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MINISTRY OF TRANSPORT

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Section	Description of ground
6(a)	as release would be likely to prejudice the security or defence of New Zealand or the international relations of the New Zealand Government
6(b)	as release would be likely to prejudice the entrusting of information to the Government of New Zealand on a basis of confidence by (i) the Government of any other country or any agency of such a Government; or (ii) any international organisation
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9(2)(a)	to protect the privacy of natural persons
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9(2)(ba)(i)	to protect information which is subject to an obligation of confidence or which any person has been or could be compelled to provide under the authority of any enactment, where the making available of the information would be likely to prejudice the supply of similar information, or information from the same source, and it is in the public
9(2)(ba)(ii)	to protect information which is subject to an obligation of confidence or which any person has been or could be compelled to provide under the authority of any enactment, where the making available of the information would be likely otherwise to damage the public interest
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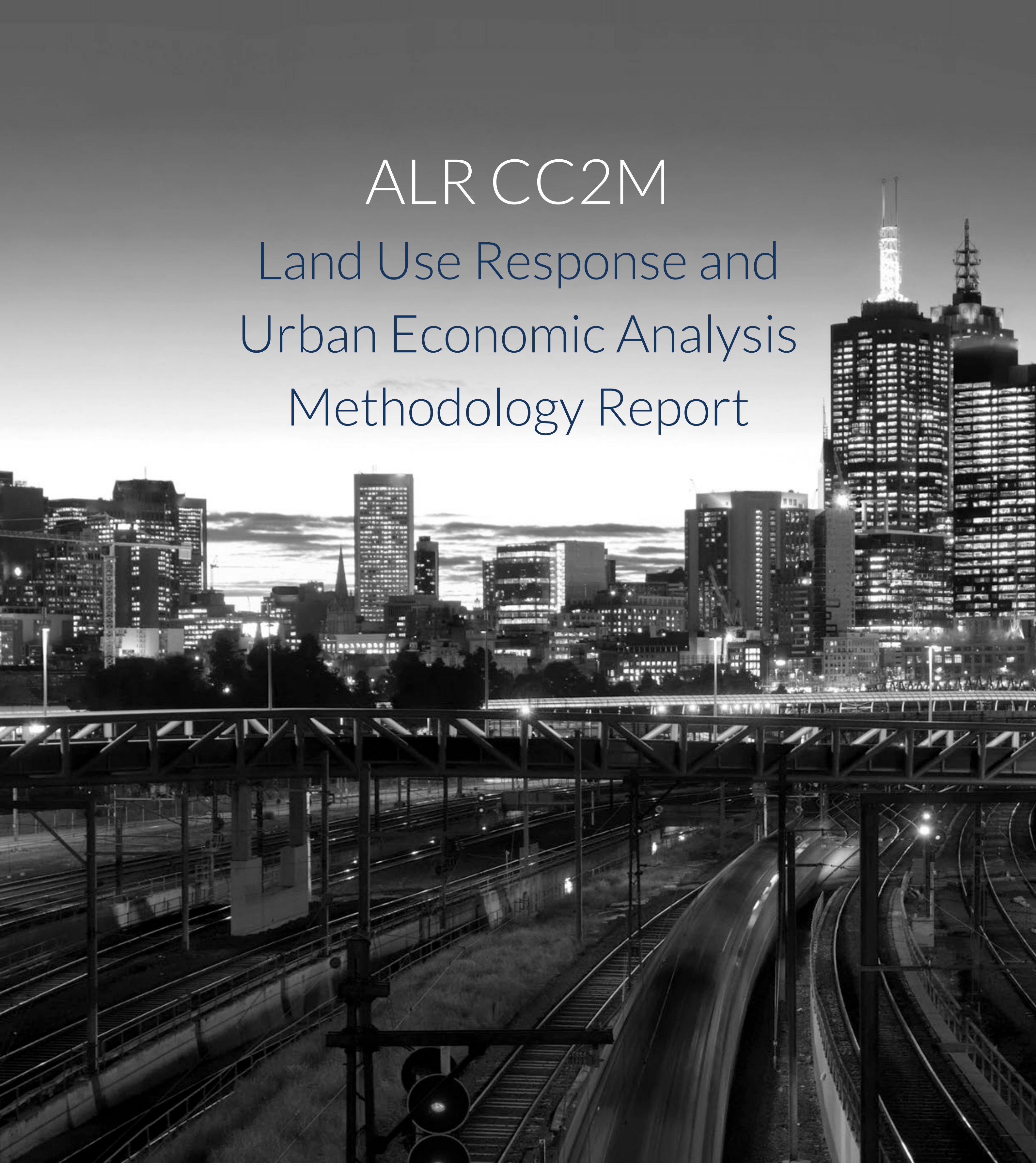
9(2)(h)	to maintain legal professional privilege
9(2)(i)	to enable a Minister of the Crown or any public service agency or organisation holding the information to carry out, without prejudice or disadvantage, commercial activities
9(2)(j)	to enable a Minister of the Crown or any public service agency or organisation holding the information to carry on, without prejudice or disadvantage, negotiations (including commercial and industrial negotiations)

ALR CC2M

Land Use Response and Urban Economic Analysis Methodology Report



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Dr James McIntosh

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Assumptions and Limitations

This report presents the methodology and outputs of the land use response modelling, and the economic analyses conducted based on the modelling of land use changes conducted by LUTI Consulting for the Auckland Light Rail (ALR) City Centre to Mangere (CC2M) light rail project.

While all care was applied in the preparation of the analyses presented in this report, the findings and outcomes are sensitive to, and dependent on, the quality and reliability of the input data provided for the modelling. Additionally, it is important to note that there is an inherent degree of variability with all forecasting, particularly into more distant years. As such, LUTI Consulting do not accept any responsibility or liability for any loss or harm suffered by those seeking to use the information provided in this report.

This report should be read while considering the assumptions and limitations outlined below:

- The land use response modelling is based on outputs from the MSM travel demand model run by the Auckland Forecasting Centre (AFC). Neither the travel demand model outputs nor the land use forecasts on which they were based have been independently validated by LUTI Consulting.
- The REF2 Do Min land use forecasts were adopted as the base case forecasts for the demand modelling and economic appraisal. While some of the modelling outputs presented in this report provide a level of insight into the suitability of these forecasts as a base case for the ALR CC2M project, an in-depth analysis of the forecasts was not within the scope of works conducted by LUTI Consulting.
- The land use response modelling presented in this report is a top-down analysis of the population and employment demand response to the accessibility changes induced by the ALR CC2M project. The modelling has not considered potential development or redevelopment constraints and market-based issues related to development timing and feasibility that may affect the accuracy of the project case forecasts that have been prepared. Additional work could seek to incorporate these considerations.
- In preparing project case land use forecasts for a business case, LUTI Consulting typically conduct several rounds of testing and calibration of the forecasts to address any potential network issues caused by project-induced land use changes. However, no significant transport network issues were identified in response to any of the project case land use forecasts that were prepared. Some minor issues were identified for road links near the airport but addressing them was not deemed material, and not a priority for the project.
- In preparing the project case forecasts for the ALR CC2M project, population and employment control totals by industry sector (Industrial, Business, Wholesale, Retail, Government and Other) were maintained. This is consistent with a "closed city" modelling approach. While it is possible for additional population and employment growth to occur over and above what is forecast in the REF2 Do Min forecasts within the geographic extent of the MSM in response to the investment in the ALR CC2M project, current convention in Australia and New Zealand is to consider the total projected population and employment to be fixed. Importantly, the project-induced land use growth redistribution modelling presented in this report does not represent a stated government, or policy position, but rather a pragmatic response to the requirement for population and employment control totals to be maintained whilst employing theoretical underpinnings that are based on planning intent and transport network constraint.
- While transport investments and accompanying urban development and renewal activities may lead to changes in the demographic and economic characters of travel zones, an analysis of such potential changes has not been within the scope of works conducted. As such, the land use response modelling outcomes assumed that travel zone population and/or employment densities change in response to changes in accessibility, but the demographic and economic characters of the travel zones do not. Having said this, bespoke project case household occupancy rates and employment work-space ratios were provided by the Urban Team for inclusion in the analysis of higher value land use benefit and in the preparation of the inputs to the value capture modelling workstream.
- A final step in the preparation of the project case land use forecasts was to disaggregate them down to the lot level to facilitate their aggregation up to different geographies and catchments for use by different workstreams within the business case. While this report details the process for disaggregating the forecasts, reliance should not be placed on the accuracy of the lot level forecasts themselves as the location of future base case and project case growth will be subject to numerous factors including, but not limited to, current zoning, future zoning, the condition of existing development, the willingness of landowners to sell their properties, development constraints such as heritage or flooding, etc.
- The estimation of higher value land use benefits discussed in this report assumes that all future growth within the ALR CC2M corridor occurs by way of intensification of existing uses without any changes in use. This was a simplifying assumption made in the absence of precinct structure plans and adds a level of

conservatism to the estimated economic benefits, given that significant value can be created with changes in use. Future work could seek to incorporate more nuanced data and information on land use zoning and permissible density changes as it becomes available.

- The assessment of the infrastructure and service cost savings benefits was based on: an analysis of the growth redistribution impacts of the ALR CC2M project; a characterisation of MSM travel zones as being either infill or greenfield; and infrastructure costs for infill and greenfield environments. While all three inputs make a significant contribution to the estimated results, the infrastructure costs of servicing greenfield and infill environments are the most challenging to ascertain without detailed and costly investigation, as they can vary spatially based on latent infrastructure capacity and numerous other factors. With that said, the Urban Team conducted an analysis of infrastructure costs, expressed as a cost per dwelling, using the ALR CC2M corridor to represent an infill setting and Drury to represent a greenfield setting. While costs per dwelling were not estimated for all areas within Greater Auckland, the ALR CC2M corridor and Drury costs should provide a reasonably detailed understanding of the infrastructure cost savings facilitated by land use changes in response to the project.
- The assessment of the transit option value benefit was based on an analysis of the LRT proximity effects on land values and LRT mode share data by forecast year from the MSM. Any factors affecting the LRT mode choice, including but not limited to LRT speeds and rolling stock capacity, will affect the estimated results.

1 Introduction

This report presents the methodology applied by LUTI Consulting in the preparation of the project case land use forecasts for the ALR CC2M project and the methodologies applied in the estimation of a range of urban development economic benefits.

The project case land use forecasts were prepared as inputs to the MSM travel demand model to produce outputs for the analysis of second-round transport user and wider economic benefits, and for the estimation of project-induced urban development economic benefits. Additionally, the forecasts and land value uplift estimates were provided as inputs to the value capture modelling conducted by PwC. The forecasts were prepared by applying LUTI Consulting's integrated land use and transport modelling framework, which establishes a land use response study area, estimates an initial land use response, conducts a redistribution of growth, and then involves a calibration phase to resolve any significant transport network problems.

The urban development economic benefits assessed by LUTI Consulting included higher value land use, infrastructure and service cost savings, and transit option value. These economic benefits were based on the project case land use forecasts prepared by LUTI Consulting for the ALR CC2M project as well as a variety of other inputs, including parameters derived from a Greater Auckland Hedonic Price Model (HPM) developed by LUTI Consulting with the latest available (2021) property and rating valuation data.

2 Land Use and Transport Interaction Modelling

The land use forecast modelling methodology presented in this section of the report adheres to the latest requirements by Australian Transport Assessment and Planning (ATAP) and Infrastructure Australia (IA) for the preparation of project case land use forecasts and their application in transport project economic appraisals. While guidance in Australia (and New Zealand) is not currently prescriptive, LUTI Consulting have developed a land use and transport interaction modelling framework to assist in the preparation of project case land use forecasts for transport project business cases that was tailored to the Auckland context.

The following models and analyses developed by LUTI Consulting were applied to the ALR CC2M (and the rapid transit network) scenarios:

1. Strategic Transport Accessibility Dependence Model (STADM) – In applying the STADM to the rapid transit network and ALR CC2M scenarios, access zone demand data for trips using the new light rail services and total demand data are analysed to establish a land use response study area.
2. Transport Induced Development Response Model (TIDRM) – The TIDRM involves the application of parameters from statistical models estimated to predict changes in population and employment demand (by industry sector) in response to changes in transport network accessibility. The TIDRM uses outputs from a travel demand model to forecast land market demand responses consistent with the accessibility benefits reported in a project business case. A development take-up adjustment is also applied to reflect that development cannot respond instantaneously to accessibility changes.
3. Transport Induced Growth Redistribution Model (TIGRM) – The TIGRM is used to redistribute the difference between the base case and project case demographic forecasts within the land use response study area to maintain population and employment control totals across the geographic extent of the MSM travel demand model.
4. Land Use Interaction Modelling Calibration (LUIMC) – The application of the LUIMC involves testing a set of draft project case demographic forecasts in and comparing a series of outputs to those with the project under base case land use forecast assumptions. While the various versions of project case land use forecasts that were prepared were tested in the MSM, a complete calibration of the forecasts was not deemed necessary given the minimal issues identified.

An illustration of the interactions of the models with each other and other aspects of the economic appraisal is presented below in Figure 1. Figure 2 then presents an overview of the sequential steps in the project case land use forecast preparation process. The remainder of this report is structured as follows:

- Section 2.1 discusses the application of the STADM;
- Section 2.2 discusses the application of the TIDRM;
- Section 2.3 discusses the application of the TIGRM;
- Section 2.4 discusses the application of the LUIMC;
- Section 2.5 discusses the disaggregation of the travel zone forecasts to the lot level;
- Section 3.1 discusses the estimation of the higher value land use benefit (and land value uplift);
- Section 3.2 discusses the estimation of the infrastructure and service cost savings benefit; and
- Section 3.3 discusses the estimation of the transit option value benefit.

While the modelling tasks presented in this methodology report were conducted for numerous scenarios, including scenarios for the rapid transit network and the ALR CC2M scheme, this report refers to the ALR CC2M separated metro scenario when providing examples and illustrations. Other scenarios are occasionally referred to if they involved special considerations in their modelling.

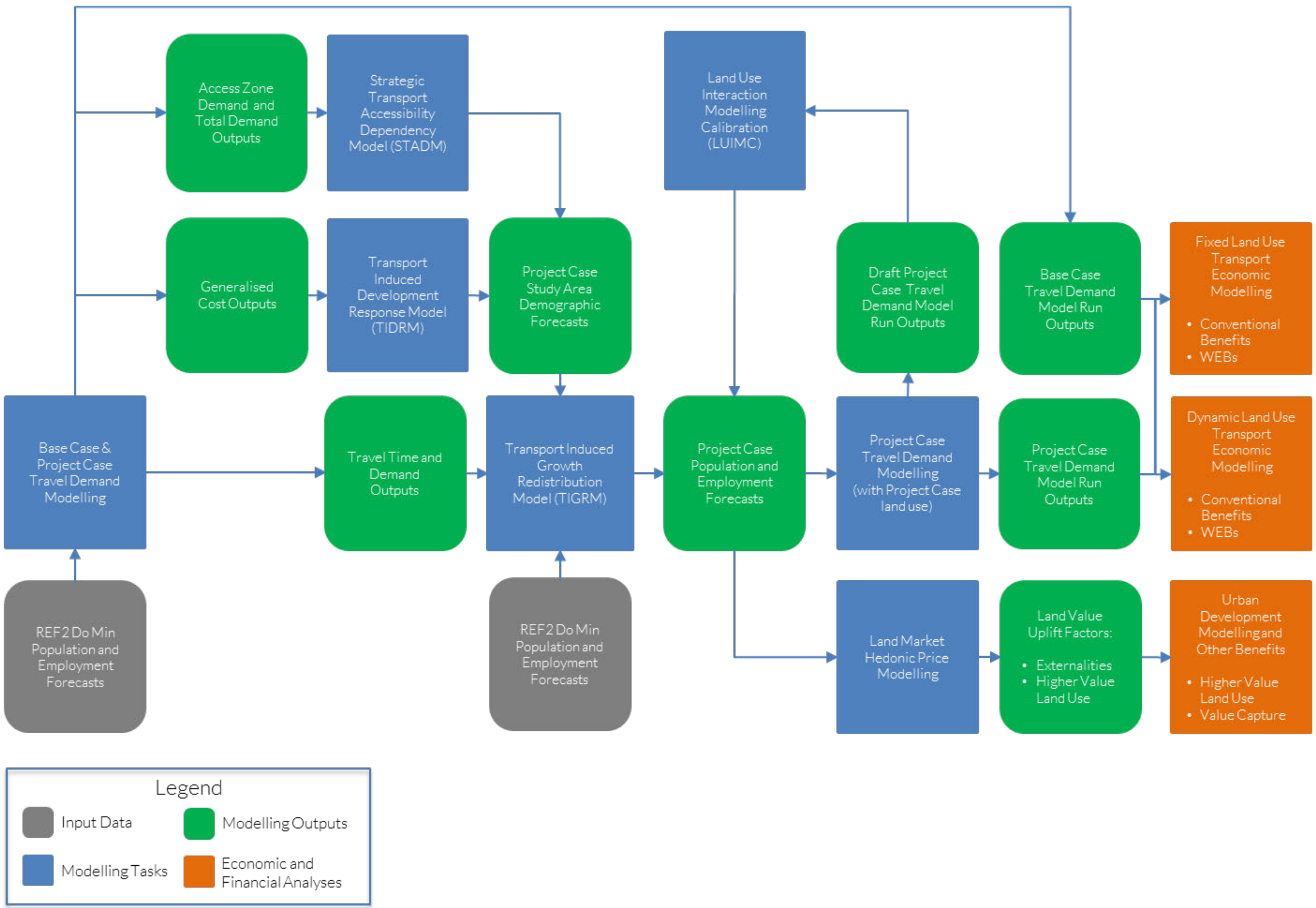

Figure 1 – LUTI Consulting's Integrated Land Use and Transport Modelling Process

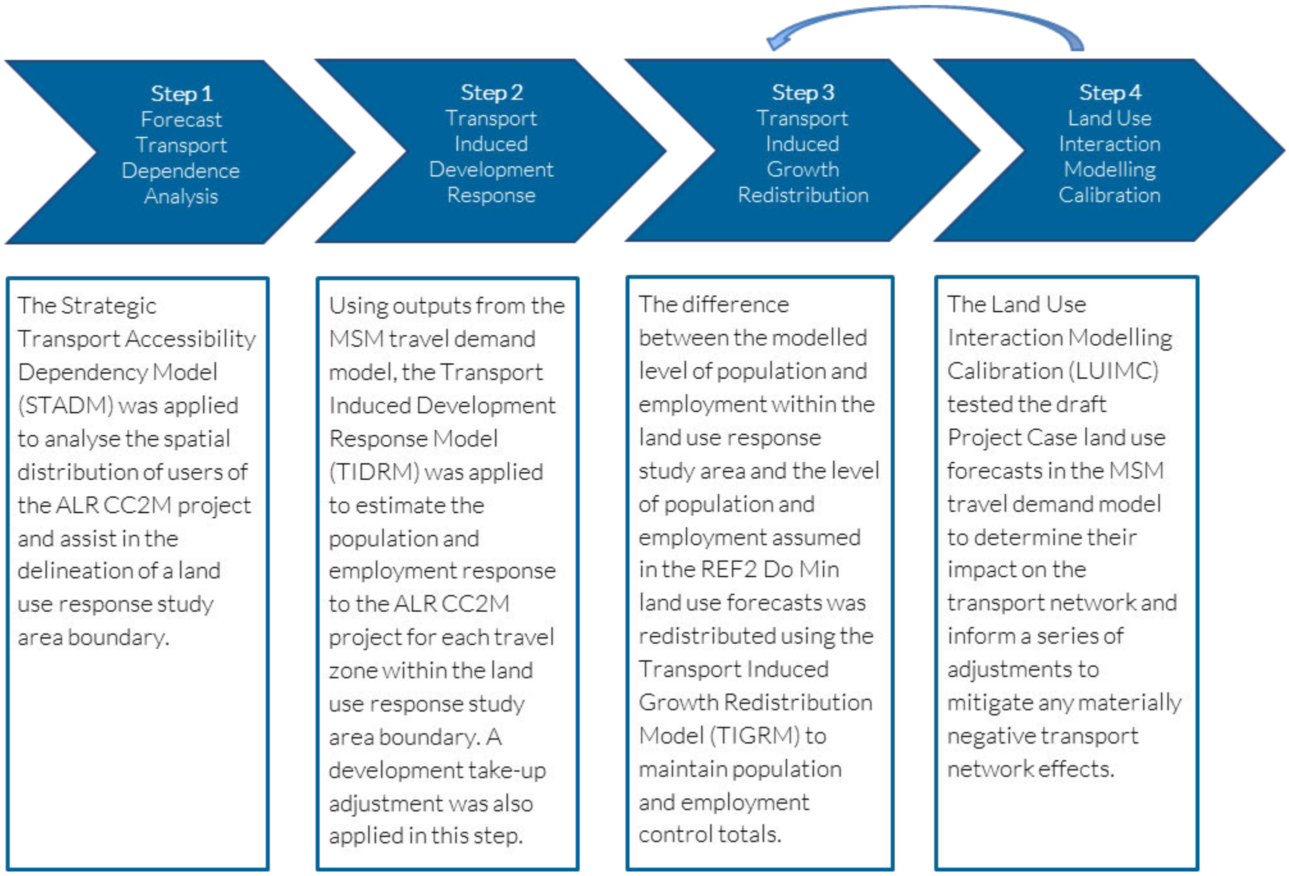

Figure 2 – Steps in the Project Case Land Use Forecast Preparation Process

2.1 Strategic Transport Accessibility Dependence Model

The first step of the modelling process presented in Figure 2 provided an understanding of the spatial distribution and usage intensity of the new public transport (PT) services comprising the ALR CC2M project and set the land use response study area for the application of the TIDRM. Understanding this provided the evidence base for a nexus between the transport investment and land use change.

The dependence analysis conducted in Step 1 enables second-round transport user and wider economic benefits and urban development benefits to be estimated and included in business cases. To achieve this land market dependence basis for the ALR CC2M project, LUTI Consulting applied its Strategic Transport Accessibility Dependence Model (STADM).

The application of the STADM involved the utilisation of outputs of a select link analysis (illustrated in Figure 1) in addition to data on total travel demand to calculate the percentage of daily travel by origin zone using the ALR CC2M project. The analysis was used to identify the spatial distribution and usage intensity of the transport investment and aided in the narrative for project-dependent land use change. Establishing this nexus enabled the inclusion of project-induced land use benefits in the business case. This analysis was conducted for all scenarios for which project case land use forecasts were prepared.

Figure 3 presents a map of the percent of daily travel by origin travel zone accessing ALR CC2M project services in 2065 using outputs for the separated metro scenario as an illustration of how access zone demand data was utilised to delineate a land use response study area boundary. Additionally, land use response study areas were set such that they also included all travel zones with at least 10% of their areas covered by a 10-minute walking catchment of an LRT station. Figure 4 presents the resulting land use response study area boundary again for the separated metro scenario.

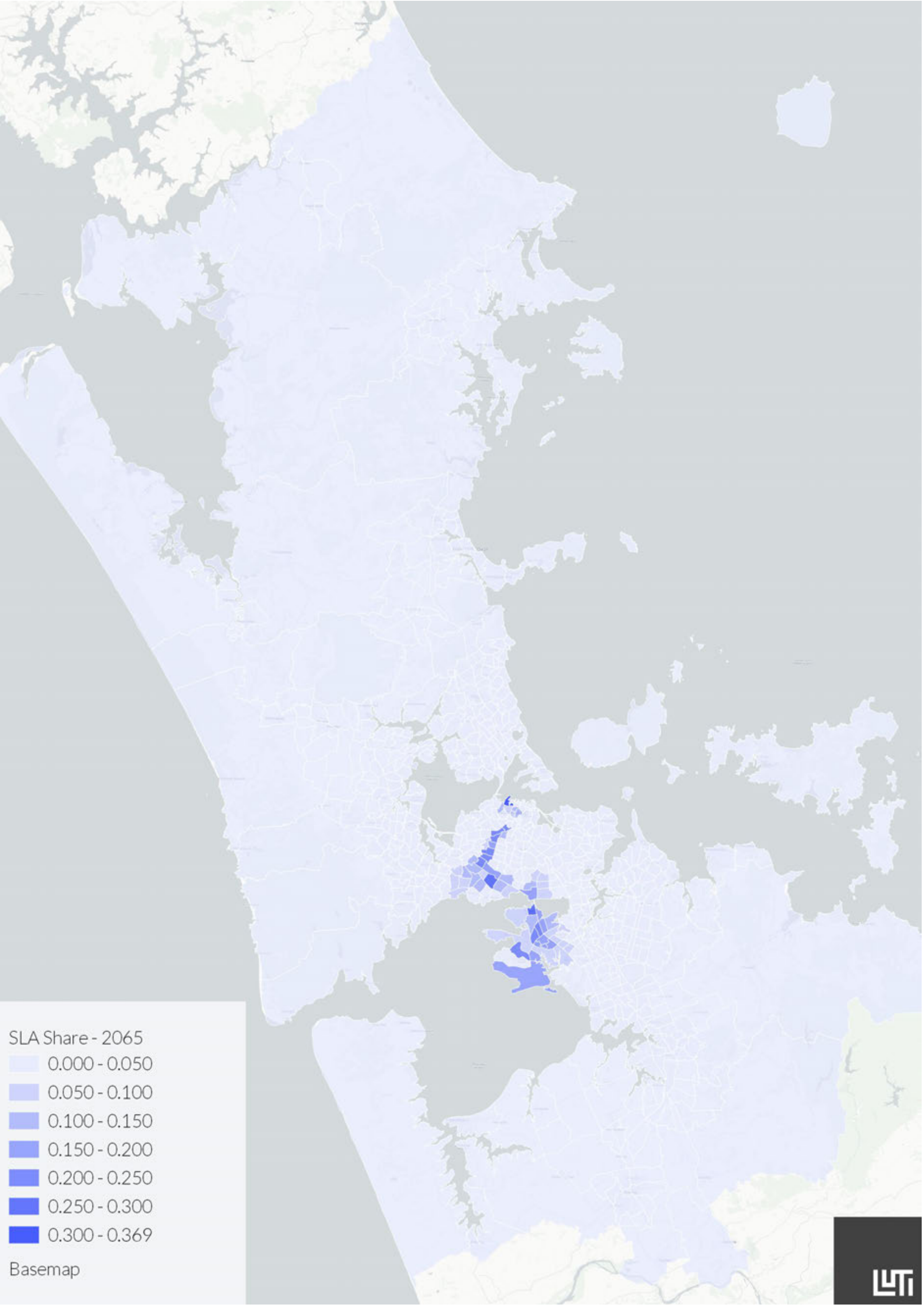

Figure 3 – Share of Daily Travel Using Separated Metro Services in 2065

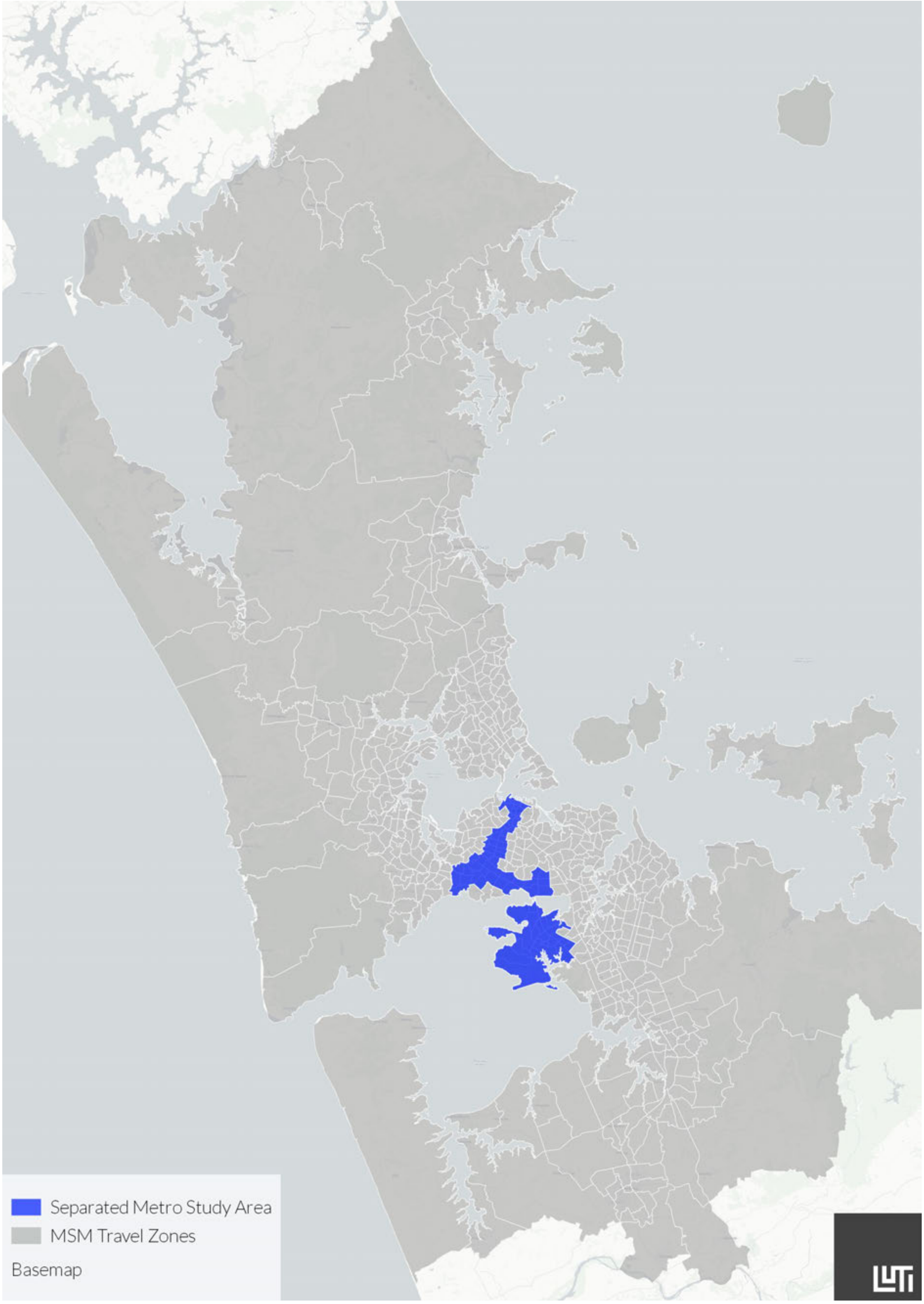

Figure 4 – Separated Metro Land Use Response Study Area Boundary

2.2 Transport Induced Development Response Model

The second step in LUTI Consulting's integrated transport and land use modelling process presented in Figure 2 involves estimating the population and employment development response to the changes in accessibility created by the ALR CC2M project within the land use response study area boundary delineated in Step 1. To estimate the population and employment (by industry sector) response to the project, LUTI Consulting calibrated its Transport Induced Development Response Model (TIDRM) to the geographic extent of Greater Auckland and applied it to the land use response study area boundaries defined by the application of the STADM. The TIDRM calibration process was based on the observed 2018 travel zone population and employment estimates prepared for the MSM zone system.

LUTI Consulting's TIDRM is based on a series of statistical models that can be used to predict changes in travel zone demand for population density and employment density by industry sector in response to a transport investment. The model is applied to determine the geographic extent of accessibility impacts resulting from a transport investment, and to estimate the change in demand for residents and businesses to locate in a project's benefitting areas. When applied, the TIDRM pivots from an underlying set of base case (or Do Min) land use forecasts, which in the case of the ALR CC2M project was the REF2 Do Min land use.

While numerous variables were tested in estimating the statistical models comprising the TIDRM, the final population and job predictors included the following:

- effective job density (EJD) as the key accessibility metric;
- train station catchment coverage;
- distance to coast;
- population/employment mix;
- employment diversity;
- the Stats NZ Deprivation Index; and
- Community Board level fixed effects to control for local character.

When estimating the statistical models for the TIDRM, an important requirement was to measure the causal relationship between accessibility and population and employment (by industry) density while controlling for reverse causation or simultaneity bias. As noted in the ATAP guidelines on incorporating land use changes in transport project business cases, a simultaneity bias can occur if higher density locations attract greater levels of transport infrastructure investment, which would result in a biased parameter estimate for the accessibility metric, EJD. To control for this, two-stage least squares estimators were tested along with ordinary least squares (OLS) estimators while using linear distance instead of average generalised cost as a proximity weight in the EJD specifications.[1] The final statistical models were estimated using OLS and linear distance in the EJD specifications as they generated the most reliable and stable results.

Notably, EJD is adopted as the key accessibility control variable, as residents value access to locations of employment for reasons of shopping, education, entertainment, and work, while businesses value access to other businesses because of agglomeration externalities.

Table 1 below presents the statistically estimated parameters applied in the TIDRM to estimate the population and employment (by industry) response to the ALR CC2M project. The EJD parameters are interpreted as elasticities and the 10-minute walking catchment coverage parameter included in the population model provides an approximation of the percentage change in population when a travel zone goes from 0% coverage in the Do Min scenario to 100% coverage in the project case. In the case that travel goes from 0% to 50% walking catchment coverage, for example, the actual estimated population uplift would be 33.2%. When applying the walking catchment coverage parameter, the light rail and existing heavy rail systems were treated the same such that a travel zone would only experience an additional uplift in population based on the change or increase in catchment coverage.

[1] Using linear distance instead of average generalized cost as a proximity weight in the EJD specification avoids measurement of the capacity of the transport network and thus is useful in circumventing a simultaneity bias. Both average generalized cost and linear distance EJD specifications were applied in the OLS model estimations and in all cases the linear distance EJD specification produced more conservative elasticity estimates.

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[redacted]

Importantly, while the accessibility impacts of a transport project are effectively instantaneous and occur at the commencement of project operations, the benefiting land markets are likely to take some time to respond due to rezoning processes and construction timeframes. Thus, an accessibility-based development take-up adjustment was applied with two versions tested, a 'standard' approach and an 'accelerated' approach. Both versions first involved establishing a take-up rate for each travel zone based on the additional population and employment by the final forecast year (i.e. 2065), and then accessibility changes in the interim years (i.e. 2031, 2041 and 2051) relative to the final forecast year were used to factor the take-up rates either up or down for each period. The difference between the 'standard' and 'accelerated' take-up approaches comes down to the treatment of the accessibility changes over time.

The 'standard' approach involved blending the accessibility changes over time, which reflects an assumption that the development industry makes decisions on where to develop based on real-time differentials in accessibility. The 'accelerated' approach, on the other hand, did not involve blending the accessibility changes over time, which reflects an assumption that the development industry makes decisions based on (near) future or anticipated differentials in accessibility. Ultimately, the 'accelerated' approach to preparing the take-up adjusted project case forecasts for the land use response study areas was adopted because it was assumed that the level of land use and transport coordination around the ALR CC2M project would be relatively high. Moreover, testing of the project case forecasts in the MSM suggested that the local transport networks can accommodate the more accelerated take-up of development without material consequences on the local transport network.

Notably, all scenarios included leading impacts of the ALR CC2M project on land use change, whereby project case land use changes were assumed to commence 4-years prior to the commencement of operations.

Figure 5 presents a map of EJD ratios for the ALR CC2M separated metro scenario in 2065 as an illustration of how accessibility changes in the land use response study area travel zones input to the estimation of additional future development. Figure 6 then presents a map of the 10-minute heavy rail and separated metro walking catchments that were also applied in the estimation of the population response to the project, noting the location and number of stations vary by scenario.

2.2.1 Accounting for the Effects of Staging in the Preparation of the Project Case Land Use Forecasts

While initial scenarios for which project case land use forecasts were prepared assumed no staging, with services in the corridor beginning in the first forecast year (i.e. 2031), the final scenarios assumed different staging options and different dates for the commencement of operations. A list of the final ALR CC2M scenarios and their assumed staging is provided below.

- Separated metro: Stage 1 - 2032, Stage 2 - 2034, Stage 3 - 2036
- Street-running light rail: All Stages - 2034
- High Growth: Stage 1 - 2033, Stage 2 - 2036, Stage 3 - 2038
- Very High Growth: Stage 1 - 2033, Stage 2 - 2036, Stage 3 - 2038

When preparing the project case forecasts for these scenarios, a delay in the commencement of operations was accounted for by adjusting the start year when additional project case growth would commence. So, for example, instead of commencing additional project case growth in 2027 for a scenario commencing operations in 2031, additional project case growth would commence in 2029 for a scenario commencing operations in 2033. Additionally, to account for the impacts of staging, EJD ratios for 2041 were calculated as the time weighted average EJD ratio for Stages 2 and 3.

2.2.2 Preparing Forecasts for the Urban Options

In response to the requirements of the Urban Team, two additional versions of land use forecasts were prepared based on an initial set of project case forecasts prepared by LUTI Consulting for the separated metro scenario. These two additional sets of land use forecasts were referred to as "urban options" and involved accelerating the population and employment growth within the ALR CC2M corridor.

One version, referred to as the High Growth (B1) scenario, involved bringing forward additional project case growth within the ALR CC2M corridor by one period. Another version, referred to as the Very High Growth (C1) scenario, involved bringing forward additional project case and base case growth within the ALR CC2M corridor by one period. Both scenarios maintained the 2031 project case forecasts of the initial separated metro scenario. With regards to final forecast year, the High Growth scenario involved maintaining the 2051 difference in population and employment in 2065, implying an acceleration of additional project case growth to 2051 and then only additional base case growth in the years after. The Very High Growth scenario, on the other hand, included a degree of additional project case growth from 2051 to 2065, which was the difference between the (take-up) unadjusted and adjusted project case growth from the TIDRM, noting that the difference between the base case and project case narrows for this scenario in 2065 due to a "catching up" of growth in the base case.

In addition to the High Growth (B1) and Very High Growth (C1) scenarios prepared by LUTI Consulting, the Urban Team prepared revised versions of these two scenarios that involved redistributing some of the base case and project case growth within the project corridor. These revised versions maintained the same forecasts outside the land use response study area boundary and were referred to as B2 and C2 for the revised High Growth and Very High Growth scenarios, respectively.

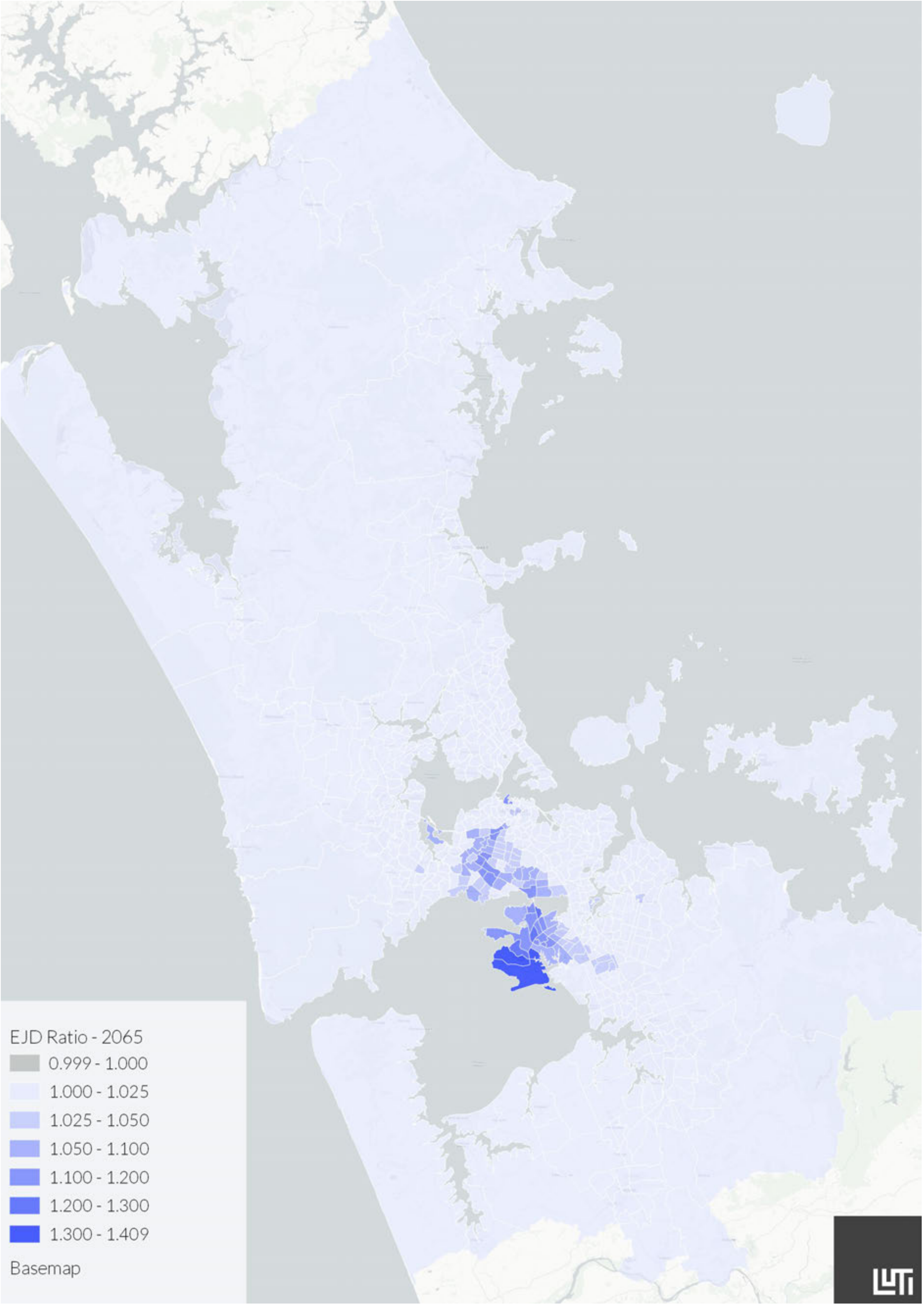

Figure 5 – Separated Metro versus Do Min EJD Ratios in 2065

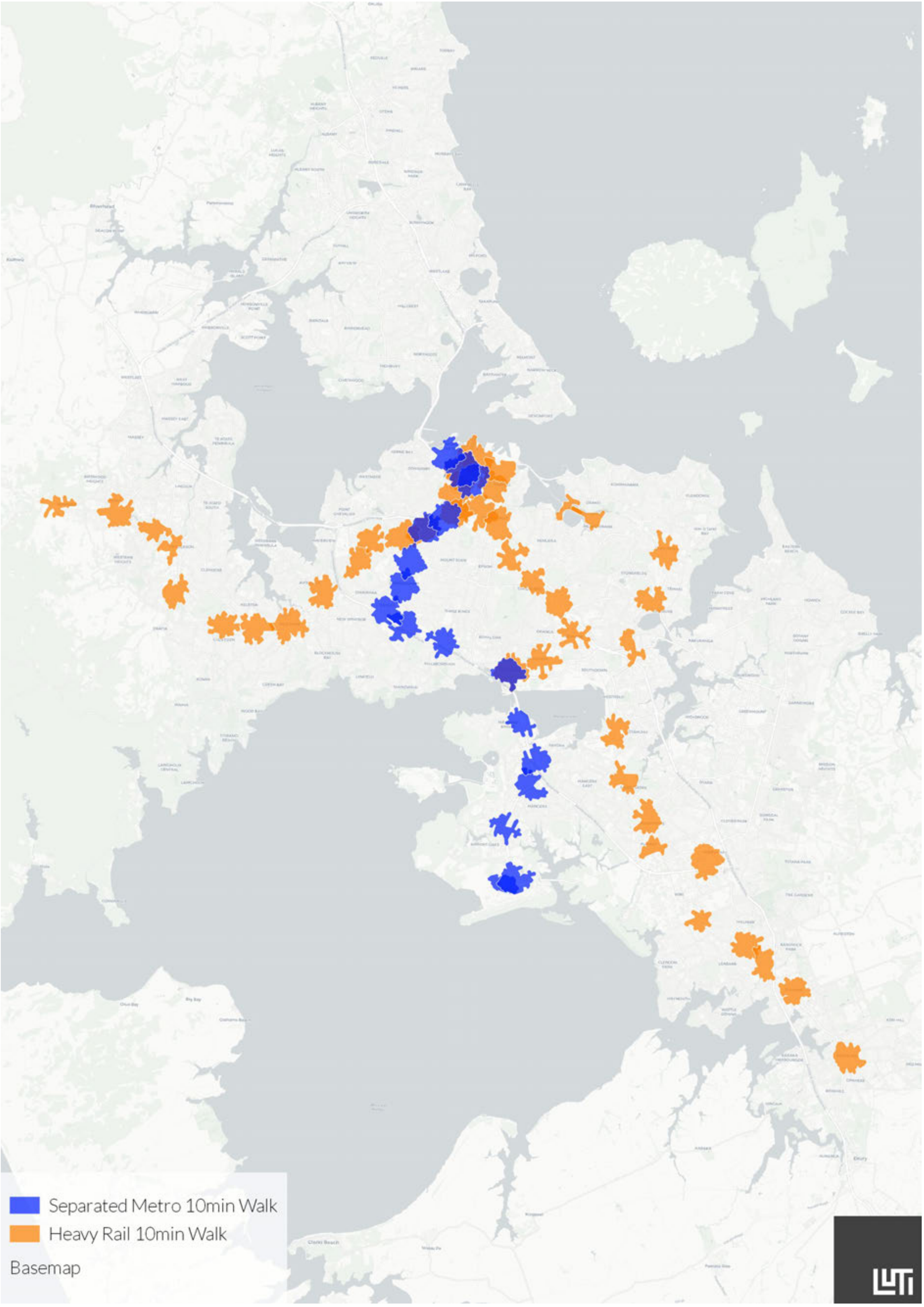

Figure 6 – Heavy Rail and Separated Metro 10-Minute Walking Catchments

2.3 Transport Induced Growth Redistribution Model

Once the initial project case land use forecasts had been prepared for the ALR CC2M land use response study area based on the TIDRM outputs, the difference between the Do Min and project case forecasts within the land use response study areas were redistributed to maintain population and employment control totals as Step 3 of the modelling process presented above in Figure 2. This redistribution of growth was conducted by applying LUTI Consulting's Transport Induced Growth Redistribution Model (TIGRM), and the effect of the redistribution modelling is a reduction in the growth rates in transport constrained areas external to the land use response study areas to compensate for the additional accessibility induced growth within the land use response study area.

LUTI Consulting's TIGRM redistributes the difference between the TIDRM modelled level of population and employment growth in a land use response study area, and the level of population and employment assumed in a base case (or Do Min) set of forecasts while maintaining population and employment control totals in each forecast year. The redistribution modelling process is based on two key factors: planning intent and transport network constraint.

- Planning Intent - Planning intent is represented by the travel zone population growth rates and employment growths rate by industry for each forecast year in the Do Min forecasts. This prevents population and employment from being allocated to areas where they are not intended to exist in the future, or where they are assumed to not increase in the future, in the case of a Do Min redistribution. In the case of a project case redistribution, the planning intent factor ensures growth is taken from competing locations and avoids inducing negative growth on travel zones. Ultimately, this input ensures that locations with significant growth are prioritised in the redistribution process over slow-growing locations.
- Transport Network Constraint – The other key factor in the modelling process is transport network constraint as measured by LUTI Consulting's Network Delay (ND) index. The ND index is a measure of the network constraint experienced by origin zone and is calculated as the normalised value of the demand weighted average road network travel time delay by origin zone.

When redistributing employment, the TIGRM was applied to individual industry sectors to avoid making economic character changes within the geographic extent of the MSM. Not controlling for industry sector in the redistribution modelling process could, for example, convert agricultural industry employment to financial or professional industry employment by modelling employment growth in a strategic or major centre and triggering employment to be redistributed from rural or fringe locations.

Figure 7 below presents a diagram depicting the redistribution modelling process, which was applied to all four forecast years (2031, 2041, 2051 and 2065) despite the diagram only showing the process out to 2051 for brevity. The redistribution process is applied incrementally for each forecast year, with each year's land use forecasts building on the previous year's forecasts to prevent unintended negative growth from occurring in travel zones where growth rates vary over time. The 2065 ND index for the Greater Auckland extent is presented below in Figure 8 for the separated metro scenario. Figures 9 and 10 then present the population and employment growth redistribution impacts for the separated metro scenario as an illustration of the effects of the modelling process.

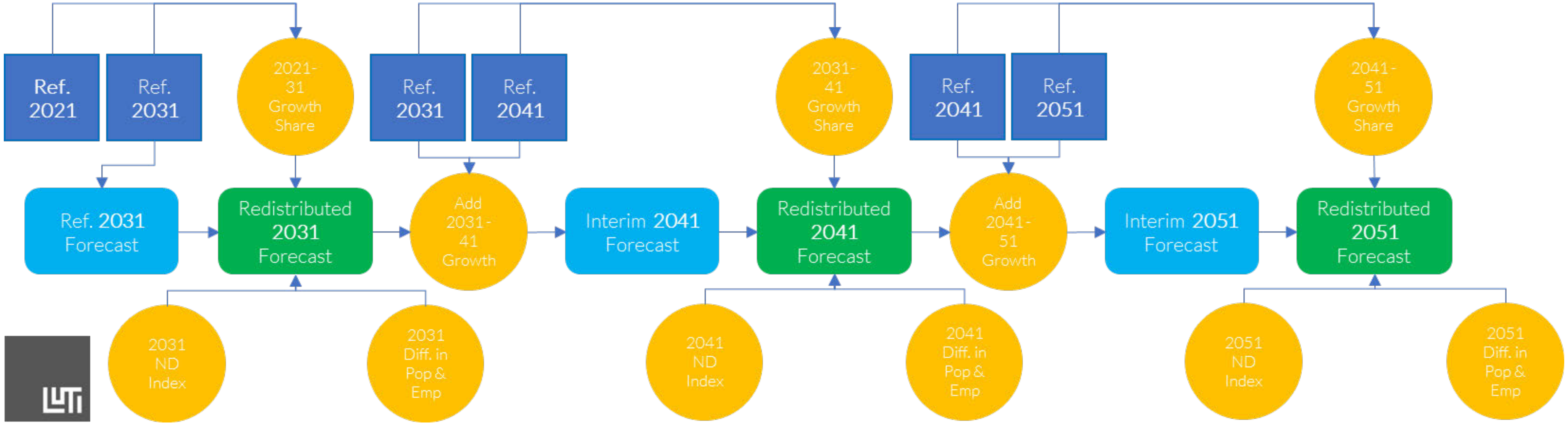

Figure 7 – LUTI Consulting's Land Use Forecast Growth Redistribution Modelling Process

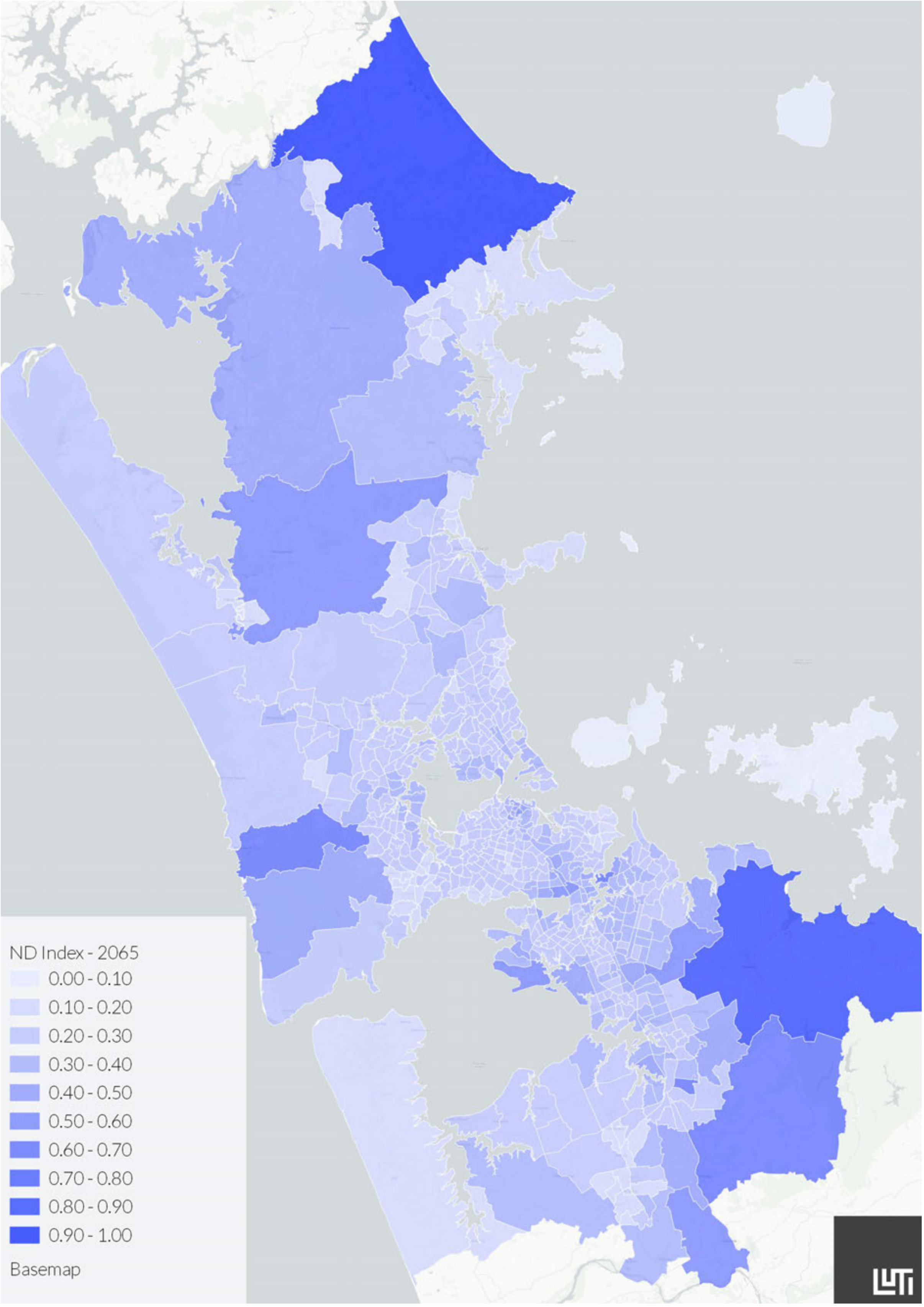

Figure 8 – Separated Metro Network Delay Index in 2065

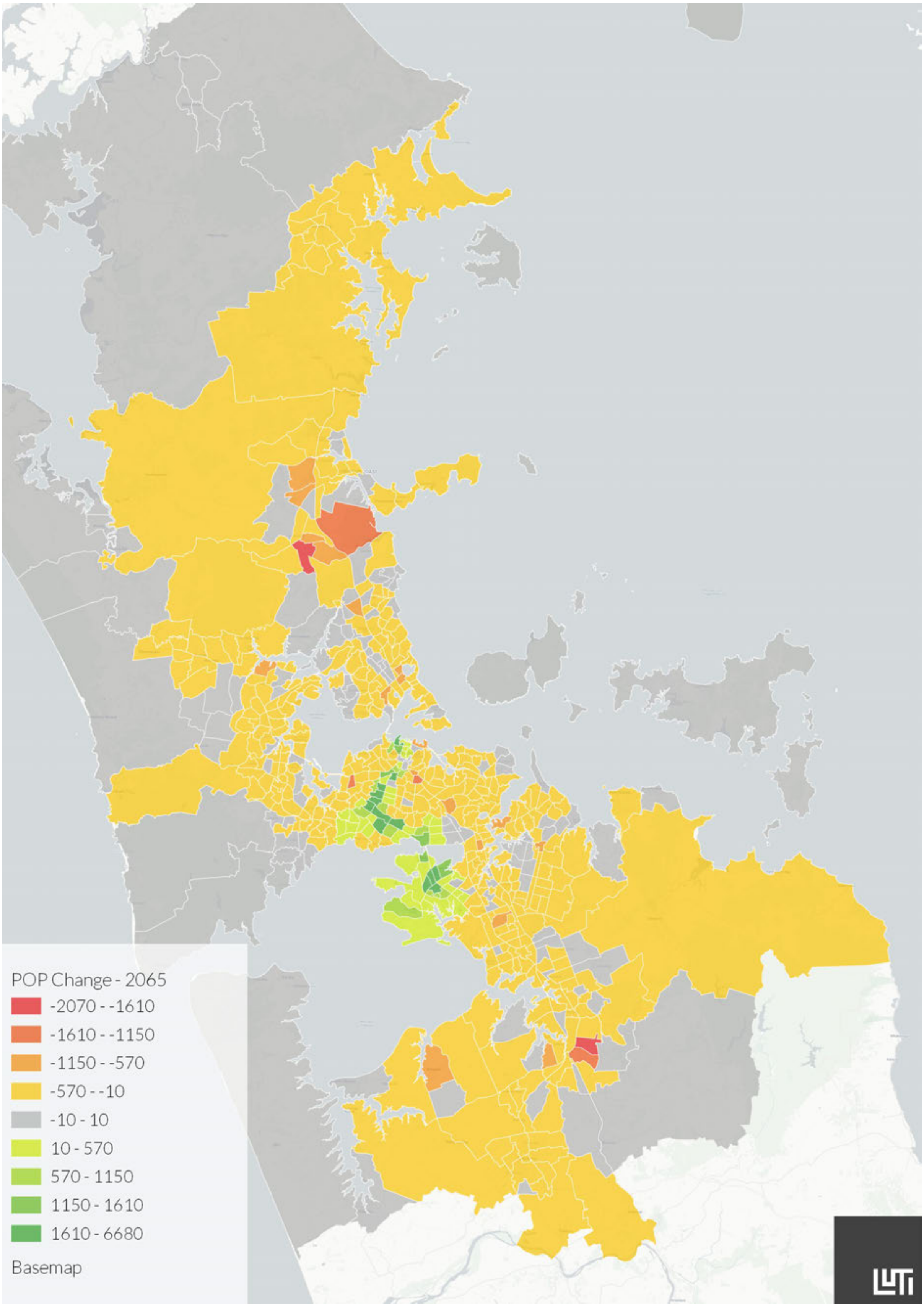

Figure 9 – Separated Metro Population Growth Redistribution Impacts in 2065

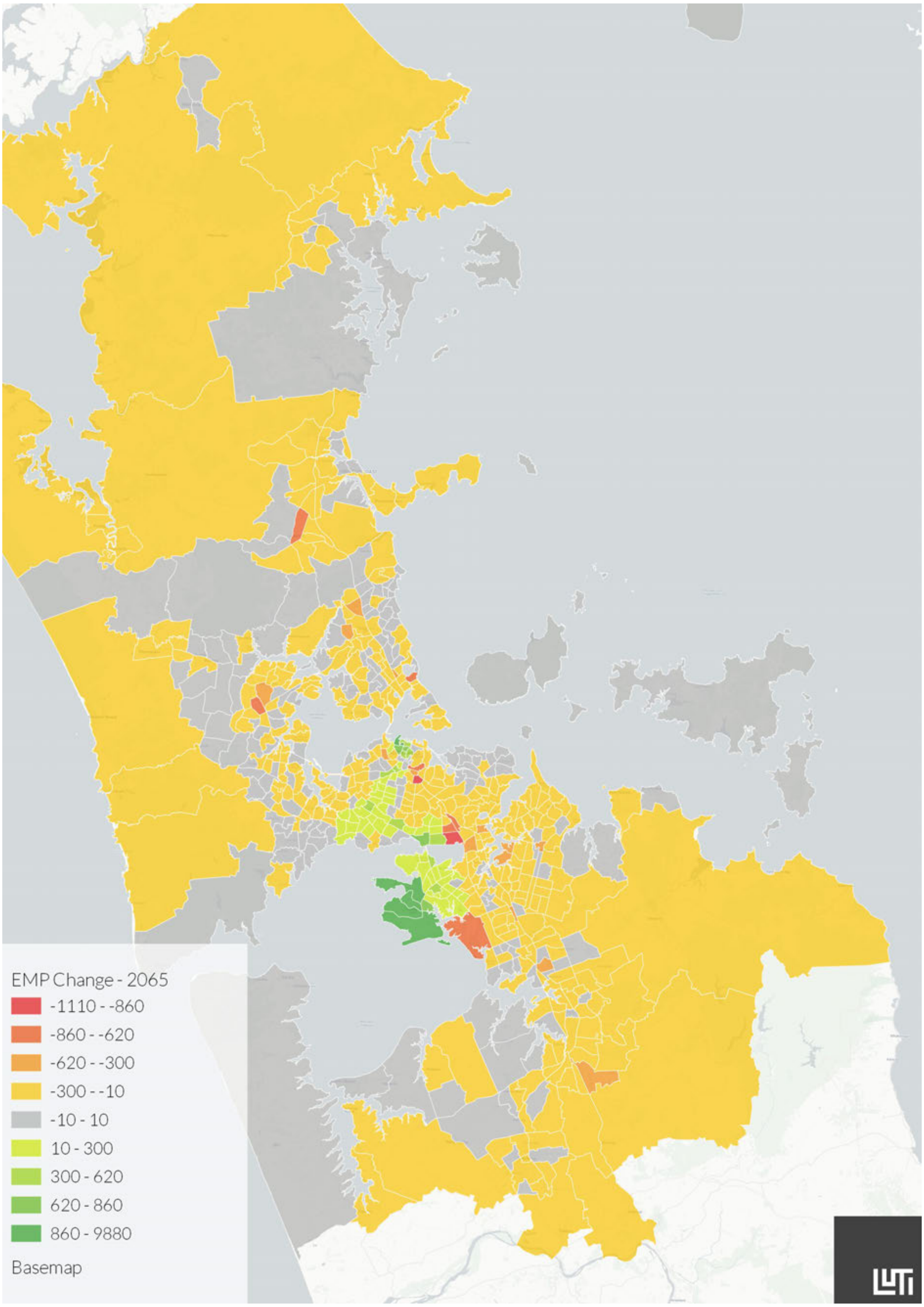

Figure 10 – Separated Metro Employment Growth Redistribution Impacts in 2065

2.4 Land Use Interaction Model Calibration

The final step in LUTI Consulting's modelling workflow presented in Figure 2 addresses the issue that while the TIDRM estimates the land market demand response to changes in accessibility, it cannot account for induced transport demand, and the marginal impacts of additional trips within the land use response study area from land use change that may erode some of the project benefits, and even potentially result in disbenefits in some locations.

Examples of such negative transport network impacts include increased traffic volumes on local roads, or at key intersections that are not able to accommodate much additional land market growth without additional investments in the transport network over what has been committed and funded and included in the travel demand modelling assumptions.

While each version of project case land use forecasts produced was run through the MSM for testing, none of the versions were eventually calibrated and re-run through the MSM due to the minimal level of network issues identified and a decision by the project team to prioritise testing additional scenarios over calibrating ones already prepared. However, after each iteration of testing, the following analyses and checks are made based on select outputs from the MSM:

- Effective job density changes – EJD ratios are compared between the scenarios with and without land use change to identify any travel zones within the land use response study area experiencing an accessibility reduction due to land use changes resulting in significant average generalised cost increases.
- Travel time savings by travel zone – travel time savings benefits are calculated at the origin zone level for the project, with and without land use change, and then compared to identify travel zones experiencing project disbenefits with land use change.
- Link volumes and capacities – a.m. and p.m. peak volume-to-capacity ratios in the land use response study area are compared with those without land use change to identify any links significantly impacted by the land use changes.

To illustrate the project case land use forecasts calibration review process, Figures 11 to 14 present a series of maps for the separated metro scenario with land use change. Firstly, Figure 11 shows a map comparing the project case scenario with land use change against the Do Min scenario in 2065 and indicates only accessibility improvements within the land use response study area, noting that accessibility reductions in some locations external to the land use response study area are expected given that their employment numbers have been reduced through the growth redistribution modelling process. Accessibility improvements external to the land use response study area boundary are a result of the transport network decongestion impacts outweighing the employment reduction impacts in the EJD calculation.

Figures 12 and 13 then present the average daily car and PT travel time savings (in minutes) in the project case with land use changes in 2065. Car travel time savings are experienced across the transport network due to mode shift from car to PT in the ALR CC2M corridor and the redistribution of growth decongesting the road network. The only locations showing some minor car user disbenefits are a few travel zones on the west side of Mangere. With regards to PT travel time savings, improvements are experienced across the network with benefits concentrated in the ALR CC2M corridor.

Lastly, Figure 14 presents the changes in a.m. peak road link volume-to-capacity (V-to-C) ratios between the project case and the Do Min scenario in 2065. Road link V-to-C ratio changes are expected to be positive (red) in the ALR CC2M corridor given that not all people redistributed into the corridor will be users of the PT network and thus will have a marginal impact on road network congestion, but extreme changes can be useful in identifying potential issues. V-to-C ratio changes external to the ALR CC2M corridor, on the other hand, are expected to be negative (green) given that the redistribution of growth will reduce road network congestion in these areas. Changes in PT service V-to-C ratios were also mapped and reviewed but examples have not been shown as the PT crowding function in the MSM prevents PT services from having their capacities exceeded.

Of the various calibration checks conducted, only some identified potential issues experienced by a few travel zones on the east side of Mangere. However, given the low levels of land use change experienced by these zones, the fact that these zones are still having their accessibility improved in aggregate terms, and given that the road network impacts experienced by these zones are likely driven but the increased economic activity at the airport, it was not deemed pertinent to adjust or revise the forecasts for these zones.

Overall, testing conducted on the separated metro land use forecasts indicated that car travel time savings improve in the range of 5%-35% and PT travel time savings improve in the range of 0% to 25% in aggregate with land use change, with results improving over time in each forecast year.

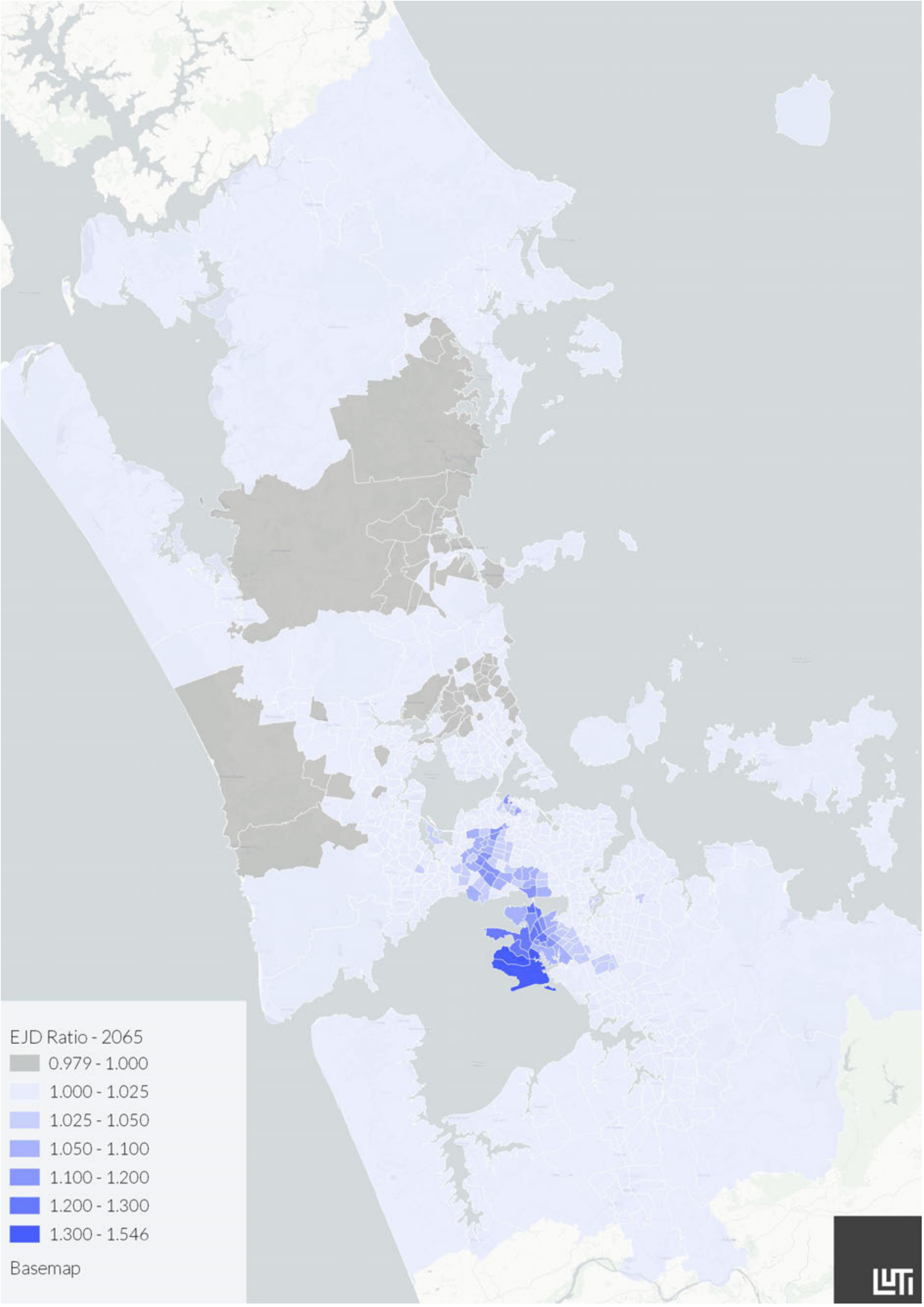

Figure 11 – Separated Metro with Land Use Change versus Do Min EJD Ratios in 2065

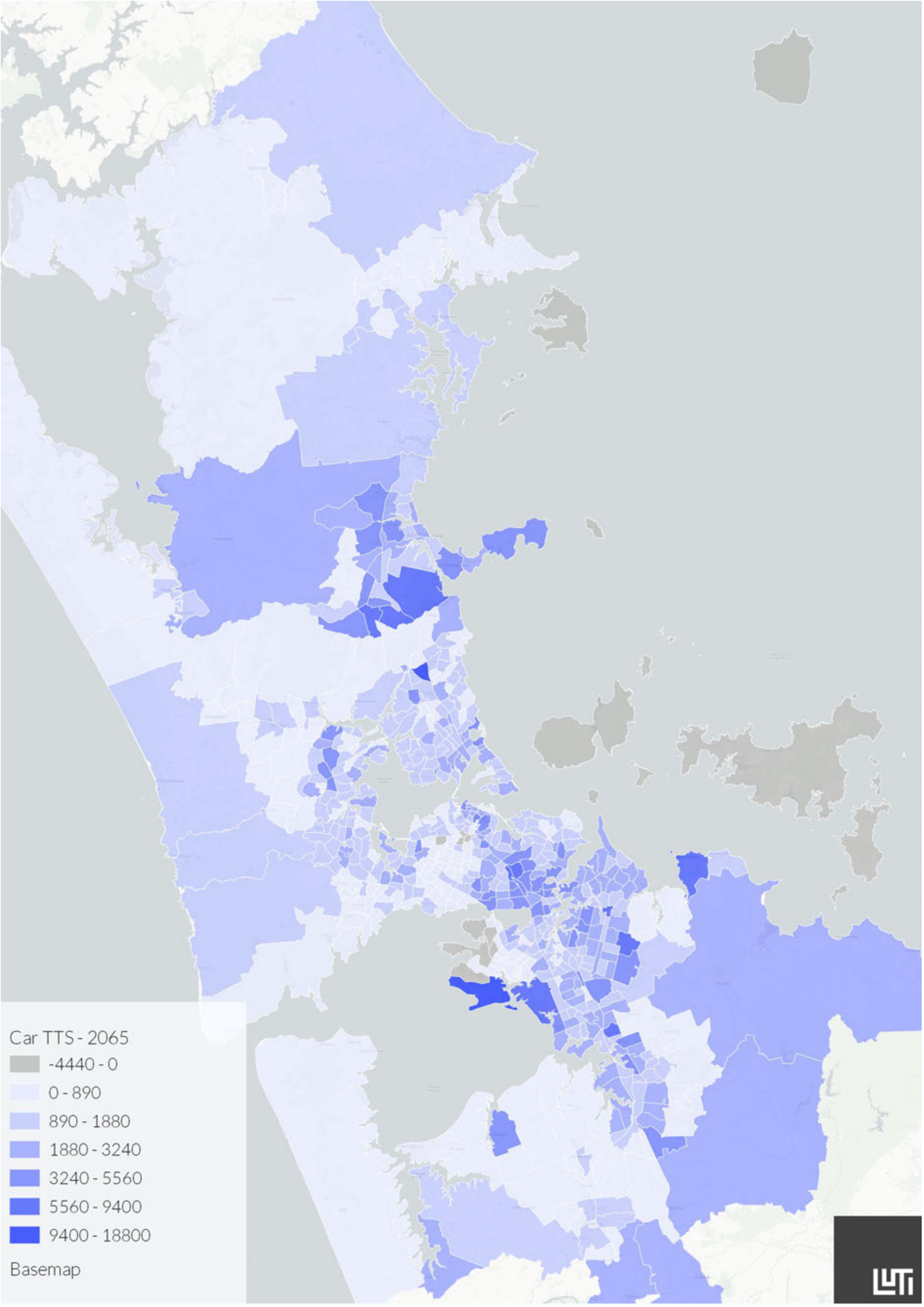

Figure 12 – Separated Metro with Land Use Change versus Do Min Average Daily Car Travel Time Savings (in Mins) by Origin Zone in 2065

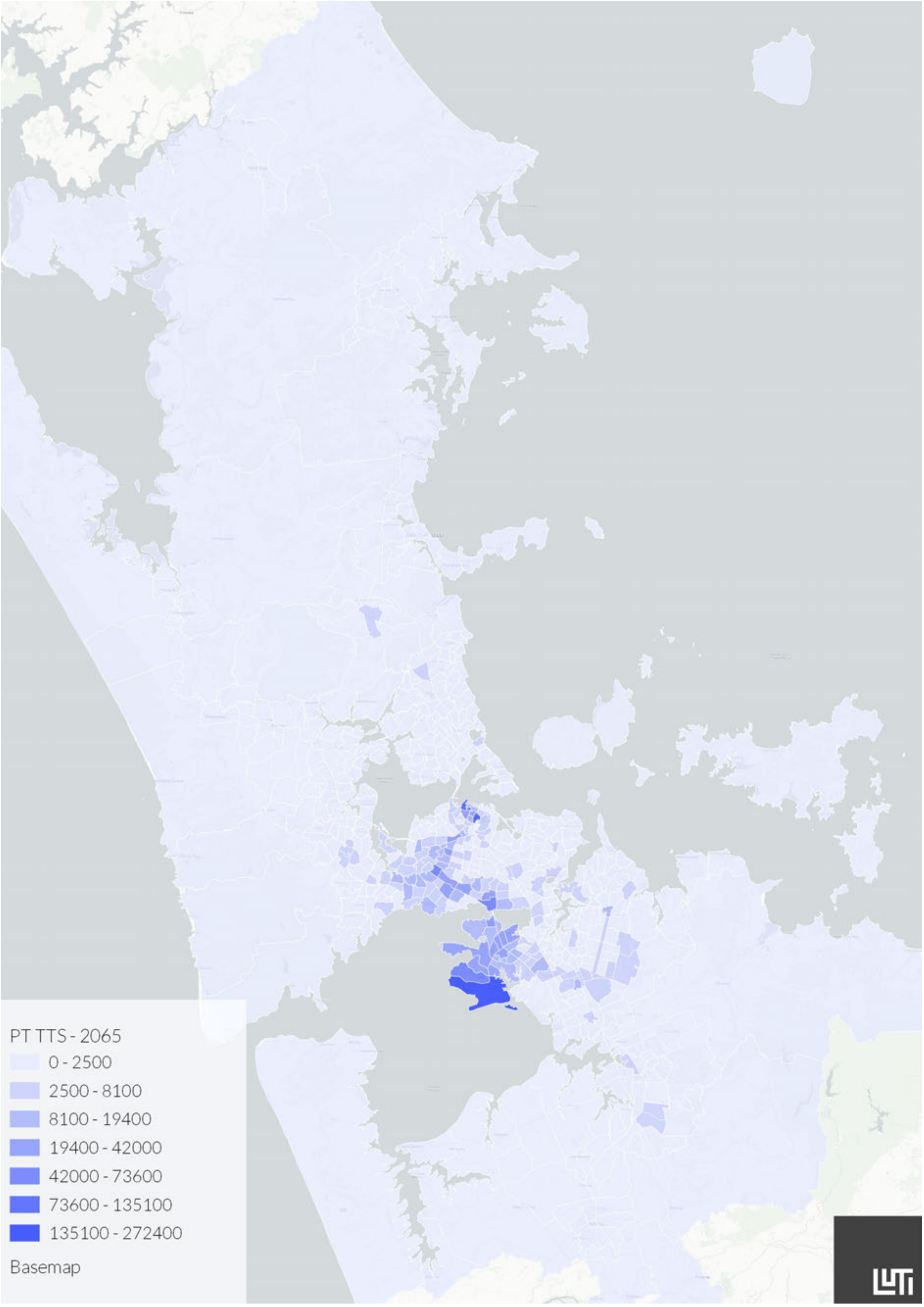

Figure 13 – Separated Metro with Land Use Change versus Do Min Average Daily PT User Travel Time Savings (in Mins) by Origin Zone in 2065

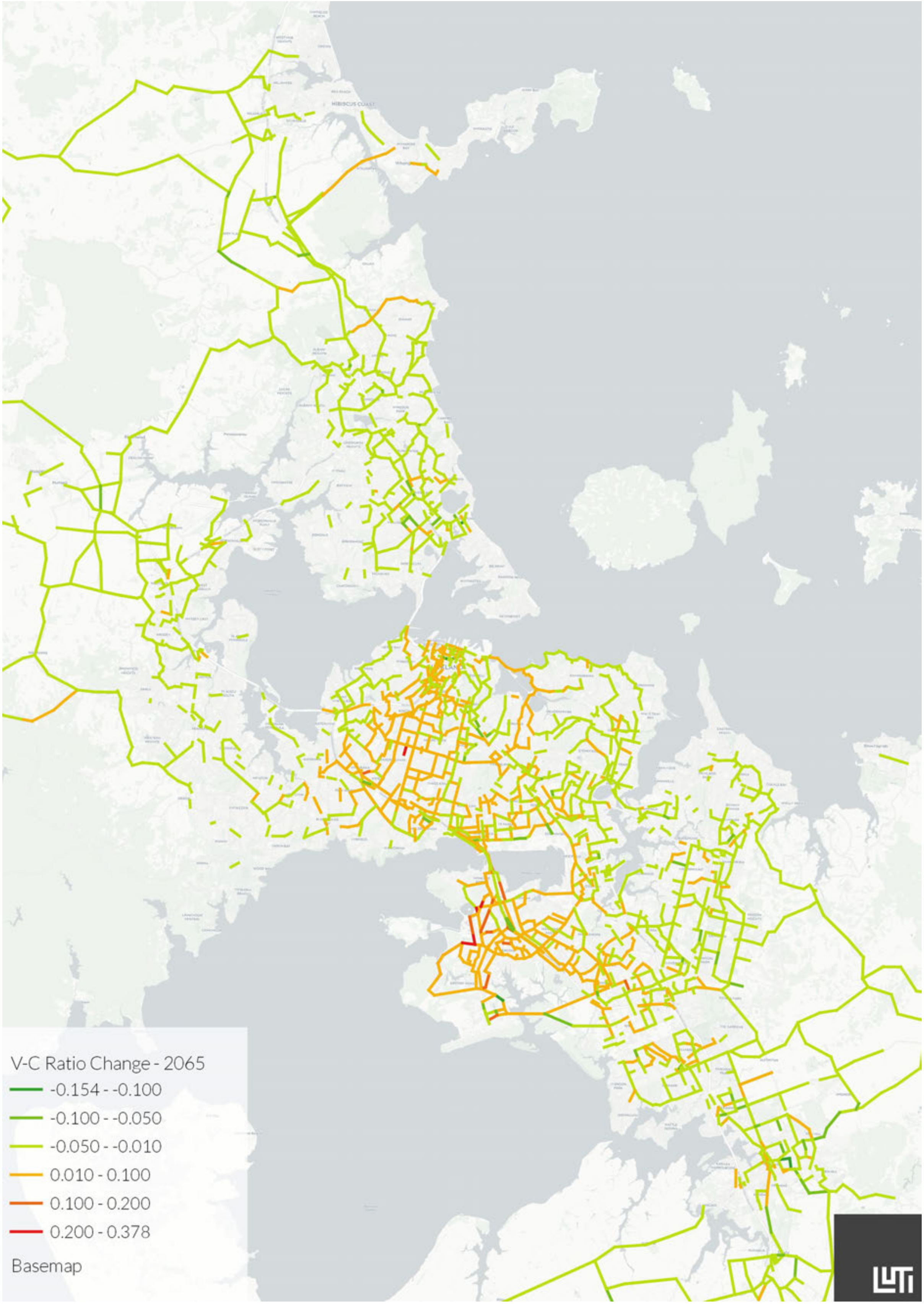

Figure 14 – Separated Metro with Land Use Change versus Do Min Road Link V-to-C Changes in 2065

2.5 Disaggregating the Land Use Forecasts to the Lot Level

As a final step in the project case land use forecast preparation process, LUTI Consulting developed an approach to disaggregate the Do Min and project case travel zone forecasts down to the lot level to facilitate their use by different specialist streams within the business case program.

To carry out this task, a key simplifying assumption was made, which was that all future population and employment growth would be accommodated by intensifying existing uses. This meant no changes to land use zoning, only changes to the permissible development density of land parcels. Thus, existing residential uses could accommodate additional residential development in the future and existing employment uses could accommodate additional employment in the future, but employment uses were assumed to not convert over to residential uses and the opposite was also assumed to hold true. This was deemed to be a conservative and pragmatic assumption given the absence of precinct structure plans to guide a more nuanced allocation of future growth at this stage of the project. The process also excluded certain uses such as parks, parking lots, and other types of infrastructure from the future population and employment growth allocation process.

The first step in the land use forecast disaggregation process involved disaggregating the REF2 Do Min forecasts. This was done by allocating future population and employment growth from 2021 onwards to residential and employment land parcels based on lot size. This meant that larger land parcels received a larger amount of additional future development than smaller land parcels.

When it came to disaggregating the project case forecasts, additional project case growth above the REF2 Do Min growth was allocated down to the lot level based on the monetisation of accessibility changes and LRT proximity changes estimated by applying LUTI Consulting's hedonic land price model for Greater Auckland, which was updated for the business case with 2021 Auckland rates data. When monetising LRT proximity benefits, the benefits were assumed to equal the proximity benefits of heavy rail. As such, the same coefficients were applied and only the change in proximity was monetised (e.g. a proximity uplift was not applied if a property was within the 0-400m catchment of a light rail and heavy rail station). With the LRT accessibility and proximity benefits monetised at the lot level, land parcels experiencing greater uplift received a greater share of their respective travel zone's additional project case growth.

Note, when converting the travel zone population forecasts to dwellings and employment forecasts to GFA, bespoke household occupancy rates and employment work-space ratios prepared by the Urban Team were applied. Table 2 below shows the bespoke household occupancy rates and employment work-space ratios prepared by the Urban Team, which vary by ALR CC2M station catchment. A separate concordance was provided that associated the travel zones with the station catchments. Note, where household occupancy rates and employment work-space ratios were undefined, they were calculated from the REF2 Do Min forecasts.

Table 2 – Bespoke Household Occupancy Rates and Work-space Ratios Prepared by the Urban Team

Station Catchment	HH Size	WSR
Wynyard, Te Waihorotiu, Universities	2.3	27
Kingsland, Dominion Junction	2.5	33
Balmoral, Sandringham	2.8	33
Wesley, Puketapapa	3	37
Hayr Road	3	37
Onehunga	2.3	38
Mangere Bridge	2.5	34
Mangere Town Centre, Te Ararata	4	34
Airport Industrial	3.1	41
Airport Stations	3.1	41
Remaining Corridor		35

While the assumptions applied to the forecast disaggregation process are based on reasonable theoretical underpinnings, it is important to stress that the accuracy of such lot level forecasts should not be relied upon. This is equally true of the disaggregation of the REF2 Do Min forecasts and the project case forecasts. Additionally, land value uplift estimates based on the lot level forecasts can be considered conservative given that they account for the value associated with the intensification of uses but not the value associated with any potential changes in use.

3 Estimation of Urban Development Benefits

Transport infrastructure investments have the potential to unlock population and employment growth and relieve development supply issues within cities by relieving transport network constraints that hinder or limit future development. Also, by changing accessibility within a region, transport infrastructure investments can reshape cities around them. This section discusses the methodologies that were applied to monetise the urban development benefits associated with land use change in response to the project, including:

- Higher value land use benefit;
- Infrastructure and service cost savings benefit; and
- Transport option value benefit.

Each of these benefit categories will be introduced and the analytical methods unpacked to enable an understanding of their application on the project.

3.1 Higher Value Land Use (and Land Value Uplift) Benefits

The most significant urban development benefit that arises from the unlocking of additional development capacity induced by a transport investment, particularly in areas of high land market demand, is that of higher value land use (HVLU).

The higher value land use benefit was assessed by LUTI Consulting for the ALR CC2M project by applying its Greater Auckland hedonic land price model (HPM), which was updated with recent 2021 rates data. A hedonic land price model is a statistical model that can be used to predict land values, or changes in land values, based on a wide range of land attributes. Separate models were estimated for residential and employment uses to model the value impacts of population (dwelling) and employment changes, respectively.

The residential and employment HPMs were applied at the lot level to the Do Min and project case forecasts, taking as inputs the growth in population (dwellings) and employment from 2021. As mentioned in Section 2.5 that discussed the lot level land use forecast disaggregation process, future population and employment growth was assumed to occur by way of intensifying existing uses. This was a simplifying assumption made in the absence of detailed precinct structure plans and suggests that the estimated HVLU benefits are likely to be conservative, given that they exclude the potential monetisation of changes in use.

The modelling of the HVLU benefits pivoted from the latest (2021) land valuations data and avoid double-counting with the transport user benefits by separately controlling for transport accessibility in the HPM specifications. Table 3 and Table 4 present the outputs of the 2021 Greater Auckland residential and employment HPMs, respectively, with suburb fixed effectives omitted for brevity. Both models employed the log of unimproved land value per square metre as their dependent variables.

The key parameters applied from the estimated HPMs included the dwellings per hectare (DpH) and employment floor space ratio (FSR) elasticities. Both models perform well with 83.2% and 82.5% of the variation in land values explained for residential and employment uses, respectively. Table 5 then presents the formulas for calculating the HVLU benefit.

Note, in addition to calculating the HVLU benefits, LUTI Consulting also calculated the combined benefits of land use change, accessibility change, and station access change to the new LRT services. These estimates of land value uplift (LVU) were provided to the team responsible for the modelling of the project's impacts on a range of value capture mechanisms. The difference between the HVLU and LVU estimates is that the former excluded the monetisation of accessibility benefits to avoid double-counting with the transport user benefits in the economic appraisal, while the latter included the monetisation of accessibility benefits in order for then to be accounted for in the value capture mechanism financial modelling.

Table 3 – Greater Auckland Residential HPM Outputs

Coefficients	Estimate	Std. Error	t value	Pr(>|t|)	Sig.
(Intercept)	2.3117	0.1426	16.2110	< 2e-16	***
log(area)	-0.2538	0.0014	-177.5290	< 2e-16	***
log(dwellings per hectare)	0.3485	0.0014	243.8400	< 2e-16	***
log(dist. to coast)	-0.0526	0.0006	-83.7760	< 2e-16	***
Motorway 0 - 100m	-0.1023	0.0035	-29.3830	< 2e-16	***
Motorway 100m -200m	-0.0267	0.0031	-8.6430	< 2e-16	***
Motorway 200m – 400m	-0.0121	0.0023	-5.2820	0.0000	***
Main road 0m – 100m	-0.0138	0.0012	-11.1900	< 2e-16	***
Main road 100m – 200m	0.0098	0.0013	7.3910	0.0000	***
Secondary Road 0 – 100m	0.0339	0.0013	26.0590	< 2e-16	***
Secondary Road 100m – 200m	0.0314	0.0014	21.7670	< 2e-16	***
Heavy Rail Freight 0 – 100m	-0.1086	0.0043	-25.2660	< 2e-16	***
Heavy Rail Freight 100m – 200m	-0.0560	0.0040	-13.9560	< 2e-16	***
Heavy Rail Freight 200m – 400m	-0.0344	0.0028	-12.2140	< 2e-16	***
Industrial Buffer 0 – 100m	-0.0700	0.0026	-26.4990	< 2e-16	***
Industrial Buffer 100m – 200m	-0.0410	0.0024	-16.7900	< 2e-16	***
Industrial Buffer 200m – 400m	-0.0427	0.0017	-25.8560	< 2e-16	***
Train Station 0 – 400m	0.1147	0.0048	23.8290	< 2e-16	***
Train Station 400m – 800m	0.0542	0.0029	18.5210	< 2e-16	***
Train Station 800 – 1200m	0.0354	0.0022	16.1370	< 2e-16	***
Public Open Space 0 – 400m	0.0591	0.0039	15.1490	< 2e-16	***
Special Character	0.1045	0.0030	34.8610	< 2e-16	***
Heritage	0.1463	0.0082	17.9050	< 2e-16	***
Flood - any	-0.0417	0.0011	-37.0840	< 2e-16	***
Air Craft Noise - any	-0.0264	0.0035	-7.5880	0.0000	***
log(ejd)	0.4367	0.0094	46.2750	< 2e-16	***
Single units, excluding bachelor	0.1334	0.0021	62.5230	< 2e-16	***

Residual standard error: 0.2803 on 373,286 degrees of freedom

Adjusted R-squared: 0.832

F-statistic: 5,571 on 331 and 373,286 DF, p-value: < 2.2e-16

Table 4 – Greater Auckland Employment HPM Outputs

Coefficients	Estimate	Std. Error	t value	Pr(>|t|)	Sig.
(Intercept)	5.4813	0.2199	24.9220	< 2e-16	***
log(area)	-0.1854	0.0031	-59.3330	< 2e-16	***
log(Floor Space Ratio)	0.1942	0.0042	45.7120	< 2e-16	***
Motorway 0 - 100m	-0.0747	0.0155	-4.8130	0.0000	***
Motorway 100m -200m	-0.0035	0.0143	-0.2490	0.8037	
Motorway 200m – 400m	0.0164	0.0105	1.5590	0.1191	
Main road 0m – 100m	0.1617	0.0083	19.4790	< 2e-16	***
Main road 100m – 200m	0.0651	0.0104	6.2600	0.0000	***
Secondary Road 0 – 100m	0.1039	0.0079	13.1040	< 2e-16	***
Secondary Road 100m – 200m	0.0705	0.0094	7.4970	0.0000	***
Heavy Rail Freight 0 – 100m	-0.1472	0.0125	-11.7460	< 2e-16	***
Heavy Rail Freight 100m – 200m	-0.1046	0.0130	-8.0720	0.0000	***
Heavy Rail Freight 200m – 400m	-0.0709	0.0118	-6.0300	0.0000	***
Train Station 0 – 400m	0.1863	0.0134	13.9140	< 2e-16	***
Train Station 400m – 800m	0.0892	0.0114	7.8420	0.0000	***
Train Station 800 – 1200m	0.0068	0.0107	0.6370	0.5239	
Green Space 0 – 200m	0.0726	0.0169	4.3060	0.0000	***
Green Space 200m – 400m	0.0688	0.0177	3.8920	0.0001	***
Special Character	-0.1323	0.0134	-9.8490	< 2e-16	***
Flood Any	0.0178	0.0068	2.6060	0.0092	**
log(ejd)	0.3735	0.0217	17.2220	< 2e-16	***
Industrial	-0.3369	0.0078	-43.4160	< 2e-16	***
Residual standard error: 0.3794 on 16,176 degrees of freedom Adjusted R-squared: 0.825 F-statistic: 1,863 on 41 and 16,176 DF, p-value: < 2.2e-16					

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3.2 Infrastructure and service cost savings

Infrastructure and service cost savings (also known as 'avoidable costs') are potential benefits that can be accrued by facilitating greater rates of urban infill over the alternative of greenfield expansion (i.e. urban sprawl). The infrastructure inefficiencies of greenfield development are numerous and have been documented and assessed in several studies[2], and the enhanced infrastructure costs are predominantly driven by the inefficient use of infrastructure and services (such as power, water, sewerage, schools, hospitals, etc.).

The rationale for quantifying infrastructure and service cost savings is that the same level of infrastructure provision can be provided at a lower cost on a per dwelling basis in infill areas than in greenfield areas due to existing capacity and infrastructure being used more efficiently. Moreover, the development costs (or share of costs) are those not borne by developers in the form of developer contributions, and thus are not passed on to consumers in purchase prices. As such, these costs are negative externalities imposed on the broader population through system charges and/or taxes.

The lower average infrastructure costs associated with higher density, infill development are generally understood to be a result of the following two factors:

- Infill environments may have excess infrastructure capacity that can be utilized to support additional growth, or that can support additional growth with lower marginal costs
- Higher density environments stimulate economies of scale in the provision of infrastructure whereby average costs are lower than when providing new infrastructure to un-serviced areas.

It is difficult to determine which of these two factors play a more important role in reducing infrastructure and service costs resulting from new developments, as they are likely to vary on a case-by-case basis and detailed data on infrastructure costs is limited. Ideally, the assessment of infrastructure and service costs associated with new development would be conducted on a detailed, case-by-case basis such that the estimated costs closely reflect the true costs of development in a case study location. However, the challenges of this approach are several and include the following:

- There are many types of infrastructure that need to be provided for households and businesses, so conducting a detailed assessment of them all for a study area would likely be a very resource intensive process
- Excess capacity of existing infrastructure can be difficult to determine and supporting data may simply not be available for some types without detailed and costly investigation
- The marginal costs of enhancing capacity of existing infrastructure can be difficult to determine and supporting data may simply not be available for some types without detailed and costly investigation
- For infrastructure and service cost savings to be quantified for a given study area, the same impact assessment would have to be conducted for the alternative locations from where the population growth is being diverted (redistributed) from. As growth redistributions generally impact a broad area, this can add to the complexity of detailed assessments.

While specific infrastructure cost estimates are not readily available for all locations around Greater Auckland, the Urban Team investigated the infrastructure costs for the ALR CC2M corridor and Drury, with the ALR CC2M corridor representing an urban infill (brownfield) environment and Drury representing a greenfield location. All cost estimates were prepared on a per dwelling basis. These estimates, shown below in Table 6, were provided to LUTI Consulting for including the estimation of the infrastructure and service cost savings benefits.

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[2] For example, SGS has conducted a review of avoidable cost estimates and studies: https://yoursay.infrastructurevictoria.com.au/30-year-strategy/application/files/1714/7546/2887/SGS_Economics_and_Planning_-_Comparative_costs_of_infrastructure_across_different_development_settings.PDF

Table 6 – Infrastructure Cost Estimates Provided by the Urban Team

	Drury (Greenfield)	ALR Corridor (Brownfield)					
		W/O ALR	A Urban Do-min	B1	B2	C1	C2
Water	$2,872	$3,039	$4,622	$3,934	$4,856	$3,758	$3,798
Wastewater		$6,753	$8,787	$10,558	$7,504	$8,200	$8,287
Stormwater	n/a	n/a	n/a	n/a	n/a	n/a	n/a
Power	n/a	n/a	n/a	n/a	n/a	n/a	n/a
Park	$18,299	$3,558	$3,856	$4,061	$4,084	$4,182	$4,214
Community	$8,409	$4,537	$4,631	$4,037	$4,690	$4,273	$4,794
Subtotal	**$29,580**	**$17,887**	**$21,896**	**$22,591**	**$21,134**	**$20,413**	**$21,093**
Transport	$85,548	$16,473	$20,338	$17,310	$17,368	$13,443	$13,586
Total Incl. Transport	**$115,128**	**$34,360**	**$42,234**	**$39,900**	**$38,502**	**$33,855**	**$34,679**

While the infrastructure costs for Drury were assumed for greenfield locations, the A Urban Do-min costs were adopted for infill locations external to the ALR CC2M land use response study area. Within the ALR CC2M land use response study area, the A Urban Do-min costs were adopted for the separated metro and street-running light rail scenarios, while the B2 costs were adopted for the High Growth scenario and the C2 costs were adopted for the Very High Growth scenario. The B2 and C2 costs were adopted for the Urban Options as the infrastructure and service cost savings benefit for these scenarios was based on the versions of the scenarios that were adjusted by the Urban Team. The calculation of the infrastructure and service cost savings benefit is presented below in Table 7. This is followed by Figure 15 that presents a categorisation of the travel zones in Greater Auckland as either Rural, Future Urban (greenfield), or Urban (infill). For the purposes of estimating the infrastructure and service cost savings benefits, Rural and Future Urban were treated the same.

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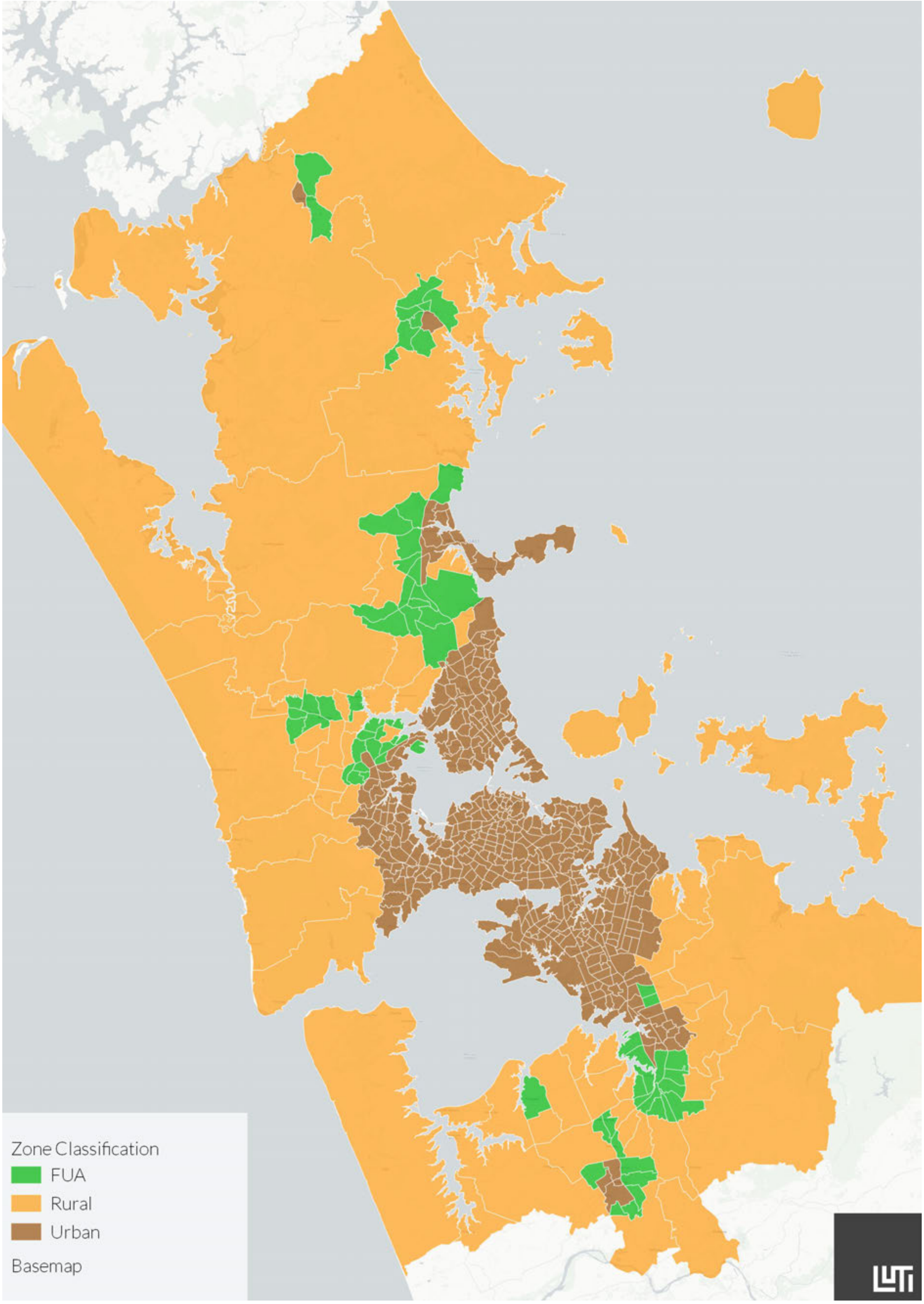

Figure 15 – Categorisation of Travel Zones in Greater Auckland

As a sensitivity, the assessment of the infrastructure and service cost savings benefit was also conducted using the greenfield cost estimates prepared by LUTI Consulting based on data for Australian cities shown below in Table 8. However, after converting the average cost per dwelling for greenfield locations of $106,725 from AUD to NZD (i.e. $114,196 using a currency conversion rate of 1.07), the greenfield cost estimates are very similar to those estimated for Drury so the impacts on the estimated benefits were minimal.

Table 8 – Infrastructure Cost Estimates Prepared by LUTI Consulting Based on Data for Australian Cities (2022/23 AUD)

Category	Infill	Greenfield
Roads	$7,695	$45,958
Water and Sewerage	$22,311	$33,853
Telecommunications	$3,897	$5,615
Electricity	$6,176	$14,669
Gas	$0	$5,584
Fire and Ambulance	$0	$458
Police	$0	$588
Total	$40,709	$106,725

Source: Infrastructure cost estimates from Trubka et al. (2010)

3.3 Estimation of Transit Option Value Benefits

Transit option value (TOV) refers to the land market value that individuals who are not forecast to be transit project users (based on the station access demand from the demand model), place on a transit investment over and above their expected user benefit. The transport option value benefit was assessed by LUTI Consulting for the ALR CC2M project by applying its Greater Auckland hedonic land price model (HPM), which was updated with recent 2021 rates data as discussed above in the section on the estimation of HVLU (and LVU) benefits.

A hedonic land price model is a statistical model that can be used to predict land values, or changes in land values, based on a wide range of land attributes. Separate models were estimated for residential and employment uses, but only the residential HPM was applied in the estimation of the TOV benefit as it primarily applies to residential uses.

The TOV benefit was estimated based on the monetisation of the LRT station walking catchment parameters for residential uses, and an analysis of mode share data by travel zone, whereby the option value was estimated by multiplying the share of non-LRT mode share by the LRT proximity benefit for each travel zone.

The rationale for the benefit estimation approach is that the proximity benefits of LRT stations get monetised into land values despite not all travel by residents proximate to those stations being by LRT. Residents choosing to live near an LRT station do not have a choice of paying the premium for locating there as the market sets the price. Thus, the premium that residents pay to located near an LRT stop is considered an option value if they are not users of the infrastructure. Importantly, only a change in rail proximity was monetised in this process, whereby an LRT proximity uplift was only quantified if there was an LRT station within a closer proximity band of a residential property than an existing heavy rail station, in which case only the incremental impact was captured.

Table 9 presents the calculation of the TOV benefit. The residential uplift estimates for the 0-400m, 400-800m, and 800-1200m catchments, expressed in relation to being beyond 1200m from a station, are 12.2%, 5.6% and 3.6%, respectively.

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