Disclaimer
This Background Paper has been prepared as part of the supporting analysis for the National Investment Framework for Transport in Ireland. It reflects the latest data and information available to the author at the time of writing. The views presented in this paper do not represent the official views of the Department of Transport or the Minister for Transport.
## Contents

List of Figures ........................................................................................................................................... 2
List of Tables ............................................................................................................................................ 2
1. Introduction ........................................................................................................................................... 3
2. Commuting Travel Demand .................................................................................................................. 5
3. Commercial Travel Demand ................................................................................................................ 11
4. Industrial Freight Demand ................................................................................................................... 16
5. Leisure Travel Demand ....................................................................................................................... 20
6. Scenario Analysis ............................................................................................................................... 24
7. Conclusions ......................................................................................................................................... 29
8. References .......................................................................................................................................... 30
List of Figures

Figure 2.1: Percentage of Workforce that Engages in Teleworking at Least Some of the Time........................................... 5
Figure 2.2: Teleworking Rates by Occupational Sector.................................................................................................. 6
Figure 3.1: Rates of Online Cross-Border Shopping........................................................................................................ 11
Figure 3.2: Counties with the Highest Percentage Share of Online Retail........................................................................... 14
Figure 5.1: Regional Breakdown of Tourist Destinations.................................................................................................. 21
Figure 5.2: UK and USA Tourist Destinations................................................................................................................... 22
Figure 6.1: Triple Access System........................................................................................................................................... 24
Figure 6.2: CoVID-19 Scenario Analysis............................................................................................................................ 26
Figure 6.3: Policy Testing Matrix........................................................................................................................................... 28

List of Tables

Table 2.1: Increased Teleworking Scenario Summary......................................................................................................... 10
Table 3.1: Increased e-commerce Scenario Summary........................................................................................................ 15
Table 4.1: Increased Additive Manufacturing Scenario Summary............................................................................................ 19
Table 5.1: Reduced Aviation Demand Scenario Summary................................................................................................... 23
1. Introduction

The National Investment Framework for Transport in Ireland (NIFTI) is the Department of Transport’s contribution to Project Ireland 2040. The purpose of NIFTI’s is to put in place a transport investment framework which delivers a land transport network that meets the travel needs of the population in the coming decades and which supports the realisation of Project Ireland 2040’s National Strategic Outcomes. As part of the development of this framework, five areas relating to the future transport network are being analysed. These are:

1. Compact growth;
2. Interurban connectivity;
3. Rural and regional accessibility;
4. Supporting international connectivity; and,
5. Alternative demand scenarios.

This paper looks at the fifth of these areas, alternative demand scenarios. The other four future network analysis background papers were based on analysis of Transport Infrastructure Ireland’s (TII) National Transport Model (NTpM) and the National Transport Authority’s (NTA) Regional Transport Models. These models were used to estimate travel demand under a National Planning Framework population growth scenario. While these models serve as a useful input into the transport planning process, they are also and calibrated using observed data and based on a set of assumptions in relation to travel patterns, economic conditions and settlement patterns.
Because it is generally beyond the scope of transport models to consider changes in these underlying assumptions, this background paper will consider a range of different potential demand scenarios, and the implications which they would have for future investment in the transport network.

The impact of the CoVID-19 pandemic and the resulting lockdown on transport demand is a good illustrative example of the impact that a sudden change in travel patterns can have on assumptions around travel demand and public transport usage rates. At the height of travel restrictions, part of public health efforts to contain the pandemic, traffic volumes had fallen to approximately 30% of normal levels (Transport Infrastructure Ireland, 2020). Falls in public transport patronage were even more precipitous with the three major operators, Bus Éireann, Dublin Bus and Irish Rail all reporting passenger numbers falling to at least 15% of normal levels during the height of movement restrictions. The crisis has also led to an unprecedented rise in teleworking and a significant uptick in walking and cycling (Sport Ireland, 2020). It is difficult to say whether these changes constitute a transitory disruption to mobility patterns or will lead to significant lasting change. However, research by the International Transport Forum (ITF) indicates that periods of significant disruption can lead to innovation in travel patterns, as people are shifted out of travel patterns which may have been suboptimal for them (ITF, 2016).

The purpose of this paper is not to estimate the impact of the CoVID-19 crisis on the future transport system, but rather to use the crisis as a lens to examine how changes to underlying transport demand can impact on future network requirements. The paper will also consider how gradual changes in transport demand can impact on future transport planning.

The remainder of this paper is laid out as follows. Section 2 will examine the potential changes in commuting demand as a result of an increase in remote working. Section 3 will discuss the potential impact that an increase in e-commerce will have on transport demand in the commercial sector. Section 4 will provide an overview of potential changes in industrial freight transport as a result of new technologies and rising demand in sectors such as construction. Section 5 will review potential changes to leisure travel demand as result of an increase in international aviation and due to urbanisation. Section 6 will examine how scenario analysis can be used to address this uncertainty in future transport patterns in the transport planning process. Section 7 will conclude by reviewing the implications for NIFTI and the transport appraisal process in Ireland.
2. Commuting Travel Demand

Teleworking refers to workers performing their tasks and duties from their own homes via email, phone or the internet. Teleworking can also refer to those workers performing their duties and tasks from a shared work space or hub, located away from their organisation’s main offices. The practice of teleworking has become increasingly popular in recent years with workers within certain professions as improvements in internet infrastructure and communication technologies, particularly video conferencing, have proliferated.

Alongside these improvements in technology and infrastructure, there have been positive shifts in attitudes towards teleworking and increased levels of flexibility being offered by employers in terms of work practices. These improvements are reflected in the growing numbers of Irish workers engaging in teleworking at least some of the time. In the ten years between 2009 and 2019 the proportion of Irish employees who reported working from their home increased from 6.9% to 12.7% (Eurostat, 2020). While this increase is consistent with the broader international trends, it is worth noting that members of the Irish workforce were significantly less likely to telework than some of their European peers. Countries such as Denmark, the Netherlands, Sweden and the UK all reported higher proportions of their workforces engaging in teleworking at least some of the time as highlighted in Figure 2.1 (Eurostat, 2020).

However, the onset of the CoVID-19 pandemic and the resultant public health protocols has seen a large increase in the number of workers engaging in teleworking on a regular basis. This sudden shift in working practices and attitudes among certain workers could accelerate the pre-existing trend of increased utilisation of teleworking which in turn would have implications for both travel demand and travel patterns.
2.1 Impact on Transport and Travel Patterns

In order to understand the potential impacts of increased levels of teleworking on transport demand and travel patterns, it is important to identify the potential beneficiaries and users of teleworking. Most available data on the subject of teleworking indicates that teleworking as a mode or method of working is primarily enjoyed by those currently employed in ‘non-essential’ jobs, including industries such as finance, professional services, and ICT. Conversely, the opportunity to engage in and the overall use of teleworking are significantly lower among those employed in service industries such as accommodation, food and retail. Economic and Social Research Institute (ESRI) analysis published in May 2020 indicates that these trends are broadly replicable in Ireland with workers in ‘non-essential’ sectors having higher reported rates of teleworking compared to their counterparts in ‘essential’ service sectors. It is therefore reasonable to expect that increased levels of teleworking will largely be among those employed in the ‘non-essential’ sectors while those employed in sectors such as construction and retail will still largely be restricted to physically travelling to their place of work. As such, local employment shares by sector are likely to have a significant impact on travel patterns and behaviours in a particular area.

Figure 2.2: Teleworking Rates by Occupational Sector

The most likely impact of increased levels of teleworking will be reduced demand for peak-time travel (ITF, 2019). Those with the opportunity to telework are also provided with the opportunity to avoid the congestion and time costs typically associated with peak-hour travel. As such, they have the ability to avoid making peak hour trips entirely or to shift when they travel to outside the peak hours. This may lead to a more even distribution of trips throughout the day. However, with a large increase in the number of former commuters now teleworking at least some of the time, demand for certain transport infrastructure and services could be reduced, in particular during peak hours. Indeed, the ITF cites empirical studies which suggest traffic volumes fall in line with increased levels of teleworking (ITF, 2019).
The impacts of reduced travel demand resulting from teleworking will likely be most acute in urban centres, where large clusters and concentrations of the ‘non-essential’ service jobs are located. As previously discussed, these jobs provide the greatest opportunity to adopt flexible working practices, including teleworking. However, as these workers opt to decrease their time spent in central business district offices, there is the potential that this will lead to reduced demand for the commercial services that typically support office-based activities in centralised locations such food outlets and cleaning companies. Noting potential declines in physical retail space and associated employment in the same urban centres due to the effects of e-commerce, it is possible that the incidence of travel to urban centres among workers who do not engage in teleworking will also be suppressed to some extent.

There are a number of complications, however, when trying to assess the overall impact of teleworking on travel demand. While it is likely that the number of trips to urban centres will decrease, it is highly unlikely that office space will disappear entirely from central, urban business districts due to the continued value of a certain level of face-to-face interactions among workers (Glaeser, 2011). As such, a baseline level of demand is likely to remain for transport connections to central business districts despite increased levels of teleworking and potentially lower overall activity in office districts. Understanding what that baseline level is will be important in attempting to more precisely determine the impacts of teleworking on transport infrastructure requirements.

Increased levels of teleworking also do not necessarily imply that the overall number of trips being made on the transport network will be reduced. Increasingly, evidence to the contrary is arising as those engaged in teleworking, while making fewer trips associated with commuting, appear to increase the number of trips associated with leisure activities, business and other purposes (Budnitz, et al, 2020). While some of these trips are more likely to be confined to a worker’s locality, further evidence arising from the available data also indicates that some of those increasing their use of teleworking are also willing to participate in longer commutes during the days which they must travel to the office (de Vos, et al., 2018). This may mean some workers choosing to relocate to more rural areas to avail of more privacy or larger properties. Accordingly, the net impacts on total distances travelled may be minimal. The increase in other types of trip undertaken as well as the potential willingness to move to areas where longer commutes are required but are not undertaken as frequently could offset the reduced number of commuting trips resulting from increased teleworking.

Another consideration under the scenario of increased rates of teleworking is the travel modes utilised. While dependent on number of factors, such as number of persons in a household, data from the UK’s National Travel Survey (NTS) suggests that the higher frequency of trips in the ‘other’ or leisure categories taken by teleworkers are taken using personal cars (de Abreu e Silva & Melo, 2018). This effect could be compounded in the event teleworkers are more likely to decide to locate to areas with lower levels of public transport provision and active travel infrastructure. Any increase in car use, particularly where public transport or active travel is replaced as potential modes for a trip, will likely offset any emission reductions resulting from less commuting trips, at least in the short term.

2.2 Impact on Future Network Analysis

This section examines the impact which a significant increase in teleworking would have the four other future network analysis areas.
Compact Growth

Increased levels of teleworking could have a significant impact on settlement patterns in Ireland although the extent of the impact is unclear and will depend on preferences regarding a number of factors. There is some evidence to suggest that teleworking may encourage households to locate further away from cities due to lower costs and a desire to live in a more private or spacious environment (ITF, 2019; de Vos, et al., 2018). However, some empirical analysis indicates that teleworkers prefer to locate to the suburbs of a city rather than resettle in more rural areas (Ellen & Hempstead, 2002; Larson & Zhao, 2016). Teleworking appears to encourage suburban settlement through a combination of lower commuting and travel costs, larger dwellings and proximity to the amenities and services still offered in city centres. In fact, the potential for lower congestion costs that teleworking may bring about in urban areas may act as a demand stimulant and encourage more people to settle in urban areas (Larson & Zhao, 2016). However, a likely result of this additional demand for suburban living and any additional migration to urban suburbs is some form of urban sprawl if appropriate planning policies are not in place (Larson & Zhao, 2016).

Interurban Connectivity

There are number of potential outcomes of increased teleworking on interurban connectivity. As discussed, increased levels of teleworking is likely to result in some decrease of long-distance commuting on interurban links. However, the degree to which lower congestion costs on interurban links may partly offset any decrease in use of interurban transport infrastructure and services must be explored. While teleworkers appear to favour suburbs and may be disinclined to locate to more rural areas, there remains the prospect that some teleworkers and service sector workers to relocate from larger cities to smaller urban centres with good transport links to the major settlements where they can take advantage of lower living and congestion costs. For example, data from the UK’s NTS suggests teleworkers will settle in areas with access to heavy rail links for commuting purposes (Budnitz, et al., 2020). Teleworking may also influence the degree to which the interurban transport network is used for other types of trips, especially trips made for leisure purposes. As such, increased rates of teleworking in the Irish workforce may lead to some decrease in existing commuting trips made on interurban networks, but there is potential that these trips will be offset through new commuters or other trips such as those made for leisure purposes.

Strategic Links

The most obvious impact of increased levels of teleworking on strategic links to the state’s ports and airports relate to a reduction in the need to take flights for international business trips. Business travellers account for a significant proportion of footfall in Dublin and Shannon Airports. Among total passengers surveyed, the proportion of trips at Dublin and Shannon airports for business purposes was 27% and 32% respectively in 2016 (National Transport Authority, 2016). However, the degree to which increased levels of teleworking will affect the number of business trips made via Irish airports is uncertain. Noting that UK workers have historically engaged in teleworking at higher rates than their Irish counterparts, data from the UK’s International Passenger Survey shows that business travel has remained steady between 2009 and 2019 accounting for 16% to 17% of total passengers surveyed throughout the period (Office for National Statistics, 2020). With CoViD-19 forcing increased utilisation of online meetings, conferences and webinars, it remains to be seen if there will any marked impact on business travel in future. However, given business travel is not the primary reason for air travel at Irish airports, a decrease in the proportion of business travellers should result in a limited potential impact on travel to and from the airports.
Rural and Regional Accessibility

Teleworking has the potential to encourage workers to relocate to rural areas. Although there is little evidence to suggest that teleworkers relocate in large numbers to the more rural areas of a country (Ellen & Hempstead, 2002), in an Irish context there is the potential for increased levels of settlement in rural areas immediately adjacent to urban centres and conurbations. The rollout of the National Broadband Plan and ongoing improvements in the broader national telecommunications network may further encourage workers to relocate to more rural areas in Ireland. As such, the biggest impact of increased teleworking rates on rural and regional accessibility could be demand for improved transport infrastructure in and around those regional urban centres with high-quality transport links to the major urban areas. There is also a possibility that improved infrastructure and services in more rural areas will be required if workers move to these areas in significant numbers. This is particularly relevant for those rural areas close to the major urban centres, where residents will enjoy relatively short commute times and access to the amenities and services provided in the urban centres. However, the degree to which this occurs will also depend on local planning policies. Lastly, there is the potential that teleworking may encourage further depopulation of more remote rural areas through the dynamics of lower congestion costs in urban areas (Larson & Zhao, 2016). In this case, teleworking may actually lead to decreased demand for transport infrastructure and services related to rural and regional accessibility. Indeed, there is international evidence that suggests workers with the opportunity to telework are more likely to relocate to the suburbs of the urban areas in which their offices are based and, to a lesser extent, smaller urban hubs with good transport links for commuting (Budnitz, et al., 2020). As such the net impact of teleworking on demand for rural and regional transport networks is unclear.

2.3 Summary

There is significant potential for an increase in teleworking in Ireland. While offices will likely remain as a common working environment, a significant increase in workers working from home or closer to home, will impact on travel patterns and behaviours in a number of ways. Some reduction in trips made to the city centre offices is to be expected, especially around peak hours as workers take advantage of the flexible working practices which teleworking can enable. However, the evidence available does not suggest that the overall level of trips made by teleworkers decreases as commuting trips are replaced with trips for other purposes such as leisure, although these trips maybe more localised in nature. There are also no clearly defined impacts on distances travelled on transport networks. While some decrease in long-distance commuting is possible, this may be offset through increased distances travelled in local areas. Also, some teleworkers may opt to live further from their usual place of work if commutes are required less frequently. With a decrease in peak hour travel to city centres, there may be some decline in demand for public transport services, although some demand might also become evenly distributed throughout the day. While there is potential that active travel modes will be utilised more frequently by teleworkers, particularly where infrastructure and distances easily accommodate it, there is evidence that teleworkers are inclined to use personal motor vehicles. While contingent on a number of other factors, this raises the issue of the overall sustainability of teleworking in terms of transport patterns and behaviours.
### Table 2.1: Increased Teleworking Scenario Summary

<table>
<thead>
<tr>
<th>Variable</th>
<th>Potential Impact</th>
</tr>
</thead>
<tbody>
<tr>
<td>When People Travel</td>
<td>Fewer trips made during peak hours; possibility for more even distribution of trips during the day</td>
</tr>
<tr>
<td>Distance Travelled</td>
<td>Unclear impacts on distance travelled</td>
</tr>
<tr>
<td>Mode Used</td>
<td>Potential increase in private car and localised active travel modal shares, decrease in peak-time public transport use</td>
</tr>
<tr>
<td>Travel Destinations</td>
<td>Likely reduction in trips to/from urban centres; increase in locally based trips</td>
</tr>
<tr>
<td>Emissions Impact</td>
<td>Unclear impact on emissions</td>
</tr>
</tbody>
</table>
3. Commercial Travel Demand

E-commerce can be defined as "the sale or purchase of goods or services, conducted over computer networks by methods specifically designed for the purpose of placing orders" (ITF, 2019). The numbers of Irish customers utilising online shopping grew sharply during the CoVID-19 crisis, with some retailers reporting a growth in online sales of over 50% (Gleeson, 2019). However, even before the pandemic e-commerce was a major trend impacting on the transport sector both in Ireland and abroad. Irish consumers have one of the highest rates of online cross border shopping in the world; research conducted by PayPal in 2018 indicated that 84% of Irish consumers engage in online cross border retail, which is significantly higher than other comparative European countries (PayPal, 2018). That said, only approximately 25% of Irish consumers engaged in e-commerce on a weekly basis in 2018 compared to 51% of consumers in the UK, which suggests there is significant scope for growth in the Irish market (PwC, 2018).

Figure 3.1: Rates of Online Cross-Border Shopping

![Figure 3.1: Rates of Online Cross-Border Shopping](source)

3.1 Impact on Transport and Travel Patterns

The growth of e-commerce has the potential to have a significant impact on the transport sector both in terms of its impact on personal travel patterns and its impact on freight. Identifying the potential impacts of e-commerce on transport is a highly complex process. Assessing its impact on consumer behaviour, individuals' travel patterns and the freight sector is extremely difficult due to the complex relationships and interdependences that exist between these three areas. In general there are three competing theories for the impact which e-commerce has on personal travel demand (Rotem Mindali & Weltevreden, 2013). These are:

- Substitution Effect;
- Complementary Effect; and,
• Neutral Effect.

<table>
<thead>
<tr>
<th>Potential personal travel demand effects of e-commerce</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Substitution Effect</strong></td>
</tr>
<tr>
<td>This theory contends that e-commerce will lead to a reduction in the number of personal trips undertaken by consumers. Reasons cited for this reduction in personal travel behaviour include the elimination of &quot;fruitless trips&quot; which are replaced with home delivery and the shift from personal to freight transport.</td>
</tr>
<tr>
<td><strong>Complementary Effect</strong></td>
</tr>
<tr>
<td>The second theory is that e-commerce will result in an increase in personal travel. This theory points to factors such as cheaper online goods allowing consumers to purchase more goods for the same amount of money, and online marketing of goods which generate new consumer demands for goods and products often located far from their home as a driver of increased travel. Other reasons cited include the need for consumers to drive to collection and delivery points, post offices or physical stores to collect the goods they purchase online, which also generates return trips as it increases the number of goods that must be returned to the sender, increasing trips to post offices or other distribution points.</td>
</tr>
<tr>
<td><strong>Neutral Effect</strong></td>
</tr>
<tr>
<td>This theory contends that e-commerce will have a limited or neutral impact on the number of personal trips and distance travelled. This is based on the idea that many shopping trips are &quot;linked&quot; with other activities. For example, people often engage in grocery shopping along with commuting. Therefore the elimination of the shopping element of this trip will only lead to a partial reduction in the total distance travelled.</td>
</tr>
</tbody>
</table>

The total impact of e-commerce on personal travel demand depends on which one of these competing effects is dominant. The empirical evidence is mixed, with different studies lending support to different theories and some producing results which support two theories simultaneously. Results also vary considerably depending on the product being purchased and the research methodology being deployed. Overall most studies conclude that the complementary effect is likely to dominate the substitution effect, leading to a net increase in personal travel (ITF, 2019).

There have been few studies which consider the impact of e-commerce on freight transport. This is likely due to the fact the data is held by commercial enterprises and is therefore difficult for researchers to gain access to (ITF, 2019). However, a number of studies that have taken place have found that e-commerce has a positive impact on freight transport demand. As with personal travel this effect varies with product type (Rotem Mindali, 2013). Research also indicates that while conventional mass market retailers tend to have return rates of 6-15%, e-commerce retailers can have return rates as high 35%. This will fuel the demand for “reverse logistics" to facilitate the free returns policies of many online retailers (Rotem Mindali, 2013). A report by Allied Irish Bank on the Transport and Logistics Outlook noted that there has been significant demand for e-commerce operators, such as parcel delivery specialists, in recent years, particularly around Dublin city and the M50. There is significant potential for growth in this market as large e-commerce companies, such as Amazon, may look to establish...
dedicated distribution facilities in Ireland to ensure access to the European Single Market following Brexit (AIB, 2018).

In terms of the emissions impact of e-commerce, the ITF estimates that global road freight emissions will increase by 6% by 2050 due to the growth of e-commerce. This increase is a result of increased kilometres travelled. Changing business models could also lead to an increase in emissions— as logistics operators move to facilitate next-day delivery, their ability to optimise loads and maximise the efficiency of available vehicles capacity will be constrained (ITF, 2019).

3.2 Impact on Future Network Analysis

This section will examine the impact which a significant increase in e-commerce would have the four other future network analysis areas.

Compact Growth
Certain types of products, such as clothes and books, are more likely to be impacted by the substitution from physical retail to e-commerce. Physical retailers selling these products tend to be concentrated in city centre locations. For this reason, studies have found that city centres are the most likely areas to be impacted by e-commerce, with village centres the least impacted. This has implications for transport, suggesting a reduction in the number of personal trips made to city centres (Petterson et al, 2018). Long term this trend may also undermine compact growth as people choose to locate in more rural towns and villages because they no longer need to be located close to cities to purchase the products they want. However, the trend away from consumer spending on goods and towards more “experiential” shopping may make urban centres an attractive place to locate, as cafes, bars, restaurants and barbers replace conventional retail outlets on the high street (SCSI, 2019).

Interurban Connectivity
The growth in last-mile logistics, i.e., delivery services that facilitate the movement of goods from a distribution centre to their final destination, which serve the e-commerce market, tends to be focused along arterial routes close to major urban centres. In Ireland to date growth has been concentrated around Dublin and inside the M50. According to online sales data from AIB, Dublin accounts for the highest proportion of online sales with 30%, Cork and Galway account for 13% and 5% respectively (AIB, 2018). This suggests that e-commerce may result in greater traffic volumes on the interurban road network as goods are transported across the country towards urban centres where demand for them is the highest.

Strategic Links
If large global retailers such as Amazon were to locate distribution centres in Ireland, to secure access to the Single Market following Brexit, this could contribute to an increase in freight traffic on the routes serving our ports and airports.
Retailers based in rural towns are less well-positioned to take advantage of opportunities from online retail. A survey of Irish small and medium enterprises (SMEs) revealed that only 69% have a website and only 32% are set up to conduct e-commerce (TechCentral, 2019). SMEs located in rural settings also face the additional barrier of poor broadband connectivity, making it more difficult to conduct e-commerce. These factors are likely to further undermine the viability of rural towns in the short term, exasperating trends in rural depopulation and contributing to a fall in transport demand in rural areas (SCSI, 2019). However, the growth of e-commerce may also actively support more dispersed settlement patterns in the long run, as the home delivery of products reduces the need to live near urban centres. The roll out of a high speed broadband network under the National Broadband Plan may also contribute to the number of Irish SMEs engaging in e-commerce, enhancing the viability of rural towns and resulting in an increase in the number of journeys in rural areas.

3.3 Summary

Research to date has not focused on the impact that e-commerce will have on when people choose to travel. Given that shopping is often associated with other "linked" trips, such as trips to work, which consumers will still take even if they engage in e-commerce, it is assumed in this scenario that e-commerce will have a neutral impact on peak travel times. The impact of e-commerce on distance travelled will depend on the degree to which the substitution or complementary effects dominates and the knock on impact that this will have on freight travel demand. The impact is also likely to vary by product class, and the degree to which any efficiencies gained by transporting goods via freight rather than through a range of private car trips is offset by increased demand for freight services to facilitate next day deliveries and high rates of returns associated with e-commerce. In this

![Figure 3.2: Counties with the Highest Percentage Share of Online Retail](image-url)
scenario it is assumed that e-commerce will lead to an increase in personal and freight km travelled. In terms of the transport mode used, it is assumed that private car use and freight traffic increases in line with assumed increased distances travelled for both modes. Research has found that certain types of products, such as clothes and books, are more likely to be impacted by the substitution from physical retail to e-commerce. Physical retailers selling these products tend to be concentrated in city centre locations, which may lead to a reduction in trips to city centre locations (Petterson, 2018). Finally, the total emissions impact of e-commerce will depend on the extent to it which leads to an increase in personal and freight kilometres travelled. It will also depend on the extent to which serving demand for next day delivery constrains freight operators from optimising their loads. It is assumed that e-commerce will lead to an increase emissions from both personal and freight transport emissions as a result of increased distance travelled.

Table 3.1: Increased e-commerce Scenario Summary

<table>
<thead>
<tr>
<th>Variable</th>
<th>Potential Impact</th>
</tr>
</thead>
<tbody>
<tr>
<td>When People Travel</td>
<td>Neutral impact on peak travel times</td>
</tr>
<tr>
<td>Distance Travelled</td>
<td>Increase in personal and freight vehicle kilometres travelled</td>
</tr>
<tr>
<td>Mode Used</td>
<td>Increase in private car use and increase in freight traffic</td>
</tr>
<tr>
<td>Travel Destinations</td>
<td>Reduction in city centre trips</td>
</tr>
<tr>
<td>Emissions Impact</td>
<td>Increase in personal and freight transport emissions</td>
</tr>
</tbody>
</table>
4. Industrial Freight Demand

Additive manufacturing, commonly known as ‘3D printing’, is a manufacturing process whereby goods are produced through the layering of materials using specialised printers following digital instructions (Silva & Rezende, 2013). While the technology has existed for more than 30 years, until recently its use has largely been confined to specialist manufacturing applications and prototyping of new parts and items. However, the technology is now proliferating rapidly, not only among firms, but also among consumers who are now benefitting from falling costs in the specialised equipment required for additive manufacturing (Boon & van Wee, 2018). This is widely regarded as a source of disruption to traditional manufacturing processes, and in the context of the transport sector is likely to affect existing supply chains and logistics. This disruption will arise from firms’ abilities to adopt more flexible, customised and efficient manufacturing processes and consumers’ abilities to produce certain goods for themselves at home. With the technology forming part of the Government’s ‘Ireland Industry 4.0 Strategy’ (Government of Ireland, 2019), it is reasonable to expect that Irish firms and consumers will continue to increase their use of 3D printing to the extent that there will be some tangible impacts on the transport sector.

4.1 Impact on Transport and Travel Patterns

The degree to which increased use of additive manufacturing, either in Irish firms or homes, will result in changes to transport patterns and user behaviours will also be dependent on a number of other factors including the type of manufacturing taking place in a given locality. The increased use of additive manufacturing within existing manufacturing firms is likely to encourage some rationalisation of supply chains due to the increased feasibility of manufacturing certain products such as spare parts, either on site or in the immediate vicinity of the firm (Jiang, et al., 2017). The ability of Irish firms to manufacture certain products or inputs which were previously manufactured elsewhere could lead to some reduction in specific types of imports. However, any reduction in freight traffic associated with imports would be offset somewhat through the potential increased importation of raw materials needed for additive manufacturing processes (Boon & van Wee, 2018). Additive manufacturing may also reduce the need to hold inventories of certain inputs or goods thereby reducing some of the trips associated with the warehousing of these inputs or goods (Silva & Rezende, 2013; Akbari & Ha, 2020). The potential for increased output of the firms who adapt additive manufacturing into their processes will also lead to changes for the movement patterns in the transport network depending on the final destination of the outputs. Additive manufacturing may lead to an increase in the number of direct shipments to consumers with implications for local transport networks (Silva & Rezende, 2013). More efficient firms producing products for export may also increase activity on the transport links to the ports and airports. In either case, an increase in activity on the transport network is possible.

It is also worth noting that transport patterns and behaviours may also be influenced through the establishment of new Irish firms involved in additive manufacturing processes. There is some debate on how such firms would locate given the flexibility offered through the technologies involved (Gress & Kalafsky, 2015). The degree to which additive manufacturing will contribute to the growth of decentralised manufacturing firms will likely depend on the scale and complexity of the products being made as well as traditional location decision factors such as size of markets. For more complex and specialised additive manufacturing it is somewhat expected that new firms will behave similar to those in other specialised manufacturing sectors and cluster at city level to take advantage of the benefits offered through agglomeration effects (Boon & van Wee, 2018). While the potential increased levels of local sourcing may lead to some additional traffic on rural and regional transport networks (Boon & van Wee,
the growth of clusters of additive manufacturing firms in urban areas may significantly alter transport patterns and behaviours in those areas depending on the levels of traffic generated by the respective firms.

The other potential source of disruption to transport patterns and behaviours is the increased use of additive manufacturing by consumers in their homes. In this case, consumers will likely utilise 3D printing and similar technologies to produce more simple consumer goods utilising online digital design databases, especially as the cost of accessing the necessary equipment falls. However, in the short term this type of home manufacturing is likely to be limited to the certain segments of the population such as those interested in the technology and students (Jiang, et al., 2017). However, this still leaves the prospect for significant growth in this new type of consumer activity, especially in the long-term. In terms of travel patterns and behaviours, growth in consumers directly manufacturing products may result in a reduced number of trips to local retail outlets or reduced trips associated with e-commerce deliveries. The extent to which this will occur will depend on the range of goods consumers will be able to produce. Also, as with firms engaging in additive manufacturing processes, consumers will generate some trips directly or indirectly in procuring the necessary raw materials for home manufacturing. Again, this may potentially offset some of the reduction in trips arising from consumers producing certain goods at home.

With regard to emissions in the transport sector, some analysis suggests that additive manufacturing may reduce the environmental impact associated with freight transport, although there is a lack of study and data on the topic (Kellens, et al., 2017). However, given additive manufacturing may lead to some rationalisation of supply chains, it can be expected that there would be some reduction in emissions associated with the implied reduction in freight movements. Consumers’ ability to produce certain goods at home via 3D printing may also eliminate some trips associated with shopping or e-commerce, leading to some emissions savings. However, the degree to which this might lead to substantial emission savings will ultimately be dependent on the range of goods that consumers will be able to manufacture for themselves and the proliferation of the technology among households.

4.2 Impact on Future Network Analysis

This section will examine the impact which a significant increase in additive manufacturing would have the four other future network analysis areas.

Compact Growth

Additive manufacturing provides more potential flexibility for firms in terms of where they locate. The degree to which this will impact compact growth will likely be dependent on a range of factors including the complementary or substitutive effects of additive manufacturing in existing manufacturing processes and the complexity of the goods being manufactured. There is debate as to how strong traditional firm location factors such as distance to market and distance from inputs will be in the face of the growth of additive manufacturing (Gress & Kalafsky, 2015). However, there is some consensus that the more complex the goods being manufactured, the more likely that the firms involved will be influenced through traditional location factors and will have increased propensity to cluster (Gress & Kalafsky, 2015). Such clustering of additive manufacturing firms will likely occur in larger urban areas (Boon & van Wee, 2018). As such, the increased adoption of additive manufacturing in firms will likely have a neutral impact on compact growth in and of itself.
There is less research to date on the impact that additive manufacturing may have on consumers’ choices and location preferences. The ability to produce certain goods at home using 3D printers and similar tools may lower the costs associated with living in more rural areas through the need to make fewer trips for shopping or deliveries. This lowering of transport costs, if sufficient, may act as a pull factor in people relocating to more isolated areas, or at least discourage some depopulation of these areas. However, there are a number of other factors that influence an individual’s choice to live in a certain location. In order for 3D printing to be a significant factor among these, it is likely that consumers will need to enjoy the ability to produce a wide array of various goods at home and readily have access to the materials and support needed. As the technology continues to develop and proliferate, it is expected that the effect of additive manufacturing on consumer choice and preferences for location, and in turn the effect on compact growth, will become clearer.

**Interurban Connectivity**

The degree to which additive manufacturing will affect interurban connectivity will likely result from the location choices of firms utilising the associated technologies and processes. The flexibility and potential efficiencies of decentralising manufacturing processes that additive manufacturing can potentially offer may result in rationalisation and consolidation of supply chains domestically and internationally (Kellens, et al., 2017). It is reasonable to expect that rationalisation of supply chains will lead to some decrease in freight traffic on interurban networks, although this will be influenced by the type of manufacturing and goods being produced. Some reduction in traffic might also be expected where consumers can eliminate trips through the production of goods at home although, again, this will be dependent on the proliferation of the technology among households and the range of goods they will be able to manufacture. It is also worth noting the possibility that households will simply replace trips once associated with shopping with trips for other purposes.

**Strategic Links**

Any widespread uptake of additive manufacturing among Irish firms and households could result in increased bulk importation of the raw materials necessary for additive manufacturing processes (Boon & van Wee, 2018). This would generate some additional traffic at ports and airports and on the transport links connecting them to other areas of the State. However, depending on the nature of the goods being manufactured by firms and consumers, there may a reduction in other types of good imported and a corresponding decrease in freight traffic on the strategic links to the State's ports and airports. Another possibility is that additive manufacturing will increase the efficiency of Irish exporting firms, thereby increasing demand on the State's strategic transport links. The overall effect on strategic links is likely to be dependent on the proliferation of additive manufacturing processes as well as the nature of the manufacturing in which it is used.

**Rural and Regional Accessibility**

It is unclear whether the decentralisation of manufacturing enabled by additive manufacturing processes would have a significant impact on rural areas. Jiang et al. indicate that a firm’s decision to decentralise or establish new manufacturing facilities in a particular location will likely be influenced by the number of potential customers in that location. Furthermore, there will be benefits to those firms who decide to cluster in specific locations (Gress & Kalafsky, 2015). This suggests that if additive manufacturing is to have any impact on regional and rural transport networks, it is more likely to arise from the growth of new manufacturing clusters in larger regional centres. This in turn may increase demand for access to and from those regional centres. Rural households stand to benefit from the potential of having to take fewer trips associated with shopping or maintenance purposes if
they can produce the items required in their own homes thanks to 3D printers. This could potentially reduce the
number of trips on the rural transport network. However, the ability of households to replace one trip with one for
another purpose may cancel out any reduction in use of transport networks that may arise from the ability to
produce certain goods in one's home.

4.3 Summary

Additive Manufacturing as a technology has advanced to the extent it is beginning to proliferate across firms and
households. It is largely regarded as a disruptive technology with the ability to influence manufacturing supply
chains and provide consumers with the ability to produce certain goods in their own homes. This will likely have
some effect on transport patterns and behaviours, particularly in the freight sector. Rationalised supply chains
have the potential to reduce the number of freight movements while consumers may require fewer trips for retail
and e-commerce purposes. However, the degree to which this will occur will be dependent on a number of
factors, including the nature of existing Irish manufacturing and the number of households that purchase the
necessary equipment. The technology could potentially give rise to new types of manufacturing in Ireland which
may be more nationally dispersed and localised in nature. The exact impact of this possibility is unclear although it
is likely any new additive manufacturing firms of reasonable scale will cluster in existing urban areas. Clusters of
sufficient size would impact transport patterns in the immediate vicinity and the broader region in some manner.
With the technology only beginning to be used more widely, it remains to be seen to what extent Irish firms and
households will utilise it. As such, potential impacts remain largely speculative in nature.

Table 4.1: Increased Additive Manufacturing Scenario Summary

<table>
<thead>
<tr>
<th>Variable</th>
<th>Potential Impact</th>
</tr>
</thead>
<tbody>
<tr>
<td>When People Travel</td>
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<tr>
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<tr>
<td>Mode Used</td>
<td>Increase in private car use and increase in freight traffic</td>
</tr>
<tr>
<td>Travel Destinations</td>
<td>Reduction in city centre trips</td>
</tr>
<tr>
<td>Emissions Impact</td>
<td>Increase in personal and freight transport emissions</td>
</tr>
</tbody>
</table>
5. Leisure Travel Demand

The CoVID-19 crisis has resulted in an unprecedented decline in air travel demand, with passengers numbers in Dublin Airport down 99% in April 2020 compared to the same period in 2019 (DAA, 2020). The long-term impacts of CoVID-19 may result in some airline carriers reducing or permanently ceasing operations and a corresponding rise in the price of aviation, as airlines look to repay large debts accumulated during the crisis (Powley, et al., 2020). Research has shown that passenger demand for aviation is price elastic, meaning that a rise in the cost of aviation is associated with a fall in demand. Price elasticity varies by flight distance and geographic area, for example, the price elasticity was -0.92 for Intra-European short haul flights and -0.84 for Intra-European long haul flights, indicating that a 10% increase in a ticket price would result in a 9.2% and 8.4% reduction in passenger demand respectively (InterVISTAS, 2007).

In addition to the impact of CoVID-19, the aviation industry also faces growing international pressure to account for the externalities which it produces such as greenhouse gas emissions. There have been calls from national governments and the European Commission to introduce measures such as a carbon tax or ticket tax. The impact on passenger demand of any aviation carbon pricing regime would depend, to some extent, on whether it was levied on airlines through a tax on fuel or on passengers directly through a ticket tax and on the rate at which it is applied. For example, one study found that a counterfactual carbon-based flight ticket tax of €35 per tonne of CO₂ emissions would have reduced passenger growth at Irish airports from 6.95% to 2.87% over the period 2013-2014 (Krenek & Schratzenstaller, 2016).

This scenario considers the potential for future rises in the cost of aviation and examines its implications for the transport sector. As NIFTI is primarily concerned with land transport, this scenario will focus on the impact of a reduction in aviation passenger demand on the land transport network rather than on changes in air traffic volumes.

5.1 Impact on Transport and Travel Patterns

A significant increase in aviation prices is likely to result in a fall in the number of overseas visitors to Ireland. It may also result in a corresponding rise in the number of Irish people choosing to engage in domestic tourism rather than travel abroad. This could have knock-on impacts for the land transport network. Research by Fáilte Ireland indicates that 57% or approximately 5.5 million overseas visitors did not use a car during their stay in 2018 (Fáilte Ireland, 2019). By contrast a review of public transport usage in the Irish tourism sector found that 86% of domestic tourists used a car (ITIC, 2019). Therefore a change in the balance of tourists from overseas visitors to domestic tourists, as a result of increasing air fares, may be associated with an overall increase in private car use, particularly in summer months. Changes to the profile of tourist also have implications for the destinations which they choose to visit. Figure 5.1 shows that Dublin has a much higher proportion of overseas visitors compared to domestic tourists, whereas the Mid-East, South-East and Border regions all had higher numbers of domestic tourists compared to international visitors. This will have implications for the numbers traveling on the road network and availing of public transport within these areas; with a potential fall in demand in regions with higher numbers of overseas visitors and an increase in regions which are more popular with domestic tourists.
A key variable impacting on price elasticity of demand for air travel is the flight distance, with higher air fare elasticities generally observed for short-haul flights compared to long-haul flights. In other words, passengers travelling a shorter distance tend to be more price sensitive than those travelling a longer distance. This is due in part to the lack of alternative modes such as rail or ferry services for long haul flights (Krenek & Schratzenstaller, 2016). This could result in a greater reduction in demand from visitors travelling a short distance to Ireland, such as from the UK compared to more distant destinations, such as the USA. This change in the profile of overseas visitors could also have potential impacts on the popularity of different tourist destinations and subsequent demand for transport services. Figure 5.2 shows that American tourists are more likely to visit locations in the West, South West, South-East and Border Regions compared to visitors from the UK.

However, visitors from the UK or continental Europe could also potentially respond to higher air fares by choosing to travel by ferry instead. This would result in increased traffic volumes at Dublin and Rosslare ports.
5.2 Impact on Future Network Analysis

This section will examine the impact which a rise in the price of aviation and corresponding fall in passenger demand would have the four other future network analysis areas.

**Compact Growth**
There is likely to be minimal impacts on compact urban growth as a result of this scenario. A reduction in overseas visitors may contribute to a marginal reduction in public transport usage in urban centres due to a loss of overseas visitors.

**Interurban Connectivity**
Higher car usage rates by domestic tourists, compared to overseas visitors, coupled with their preference to travel to more rural destinations could result in an increase in traffic volumes on the inter-urban road network.

**Strategic Links**
A fall in aviation passenger demand would result in a reduction in the traffic on the strategic routes serving the airports. Higher air fares could also result in visitors from the UK and continental Europe choosing to travel by ferry instead, resulting in an increase in traffic on the routes serving the Dublin and Rosslare ports.

**Rural and Regional Accessibility**
Domestic tourists are more likely to visit rural destinations than overseas visitors. Therefore, a significant fall in air passenger demand could result in an increased demand for rural public transport services and increased traffic volumes on the rural road network. Rural destinations are also popular with US visitors, who are likely to be less sensitive to increases in air fares. Therefore any fall in overseas tourist numbers in rural areas may be less
pronounced compared to destinations such as Dublin, which is popular with those traveling shorter distances from the UK or mainland Europe.

5.3 Summary
A significant, long-term fall in passenger demand may result in cost increases for passengers (Powley, et al., 2020). Some travellers may respond to these price increases by reducing the number of flights they take per year, and this impact is likely to be particularly pronounced for short-haul flights which tend to be more price sensitive. This could result in a change in the time of year people choose to travel to and from Ireland. Given the higher car usage rates of domestic tourists, compared to overseas visitors, a reduction in air passenger demand may be associated with an increase in private use and distance travelled, as more people opt for “staycations” rather than travelling abroad. This scenario could lead to a fall in traffic serving the strategic routes around airports, with a potential increase in traffic at ports, as some visitors from the UK or continental Europe respond to higher prices by choosing to travel by ferry instead. It may also result in a fall in tourist traffic in urban destinations popular with overseas visitors and a potential increase in more rural destinations popular with domestic tourists. The scenario would also likely lead to a marginal increase in CO₂ emissions from land transport as a result of increased car use. It is beyond the scope of this paper to consider the emissions impact due to a reduction in air traffic

Table 5.1: Reduced Aviation Demand Scenario Summary

<table>
<thead>
<tr>
<th>Variable</th>
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</tr>
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<tr>
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</tr>
</tbody>
</table>
6. Scenario Analysis

The case studies outlined above illustrate the range of potential futures which could emerge across the transport sector. These case studies are only examples but they serve to highlight how underlying changes in travel behaviour can have significant impacts on future network requirements. Drawing on these case studies, this section will outline techniques such as scenario analysis can be deployed to address uncertainty in the transport planning process.

6.1 Uncertainty in Transport Planning

Transport planning cannot be considered in isolation; rather, it should be considered in relation to society’s accessibility needs. This means we need to consider the relationship between transport, the built environment and digital connectivity. This can be framed as a ‘Triple Access System’, as illustrated in Figure 6.1 (Lyons & Davidson, 2016). NIFTI has made a significant contribution towards understanding the interactions between transport and land use planning. However, further work is required to understand the complex relationship between these areas and digital connectivity; this is highlighted by the teleworking and e-commerce scenarios outlined above. The relationship between each of these areas will determine our future accessibility needs and transport infrastructure requirements. Because it is unclear how these areas will interact in the future it is imperative that the planning system is adaptable enough to deal with this inherent uncertainty.

Figure 6.1: Triple Access System

Source: Lyons & Davidson (2016)
When discussing how uncertainty is dealt with in the transport planning process we can distinguish between two policy making pathways. These are a Regime Compliant Pathway and a Regime Testing Pathway. The Regime Compliant Pathway is characterised by an implicit reliance on current trends in the transport sector continuing, for example private car use continuing to be the primary mode of mobility. It is underpinned by techniques such as Cost-Benefit Analysis (CBA) which measures potential investment decisions against a Do-Nothing/Do-Minimum scenario based on projections and leads to a "predict and provide" approach, which is vulnerable to the impacts of unanticipated changes. By contrast, a Regime Testing Pathway embraces uncertainty. It considers if the current transport regime is undergoing a period of transition such as a change in travel patterns or behavioural change. It uses Real Option Analysis (ROA). ROA is a methodology that can be used to prioritise interventions while considering the possibility to adjust them in the future. ROA can be used to determine whether interventions should be immediate or delayed and test the value of interventions that present greater flexibility down the road (ECONADAPT). Adopting this approach allows the assessment of alternative plausible policy pathways and leads to a "decide and provide" approach, which helps guard against the impacts of unanticipated uncertainty by instilling increased adaptability into the transport planning process (Lyons & Davidson, 2016).

While these pathways should be thought of as illustrative examples, in reality more planning pathways exist and some combine elements of both the regime testing and compliant pathways. However, they do serve to highlight the need to move beyond traditional approaches to transport planning, which tend to be over-reliant on extrapolating historic trends to forecast future transport needs (Lyons & Davidson, 2016). The traditional Regime Compliant Pathway and the tools which underpin it, such as CBA, are sufficient for dealing with lower levels of uncertainty where a "clear enough future" emerges or alternative futures can be examined with differing probabilities. A Regime Testing Pathway is better suited to dealing with "deep uncertainty", which occurs when decision makers do not know or cannot agree on a likelihood of future events.

### 6.2 Scenario Planning

One way to accommodate uncertainty and build enhanced adaptability into the transport planning process is to use scenario planning. This involves making evidence based predictions about changes to key variables such as:

- Changes in employment;
- Changes in population;
- The number of people teleworking;
- The number of people engaging in e-commerce;
- Mode choice.

Rather than considering these changes in isolation, policy makers can then vary them together to assess how changes in different variables interact and to develop a range of potential future equally likely scenarios or "states of the world". Figure 6.2 provides an illustrative example of how scenario analysis can be applied to assess the impacts of CoVID-19. The key variables in this example are:

- Behavioural Change: the change in the travel behaviour as a result of the crisis, e.g., increased teleworking;
- Economic Impacts: the degree to which the crisis causes adverse economic impacts, e.g., job losses, reduction in consumer spending; and,
- Policy Interventions: how the government responds to the crisis, e.g., providing support to businesses, reducing the capacity on public transport, etc.

Figure 6.2: CoVID-19 Scenario Analysis

In the above example, 0 represents a Business as Usual scenario, 1 represents a scenario with negative economic impacts and no lasting behavioural change, 2 represents an economic recovery with the maintenance of behavioural changes while 3 combines scenarios 1 and 2 (SYSTRA, 2020). The key variables can easily be changed or adjusted. For example, the levels of people engaged in e-commerce and teleworking can be varied to estimate the future demand for public transport and transport infrastructure under a range of different scenarios.

6.3 Application to Transport Planning

NTS Scotland

An example of this approach being applied to policy was the development of a scenario planning tool to inform the development of the latest iteration of the National Transport Strategy in Scotland. The tool was developed through a consultation process with stakeholders across the transport sector. The first stage involved the group identifying a list of the key drivers of change in the transport sector, such as population, GDP and personal travel patterns. The group then considered how each of these drivers interacted with each other, which allowed them to identify three primary drivers of change. These were:

- Population change;
• Travel cost; and,
• Trip rate.

Each of these variables was assigned an adjustable elasticity level which was used to develop a scenario planning tool. The value of this tool is not in providing a detailed examination of the cause-effect relationships but rather to help inform the assessment selection of different potential policy options at an early stage (Lyons, et al., 2018).

**NTA Public Transport Market Demand Estimation Tool**

In response to the disruption caused by the CoVID-19 crisis, the NTA developed the Public Transport Market Demand Estimation Tool to assess the potential impact of different potential future demand scenarios for public transport services. The tool examines demand for public transport across all operators and across geographic areas. It also disaggregates demand by time of day. Census small area data is then combined with data collected by the NTA’s National Household Travel Survey (NHTS) to examine journey purpose. Because trips to work and education account for the majority of trips on public transport these variables are disaggregated further into primary, secondary and third-level education, and blue collar white collar and pink collar jobs respectively. The tool uses data from behavioural and attitude surveys, ESRI projections and studies undertaken by University College Cork (UCC) to assess the propensity of each employment group to engage in teleworking. An overview of the tool is presented in Figure 6.3. The tool can be used to estimate the impact of a range of potential scenarios, such as different rates of teleworking, across geographic regions. Work between the NTA and UCC is ongoing to update the tool to make it capable of assessing the impact on public transport demand on a corridor basis.

The tools described above provide a high-level assessment of the impact of different potential future scenarios. This can be used to guard against unanticipated change and ensure that large scale investments in the transport sector are designed with enough flexibility to adjust to a number of different future states of the world. An example of applying this approach to the transport planning process could be ensuring that attempts are made to determine how the planned investment would fare across a range of different future scenarios. This could be done by integrating scenario analysis into existing cost-benefit analysis sensitivity testing.

In Figure 6.3 the letters A-D represent potential project options. These could include the use of public transport modes or different route designs for a road project. While the values 1-8 represent different potential scenarios, which could include variations to assumptions around population, economic growth or travel patterns, for example, adopting the teleworking scenario outlined above. By assigning each of these option scenario combinations a RAG (red, amber green) status, based on its potential performance, it is possible to assess how each option performs across a range of potential future scenarios and choose an option which is more resilient to unanticipated change.
Figure 6.3: Policy Testing Matrix

Without-policy plausible futures

1  2  3  4  5  6  7  8

Policy option applied

A

B

C

D

Source: Lyons et al. (2018)
7. Conclusions

The impacts of the current CoVID-19 crisis have demonstrated the need for transport planning to account for low-probability, high-impact events. Furthermore, the complex interactions between transport, land use planning and digital connectivity have also led to increased uncertainty about society’s future accessibility needs and how the transport system should be designed to address them.

One way to address this uncertainty is to adopt a scenario planning approach within the transport planning process. This involves making evidence based predictions about changes to key variables which impact on transport demand to develop a range of potential future scenarios or “states of the world”. Examples from the development of the National Transport Strategy in Scotland and the Public Transport Demand Estimation Tool in Ireland show how this approach can be integrated into the existing policy making process.

It is expected that NIFTI will be reviewed and updated periodically. It is recommended that the next iteration of the framework uses scenario planning tools such as those currently being developed by the NTA to assess plans for future network developments against a range of potential future states of the world. These tools should also be adopted when updating future transport strategies. It is also recommended that when large-scale investments in the transport sector are being assessed, attempts are made to determine how the planned investment would fare across a range of different future scenario by, for example, applying scenario testing as part of the sensitivity testing process within a project’s cost-benefit analysis. This approach could involve varying a range of key parameters simultaneously, rather than independently.

Further research is required to develop a suite of scenario analysis tools for the transport sector. While it is important to remember that these tools are also built on a series of assumptions, they can be used to reveal uncertainty in the transport planning process, helping to introduce enhanced adaptability and guarding against the impacts of unanticipated change.
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