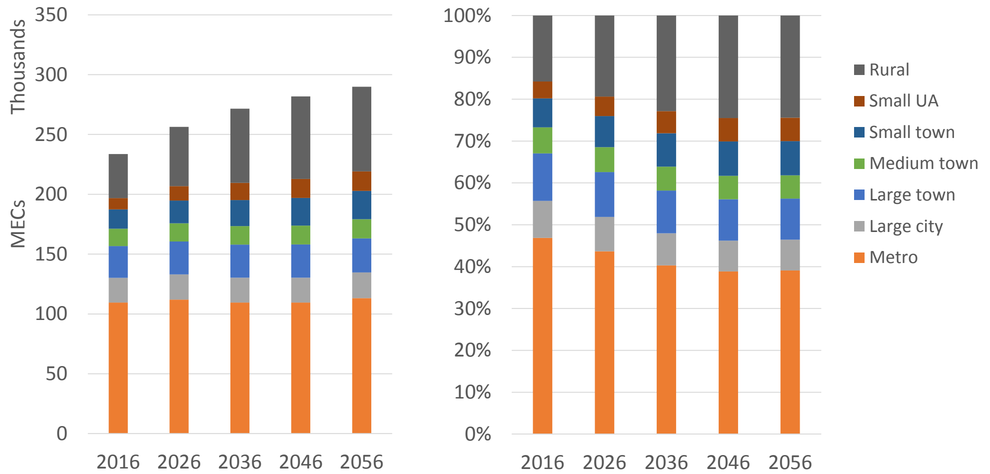
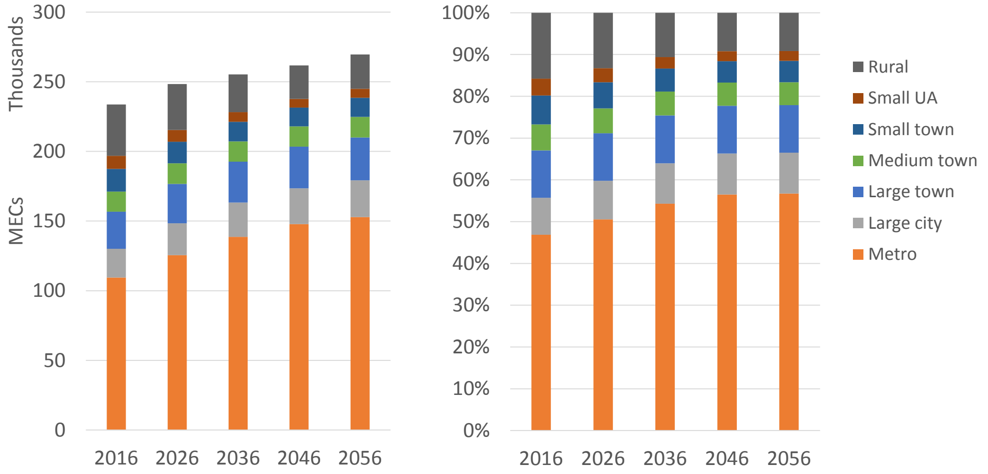


Figure 5.42 Spatial distribution of transport employment (lesser automation, concentration)



5.3.3 Retail and services

Total national retail and services employment is currently 380,000 MECs, a number which is projected to increase to 487,000 by 2056 under a BAU future. Currently 51% of retail and services employment (192,000 MECs) is in metropolitan centres (Auckland, Wellington, Christchurch), and that share is projected to increase significantly to 61% (to 265,000 MECs), under the BAU future. That concentration in the largest cities is consistent with Statistics New Zealand's projections of growth (Statistics New Zealand 2016d) continuing to concentrate in the country's largest urban areas, and the strong link between this sector and the population base.

That link between population and retail and services workforce is evident across all urban areas, where that workforce is broadly proportional to the population. The three large cities (Hamilton, Tauranga and Dunedin) have a combined population of 439,000 and a retail and services workforce of 38,000, while the eight large towns have a combined population of 466,000 and a retail and services workforce of 48,000. There is a significant employment base spread throughout all smaller urban areas, as well as the rural areas. There are, for example, many small supermarkets and grocery stores located in small towns across New Zealand which fall below Statistics New Zealand's urban area threshold.

Under the greater automation scenarios total national retail and services employment would increase more slowly than under the BAU future, to between 423,000 and 439,000 MECs by 2056, still a significant increase over 2016 levels. This increase reflects the slightly lower vulnerability of employment in the sector than in, say, manufacturing and transport, given the literature's general consensus that there is likely to be a strong place for physical outlets in future retailing, given the value of shopping as an activity (Cullinane 2009). Because demand for retail and services is linked strongly to population size, the population growth projected by Statistics New Zealand over the horizon of this study is a key driver of employment growth in the sector. Under the lesser automation scenarios retail and services employment would increase to slightly below 2,056 BAU levels, to between 467,000 and 481,000 MECs.

The effect of the concentration/dispersal assumptions is apparent from the right-hand chart in figures 5.43 to 5.47. They show rural and smaller urban areas will increase their shares of total national employment under dispersal scenarios, possibly quite significantly. For example rural areas would increase from 6% in 2016 to 9%, small urban areas from 6% to 8%, and small towns from 9% to 11%. Under the BAU future the current urban structure is maintained. Under the dispersal scenarios, the share of retail and services employment in metropolitan areas could drop from 51% to around 45%, whereas under the concentration scenarios a movement towards larger urban areas would see that share increase to 60% to 61%.

The projections show a greater similarity between greater and lesser automation scenarios than is true of the manufacturing and transport sectors, due to the lower assumed automation in retail and services. A more significant driver of likely change in the sector will be the ability of retail and service businesses to service customers from more remote locations, for example using online retail. This could have a range of effects, encouraging concentration into larger urban areas (near warehouses, ports etc), dispersal (boutique type retailers in small towns that can suddenly access a nationwide market), or no notable change from current patterns. As discussed above, the merit of face-to-face contact, and ability to physically interact with products is valuable, and is expected to drive some retention of stores close to their population base. The key uncertainty in this sector is how much.

Figure 5.43 Spatial distribution of retail and services employment (BAU)

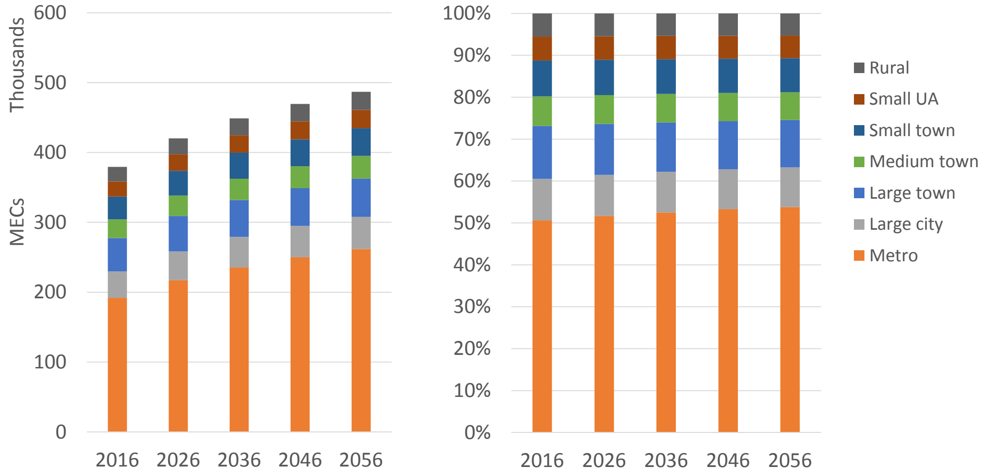


Figure 5.44 Spatial distribution of retail and services employment (greater automation, dispersal)

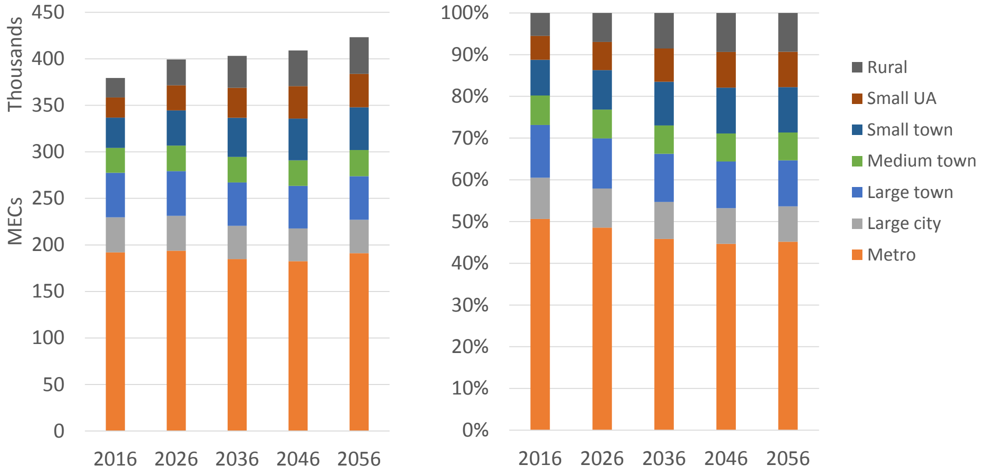


Figure 5.45 Spatial distribution of retail and services employment (greater automation, concentration)

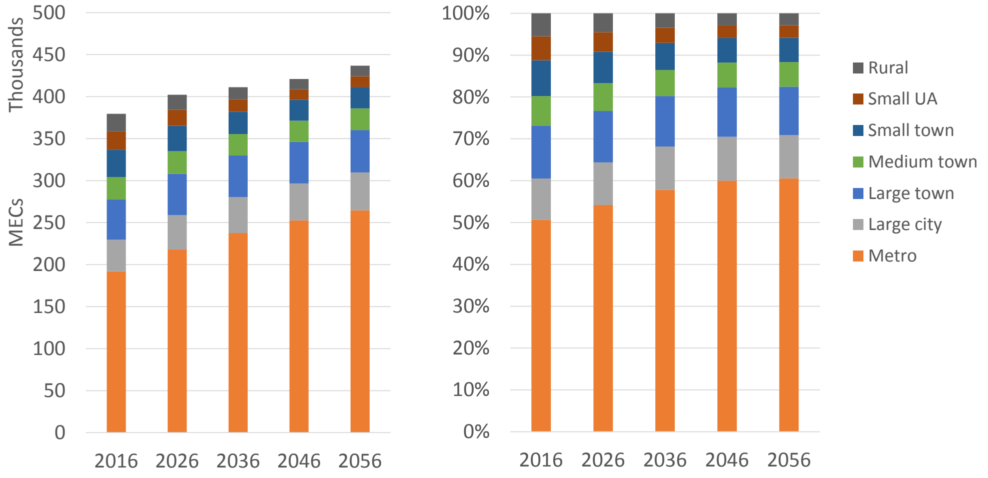


Figure 5.46 Spatial distribution of retail and services employment (lesser automation, dispersal)

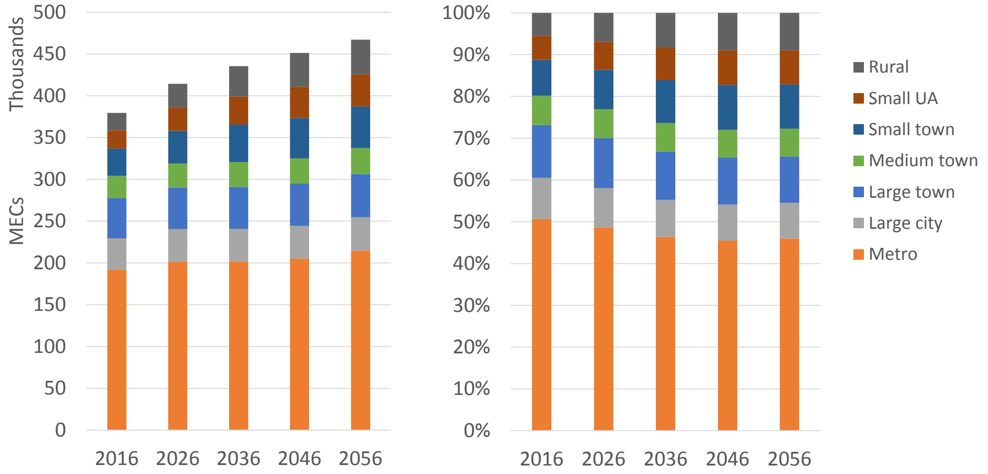
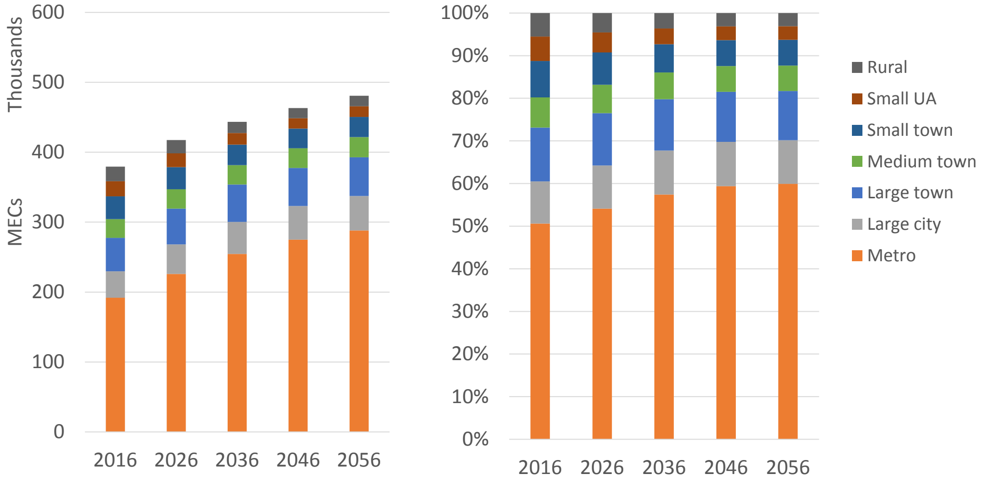


Figure 5.47 Spatial distribution of retail and services employment (lesser automation, concentration)



5.3.4 Offices

Total national office employment is currently 5670,000 MECs, a number which is projected to increase significantly to 722,000 by 2056 under a BAU future. Currently 66% of office employment (375,000 MECs) is in metropolitan centres (Auckland, Wellington, Christchurch), and this share is projected to increase slightly to 68% (to 494,000 MECs), under the BAU future. As for retail and services, the concentration in the largest cities is consistent with Statistics New Zealand's projections of growth in the country's largest urban areas, and the strong link between this sector and the population base.

The link between population and offices workforce is evident across all urban areas, although is more notably focused on larger urban areas than in the retail and services sector. The three smallest urban area types (small town, small urban area and rural areas) make up 11% of employment in offices, but 20% in retail and services. The three large cities (Hamilton, Tauranga and Dunedin) have a combined population of 439,000 and an office workforce of 48,000, while the eight large towns have a combined population of 466,000 and an office workforce of 56,000. Although a smaller share of office employment is located in smaller urban areas, these areas do accommodate a large employment base (65,000 MECs in 2016), including in commercial buildings and individuals and small businesses working from home.

Historically office employment has not been subject to automation, although this is expected to change in the future, and with the introduction of AI, a wide range of occupation types might be replaced by automation (Bassan et al 2008). Under the greater automation scenarios total national office employment would therefore increase more slowly than under the BAU future, to between 555,000 and 644,000 MECs by 2056, and at the lower end of this range would represent a decline in employment from 2016 levels (566,000). Under the lesser automation scenarios office employment would increase over 2016 employment, but below 2056 BAU levels, to between 642,000 and 730,000 MECs.

The effect of the concentration/dispersal assumptions is apparent from the right-hand chart in figures 5.48 to 5.52 below. They show that rural and smaller urban areas will increase their shares of total national employment under the dispersal scenarios, although larger urban areas will remain by far the most popular location for office-based businesses to locate. For example the three largest urban area types (metropolitan, large city and large town) currently accommodate 85% of office employment. That share would fall only slightly to between 77% (greater automation, dispersal) and 79% (greater automation, concentration). Under the BAU future the current urban structure is maintained.

The projections show a greater similarity between greater and lesser automation scenarios than is true of the manufacturing and transport sectors, although as discussed above, automation will potentially still be a strong influence on the sector. The difference between the dispersal and concentration scenarios is significant, and reflects the uncertainty and lack of any consensus from the literature review about what the future holds for office-based employment. Because technology is continually improving, and internet accessibility and speeds make a broader range of applications possible, many commentators expect that telecommuting will increase (Greenwood 2012; Rasmussen and Corbett 2008).

Whether this will result in a dispersal of office activity around New Zealand (to regions where office space and dwellings are cheaper), or office workers still living in the larger centres but spending some of the week working from home, is unclear. The merit of face-to-face contact, and ability to physically interact with colleagues and clients will remain important, and is expected to create a strong inertia that will limit dispersal of office activity. As for retail, the key uncertainty in the office sector is how strong that inertia will be, and whether any new applications become available which are 'game changers' and result in new practices that are not currently foreseeable.

Figure 5.48 Spatial distribution of offices employment (BAU)

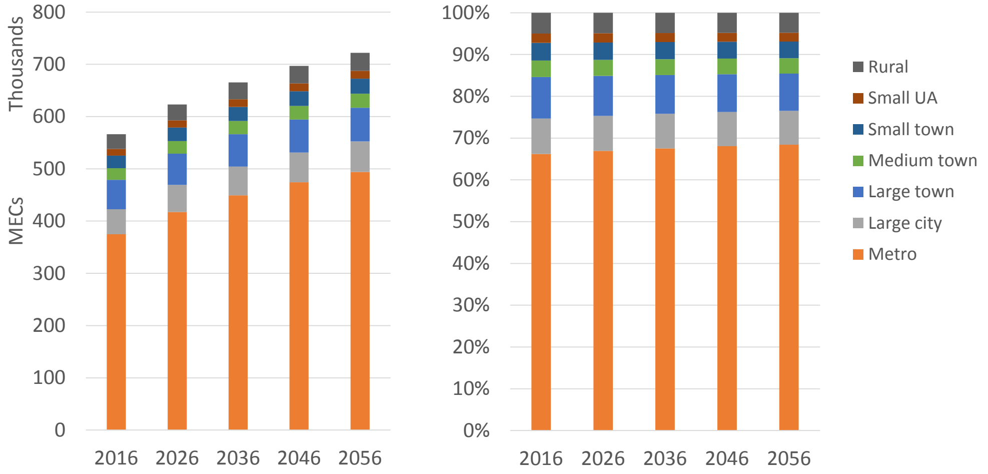


Figure 5.49 Spatial distribution of offices employment (greater automation, dispersal)

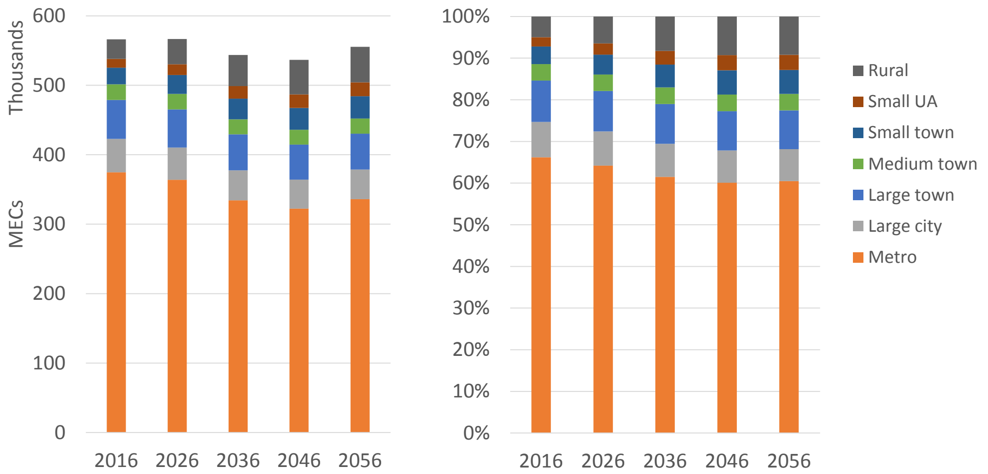


Figure 5.50 Spatial distribution of offices employment (greater automation, concentration)

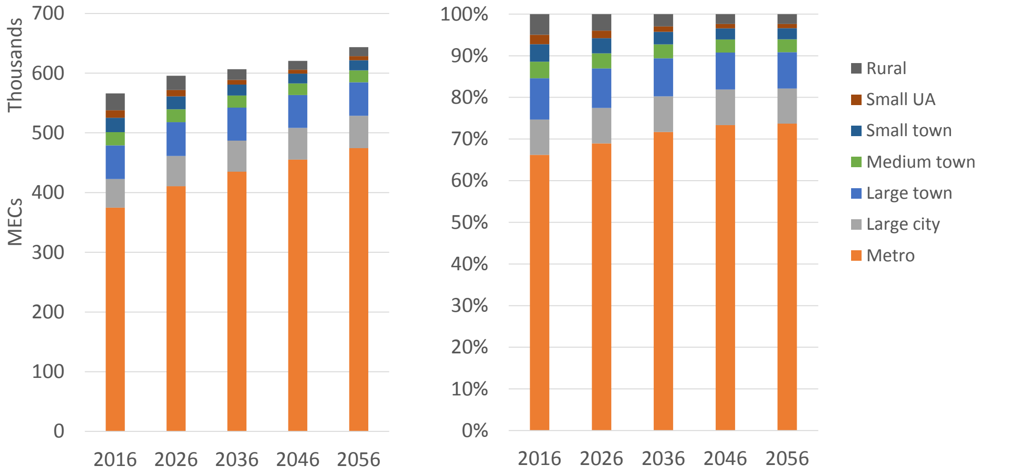


Figure 5.51 Spatial distribution of offices employment (lesser automation, dispersal)

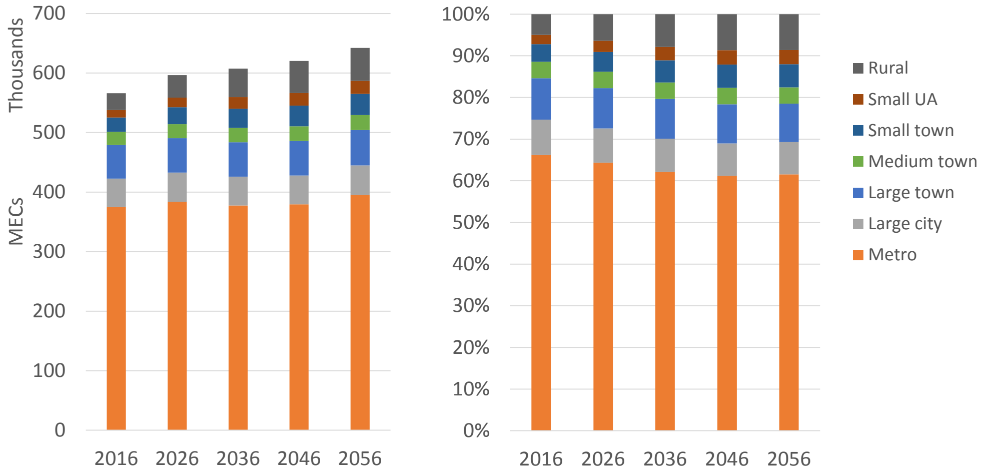
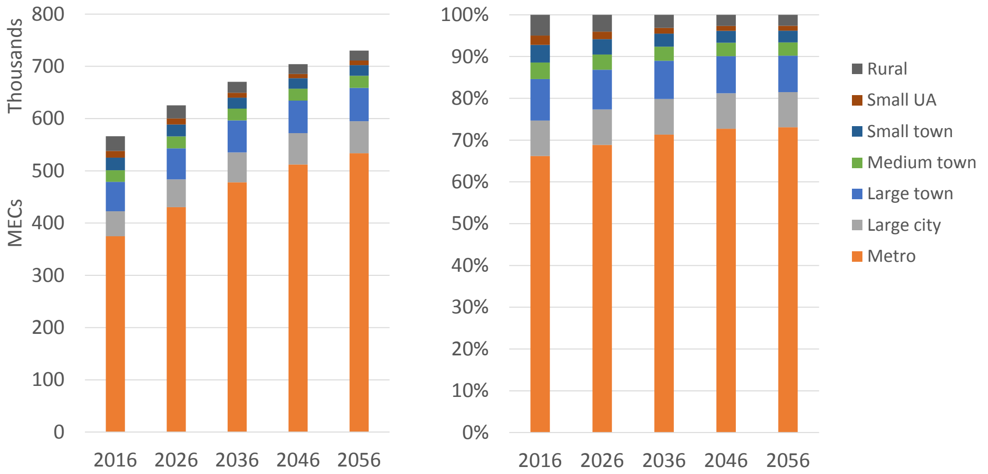


Figure 5.52 Spatial distribution of offices employment (lesser automation, concentration)



6 Assessment of implications

This section summarises the transport and planning implications of the employment and land use projections presented in chapter 5, first from a spatial perspective, and then from a sectoral perspective.

6.1 Spatial perspective

6.1.1 Large metropolitan city: Auckland

The implications of changes in land use on transport in a metropolitan area are generally related to the level of concentration of jobs in the metropolitan area. Scenarios involving a dispersal of activity to outlying areas are the only ones that are expected to result in a reduction in employment from the BAU case. Indeed it is only the dispersal scenarios that come close to maintaining the status quo in employment, with significant growth projected under the concentration scenarios. While dispersal scenarios would result in lower employment growth, and therefore would lessen the impact on the transport network within the metropolitan area, they would likely result in an increase in the level of transport movements from residential areas to other outlying suburban or rural employment areas set up to support the dispersal of employment. Improved road and public transport (PT) networks feeding outer areas may be required.

The concentration of economic activity in metropolitan areas, however, would result in an expected increase of employment in most sectors but particularly those associated with retail, health and offices within the metropolitan area. While this could result in more transport demand to and from the already congested metropolitan network, there are several ways this increase might be mitigated. A large proportion of this increased employment would involve regular commuter travel typically associated with offices where improved or targeted PT and new transport innovations may offset the possible travel increases associated with this increased activity. Innovations such as TaxiBots and AutoVots would make mobility as a service more economic and efficient, and could achieve the same mobility with as little as 10% the number of vehicles on the roads (ITF 2015). Concentration of activities, especially in the urban core, would increase the patronage and viability of expanded PT and shared mobility services, further increasing the potential for ongoing density increases. More work, however, will be needed to understand the behavioural drivers behind transport-sharing decision (ATAP 2017).

Research indicates that the global environmental benefits of intensification, such as low energy PT and reduced overall car use, will be less than proportional to the worsening local traffic that arises from the intensification. Melia et al (2011) find that where intensification occurs, greater concentrations of traffic tend to occur, which is referred to as the ‘paradox of intensification’. Limiting intensification shifts the balance between global and local problems and Melia et al (2011) conclude urban intensification should be accompanied by more radical measures to constrain traffic generation in intensified areas. This has implications for New Zealand’s largest cities, especially Auckland, because ongoing intensification may lead to a reduction in land required, but an increase in vehicle movements, especially shorter movements. The consequence of this is the worsening local traffic identified by Melia et al (2011). It is important to understand therefore that traffic movements will not necessarily change in the same way as employment and land use.

The concentrated scenarios would also result in increases in retail, service, education and health employment within the metropolitan area along with their expected increases in vehicle movements. Increases in these sectors are less likely to be offset by improved PT as they involve activities that are less conducive to PT use and which do not necessarily occur during traditional commuter times. This could increase the use of private motor vehicles, placing additional demands on the inner metropolitan road network. Parking demands associated with the increases in retail and health activity may also require additional facilities.

While the increased use of automated vehicles may go some way to making metropolitan road networks more efficient and therefore offset some of the possible increase in vehicular activity, real efficiencies may only be evident when the whole system is fully automated. Only then could the metro system be fully optimised, allowing the most efficient movement of people and products through the metropolitan area.

To accommodate the broad range of possible future outcomes, it is evident that flexibility, and thus potentially a relatively accommodating and permissive planning approach is likely to be required within any future land use planning framework in Auckland. This includes approaches that provide for mixed land uses, while continuing to ensure that incompatible activities or activities that have the potential to give rise to reverse sensitivity issues cannot locate within the same area (eg heavy manufacturing in close proximity to hospitals or residential activities).

Specific land use planning provisions might include ensuring that Auckland’s CBD remains a key service delivery location for the city, while the different suburban communities retain the ability to accommodate service centres that provide for the sectors that need to be located in these areas. Growth in these areas may need to be provided for by intensification, expansion into zones put aside for other uses or the use of vacant land or buildings zoned for other activities where land demand has contracted.

Given the modelled contraction of manufacturing within the urban area under three of the four scenarios, including other sectors under the dispersal scenarios, it is important the land use planning framework enables other compatible land uses to develop in areas that may become vacant or significantly underutilised as a result of reduced demand for land for specific activities. This includes, but is not limited to, providing for brownfields development and mixed uses, rather than single uses, within specific zones.

Under the dispersal scenarios, land use planning provisions will need to give consideration to the protection of primary production activities where this is important to the social and economic well-being of Auckland, while also providing flexibility for potential expansion into these rural areas and/or mixed land use provisions.

It is noted that the Auckland Unitary Plan (AUP), which has recently come into effect (Auckland Council 2017), has been developed following a robust and comprehensive strategic planning approach that considers the potential form of the city in the future. Therefore, broadly speaking it is considered that the AUP provides for the land use planning approaches discussed above.

6.1.2 Large city: Hamilton

The implications of changes in land use on transport in a large city are generally expected to be very similar to those for a metropolitan area, as a result of similar changes in employment patterns between the two types of areas. Although the nature of the employment changes is projected to be similar, the quantum of change is projected to be much less in large cities, and so the impact on transport movements is expected to be correspondingly lower. One key difference is the less comprehensive nature of PT networks in large cities, with their greater reliance on buses and less availability of other forms of PT such as trains and ferries.

As with metropolitan areas, the concentration of economic activity in large cities is projected to result in an increase of employment in most sectors but particularly those associated with retail, health and offices. Again, a large proportion of this increase in likely to involve regular commuter travel typically associated with offices where improved or targeted PT may offset the probable travel increases associated with this increased employment. Large city PT systems in New Zealand are generally well developed and could cater for the expected increase, but generally only involve bus systems rather than a combination of bus and rail.

The dispersed scenarios would result in relatively little change in employment within the large cities, with only the manufacturing and transport sectors having significant reductions in employment. That means that under these dispersed scenarios, little change in total current vehicle movements is likely. However, there is likely to be some redistribution of where those movements occur. The reduction in manufacturing and transport employment will result in some decrease in employment and hence heavy commercial vehicle (HCV) activity in more central parts of the city, and increase those metrics in the urban fringe and to other rural areas and towns. The net effect under those dispersal scenarios would be a reduction in existing HCV movements that currently originate within the urban area, especially near the core, but there would be some (smaller) increase in peripheral parts of the urban area.

As for Auckland, it is considered that flexibility and a relatively permissive planning approach (ie provision for mixed land uses, avoiding reverse sensitivity effects etc) will be required within any future land use planning framework in Hamilton and the wider Waikato region. In this regard, it is important to note that Hamilton City Council, in conjunction with the Waikato and Waipa District Councils and Waikato Regional Council, prepared a *Future proof strategy and implementation plan* in 2009 (Futureproof 2009). The plan (currently being reviewed), which aims to manage future growth in the area for the next 50 years, has been reflected within the local authorities' recently updated district and city plans.

Based on potential outcomes from the modelling land use planning, responses should include ensuring that Hamilton, and in particular the CBD, remains a key service delivery location for the region, while the regional townships retain the ability to accommodate service centres that provide for the sectors that need to be located in these areas. Growth in these areas may need to be provided for by intensification, expansion into zones put aside for other uses and use of vacant land or buildings zoned for other activities where land demand has contracted.

Given the modelled contraction of manufacturing within the urban area under three of the four scenarios, and other sectors under the dispersal scenarios, it is important that the land use planning framework enables other compatible land uses to develop in areas that may become vacant land as a result of reduced demand for land for specific activities. This includes, but is not limited to, providing for brownfields development and mixed uses, rather than single uses, within specific zones.

Under the dispersal scenarios, land use planning provisions will need to give consideration to the protection of primary production activities where this is important to the social and economic well-being of the Waikato region, while also providing flexibility for potential expansion into these rural areas and mixed land use provisions.

6.1.3 Large town: Nelson

The scenarios for large towns appear to be the result of relatively little change in employment within the town irrespective of the scenario assumed. The dispersal scenarios result in employment between current (2016) and BAU 2056 levels, and the concentration scenarios indicate similar or lower levels of employment to current. The impact of all scenarios on the operation of the transport network is therefore likely to be similar.

Under a dispersed scenario, the movement of employment to surrounding satellite rural towns may result in small changes in vehicle flows between town and these rural communities but the number of movements is likely to be small, and result in a corresponding small change in network operation. Any increase in transport requirements could eventually be met in large part by new mobility as a service

(MaaS) schemes. Such schemes could replace the need for private vehicle ownership in places where PT coverage and frequency is currently poor, necessitating private vehicle ownership for mobility.

As for the larger urban areas, flexibility and a relatively permissive planning approach (ie providing for mixed land uses, avoiding reverse sensitivity effects etc) will be required within any future land use planning framework in Nelson and Tasman.

Specific land use planning responses might include ensuring that Nelson and the regional townships retain the ability to accommodate service centres, whether they are expanding or contracting, that provide for the sectors that need to be located in these areas. A key matter for consideration, given the reduction in land demand in Nelson under all scenarios and other parts of the region under the concentration scenarios, is providing for mixed use and the use of vacant land or buildings zoned for other activities where land demand has contracted.

Given the modelled contraction of all modelled service sectors within Nelson under all four scenarios, it is important the land use planning framework enables other compatible land uses to develop in areas that may become vacant land as a result of reduced demand for land for specific activities. This includes providing for brownfields development and mixed uses, rather than single uses, within specific zones.

6.1.4 Small town: Ashburton

As with large towns, the different land use scenarios for small towns would result in little change in employment within the town. The two lesser automation scenarios would result in employment increasing by 12% and 22% over current levels, although still much less than the increase under a BAU future by 2056 (28% increase). The only employment decline is projected under a greater automation, concentration scenario. The impact of these different scenarios on the operation of the transport network is therefore likely to be very similar.

Unlike the other urban areas summarised, small towns would benefit from the dispersal scenarios, notwithstanding the additional modelled effects arising from automation. Under the dispersed scenarios employment, including that generating HCV movements, would be more likely to locate in smaller communities. Given that smaller urban areas are generally serviced by commercial vehicles from surrounding metropolitan and larger areas, the change in HCV movements may not be appreciable. As discussed above for large towns, towns such as Ashburton could benefit from MaaS, through introducing alternatives to private vehicle ownership, and to mitigate the effects of any increased presence of economic activities.

Flexibility and a relatively permissive planning approach will be important for Ashburton and the broader Canterbury region, as for the other urban areas assessed above. Other key considerations for planning will be ensuring regional townships retain the ability to accommodate service centres that adequately provide for the sectors that need to be located in these areas to service local communities. Growth should be accommodated through a combination of methods, including intensification, changed land use and occupation of vacant land or buildings by activities other than originally intended.

Given the modelled contraction of a number of specific sectors, particularly in manufacturing, it is important the land use planning framework enables other compatible land uses to develop in areas that may become vacant land as a result of reduced demand for land for specific activities. Being an area where primary production is a key economic sector, land use planning provisions will need to give consideration to the protection of primary production activities, while also providing flexibility for potential expansion into rural areas.

6.2 Sector perspective

6.2.1 Manufacturing

The level of manufacturing activity is heavily dependent on the extent of automation assumed. The greater automation scenarios result in a decrease in overall employment associated with manufacturing. This will result in a reduction in the number of personal vehicle movements to and from manufacturing areas, and potentially also in the HCV movements to and from manufacturing businesses. The lesser automation scenarios would yield an increase in manufacturing employment and therefore imply a corresponding increase in HCV movements wherever the activity is located.

The main difference between the concentrated and dispersed lesser automation scenarios is where that growth in manufacturing, and therefore private vehicle and HCV movements, are centred. A lesser automation, concentrated scenario increases manufacturing and HCV activity overall with the majority of the increase centred on larger urban areas, and metropolitan areas in particular. This is the only scenario where built-up areas already experiencing congestion may have to deal with additional manufacturing activity and associated vehicle movements.

Conversely, a lesser automation, dispersed scenario could result in a doubling of HCV movements to/from and around rural communities, over current levels. Strategic rural routes and intersections may need improvements to allow for the increased HCV demand in particular, as well as additional passing lanes on already heavily trafficked roads.

As provided in relation to the urban areas, flexibility for planning frameworks will be important in appropriately managing the uncertainty inherent in the assessed scenarios, and this is especially true for manufacturing given the wide range of potential responses the literature indicates might occur in the sector as a response to technology.

A key challenge for the manufacturing sector will be to ensure that sufficient land is provided in locations separated from incompatible activities, to avoid reverse sensitivity effects. This may include providing for mixed uses within industrial zones, in non-residential or other sensitive locations. Growth in the sector could be provided through intensification within existing industrial zones or expansion into existing (brownfields) zones where demand for other activities has contracted, as long as reverse sensitivity issues are avoided.

Under the dispersal scenarios where manufacturing activity in rural areas increases, land use planning provisions will need to give consideration to the protection of primary production activities where this is important to the social and economic well-being, while also providing flexibility for potential expansion into these rural areas, which may include providing for mixed land uses.

6.2.2 Transport

Transport and manufacturing activity are closely aligned, and therefore it is not surprising that the transport industry shares a similar set of expected changes as a result of the different scenarios. The level of transport activity is heavily dependent on the level of automation assumed, with greater automation projected to have a larger impact on transport that in any other sector. The possibility that 3D printing could lead to an emergence of 'private self-manufacturing' (Frey and Osborne 2015) and the likely gains in manufacturing productivity will mean less need for HCV transport. The ability to automate transport, including HCVs, will reduce the need for drivers and therefore commutes to work.

Scenarios involving lesser automation result in small increases in transport activity and therefore vehicle movements. Again the main different between the concentration and dispersal variants of the lesser automation scenario is where the growth in transport, and therefore private vehicle and HCV movements, will be centred. A lesser automation, dispersal future results in the status quo overall for the transport industry with small reductions in larger urban areas (where there is most pressure on existing infrastructure) but with larger increases in transport and associated vehicles in the rural areas (where there is more extant capacity to accommodate growth).

The implications for developing a future planning framework that appropriately accommodates the requirements of the transport sector are very similar to those discussed for the manufacturing sector, and include the need to provide flexibility to accommodate a potential range of transport solutions for the different land use change scenarios.

6.2.3 Retail and services

In all scenarios, retail and services employment increases irrespective of the level of automation and other outside influences such as online shopping. This is the case because even though an increasing number of purchases are being made online, many consumers still prefer in-person comparisons of goods and services before purchasing. Others will research items and compare prices online but finalise their purchase in-person.

Retail and service activities generate private and both light and heavy commercial vehicle movements, the latter for delivery of stock and the former for consumers and staff. Increasing online shopping will result in additional movements of courier vehicles, and these may be concentrated at times of the day when people are home to take delivery of purchases, or during the workday to work addresses. The possibilities for change in this area are further broadened by innovations such as UAVs and multicopters, which are likely to become feasible opportunities for automated deliveries, and might effectively replace private vehicle movements (DHL 2014). Most consumers do not use PT as a means of accessing retail and services providers (unless they live very close to PT stops), due to the difficulty of transporting purchases. Many consumers also use private vehicles not only for getting to retail destinations, but also for moving between precincts within them.

The increasing prevalence of AVs may give rise to different outcomes. First, there would be a reduced need for parking within walking distance of retail stores, as AVs could drop shoppers at the door and drive away. Second, that ability may give rise to increased congestion on the roads, as AVs could, especially if cheap to run once electric vehicles become mainstream, circle on roads waiting to collect passengers instead of travelling away to a remote parking location.

There would be an increase in activity in rural and smaller towns under the dispersal scenarios. There are two possible outcomes from this. First, dispersal could be broadly spread across many locations, in which case few access issues would be foreseeable. Alternatively, dispersal away from larger urban areas could result in dispersed activity establishing in a few specific small towns or rural areas. This would effectively result in large nodes of activity concentrating in these areas, possibly due to some particular geographic attractant or due to agglomeration benefits offered. Any such concentration may become noticeable and require a considered approach to facility design in those places.

The lesser automation scenarios would result in a significant increase in employment in metropolitan areas. The lesser automation, concentration scenario projects a significant increase in retail employment in the metropolitan areas (of 50%, to 2056), and is likely to have a significant impact on vehicle flow associated with retail within those largest cities.

The employment and land use scenarios indicate that there will be continued demand for retail and associated services to be provided in all communities. Therefore it is important the planning framework continues to provide for these services locating within these communities to meet their needs. As identified for other sectors, these needs can be met through intensification in existing zones, or a move to more of a mixed use environment, where the compatibility of neighbouring land uses in the future may be much changed from the current situation. To meet these needs the planning framework will need to be flexible and permissive, which might include providing for mixed use, intensification, expansion into zones put aside for other uses and development in brownfields areas.

6.2.4 Offices

In all four types of urban area assessed, a lesser automation, concentrated scenario will result in a large increase in office activity. Office activity generally involves light vehicles only, implying a likely large increase in vehicle activity to move employees to and from office-based jobs under this scenario. However, regular hours and a tendency for offices to agglomerate in centres make office activity the sector most readily served by PT, because travel generally occurs during commuter times, at regular hours and to fewer, concentrated locations. Irrespective of the size of town or city, if PT serves commuter travel times and areas of large-scale office activity, a large proportion of the potential increase in vehicle activity associated with this increase could be accommodated by PT movements.

Most other scenarios are not expected to result in an increase in office activity to a similar level. There are differences between the scenarios, but only relating to where increase would occur. Only a greater automation, dispersal scenario is expected to result in little overall change in office activity. However, that scenario would result in a move to outlying areas, which could result in longer commutes and increased vehicle flow in suburban and rural areas.

The projected continued demand for offices in all communities will require continued flexibility of zoning for office activities. Most planning documents around the country now apply a reasonably permissive approach to office-based activities, and maintaining this approach will provide the flexibility required to manage the challenges of future, technologically affected environments.

7 Conclusions

7.1 Literature review and stakeholder interviews

Automation and new technologies are expected to have significant impacts on the type, nature and characteristics of employment in the industrial, service and commercial sectors. Little research has been carried out to determine whether such changes will have an impact on the location of employment and land use patterns, and any consequent transport sector implications.

Future technological changes are likely to be profound, as a result of several significant, foreseeable innovations, and possibly others that are not anticipated. While historically the introduction of new technologies has not tended to result in a net decrease in employment, this may not be the case in the future, when change may be significantly more disruptive.

Major new innovations such as AVs, drones, online retail and the internet of things will potentially have a much more different effect on employment and land use than have previous innovations, although commentators are notably split about the potential implications of new technology. There is very little consensus on this issue, with expert opinion varying from expectations of limited effects at one extreme to very significant effects at the other.

The literature review found that understanding future pathways and effects is generally accepted to be difficult and highly uncertain. Most studies focus on only individual innovations, and do not attempt to quantify the effects of multiple innovations or across whole economies or large spatial areas.

The sector interviews were generally consistent with the literature review's findings. The potential for technology-driven change is well recognised and anticipated by New Zealand organisations, and although respondents are not expecting major changes in the very near future, beyond the next one to two decades there is high degree of uncertainty as to how technology might affect the way we live, how businesses operate and the nature of employment and land use demand.

There are many divergent opinions, and little consensus on the potential future of land use and employment as a result of the various particular innovations that are now anticipated. The high degree of uncertainty revealed in the literature search justifies the position described by respondents in the sector interviews that there is a general preference to be followers rather than leaders in the adoption of new technology. Attempting to lead in the use of new technology can be a costly endeavour and it is very hard to confidently pick winners. For this reason, planning for the location of employment and land use patterns and consequent transport sector implications is also difficult. Techniques such as scenario or horizon planning that can accommodate divergent future development outcomes and their associated uncertainty may represent a sound basis for planning.

7.2 Employment and land use projections and implications

7.2.1 National projections

Total New Zealand employment is currently 2.34M MECs, and is projected to increase to 2.99M MECs by 2056 under a BAU future. This future is the baseline against which are compared projections from the four alternative scenarios, defined as combinations of either lesser or greater automation, and geographic concentration or dispersal. The scenarios are intended to reflect the broad range of possible outcomes indicated, and the absence of consensus presented in the relevant literature. Note that these are not predictions of future employment, they are rather projections of employment under the assumed combination of future circumstances.

The BAU future would yield more employment than any of the four scenarios modelled, because all four scenarios assume some increased level of automation over current levels, and therefore a slowing of employment growth compared with the BAU projections (which make no specific assumptions about automation). Under the two lesser automation scenarios, total national employment in 2056 would increase slightly less than under the BAU and be around 97% of the BAU level, whereas under the greater automation scenarios employment would be only 84% of the BAU level.

There are notable exceptions to these national trends, and under some scenarios certain urban area-sector pairings might exhibit much stronger growth (or larger declines) than under the BAU future. Currently more than half of New Zealand employment is located in the three large metropolitan centres of Auckland, Wellington and Christchurch. Under the two concentration scenarios those metropolitan cities and New Zealand's large cities and towns would attract greater shares of employment, and require larger areas of land to accommodate workers, while rural and smaller urban areas would have a declining share and number of workers. Those scenarios are consistent with a significant body of opinion in literature that expects concentration to continue.

Under the dispersal scenarios the situation would be reversed, with a move away from larger centres facilitated by technological improvements giving business more flexibility with where they locate, and providing workers with more options of where to live. Dispersal scenarios would be contrary to long-term trends in New Zealand, although there is the possibility that imminent technological advances might result in changes to long-established patterns, meaning these dispersal scenarios are realistic.

The total land area required to accommodate the workforce shows similar trends, although consistent with historic productivity improvements, increasing employment density is projected. That would result in a more efficient use of business land, and slower growth in land demand than employment. At a national level the land occupied by the modelled employment would increase by only 96% as much as under the BAU future (given lesser automation), or only 81% as much (given greater automation).

Four key sectors were chosen for which to assess employment and land use trends, given possible future technology drivers of change. For the offices and retail sectors employment growth is projected to be positive under most scenarios, with growth projections in the manufacturing and transport sectors less optimistic, and in some cases indicating an expected decline in employment relative to 2016 levels. Although technology is likely to replace some employment in the office and retail sectors, the extent of that is indicated by the literature reviewed to be less than in manufacturing and transport. Continued growth in robotics and other automated technology in the latter sectors, including automated vehicles, will potentially replace large numbers of jobs in the coming decades.

In summary then, the most likely outcome of technology-driven change in employment is for a decrease, rather than an increase, in most geographic areas, and most sectors, relative to a BAU future, and in many instances relative to a 2016 base.

7.2.2 Larger urban areas

For metropolitan and large cities, the concentration scenarios modelled will result in an increase of employment in most sectors, particularly in retail and services, health and offices. In some urban area-sector pairs the growth will be less than projected under a BAU future, due to the effect of automation, but overall the concentration scenarios indicate strong growth compared with the 2016 base.

A concentration of economic activity to metropolitan areas and large cities would result in significantly more transport demand relative to current levels. While existing metropolitan networks are already congested, a large proportion of the increased employment would involve regular commuter travel typically associated with offices where improved or targeted PT may be able to mitigate the demand increases.

For other sectors that are less conducive to PT use, such as retail and services, education and health, the projected growth would likely manifest as an increase in private vehicle use. That increase would place additional demands on the metropolitan road network and on parking facilities. An increased use of automated vehicles may mitigate this increased demand to some extent, although the real benefits of automation will only be evident when some critical mass of AV use is reached, which may be several decades away. The quantum of change in large cities is expected to show similar characteristics, albeit at a reduced scale than in metropolitan areas, and so the impact on transport movements is expected to be correspondingly lower in large cities.

Under all scenarios except lesser automation, concentration, larger urban areas’ manufacturing and transport employment is projected to either decline or increase only slightly from 2016 levels, with more growth occurring in smaller urban areas instead. Only under that one scenario would there be material implications as a result of increased HCV movements in larger urban areas, although under the other scenarios HCVs would still need to enter larger urban areas to service the populations living there. Further, future HCV movements and employment will not change with a 1:1 relationship, given projected increases in manufacturing productivity as a result of automation.

The dispersal scenarios would result in lower growth in New Zealand’s largest urban areas, and therefore place less pressure on transport infrastructure than the concentration scenarios. However even under those dispersal scenarios some employment growth over current levels is still projected in larger urban areas, and would require some additional capacity to accommodate expanded PT and private vehicle trips.

7.2.3 Smaller urban areas

Outside the metropolitan and large cities, employment is distributed around many different locations, and growth would likely also be widely distributed. In large towns employment is projected to grow by less than the BAU future under all scenarios, and to decline under greater automation scenarios. The magnitude of growth is relatively small under all scenarios, and the impact on the operation of the transport network is therefore likely to be similarly small. Under the dispersal scenarios some employment would move from large towns to their hinterland, increasing vehicle flows between the towns and surrounding rural communities. However, the number of movements is likely to be small, and result in a corresponding small change in network operation.

Unlike larger urban areas, employment in small towns would increase from current levels under the dispersal scenarios, although the growth would be relatively modest, and less than under the BAU future. The modest growth and extant spare capacity in most small towns’ existing networks would mean that an increase in vehicle movements, including HCVs, may not be appreciable, and is unlikely to present major challenges for transport planning.

7.2.4 Manufacturing and transport sectors

Manufacturing employment is vulnerable to automation, and therefore heavily dependent on the extent of automation assumed. The greater automation scenarios would result in a decrease in manufacturing employment, a corresponding reduction in the number of personal vehicle movements to and from manufacturing areas, and potentially also a decrease in the HCV movements servicing those businesses.

The lesser automation scenarios would yield growth in employment and therefore imply a corresponding increase in HCV movements wherever the activity is located. The concentration scenarios focus growth into larger urban areas, and metropolitan areas in particular, and only under the lesser automation, concentration scenario would larger urban areas have to deal with additional manufacturing activity and associated vehicle movements. The dispersal scenarios would present different challenges, including the potential need to provide new passing lanes and improve strategic rural routes and intersections to allow for the increased HCV demand outside the main urban areas.

Transport and manufacturing activity are closely aligned, and expected to experience similar types of change. As for manufacturing, the transport sector is vulnerable to automation, and in fact more so than any other sector. Not only will AVs automate transport and reduce the need for drivers and therefore reduce commuting, but democratisation of manufacturing through advents such as 3D printing could lead to reductions in HCV transport. Currently most pressure on existing infrastructure is in larger urban areas, and it is only under the lesser automation, concentration scenario that employment growth in these areas would approach a BAU future. Under all other scenarios larger urban areas would see a decline in transport employment and likely also in vehicle movements.

7.2.5 Retail and services and office sectors

In all scenarios retail and services employment would increase. The sector generates private and both light and heavy commercial vehicle movements, and because few consumers use PT to access retail and service businesses, growth in employment indicates a likely comparable growth in private vehicle use. This increase could be very significant, and up to 50% in larger urban areas under concentration scenarios, requiring additional transport planning. Under dispersal scenarios the increase could be broadly spread across many locations, in which case few access issues would be foreseeable, or a less likely outcome could see a more aggregated grouping of dispersed activity in few specific small towns or rural areas. Any such aggregation may require a considered approach to facility design in those places.

Office employment is projected to experience strong growth only under the lesser automation scenarios. However, even high rates of growth are likely to be readily accommodated, because of regular hours, the tendency for offices to agglomerate make office activity the sector most readily served by PT. For this reason, irrespective of the size of town or city, a large proportion of the potential increase in vehicle activity associated with this increase could be accommodated by PT movements.

8 Recommendations

This section provides recommendations for incorporating changes in transport models and land use planning strategies.

8.1 Transport modelling

The recommendations for accommodating future potential change that might occur as a result of technology are:

- There needs to be development of detailed models to understand the dynamics between employment growth and land use by sector, to a greater degree than completed for this project. Key expansion over the work completed for this assessment might include a greater emphasis on high growth regional towns such as Queenstown, Napier/Hastings and Tauranga, and increased sectoral definition in key sectors such as manufacturing and health.
- Detailed models should investigate and recognise the paradox of intensification, where intensification results in increased traffic movements, especially shorter movements.
- The relationship between land use and transport planning needs to be explored further.
- There should be a move to increase the use of future land use scenario tests to create a spread of possible futures, rather than relying on a single scenario.
- A risk matrix assessment of the likeliness of changes in employment dispersion vs automation should be undertaken.
- As automated vehicles become more prevalent, research into the level and type of zero occupant vehicle trips should be investigated.

8.2 Land use planning

The key planning responses to accommodate future potential change that might occur as a result of technology are:

- Ensure permissive and flexible land use planning approaches to accommodate both concentration and dispersal scenarios.
- Provide for mixed use development, while ensuring incompatible activities or activities that have the potential to give rise to reverse sensitivity issues do not co-locate within the same area, or are managed appropriately where they do.
- Accommodate service centres that provide for the sectors needed to service the needs of local communities.
- Enable compatible land uses to develop in vacant or underutilised sites, including mixed use activities within specific zones.
- With respect to the dispersal scenarios, ensure the protection of primary production activities.

Within the current New Zealand regulatory framework, a range of planning tools and approaches exist which can be implemented or adapted to address the above items. The four recommendations below focus on what can be achieved within the existing regulatory framework context rather than being recommendations to the legislation, which has defined this framework.

8.2.1 Policy statement and plan development input

It is considered that the majority of the implications can, for the most part, be accommodated through New Zealand's existing regulatory framework within which policy statements and plans and formulated and resource consents and other approvals such as outline plans are considered. This first land use planning recommendation is that within the existing regulatory framework, deliberate consultation and engagement to identify and discuss issues related to technology would smooth the implementation of new technology while minimising negative outcomes related to the technology. An explanation follows.

Early and meaningful engagement by Ministry for the Environment (MfE) and councils on policy statement and plan formulation process with key stakeholders such as the NZ Transport Agency, KiwiRail, government agencies and key business interests can help identify technological developments and potential implications for consideration. Given the rate and evolution of technological change this engagement should be ongoing. Engagement can be supplemented by submissions at the plan notification stage and subsequent attendance at hearings to create a flexible and permissive regulatory framework capable of responding to the various concentration and dispersal scenarios. Such involvement will be further supplemented through involvement in non-statutory documents, and engagement where appropriate in the resource consent process.

Providing a flexible and permissive approach will overcome delays for early adapters and first movers, and provide certainty for businesses and organisations to make decisions in response to land use scenarios and technological changes without undue delay and hesitation. This will promote efficient economic development while mitigating adverse and unforeseen effects of new technologies.

This certainty could be achieved through greater use of permitted activity status, or where resource consent is required, allowing for consent to be obtained on a non-notified basis. With this certainty, businesses are more likely to adapt to technological changes and optimise land use choices. Without such certainty, business decisions are likely to be delayed owing to perceived risk and delays in consenting processes which can be further complicated if councils are not familiar with what is being proposed. First movers will be penalised and costs and delays will delay and inhibit the speed of investment and uptake, to the detriment of the national and regional economics.

Approaches which seek to accommodate changes in land use are already apparent in some recently developed plans, such as the Christchurch District Plan, which encourage the diverse use of brownfield sites which are otherwise disused, while limiting opportunities to prevent redevelopment of these sites. The above approach also allows for the protection of primary production activities through reverse sensitivity provisions limiting incompatible land uses establishing nearby, while also providing flexibility for potential expansion into these rural areas.

8.2.2 Central government advisory group

The second land use planning recommendation is for the formation of an advisory group led by a central government ministry (such as MfE), to provide overarching guidance for councils of how to deal with the challenges posed by expected technological and land use changes. Similar approaches (such as the New

Zealand Urban Design Protocol[5]) have been applied for other issues that have faced the planning community, in order to facilitate consistent adoption and implementation of good practice.

Understanding the issues facing councils and government and providing input into regulatory documents to address these items would be a key focus of such a group. The group could contribute to plan formulation as discussed above, and form the basis for working towards a national policy statement to guide planning development on the topic, a guidance note as discussed below, or alternatively seek to maximise the implementation of the National Planning Standards currently under development by MfE.

8.2.3 Quality planning guidance note

The third recommendation to manage the challenges posed by technological change is the creation of a technical working group to prepare a specific Planning Guidance Note on Transportation and Technology. This could be undertaken either in combination with or as an alternative to the central government recommendation note (above), and could be hosted on the Quality Planning Website[6]. This website was developed in 2001 to promote good practice by sharing knowledge about all aspects of practice under the Resource Management Act 1991 (RMA) among resource management practitioners, council planners, private practitioners, consultants and environmental specialists.

Regular exercises are undertaken by the Quality Planning partners to identify the need for note update and development resulting from:

- the emergence of pressing new issues, such as technology in transport planning
- changes to or new notes initiated by industry and sector
- changes to the legislative framework, evolving case law and new best practice.

A multi day workshop is often convened to enable the preparation of a guidance note involving MfE, Local Government New Zealand and key stakeholder, industry and regulatory bodies. The resulting guidance notes are freely available on the Quality Planning website and guide planners, technical experts and decision makers on good practice.

8.2.4 National Planning Standards

The National Planning Standards[7] were introduced as a part of the 2017 RMA amendments and seek to enable a nationally consistent approach to drafting plans, environmental standards, policy documents and regulations under the Act. The standards also support implementation of national policy statements and help people observe the procedural principles of the RMA.

The fourth recommendation is that there should be some provision of feedback on the National Planning Standards currently under development, or preparation of a new National Planning Standard in relation to managing the effects of technology. Either option could help overcome delays and inconsistencies with how councils provide for new approaches and provide some alternative approach to the default position of classifying activities as non-complying or discretionary activities. This approach would be intended to provide a template for facilitating and understanding changes which many smaller councils may not otherwise be well equipped to manage.

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[5] www.mfe.govt.nz/publications/towns-and-cities/new-zealand-urban-design-protocol

[6] www.qualityplanning.org.nz/

[7] www.mfe.govt.nz/rma/legislative-tools/national-planning-standards

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Appendix A: Sector interview survey questions

The sector interviews involved a structured, but open-ended discussion with respondents. Respondents were provided with a list of questions and intended scope prior to being interviewed, to guide the discussion and give respondents the opportunity to plan responses. Interviews were allowed to follow different paths in pursuit of interesting discussions. The key interview questions are provided below.

1 Can you provide a summary of the main operations of your business?

2 What have been the key changes in the last decade in your industry? Guide relevant lines of thought, and *explore the idea that change is ongoing and future changes may be just continuation of the current trends.*

- How has your company's business changed due to innovations or new technology?
- Has there been any material change in employment requirements?
- How has net employment changed: has there been a decrease in jobs for some roles, but increases in others?
- How have space requirements changed?
- To what extent are current changes part of broader, ongoing changes?

3 What do you see as the key drivers of change that will affect your sector and organisation in the future? *Guide to discuss different horizons, (short, medium and long term), and refer to following topics:*

3a Technology drivers:

- Can you identify the key technology changes expected?
- How are these likely to affect your sector and organisation?
- What rate of change do you anticipate? *For each change.*
- What extent of change do you anticipate? *(How widespread will the uptake be, for each?)*
- What factors are likely to influence the speed and extent of change?
- What planning provision and corporate structures does your entity have in place to adjust to and take advantage of changes?

3b Economic drivers:

- What are the key structural economic changes you anticipate?
- How are these likely to affect your sector and organisation?
- What rate of change do you anticipate? *For each change.*
- What extent of change do you anticipate? *(How widespread will the uptake be, for each?)*
- What factors are likely to influence the speed and extent of change?
- What planning provision and corporate structures does your entity have in place to adjust to and take advantage of changes?

4 What do you anticipate will be the main impediments to change in your business and the wider sector, and how will the challenges presented by those impediments be addressed?

5 How do you see the future of your industry, especially in terms of employment, structural changes, rationalisation, location decisions and transport implications? In particular:

- net employment changes
- types of occupations that might decline or emerge
- number of physical locations *(eg stores, warehouses, parcel collection points)*
- consumer interactions *(eg physical presence, consumer demands, retail as a showroom)*
- space requirement *(eg staff accommodation including telecommuting, goods and storage)*
- emergence of new delivery channels *(eg online sales, videoconferencing)*
- change in productivity *(eg need less space to produce the same output/turnover).*

6 Same as question 5, but in relation to respondent's business specifically (if not already addressed).

7 [*If not yet discussed]* Are you aware of any technology changes that are likely to affect your business but have not yet? If they are likely to emerge, but have not yet, why haven't they? *Guide: are they available but too expensive, not available in NZ but will be, not reliable enough yet, subject to regulatory constraints?*

Appendix B: Tabular data

This appendix contains tabular data underlying the figures in chapter 5, and is arranged in nine subsections for national level data, four urban areas and four sectors.

B1 New Zealand data

Table B.1 New Zealand employment by urban area and scenario (MECs)

Industry	2016	2056				
	BAU	BAU	Greater automation, dispersal	Greater automation, concentration	Lesser automation, dispersal	Lesser automation, concentration
Ag and horticulture	164,050	200,530	283,630	133,740	291,660	141,760
Mining	5,220	6,270	8,000	4,730	8,250	4,980
Manufacturing	233,660	289,370	214,590	194,340	289,830	269,570
Infrastructure	15,480	19,410	19,170	18,770	19,940	19,540
Construction	200,380	252,330	225,230	223,710	250,460	248,940
Transport	98,610	124,150	59,510	63,980	107,920	112,390
Wholesale trade	113,300	145,780	117,560	138,480	127,760	148,680
Retail and services	379,430	486,720	423,260	436,870	467,060	480,670
Telecommunications	42,860	54,600	42,970	52,550	47,890	57,470
Offices	566,080	722,170	555,440	643,620	642,100	730,280
Education	178,390	231,770	199,640	210,330	220,500	231,180
Health	234,170	314,310	259,030	292,600	287,310	320,880
Services	109,920	139,250	104,530	111,130	129,600	136,200
Total	**2,341,550**	**2,986,640**	**2,512,560**	**2,524,830**	**2,890,290**	**2,902,560**

Table B.2 New Zealand land use by urban area and scenario (ha)

Industry	2016	2056				
	BAU	BAU	Greater automation, dispersal	Greater automation, concentration	Lesser automation, dispersal	Lesser automation, concentration
Ag and horticulture	-	-	-	-	-	-
Mining	-	-	-	-	-	-
Manufacturing	11,230	10,820	8,460	6,970	11,270	9,790
Infrastructure	320	350	360	320	380	340
Construction	8,860	9,230	8,590	7,940	9,510	8,860
Transport	2,330	2,150	970	1,150	1,800	1,990
Wholesale trade	4,760	5,070	4,190	4,750	4,540	5,100
Retail and services	6,020	6,380	5,740	5,590	6,310	6,160
Telecommunications	640	680	540	650	610	710
Offices	5,740	5,960	4,720	5,210	5,440	5,930

Industry	2016	2056				
	BAU	BAU	Greater automation, dispersal	Greater automation, concentration	Lesser automation, dispersal	Lesser automation, concentration
Education	5,410	5,800	5,170	5,130	5,690	5,660
Health	870	970	810	890	900	970
Services	2,070	2,090	1,640	1,620	2,020	1,990
Total	**48,260**	**49,510**	**41,190**	**40,220**	**48,470**	**47,500**

Table B.3 New Zealand employment by sector and scenario (MECs)

Industry	2016	2056				
	BAU	BAU	Greater automation, dispersal	Greater automation, concentration	Lesser automation, dispersal	Lesser automation, concentration
Metro	1,228,850	1,649,620	1,116,900	1,578,800	1,331,660	1,793,560
Large city	222,320	272,960	200,500	255,090	234,890	289,480
Large town	269,580	310,900	249,600	271,360	289,240	311,000
Medium town	133,020	159,620	132,280	120,740	152,060	140,520
Small town	139,470	168,910	190,010	101,070	211,240	122,300
Small urban area	87,290	105,890	139,230	47,100	152,700	60,570
Rural	261,020	318,740	484,040	150,680	518,500	185,140
Total	**2,341,550**	**2,986,640**	**2,512,560**	**2,524,840**	**2,890,290**	**2,902,570**

Table B.4 New Zealand land use by sector and scenario (ha)

Industry	2016	2056				
	BAU	BAU	Greater automation, dispersal	Greater automation, concentration	Lesser automation, dispersal	Lesser automation, concentration
Metro	24,130	26,080	17,290	24,590	21,050	28,350
Large city	4,530	4,490	3,220	4,120	3,860	4,760
Large town	5,480	5,120	4,000	4,360	4,750	5,110
Medium town	2,950	2,870	2,320	2,110	2,730	2,520
Small town	3,420	3,350	3,710	1,940	4,190	2,420
Small urban area	2,250	2,210	2,870	950	3,190	1,260
Rural	5,500	5,390	7,780	2,150	8,700	3,070
Total	**48,260**	**49,510**	**41,190**	**40,220**	**48,470**	**47,490**

B2 Auckland data

Table B.5 Auckland employment and land demand change 2016–2056

Variable	BAU	Greater automation, dispersal	Greater automation, concentration	Lesser automation, dispersal	Lesser automation, concentration
Employment (MECs)	41%	-1%	32%	17%	50%
Land area (ha)	13%	-21%	3%	-5%	19%

Table B.6 Auckland employment (2016–2056 (MECs)

Year	BAU	Greater automation, dispersal	Greater automation, concentration	Lesser automation, dispersal	Lesser automation, concentration
2016	766,540	766,540	766,540	766,540	766,540
2021	821,960	768,990	815,020	790,290	836,320
2026	873,500	761,090	858,920	806,220	904,050
2031	917,370	740,500	894,610	811,420	965,540
2036	956,210	711,620	925,810	809,190	1,023,380
2041	990,650	674,910	952,300	800,450	1,077,830
2046	1,022,070	690,370	976,550	824,670	1,110,850
2051	1,050,900	710,110	1,004,360	847,990	1,142,240
2056	1,078,290	728,950	1,030,870	870,150	1,172,070

Table B.7 Auckland land use 2016–2056 (ha)

Year	BAU	Greater automation, dispersal	Greater automation, concentration	Lesser automation, dispersal	Lesser automation, concentration
2016	15,424	15,424	15,424	15,424	15,424
2021	16,088	14,999	15,900	15,466	16,367
2026	16,605	14,363	16,222	15,322	17,182
2031	16,952	13,527	16,375	14,989	17,837
2036	17,184	12,579	16,428	14,535	18,384
2041	17,324	11,544	16,395	13,990	18,840
2046	17,398	11,471	16,343	14,023	18,895
2051	17,404	11,488	16,361	14,030	18,903
2056	17,360	11,473	16,334	13,997	18,858

Table B.8 Auckland employment 2016 and 2056 (MECs)

Industry	2016	2056				
	BAU	BAU	Greater automation, dispersal	Greater automation, concentration	Lesser automation, dispersal	Lesser automation, concentration
Ag and horticulture	3,400	4,560	3,650	4,930	3,830	5,110
Mining	230	290	230	310	240	320
Manufacturing	74,360	99,060	53,490	81,230	79,250	106,990
Infrastructure	4,060	5,640	4,620	6,200	4,850	6,430
Construction	57,590	79,110	57,750	79,900	65,660	87,810
Transport	37,420	49,480	16,820	30,680	36,120	49,980
Wholesale trade	56,650	77,340	56,460	78,120	61,870	83,530
Retail and services	121,490	174,780	127,590	176,530	143,320	192,260
Telecommunications	22,080	29,620	21,620	29,910	24,290	32,580
Offices	225,040	309,030	210,140	296,670	247,220	333,750
Education	57,880	87,350	63,770	88,230	71,630	96,090
Health	71,010	112,210	81,910	113,330	92,010	123,430
Services	35,330	49,820	30,890	44,840	39,860	53,800
Total	**766,540**	**1,078,290**	**728,940**	**1,030,880**	**870,150**	**1,172,080**

Table B.9 Auckland land use 2016 and 2056 (ha)

Industry	2016	2056				
	BAU	BAU	Greater automation, dispersal	Greater automation, concentration	Lesser automation, dispersal	Lesser automation, concentration
Ag and horticulture	-	-	-	-	-	-
Mining	-	-	-	-	-	-
Manufacturing	3,190	3,320	1,793	2,722	2,656	3,585
Infrastructure	51	63	51	69	54	71
Construction	2,285	2,607	1,903	2,633	2,164	2,894
Transport	1,003	974	331	604	711	983
Wholesale trade	2,247	2,549	1,861	2,575	2,039	2,753
Retail and services	1,747	2,088	1,524	2,109	1,712	2,297
Telecommunications	317	354	258	357	290	389
Offices	2,138	2,400	1,632	2,304	1,920	2,592
Education	1,597	2,002	1,461	2,022	1,641	2,202
Health	245	321	235	325	264	354
Services	605	683	424	615	546	738
Total	**15,424**	**17,360**	**11,473**	**16,334**	**13,997**	**18,858**

Table B.10 Auckland employment change 2016–2056 (MECs)

Industry	BAU	Greater automation, dispersal	Greater automation, concentration	Lesser automation, dispersal	Lesser automation, concentration
Ag and horticulture	1,160	250	1,530	430	1,710
Mining	60	-	80	10	90
Manufacturing	24,700	-20,870	6,870	4,890	32,630
Infrastructure	1,580	560	2,140	790	2,370
Construction	21,520	160	22,310	8,070	30,220
Transport	12,060	-20,600	-6,740	-1,300	12,560
Wholesale trade	20,690	-190	21,470	5,220	26,880
Retail and services	53,290	6,100	55,040	21,830	70,770
Telecommunications	7,540	-460	7,830	2,210	10,500
Offices	83,990	-14,900	71,630	22,180	108,710
Education	29,470	5,890	30,350	13,750	38,210
Health	41,200	10,900	42,320	21,000	52,420
Services	14,490	-4,440	9,510	4,530	18,470
Total	**311,750**	**- 37,590**	**264,330**	**103,610**	**405,530**

Table B.11 Auckland land use change 2016–2056 (ha)

Industry	BAU	Greater automation, dispersal	Greater automation, concentration	Lesser automation, dispersal	Lesser automation, concentration
Ag and horticulture	-	-	-	-	-
Mining	-	-	-	-	-
Manufacturing	130	-1,398	-468	-534	395
Infrastructure	12	1	18	3	21
Construction	323	-381	349	-121	609
Transport	-29	-672	-399	-292	-19
Wholesale trade	302	-387	327	-208	506
Retail and services	341	-223	362	-35	550
Telecommunications	36	-59	40	-27	72
Offices	262	-506	166	-218	454
Education	405	-135	425	45	605
Health	77	-10	80	19	109
Services	79	-181	10	-58	133
Total	**1,936**	**- 3,951**	**910**	**- 1,427**	**3,434**

B3 Hamilton data

Table B.12 Hamilton employment and land demand change 2016–2056

Variable	BAU	Greater automation, dispersal	Greater automation, concentration	Lesser automation, dispersal	Lesser automation, concentration
Employment (MECs)	27%	-7%	18%	9%	34%
Land area (ha)	2%	-27%	-6%	-12%	8%

Table B.13 Hamilton employment 2016–2056 (MECs)

Year	BAU	Greater automation, dispersal	Greater automation, concentration	Lesser automation, dispersal	Lesser automation, concentration
2016	99,870	99,870	99,870	99,870	99,870
2021	105,310	99,850	104,060	102,400	106,610
2026	110,360	98,940	107,760	104,270	113,090
2031	114,450	96,690	110,420	104,970	118,710
2036	117,850	93,530	112,390	104,850	123,710
2041	120,660	89,580	113,720	104,040	128,170
2046	122,950	90,400	114,990	105,860	130,450
2051	124,790	91,740	116,700	107,440	132,400
2056	126,530	93,020	118,330	108,940	134,250

Table B.14 Hamilton land use 2016–2056 (ha)

Year	BAU	Greater automation, dispersal	Greater automation, concentration	Lesser automation, dispersal	Lesser automation, concentration
2016	2,039	2,039	2,039	2,039	2,039
2021	2,095	1,977	2,061	2,037	2,120
2026	2,133	1,894	2,064	2,014	2,185
2031	2,151	1,790	2,049	1,972	2,230
2036	2,156	1,675	2,020	1,917	2,262
2041	2,150	1,552	1,982	1,853	2,283
2046	2,136	1,525	1,953	1,837	2,264
2051	2,113	1,510	1,933	1,818	2,241
2056	2,086	1,491	1,908	1,795	2,212

Table B.15 Hamilton employment 2016 and 2056 (MECs)

Industry	2016	2056				
	BAU	BAU	Greater automation, dispersal	Greater automation, concentration	Lesser automation, dispersal	Lesser automation, concentration
Ag and horticulture	4,020	5,120	4,350	5,380	4,560	5,580
Mining	60	80	70	80	70	90
Manufacturing	10,990	13,840	8,170	10,930	11,760	14,530
Infrastructure	710	910	790	970	820	1,000
Construction	8,790	11,050	8,620	10,830	9,720	11,930
Transport	2,800	3,520	1,370	2,080	2,740	3,450
Wholesale trade	4,140	5,010	3,910	4,910	4,260	5,260
Retail and services	15,070	19,150	14,940	18,770	16,660	20,490
Telecommunications	1,320	1,650	1,290	1,620	1,440	1,770
Offices	22,950	28,720	20,970	26,710	24,410	30,160
Education	9,080	11,560	9,020	11,330	10,060	12,370
Health	15,000	19,760	15,410	19,360	17,190	21,140
Services	4,930	6,170	4,130	5,360	5,240	6,470
Total	**99,860**	**126,540**	**93,040**	**118,330**	**108,930**	**134,240**

Table B.16 Hamilton land use 2016 and 2056 (ha)

Industry	2016	2056				
	BAU	BAU	Greater automation, dispersal	Greater automation, concentration	Lesser automation, dispersal	Lesser automation, concentration
Ag and horticulture	-	-	-	-	-	-
Mining	-	-	-	-	-	-
Manufacturing	511	503	297	397	428	528
Infrastructure	19	21	18	22	19	23
Construction	374	391	305	383	344	422
Transport	57	52	20	31	41	51
Wholesale trade	176	177	138	174	151	186
Retail and services	233	246	192	241	214	263
Telecommunications	20	21	17	21	18	23
Offices	234	239	175	223	204	251
Education	269	284	222	279	247	304
Health	56	61	47	60	53	65
Services	90	90	60	78	77	95
Total	2,039	2,086	1,491	1,908	1,795	2,212

Table B.17 Hamilton employment change 2016–2056 (MECs)

Industry	BAU	Greater automation, dispersal	Greater automation, concentration	Lesser automation, dispersal	Lesser automation, concentration
Ag and horticulture	1,100	330	1,360	540	1,560
Mining	20	10	20	10	30
Manufacturing	2,850	-2,820	-60	770	3,540
Infrastructure	200	80	260	110	290
Construction	2,260	-170	2,040	930	3,140
Transport	720	-1,430	-720	-60	650
Wholesale trade	870	-230	770	120	1,120
Retail and services	4,080	-130	3,700	1,590	5,420
Telecommunications	330	-30	300	120	450
Offices	5,770	-1,980	3,760	1,460	7,210
Education	2,480	-60	2,250	980	3,290
Health	4,760	410	4,360	2,190	6,140
Services	1,240	-800	430	310	1,540
Total	**26,660**	**- 6,850**	**18,460**	**9,070**	**34,380**

Table B.18 Hamilton land use change 2016–2056 (ha)

Industry	BAU	Greater automation, dispersal	Greater automation, concentration	Lesser automation, dispersal	Lesser automation, concentration
Ag and horticulture	-	-	-	-	-
Mining	-	-	-	-	-
Manufacturing	-8	-215	-114	-84	17
Infrastructure	2	-1	4	0	5
Construction	17	-69	9	-30	48
Transport	-4	-36	-26	-16	-5
Wholesale trade	1	-38	-3	-26	10
Retail and services	13	-41	8	-19	30
Telecommunications	1	-4	0	-2	2
Offices	5	-59	-11	-31	17
Education	15	-47	10	-22	35
Health	5	-8	4	-3	9
Services	0	-30	-12	-13	5
Total	**47**	**- 548**	**- 130**	**- 244**	**173**

B4 Nelson data

Table B.19 Nelson employment and land demand change 2016–2056

Variable	BAU	Greater automation, dispersal	Greater automation, concentration	Lesser automation, dispersal	Lesser automation, concentration
Employment (MECs)	14%	-8%	0%	6%	14%
Land area (ha)	-8%	-29%	-22%	-15%	-8%

Table B.20 Nelson employment 2016–2056 (MECs)

Year	BAU	Greater automation, dispersal	Greater automation, concentration	Lesser automation, dispersal	Lesser automation, concentration
2016	35,850	35,850	35,850	35,850	35,850
2021	36,960	35,540	36,050	36,450	36,970
2026	38,150	35,220	36,290	37,110	38,170
2031	39,000	34,510	36,150	37,400	39,030
2036	39,590	33,520	35,740	37,420	39,630
2041	39,920	32,290	35,080	37,190	39,980
2046	40,210	32,250	35,060	37,400	40,220
2051	40,560	32,530	35,370	37,730	40,570
2056	40,940	32,840	35,710	38,090	40,960

Table B.21 Nelson land use 2016–2056 (ha)

Year	BAU	Greater automation, dispersal	Greater automation, concentration	Lesser automation, dispersal	Lesser automation, concentration
2016	760	760	760	760	760
2021	763	730	740	752	763
2026	766	698	720	744	765
2031	762	661	693	729	761
2036	752	620	663	709	751
2041	739	578	629	686	738
2046	725	562	612	672	723
2051	713	552	602	661	711
2056	700	543	592	649	698

Table B.22 Nelson employment 2016 and 2056 (MECs)

Industry	2016	2056				
	BAU	BAU	Greater automation, dispersal	Greater automation, concentration	Lesser automation, dispersal	Lesser automation, concentration
Ag and horticulture	2,100	2,380	2,190	2,350	2,280	2,450
Mining	10	10	10	10	10	10
Manufacturing	3,880	4,340	2,870	3,170	3,990	4,300
Infrastructure	180	190	180	200	190	200
Construction	3,110	3,550	3,020	3,270	3,370	3,620
Transport	1,520	1,780	820	940	1,520	1,640
Wholesale trade	1,680	1,930	1,640	1,780	1,780	1,910
Retail and services	7,120	8,100	6,880	7,450	7,610	8,180
Telecommunications	340	390	340	360	370	400
Offices	7,100	8,080	6,460	7,030	7,430	8,000
Education	2,560	2,900	2,460	2,670	2,720	2,930
Health	4,460	5,260	4,470	4,840	4,940	5,310
Services	1,800	2,030	1,500	1,640	1,870	2,010
Total	**35,860**	**40,940**	**32,840**	**35,710**	**38,080**	**40,960**

Table B.23 Nelson land use 2016 and 2056 (ha)

Industry	2016	2056				
	BAU	BAU	Greater automation, dispersal	Greater automation, concentration	Lesser automation, dispersal	Lesser automation, concentration
Ag and horticulture	-	-	-	-	-	-
Mining	-	-	-	-	-	-
Manufacturing	179	157	103	114	144	155
Infrastructure	2	2	2	2	2	2
Construction	137	129	110	119	123	132
Transport	49	41	19	22	35	38
Wholesale trade	73	70	60	65	65	70
Retail and services	113	107	91	98	100	108
Telecommunications	5	5	4	5	5	5
Offices	75	69	55	60	64	69
Education	78	73	62	68	69	74
Health	17	17	14	15	16	17
Services	32	29	22	24	27	29
Total	**760**	**700**	**543**	**592**	**649**	**698**

Table B.24 Nelson employment change 2016–2056 (MECs)

Industry	BAU	Greater automation, dispersal	Greater automation, concentration	Lesser automation, dispersal	Lesser automation, concentration
Ag and horticulture	280	90	250	180	350
Mining	-	-	-	-	-
Manufacturing	460	-1,010	-710	110	420
Infrastructure	10	-	20	10	20
Construction	440	-90	160	260	510
Transport	260	-700	-580	-	120
Wholesale trade	250	-40	100	100	230
Retail and services	980	-240	330	490	1,060
Telecommunications	50	-	20	30	60
Offices	980	-640	-70	330	900
Education	340	-100	110	160	370
Health	800	10	380	480	850
Services	230	-300	-160	70	210
Total	**5,090**	**- 3,010**	**- 140**	**2,240**	**5,110**

Table B.25 Nelson land use change 2016- 2056 (ha)

Industry	BAU	Greater automation, dispersal	Greater automation, concentration	Lesser automation, dispersal	Lesser automation, concentration
Ag and horticulture	-	-	-	-	-
Mining	-	-	-	-	-
Manufacturing	-22	-75	-64	-35	-24
Infrastructure	-0	-0	-0	-0	0
Construction	-7	-27	-18	-14	-5
Transport	-8	-30	-27	-14	-11
Wholesale trade	-3	-14	-9	-9	-4
Retail and services	-6	-22	-15	-13	-5
Telecommunications	-0	-1	-1	-1	-0
Offices	-5	-19	-14	-11	-6
Education	-5	-16	-11	-9	-4
Health	-0	-3	-2	-1	-0
Services	-3	-11	-9	-5	-3
Total	**- 60**	**- 217**	**- 168**	**- 111**	**- 62**

B5 Ashburton data

Table B.26 Ashburton employment and land demand change 2016–2056

Variable	BAU	Greater automation, dispersal	Greater automation, concentration	Lesser automation, dispersal	Lesser automation, concentration
Employment (MECs)	28%	5%	-4%	22%	12%
Land area (ha)	3%	-16%	-23%	-1%	-9%

Table B.27 Ashburton employment 2016–2056 (MECs)

Year	BAU	Greater automation, dispersal	Greater automation, concentration	Lesser automation, dispersal	Lesser automation, concentration
2016	11,212	11,212	11,212	11,212	11,212
2021	11,863	11,454	11,283	11,751	11,579
2026	12,422	11,567	11,207	12,186	11,826
2031	12,867	11,540	10,981	12,500	11,942
2036	13,248	11,439	10,672	12,747	11,981
2041	13,569	11,264	10,283	12,930	11,949
2046	13,846	11,409	10,407	13,180	12,179
2051	14,092	11,613	10,594	13,415	12,396
2056	14,324	11,807	10,771	13,636	12,600

Table B.28 Ashburton land use 2016–2056 (ha)

Year	BAU	Greater automation, dispersal	Greater automation, concentration	Lesser automation, dispersal	Lesser automation, concentration
2016	275	275	275	275	275
2021	283	273	269	281	276
2026	288	267	259	283	275
2031	291	259	246	283	270
2036	292	249	232	281	264
2041	291	238	217	278	257
2046	289	235	214	276	255
2051	287	233	212	274	253
2056	284	231	210	271	250

Table B.29 Ashburton employment 2016 and 2056 (MECs)

Industry	2016	2056				
	BAU	BAU	Greater automation, dispersal	Greater automation, concentration	Lesser automation, dispersal	Lesser automation, concentration
Ag and horticulture	600	730	690	640	720	670
Mining	-	-	-	-	-	-
Manufacturing	1,500	1,840	1,250	1,120	1,730	1,590
Infrastructure	160	210	200	190	210	200
Construction	1,370	1,740	1,520	1,390	1,690	1,570
Transport	380	470	230	190	410	380
Wholesale trade	570	730	640	580	690	630
Retail and services	2,370	3,050	2,660	2,430	2,930	2,710
Telecommunications	270	340	300	270	330	300
Offices	1,940	2,450	2,010	1,830	2,300	2,120
Education	550	730	630	580	700	650
Health	1,020	1,390	1,210	1,110	1,340	1,240
Services	500	630	480	440	600	550
Total	**11,230**	**14,310**	**11,820**	**10,770**	**13,650**	**12,610**

Table B.30 Ashburton land use 2016 and 2056 (ha)

Industry	2016	2056				
	BAU	BAU	Greater automation, dispersal	Greater automation, concentration	Lesser automation, dispersal	Lesser automation, concentration
Ag and horticulture	-	-	-	-	-	-
Mining	-	-	-	-	-	-
Manufacturing	74	71	48	43	67	62
Infrastructure	6	7	7	6	7	7
Construction	64	68	59	55	66	61
Transport	4	3	2	1	3	3
Wholesale trade	27	29	25	23	27	25
Retail and services	40	43	38	35	42	38
Telecommunications	5	5	4	4	5	4
Offices	22	23	19	17	21	20
Education	18	20	17	16	19	18
Health	4	5	4	4	5	4
Services	10	10	8	7	9	9
Total	**275**	**284**	**231**	**210**	**271**	**250**

Table B.31 Ashburton employment change 2016–2056 (MECs)

Industry	BAU	Greater automation, dispersal	Greater automation, concentration	Lesser automation, dispersal	Lesser automation, concentration
Ag and horticulture	130	90	40	120	70
Mining	-	-	-	-	-
Manufacturing	340	-250	-380	230	90
Infrastructure	50	40	30	50	40
Construction	370	150	20	320	200
Transport	90	-150	-190	30	-
Wholesale trade	160	70	10	120	60
Retail and services	680	290	60	560	340
Telecommunications	70	30	-	60	30
Offices	510	70	-110	360	180
Education	180	80	30	150	100
Health	370	190	90	320	220
Services	130	-20	-60	100	50
Total	**3,110**	**600**	**- 440**	**2,430**	**1,390**

Table B.32 Ashburton land use change 2016–2056 (ha)

Industry	BAU	Greater automation, dispersal	Greater automation, concentration	Lesser automation, dispersal	Lesser automation, concentration
Ag and horticulture	-	-	-	-	-
Mining	-	-	-	-	-
Manufacturing	-3	-26	-31	-7	-12
Infrastructure	1	0	-0	1	0
Construction	4	-5	-10	2	-3
Transport	-0	-2	-2	-1	-1
Wholesale trade	2	-2	-4	-0	-2
Retail and services	3	-3	-6	1	-2
Telecommunications	0	-0	-1	0	-0
Offices	1	-3	-5	-1	-2
Education	2	-1	-2	1	-1
Health	1	-0	-0	0	0
Services	0	-2	-3	-0	-1
Total	**9**	**- 44**	**- 64**	**- 4**	**- 24**

B6 Manufacturing data

Table B.33 Manufacturing employment by urban area, BAU scenario (MECs)

Year	Metro	Large city	Large town	Medium town	Small town	Small UA	Rural	Total
2016	109,490	20,680	26,550	14,490	16,210	9,420	36,810	233,650
2026	121,660	22,470	28,390	15,580	17,470	10,200	39,940	255,710
2036	130,330	23,660	29,550	16,300	18,240	10,720	41,780	270,580
2046	136,870	24,480	30,270	16,750	18,740	11,070	42,980	281,160
2056	141,590	25,150	30,950	17,080	19,190	11,380	44,040	289,380

Table B.34 Manufacturing employment by urban area, greater automation dispersal scenario (MECs)

Year	Metro	Large city	Large town	Medium town	Small town	Small UA	Rural	Total
2016	109,490	20,680	26,550	14,490	16,210	9,420	36,810	233,650
2026	99,270	18,790	24,530	13,590	17,280	10,900	45,460	229,820
2036	82,370	15,900	21,510	12,130	17,840	12,180	53,340	215,270
2046	73,910	14,440	19,980	11,390	18,230	12,950	57,850	208,750
2056	76,460	14,840	20,430	11,610	18,660	13,320	59,280	214,600

Table B.35 Manufacturing employment by urban area, greater automation concentration scenario (MECs)

Year	Metro	Large city	Large town	Medium town	Small town	Small UA	Rural	Total
2016	109,490	20,680	26,550	14,490	16,210	9,420	36,810	233,650
2026	112,900	20,580	25,320	13,140	13,680	7,350	28,760	221,730
2036	111,560	19,690	23,170	11,180	10,320	4,720	18,380	199,020
2046	112,230	19,340	22,090	10,180	8,560	3,320	12,890	188,610
2056	116,100	19,870	22,590	10,380	8,770	3,410	13,210	194,330

Table B.36 Manufacturing employment by urban area, lesser automation dispersal scenario (MECs)

Year	Metro	Large city	Large town	Medium town	Small town	Small UA	Rural	Total
2016	109,490	20,680	26,550	14,490	16,210	9,420	36,810	233,650
2026	111,920	21,120	27,480	15,210	19,090	11,960	49,620	256,400
2036	109,480	20,820	27,660	15,520	21,640	14,410	62,030	271,560
2046	109,490	20,800	27,840	15,750	23,110	15,830	69,020	281,840
2056	113,270	21,370	28,470	16,050	23,660	16,280	70,730	289,830

Table B.37 Manufacturing employment by urban area, lesser automation concentration scenario (MECs)

Year	Metro	Large city	Large town	Medium town	Small town	Small UA	Rural	Total
2016	109,490	20,680	26,550	14,490	16,210	9,420	36,810	233,650
2026	125,550	22,920	28,270	14,760	15,490	8,410	32,910	248,310
2036	138,670	24,610	29,310	14,570	14,110	6,950	27,070	255,290
2046	147,810	25,700	29,960	14,530	13,440	6,200	24,070	261,710
2056	152,920	26,400	30,640	14,820	13,760	6,370	24,660	269,570

B7 Transport data

Table B.38 Transport employment by urban area, BAU scenario (MECs)

Year	Metro	Large city	Large town	Medium town	Small town	Small UA	Rural	Total
2016	56,630	8,580	11,480	4,520	4,550	3,880	8,970	98,610
2026	62,730	9,320	12,390	4,910	4,950	4,230	9,800	108,330
2036	67,170	9,820	13,010	5,170	5,220	4,470	10,350	115,210
2046	70,480	10,160	13,420	5,360	5,410	4,640	10,740	120,210
2056	73,010	10,430	13,780	5,500	5,560	4,780	11,070	124,130

Table B.39 Transport employment by urban area, greater automation dispersal scenario (MECs)

Year	Metro	Large city	Large town	Medium town	Small town	Small UA	Rural	Total
2016	56,630	8,580	11,480	4,520	4,550	3,880	8,970	98,610
2026	46,170	7,040	9,710	3,890	4,510	4,180	10,370	85,870
2036	31,700	5,030	7,390	3,020	4,280	4,360	11,560	67,340
2046	23,960	3,960	6,170	2,570	4,190	4,500	12,310	57,660
2056	24,820	4,070	6,340	2,640	4,300	4,640	12,690	59,500

Table B.40 Transport employment by urban area, greater automation concentration scenario (MECs)

Year	Metro	Large city	Large town	Medium town	Small town	Small UA	Rural	Total
2016	56,630	8,580	11,480	4,520	4,550	3,880	8,970	98,610
2026	53,200	7,790	10,060	3,740	3,480	2,710	6,270	87,250
2036	46,750	6,600	8,120	2,720	2,110	1,250	2,900	70,450
2046	43,700	5,990	7,110	2,180	1,380	460	1,070	61,890
2056	45,270	6,160	7,300	2,240	1,420	480	1,110	63,980

Table B.41 Transport employment by urban area, lesser automation dispersal scenario (MECs)

Year	Metro	Large city	Large town	Medium town	Small town	Small UA	Rural	Total
2016	56,630	8,580	11,480	4,520	4,550	3,880	8,970	98,610
2026	55,960	8,500	11,650	4,650	5,280	4,840	11,900	102,780
2036	52,660	8,090	11,450	4,640	5,900	5,760	14,790	103,290
2046	51,450	7,920	11,410	4,660	6,290	6,310	16,500	104,540
2056	53,300	8,140	11,710	4,790	6,470	6,500	17,000	107,910

Table B.42 Transport employment by urban area, lesser automation concentration scenario (MECs)

Year	Metro	Large city	Large town	Medium town	Small town	Small UA	Rural	Total
2016	56,630	8,580	11,480	4,520	4,550	3,880	8,970	98,610
2026	62,990	9,240	11,990	4,510	4,260	3,370	7,800	104,160
2036	67,710	9,660	12,180	4,340	3,740	2,650	6,130	106,410
2046	71,190	9,960	12,350	4,270	3,490	2,270	5,260	108,790
2056	73,740	10,230	12,680	4,390	3,590	2,340	5,420	112,390

B8 Retail and services data

Table B.43 Retail and services employment by urban area, BAU scenario (MECs)

Year	Metro	Large city	Large town	Medium town	Small town	Small UA	Rural	Total
2016	192,080	37,570	47,900	26,770	32,520	21,690	20,910	379,440
2026	217,200	41,090	51,040	29,060	35,390	23,620	22,810	420,210
2036	235,720	43,400	52,900	30,570	37,250	24,880	24,100	448,820
2046	250,110	44,910	53,840	31,540	38,470	25,700	24,930	469,500
2056	261,890	46,050	54,920	32,340	39,470	26,400	25,660	486,730

Table B.44 Retail and services employment by urban area, greater automation dispersal scenario (MECs)

Year	Metro	Large city	Large town	Medium town	Small town	Small UA	Rural	Total
2016	192,080	37,570	47,900	26,770	32,520	21,690	20,910	379,440
2026	193,740	37,470	47,980	27,550	37,740	27,020	27,700	399,200
2036	184,800	35,760	46,550	27,390	42,210	32,050	34,430	403,190
2046	182,580	35,030	45,760	27,440	44,860	34,950	38,300	408,920
2056	191,180	35,920	46,680	28,140	46,040	35,900	39,400	423,260

Table B.45 Retail and services employment by urban area, greater automation concentration scenario (MECs)

Year	Metro	Large city	Large town	Medium town	Small town	Small UA	Rural	Total
2016	192,080	37,570	47,900	26,770	32,520	21,690	20,910	379,440
2026	218,070	40,760	49,410	26,710	30,350	18,800	18,160	402,260
2036	237,600	42,700	49,520	25,620	26,640	14,730	14,270	411,080
2046	252,610	44,010	49,530	25,160	24,760	12,590	12,220	420,880
2056	264,510	45,130	50,520	25,800	25,400	12,940	12,570	436,870

Table B.46 Retail and services employment by urban area, lesser automation dispersal scenario (MECs)

Year	Metro	Large city	Large town	Medium town	Small town	Small UA	Rural	Total
2016	192,080	37,570	47,900	26,770	32,520	21,690	20,910	379,440
2026	201,560	38,950	49,820	28,590	39,020	27,870	28,520	414,330
2036	201,770	38,880	50,360	29,590	44,900	33,840	36,160	435,500
2046	205,090	39,070	50,610	30,280	48,330	37,270	40,540	451,190
2056	214,750	40,060	51,620	31,050	49,590	38,280	41,710	467,060

Table B.47 Retail and services employment by urban area, lesser automation concentration scenario (MECs)

Year	Metro	Large city	Large town	Medium town	Small town	Small UA	Rural	Total
2016	192,080	37,570	47,900	26,770	32,520	21,690	20,910	379,440
2026	225,890	42,240	51,250	27,750	31,630	19,650	18,980	417,390
2036	254,570	45,830	53,330	27,820	29,320	16,520	16,000	443,390
2046	275,120	48,060	54,380	28,000	28,220	14,910	14,460	463,150
2056	288,080	49,270	55,470	28,710	28,960	15,310	14,880	480,680

B9 Office data

Table B.48 Office employment by urban area, BAU scenario (MECs)

Year	Metro	Large city	Large town	Medium town	Small town	Small UA	Rural	Total
2016	374,790	47,990	56,190	22,350	23,930	12,750	28,090	566,090
2026	417,270	52,150	59,640	24,060	25,860	13,760	30,560	623,300
2036	449,300	55,030	61,860	25,240	27,150	14,440	32,270	665,290
2046	474,250	57,010	63,150	26,020	28,040	14,900	33,470	696,840
2056	494,100	58,430	64,480	26,670	28,740	15,280	34,450	722,150

Table B.49 Office employment by urban area, greater automation dispersal scenario (MECs)

Year	Metro	Large city	Large town	Medium town	Small town	Small UA	Rural	Total
2016	374,790	47,990	56,190	22,350	23,930	12,750	28,090	566,090
2026	363,860	46,520	54,870	22,330	27,080	15,470	36,500	566,630
2036	334,280	43,140	51,970	21,600	29,710	18,020	44,810	543,530
2046	322,490	41,620	50,520	21,340	31,350	19,520	49,730	536,570
2056	335,990	42,650	51,580	21,870	32,130	20,020	51,190	555,430

Table B.50 Office employment by urban area, greater automation concentration scenario (MECs)

Year	Metro	Large city	Large town	Medium town	Small town	Small UA	Rural	Total
2016	374,790	47,990	56,190	22,350	23,930	12,750	28,090	566,090
2026	410,590	50,690	56,540	21,640	21,650	10,680	23,720	595,510
2036	434,930	51,950	55,430	20,140	18,300	7,970	17,810	606,530
2046	455,280	53,020	54,940	19,460	16,600	6,560	14,730	620,590
2056	474,340	54,340	56,100	19,940	17,020	6,720	15,160	643,620

Table B.51 Office employment by urban area, lesser automation dispersal scenario (MECs)

Year	Metro	Large city	Large town	Medium town	Small town	Small UA	Rural	Total
2016	374,790	47,990	56,190	22,350	23,930	12,750	28,090	566,090
2026	383,890	49,020	57,730	23,490	28,320	16,130	37,970	596,550
2036	377,420	48,430	57,900	24,020	32,310	19,410	47,910	607,400
2046	379,400	48,460	58,100	24,460	34,710	21,310	53,750	620,190
2056	395,280	49,660	59,320	25,070	35,590	21,860	55,320	642,100

Table B.52 Office employment by urban area, lesser automation concentration scenario (MECs)

Year	Metro	Large city	Large town	Medium town	Small town	Small UA	Rural	Total
2016	374,790	47,990	56,190	22,350	23,930	12,750	28,090	566,090
2026	430,620	53,190	59,400	22,790	22,890	11,340	25,190	625,420
2036	478,060	57,230	61,370	22,560	20,900	9,360	20,910	670,390
2046	512,190	59,860	62,520	22,580	19,970	8,350	18,740	704,210
2056	533,630	61,350	63,840	23,140	20,470	8,560	19,290	730,280