# SUSTAINABLE PATHWAYS II

# Wellington Region Mediated Modelling

*Post-report supporting Action Research and Integrated Assessment*

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# EXECUTIVE SUMMARY

The Sustainable Pathways 2 (SP2) project (MAUX0906) is funded by the New Zealand Ministry for Science and Innovation (MSI). It is a six-year action research programme (2009 – 2015) with a value of NZ$3.9M. The focus of the SP2 project is developing processes and tools to support dynamic, integrated, spatially explicit, adaptive decision-making for urban planning in New Zealand.

This report is a post-assessment for the Wellington Region Mediated Modelling (MM) component of the SP2 project, which is part of Objective 1. The Wellington Region Mediated Modelling (MM) provided an opportunity for 9 - 15[1] representative stakeholders to come together over a period of three workshops (April, May, October 2011) to interactively build a scoping model to link social, cultural, economic and environmental issues in one framework. Stakeholders identified and built their understanding and mutual appreciation of the key stocks and flows in the model (such as population density, land use, infrastructure, employment) and the dynamic interaction between these variables. The scoping model with linkages and feedbacks can be run over-time to illustrate long-term intended and unintended consequences of decisions.

In this report the changing *context* in which the SP2 project operates in the Wellington Region is first outlined. The MM *process* undertaken is then described and this is followed by a *content* analysis which covers the model and scenarios produced. A discussion of the MM goals and outcomes precedes conclusions and proposed next steps.

The *contextual* analysis indicates that integration of the 4 aspects of well-being remains relevant and may increase so from a spatial planning perspective in the future. From a non-spatial perspective, a progression toward Genuine Progress Indicators is identified where the work out of the MM component could add value.

The MM *process* started without a clearly defined topic and was 'trialed' with 3 workshops. Although, this wasn't an ideal starting point, participants now better understand the MM tool for which a majority perceived value. The results of the post-survey illustrate the various aspects of the MM process that were deemed more or less useful.

The model developed is not spatially explicit and its purpose is to increase understanding based on an attempt to integrate the perceptions and reference trends identified by invited stakeholders, not to predict future outcomes. The *content* of the model allows for two scenarios to be run:

1. What if the population changes by 10% (up or down) by 2020 then what happens to "access" and "inequality"?
2. What if the relative income per person in WR changes by 10% (up or down)? How does this impact on the relative attractiveness of the WR?

[1] Attendance at the three workshops varied

These scenarios can be evaluated on: Population, GDP, Consumer Prices, Inequality/Gini-coefficient, Natural Area, Waste. This demonstrated that:

The model results for scenario 1 indicate that inequality is rather insensitive to a change in population numbers. The current model show that:

- Population decline does not necessary result in more inequality as a decline in birth rate does not significantly affect the gini-coefficient. Inequality only increased when population declines through making it more difficult for immigrants to enter the region. However, inequality does not increase not because of this decline in population, but because the timelag for immigration altered the population distribution.
- Population growth does not change inequality.

The model results for this scenario 2 illustrate that:

- When relative income in the Wellington region decreases, the (modelled) Wellington region seeks to adjust for this loss limiting its effect on attractiveness.
- When relative income in the Wellington region increases there is no spectacular increase in attractiveness of the region. Increased attractiveness also comes at a high cost as unemployment increases and income within the Wellington region decreases in absolute terms.

MM aims to model the perceptions of the participants, supplemented with available data, ideally geared toward solutions and identification of sustainable pathways going forward. Between 9 and 15 stakeholders participated, for which the SP2 team is grateful. Without these participants, an MM process could not have happened.

The next steps for the MM component under the SP2 programme is proposed to focus on the development of a Dynamic Genuine Progress Indicator and an in-depth analysis of which identified linkages from the MM component could be integrated into the Wellington Integrated Spatial Explorer.

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# 1. BACKGROUND

The Sustainable Pathways 2 is a six-year action research programme (2009 – 2015). The focus of the SP2 project is developing processes and tools to support dynamic, integrated, spatially explicit, adaptive decision-making in urban planning in New Zealand.

The Wellington Region Mediated Modelling (MM) provided an opportunity for 9 - 15[2] representative stakeholders to come together over a period of three workshops (April, May, October 2011) to interactively build a scoping model to link social, cultural, economic and environmental issues in one framework. Stakeholders identified critical trends and shared their perceptions summarized in key stocks and flows in the model (such as population density, land use, infrastructure, employment) and the dynamic interaction between these variables. The scoping model with linkages and feedbacks can be run over-time to illustrate long-term intended and unintended consequences of decisions. The model developed is not spatially explicit and its purpose is to increase understanding not predict future outcomes. The intention is for the MM process to: (i) allow stakeholders see the integrated 'big picture' and gain a greater understanding of the other stakeholderperceptions, (ii) construct a system dynamics scoping model that can be used by stakeholders to explain possible outcomes from proposed actions, and (iii) inform the development of the more data intensive Spatial Decision Support System (SDSS) or Wellington Integrated Scenario Explorer, being constructed for both Auckland and Wellington as part of Objective 2 of the SP2 project.

This post-assessment report has been written to serve four functions. The first is as a requirement of 'action research' where researchers document facts/observations as part of an on-going cycle of: planning outcomes, undertaking actions, observing outcomes and reflecting on those outcomes. For the SP2 project, action research is regarded as a collaborative process where researchers work with stakeholders to critically reflect on both the research process and actions undertaken to achieve a cycle of improved outcomes. As Wadsworth[3] (1997) states "Action research is not merely research which it is hoped will be followed by action! It is action which is *intentionally* researched and modified, leading to the next stage of action which is then again *intentionally* examined for further change and so on *as part of the research itself*." The action research component of the SP2 project contributes to the knowledge base required to integrate adaptive management processes into every-day decision-making.

The second function is to provide feedback to the participants on the process, the content of the modelling tool developed and the context in which this tool is evolving. In an ideal situation, this report supports participants to communicate the results from the MM process and model to their individual networks, if so desired.

The third function of the post-assessment report is to provide information for a review of the SP2 project by a sub-set of the National Advisory Group for Integrated Planning (NAGIP) and international advisors. NAGIP was established to provide input and guidance for integrated models to support

[2] Attendance at the three workshops varied
[3] Yoland Wadsworth, Everyday Evaluation On The Run, 2nd edition, 1997, Allen & Unwin, p. 78.

planning in New Zealand. A task for a subset of this advisory group is to review the pre- and post-assessments of the MM workshops to evaluate the action research and provide independent perspectives on how best to progress the SP2 project moving forward. The support tools developing under SP2 will ideally be valuable to other local government and central government agencies so a blueprint describing the provision of these support tools and improve efficiency of their development for other places is an envisioned output from SP2.

Finally, this report support the team understanding the interlinkages identified through the MM process with the inter-linkages incorporated in the SDSS model.

In this report the changing *context* in which the SP2 project operates in the Wellington Region is first outlined. The MM *process* undertaken is then described and this is followed by a *content* analysis which covers the model and scenarios produced. A discussion of the MM goals and outcomes precedes conclusions and next steps.

# 2. COMPONENTS OF ACTION RESEARCH: CONTEXT, PROCESS AND CONTENT

## *2.1. Context*

This part of the report documents the changes that have occurred in the policy and planning context of the Wellington region over the 6 month period of the MM process. The information contained in this segment of the report has been assembled from various strategy and discussion documents as at December 2011 by Melanie Thornton from the Greater Wellington Regional Council (GWRC).

The Wellington region comprises eight territorial authorities and a regional council. Until 2004 all councils were working in relative isolation regarding planning and development activities across the region. In 2004-2005, projections for the Wellington region revealed that certain factors relating to the ongoing prosperity and development of the region out to 2025 weren't looking as positive as in other regions. Consequently the Wellington Regional Strategy (WRS) was developed between 2005 and 2007 and signed off by all partners in 2007. The Strategy aimed to provide some solutions to those anticipated projections. The Strategy is a 'sustainable economic growth strategy' and contains a range of initiatives to realise the region's economic potential. A regional economic development agency (Grow Wellington) is responsible for driving the economic development projects identified in the strategy.

The Senior Officers Resource Team (SORT) reports to the regional Chief Executives Group which in turn reports to the Wellington Regional Strategy Committee. This committee currently comprises six of the region's mayors (the three Wairarapa councils are represented by one mayor), the Chair of the Regional Council and five independent appointees. It is currently chaired by Sir John Anderson.

The Regional Land Transport Strategy (RLTS) has a close strategic relationship with the WRS. The Regional Land Transport Strategy (RLTS) is catering for changes in population, but it is not aiming to stimulate either population or economic growth. The RLTS, Wellington Regional Strategy and Wellington Regional Policy Statement development processes have been closely aligned to ensure transport is integrated with land use outcomes. This is considered fundamental to the economic and social functioning as well as future growth and development of the Wellington region.

### 2.1.1. Strategy Review

At the time that the WRS was being adopted by Greater Wellington in early 2007, there was an agreement to undertake an independent review of the Strategy in 2010/11.

Martin Jenkins and Associates (Martin Jenkins) was appointed in September 2010 to undertake the review. Martin Jenkins completed its review, and the findings of the review were presented to the WRS Committee, all councillors in the region, and the Grow Wellington Board on the 1st of June 2011. Overall, the review report recommended the continuation of a regional approach to supporting economic development, concluding that "there remain good reasons for continuing to pursue economic development (including good regional form) at a region-wide level, and to fund and deliver economic development activities on a region-wide basis." However, the review highlighted that to fully recognise the benefits of such a region-wide approach, it is important that the Strategy itself be refreshed, and that changes are made to the governance and implementation arrangements.

### 2.1.2. WRS Refresh

While a full refresh of the Strategy has yet to be undertaken, the WRS Committee has agreed that the economic development aspects of the refreshed strategy should cover six focus areas considered to be of most importance for the region. They include innovation, investment for growth, building world class economic infrastructure, targeted marketing of the region to attract business, investment and talent, education and workforce development, and being open for business, which is about how the councils do their business and how easy they are to deal with. A decision is yet to be made on refreshing the non-economic development aspects of the WRS. It is anticipated that a draft refreshed Strategy will be completed by June 2012.

In addition to these focus areas, tourism was identified as a key aspect of the region's economic growth potential. While not currently a focus area it was identified as a key component of the future regional economic strategy.

The final decision to continue the function of regional economic development will have to be included in Greater Wellington's Long Term Plan 2012-2022. Consultation on the Long Term Plan will occur in April/May 2012.

### 2.1.3. Governance

A report on governance issues in the region was commissioned from Price Waterhouse Coopers in 2010 in response to the amalgamation of Auckland region's councils. Further conversations are happening in the community but there is currently no proposal to proceed with this.

### 2.1.4. Regional Planning

Given the requirement for spatial planning for Auckland other local government authorities throughout New Zealand are anticipating at some point also being required to produce spatial plans for their regions. Spatial planning was identified by the Mayoral Forum as a potential workstream but no decision has been made on this to date.

***Existing planning framework***

The Resource Management Act review Phase two (RMII) is expected to outline changes relating to urban form and spatial planning. The Department of Internal Affairs is currently undertaking a review of local government structure.

### 2.1.5. Genuine Progress Index

In July 2011 the Wellington Region Genuine Progress Index report was published and the website went live. The GPI is a new approach to measuring the region's well-being by enabling a process to agglomerate measures relating to the economic, social, cultural and environmental well-being of the region.

The Wellington region GPI has just won the "GHD Supreme Award 2011" in the NZ Society of Local Government Managers (SOLGM) Local Government Excellence Awards. It also won the "Joined-Up Local Government category" award. These awards recognise the collaborative work of all the region's councils and other parties on the development of the GPI.

As a result of the mediated modelling workshops in Wellington there is a proposal to apply a systems model to a set of common indicators in the Wellington region GPI, the Statistics NZ Framework for Sustainable Development and the Treasury NZ Living Standards Framework in order to understand the linkages and interplays between indicators.

## *2.2. Process*

During the preparation phase for the MM process in Wellington, the project team responded to the assessment of the Council that three workshops were the maximum number that could be asked for from participants in order to test the MM approach. The envisioned series of 10 workshops was deemed too many for an untested approach. The project team responded to make the agenda for the workshops more concise than a more free-flowing dialogue about "uncertainty and long term systemic changes"

that the MM approach is usually programmed for. This decision was based on the number of workshops being reduced to three, the experience of the 15 participants that had committed to attending the workshops, and the critical need to connect with the SDSS model. Therefore the agenda for the three workshops[4] was set as follows:

**Workshop 1 – 7 April:** Participants learn about System Dynamics as a tool to explore integrated trends.

**Workshop 2 – 19 May:** Participants develop some basic scenarios to simulate the model at a scoping level and inform the development of the SDSS model.

**Workshop 3 – 18 August:** The workshops are part of a continuous loop of improving understanding of decision support tool development.

The set agenda for each workshop was followed other than Workshop 3 was not held until October 18. The workshops were designed and facilitated by Dr. Marjan van den Belt. Discussion notes were taken by Vicky Forgie and summaries for each workshop were circulated among the project team, the participants and then posted on the www.sp2.org.nz website, also attached in Appendix A. Dr. Hendrik Stouten was largely responsible for the evolving systems model in between the workshops, also available on the website.

The remainder of section 2 interprets the survey results. The full surveys and results for each question can be found in Appendix B.

### 2.2.1. Evolving topic

The Greater Wellington Regional Council chose to not commit to a specific topic at the start of the MM process but instead allowed participants to determine the focus of the workshops (see Pre-Report for MM Wellington available on www.sp2.org.nz). The initial invitation was kept broad and emphasised learning about mediated modelling and how systems dynamic models work (both as scoping tools and as spatial decision support systems). To get the mediated modelling underway, participants were asked in the pre-workshop survey what they regarded as the predominant mid to long term issue (i.e. next 10-40 years) for Wellington Region with regard to integrating the 4 aspects of well-being. The following responses were received as relevant topics:

- Capacity to grow jobs, attract talent and reach internationally through the weightless economy.
- Transport and land use patterns not conducive to end of cheap oil.
- Need for spatial vision. Evolutionary space time vision.
  Population growth along the two State Highways. Road network unable to cope with increasing volumes, increase in traffic jams and air pollution.
- Continued growth of the economy.
- A different kind of economic activity is needed for the future that can sustain itself. Disadvantaged communities will struggle to cope with the current model.

[4] The notes for each of these workshops can be found in Appendix A.

- Public transport. Citizen participation
- Housing affordability.
- Regional form/Regional decision-making.
- Transport and transport infrastructure issues. The pressure points, limitations and opportunities for a well-functioning viable port.
- Emphasis on economic growth and the need for Wellington to compete with Auckland and cities/regions in other countries results in other well-beings may not get the same level of priority.
- Lack of population growth to stimulate economic growth.
- Loss of community resilience so can handle things like earthquakes, recession.
- Balance of where people live and work and the transport, infrastructure and time impacts of these. When people have lengthy travel between work and home this impacts on the 4 well beings.
- Retaining sufficient population growth.
- Economics, business with good paying jobs, employment.

These responses are summarized in Figure 1

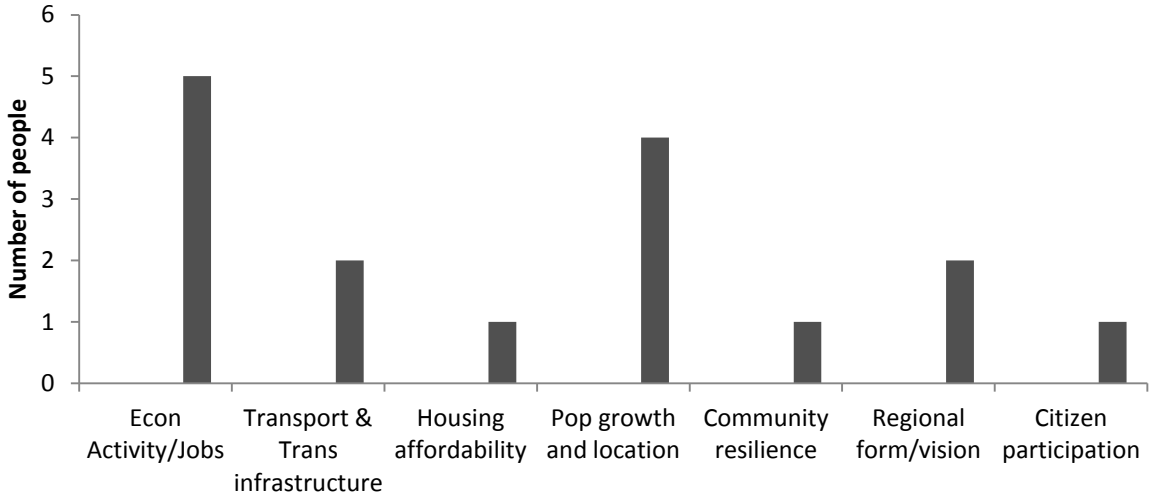



***Figure 1: Participants predominant mid to long term issue for Wellington Region with regard to integrating the 4 aspects of well-being***

Despite there being no set topic, discussion at the workshops was dominated by economics as this was a key interest for the participants as shown in Figure 1. In addition, other categories such as 'Population growth and location' were economic-related as the concerns related to lack of population growth to stimulate economic growth and people not based close to jobs.

As the process unfolded, participants began to understand how MM could be used to structure thinking and the accompanying dialogue. The MM process endeavoured to show how, mid- to long term, all the predominant issues brought to the table by participants were inter-related. Participants were asked for "what if?" scenarios that could be explored using the model they were building.

### 2.2.2. Stakeholder assessment

Participant attendance fluctuated over the course of the 3 workshops. The attendance for each of the workshops is presented in Table 1.

***Table 1: Wellington MM workshop attendance***

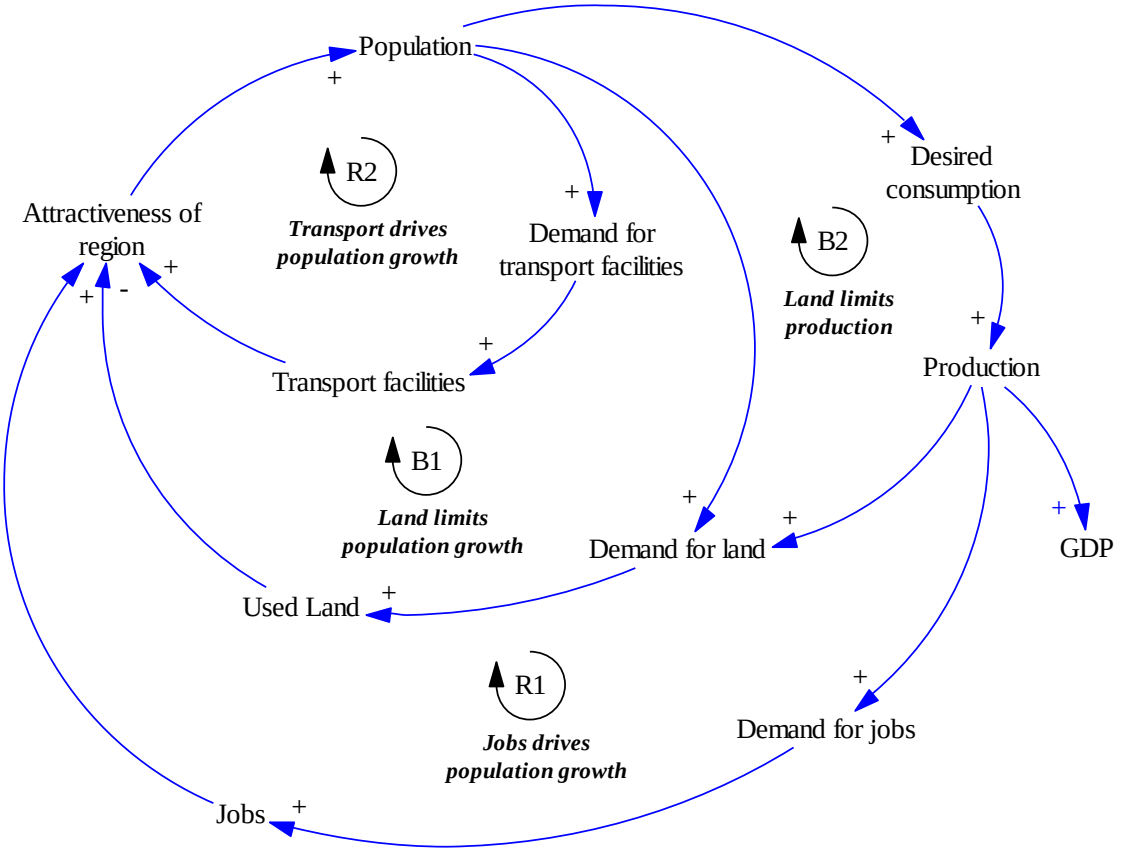
| Name | Organisation | 7 April 2011 | 19 May 2011 | 18 October 2011 |
|---|---|---|---|---|
| Anders Crofoot | Federated Farmers | ✓ | ✓ | ✓ |
| Anton Ferrari | Grow Wellington | ✓ | Sarah Peacock instead | ✓ |
| Chris Moller | Custance | ✓ | ✓ | Overseas apology at start |
| Dave Henderson | Association of Non Governmental Organisation Aotearoa | ✓ | ✓ | Did not attend |
| Gavin Armstrong | Wellington City Council | ✓ | ✓ | ✓ |
| James Kilbride | Kapiti Coast District Council | ✓ | ✓ | ✓ |
| Jeremy Harding | Wellington Employers/Chamber of Commerce | ✓ | Did not attend | Did not attend |
| Kim Kelly | Hutt City Council | ✓ | ✓ | ✓ |
| Mitch Lewandowski | Upper Hutt City Council | ✓ | Did not attend | ✓ |
| Moira Lawler | Porirua City Council | ✓ | ✓ | Apologies |
| Nicola Shorten | Greater Wellington | ✓ | ✓ | ✓ |
| Peter Salter | Ministry of Social Development | ✓ | ✓ | Did not attend |
| Stephen Oakley | Statistics New Zealand | ✓ | Did not attend | ✓ |

| | | | | |
|---|---|---|---|---|
| Stephen Palmer | Regional Public Health | ✓ | ✓ | ✓ |
| William Woods | Centreport | ✓ | Did not attend | Withdrew |
| Marjan van den Belt | EERNZ (SP2 team) | ✓ | ✓ | ✓ |
| Vicky Forgie | EERNZ (SP2 team) | ✓ | ✓ | ✓ |
| Hendrik Stouten | EERNZ (SP2 team) | ✓ | ✓ | ✓ |
| Melanie Thornton | Greater Wellington (SP2 team) | ✓ | ✓ | ✓ |
| Garry McDonald | Market Economics (SP2 team) | ✓ | | ✓ |
| Geoff Cooper | Auckland Council (SP2 team) | | ✓ | |
| Beat Huser | Waikato Regional Council (SP2 team) | | | ✓ |

Of the 15 original participants, one participant withdrew from the project. Nine stakeholders attended the final session, a 60% "survival rate". Eight of these participants were surveyed after the workshops were completed.

### 2.2.3. Model evolution: from preliminary CLD to final CLD

When the topic is defined in advance, a preliminary systems dynamic model can be shown at the first MM workshop. As the topic was not agreed on for the Wellington workshops instead of a preliminary systems dynamic model a preliminary Causal Loop Diagram (CLD) (see Figure 2) was prepared linking the various topics that the participants were interested in.




*Note: +/- moves in the same direction but is not necessarily a positive/negative.*

***Figure 2: Preliminary Causal Loop Diagram of Wellington regional dynamics***

The causal loop diagram was further developed over the course of the three workshops to reflect the greater complexity in the dialogue. The final causal loop diagram after the third workshop is given in Figure 3. When comparing the preliminary causal loop diagram with the final one, the following observation can be made:

- Production has many more links in the final CLD (10 in total)
- Transport is not specifically included but becomes part of infrastructure
- Natural capital is included rather than land as it more encompassing
- In the preliminary CLD attractiveness of the region was driven by jobs, land and transport facilities. In the final CLD housing is included as this was considered to have an impact on the attractiveness of the region as do average household income, waste/pollution and unemployment.

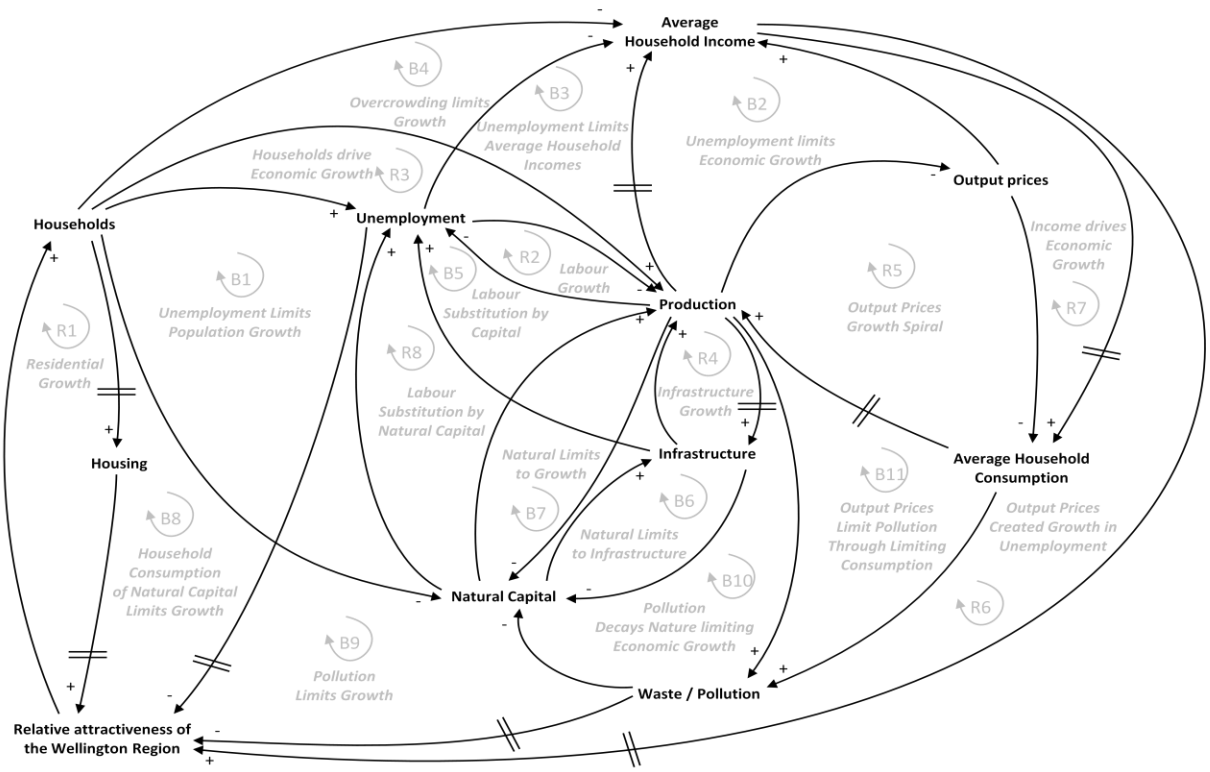



***Figure 3: Causal loop diagram of the Wellington regional dynamics at the end of the third workshop***

### 2.2.4. Participants post survey results

A survey was emailed to eight participants, including only those who completed the pre-survey and attended at the third workshop. Some participants sent a completed survey back, which was followed up by a scheduled phone call to discuss the open questions. Other participants chose to fill out the survey during the scheduled interview.

Eight questions were posed in the WR pre-assessment report as a means to test the team's anticipated outcomes from the MM process and enable a comparison to be made with what actually happened. This section answers those questions drawing on the information provided by respondents in the post-workshop survey (See Appendix B) and follow-up phone interviews.

***Question 1: Was the model used sufficiently in supporting the dialogue?***

During the workshops both Causal Loop Diagrams (CLDs) and a system dynamics model were used to support the dialogue. For the CLD, participants were either uncertain (i.e., neutral, 4 participants) or positive (i.e., agree, 4 participants) that the CLD was a good representation of the issues the group set out to investigate. All eight respondents were positive that it captured the discussion that took place and they had individually contributed to the CLD. Half of the participants were uncertain (i.e., neutral) and the other half positive (i.e., agreed) about whether the CLDs would be of interest to others. They

were, however, mixed about its value as a way of communicating problems in the WR to others and they also had mixed feelings about whether the CLD was worth developing further.

To follow the linkages within the CLD and the STELLA model, a story explaining the CLD was developed as a PowerPoint presentation which is now on the SP2 website. The advantage of using PowerPoint is that participants don't need to download STELLA (which proved problematic due the firewalls most organizations have as well as being an additional step) to show other people. Storytelling provided a good means for most respondents (except one) to follow and understand the CLD. It was also seen (except for two respondents) as a helpful way for the respondents to communicate problems facing the WR to others. However, mixed results were obtained with regard to their willingness to actually communicate the developed story to others. More people were neutral or unwilling (5 respondents) than positive (agree and strongly agree, 3 respondents), to use the story telling capacity.

Interactive model building in STELLA happened only on the afternoon of workshop 1 and the morning of workshop 2, due to a reduced number of workshops planned (see 2.2). Respondents were positive that the MM workshops helped structure thinking and discussion and the model progressed significantly over the three workshops (all respondents were positive (i.e., agree) to very positive (i.e., strongly agree). During dialogue the follow up survey, respondents reported that economic priorities were discussed more than the other well-beings and they saw this reflected in the model.

***Question 2: What is the significance of data availability and/or data translation?***

Data to run the simulation model was obtained from Market Economics and Statistic New Zealand. Collected data was mainly related to time series trends (years 1990-2010) for key variables in the model. Data used included gross domestic product, population, labour force, prices indices, unemployment, import, export, consumption, land use, gini-coefficient.

Good time series are scarce as most data is not collected on a yearly basis. For developing the current version of the model, it became clear that areas of poor data quality are related to natural capital, water (quantity and quality) and waste and pollution. Information about resilience (e.g., the amount of available food and time delays before the system starts to respond to such changes) are also limited.

When data was unavailable for variables that needed to be quantified to run the model, "guestimates" were made by group discussions at the mediated modelling workshops, thereby adding to the exchange of perceptions among participants. This was captured in the narrative summaries if not in the model structure.

Data translation was not an issue as stakeholders were generally very familiar with the type of data used. The linkages between sectors were apparent to participants and understood before the workshop so knowledge with regard to 'data translation' was not significantly added to.

***Question 3: Was the model an appropriate vehicle to reach the conclusions or address the concerns of the participants?***

At the outset it was decided to keep the workshops general and not address a specific topic. Participants defined five scenarios as part of the workshop process. A system dynamic model was constructed to address two of the five scenarios. The two scenarios were run at workshop 3 for participants to comment on and evaluate.

Participants were either uncertain (neutral, 3 participants) or in agreement (5 participants) that the model addressed the issues identified during the workshops. Most respondents (6) found that the model behaved logically and five respondents reported that they had "faith" in the results of the model (the other three respondents were neutral). The participants perceived the model as a good (i.e., agree) to very good (i.e., strongly agree) representation of the current dynamics of the Wellington Region. The model was seen by one but all respondents as a positive way to learn about the dynamics of the WR. The majority of respondents (5) thought the current model could be used for decision-making, though it should be noted that one respondent strongly disagreed (the two others were neutral).

Respondents felt the scenarios run through the model were insightful and running additional scenarios would provide new insights. Mixed responses were obtained on whether or not the model requires further improvement. Four respondents were neutral whereas three agreed and one strongly agreed that improvements in the model would aid this process.

***Question 4: Did the reflection on the group's make-up change consistently?***

The observed gaps in the stakeholder list at the outset were in order of number of times mentioned: Iwi/Maori, Community, Non-governmental organizations, Ministry for the Environment, Businesses, Department of Conservation, Senior Citizens, Youth, Education, Transport. The project team approached organizations to cover these gaps and added a representative from an umbrella group for non-governmental organizations. This person was able to cover, Community, Non-governmental organizations and older persons' interests.

After the three workshops and for future MM workshops the groups viewed by respondents as missing were those with a cultural perspective and representing vulnerable groups in the community. The suggested groups to include going forward were: Iwi, service delivery (NGOs, city mission, salvation army etc.), Department of Conservation, people with environmental interests, and a policy/ planning person. It seems that the gaps in representation at the outset of the MM workshops were not significantly different from those at the end.

***Question 5: Did we lose or gain participants? Are the observed gaps in the stakeholder list persistent or changing?***

Of the fifteen initial participants at workshop 1, eleven attended workshop 2 and nine continued on to workshop 3. Six participants participated in all three workshops. One participant formally withdrew from the process. For the others, attendance at all the workshops was not possible due to other commitments.

Eight of the nine participants in workshop 3 were surveyed. Four expressed interest in actively participating in phase 2 of the MM process. The other four either couldn't commit or thought someone else in their organization might be better suited. These participants remained sufficiently interested to want to receive updates on phase 2. For one respondent it was simply workload as opposed to a personal or organizational fit that prevented prioritizing active participation in phase 2.

As participation in the group dropped off the gaps in stakeholder representation identified in the pre-workshop survey became more of an issue. This was because the drop off included participants representing social and non-governmental organizations, which were underrepresented to start with. It is possible that the emphasis on Economics contributed to this development, as this became the most developed model sector (see 2.3.1).

***Question 6: Are participants (including those who were unfamiliar with STELLA) willing and able to demonstrate the model to others?***

None of the participants used STELLA to run the model after the workshops. Some participants tried to download the STELLA-software but their organizations IT systems fire-walled this. However, when asked, five participants could see a scenario where they themselves would use STELLA. Three did not see this happening for various reasons. Five participants thought that, if not themselves, their organizations would be interested in using STELLA in the future.

Related to showing or communicating the CLD and the STELLA model to others, three participants were uncertain (i.e., neutral) and five were positive (i.e., agreed) that the CLDs was of enough interest to show to others. Four participants expressed a willingness to use the CLD to communicate issues facing the Wellington Region to others. The stories developed to enhance the communicability of the CLD did not significantly increase the participant's willingness to communicate the CLD to others using storytelling. In fact, more people were neutral or unwilling (5 respondents) than positive (agree + strongly agree, 3 respondents), to use the storytelling capacity to tell the developed story to others. This may be due to the fact that the process was cut short to 3 workshops and outputs didn't get developed in detail, or the process went too fast for participants to see how such tools can be used in their specific context.

***Question 7: Does a significant portion (>50%) of the group want to continue the MM effort?***

Half of those interviewed (4 respondents) wanted to continue the MM process. The other half of the respondents were neutral (4) about whether their expectations were met by the workshop than agreed (3) or disagreed (1). However, if four continuing participants are compared to the fifteen who started the process, this signifies a 27% continuation rate.

Most participants agreed (5) to strongly agreed (1) with the fact that their issues can benefit from an extended mediated modelling process. Half of the participants also agreed that it could be useful to continue developing the CLD. Some participants saw potential for the STELLA model to function as a decision support tool for the Wellington Region if the model is further developed. Hence, responses that improvements to the simulation are still desired.

***Question 8: Is the website serving well as a communication tool?***

Since we didn't set a bench mark for what constitutes "well" this question is hard to answer. Survey responses indicate usage of the website by the more active participants but the website was not used extensively. Only four participants visited 2-5 times, the remaining participants visited the website less than twice or never.

## *2.3. Content*

### 2.3.1. Model description

Figure 4 is a sector-representation of the model that emerged after three mediated modelling workshops. The model currently contains five sectors: (1) Population and Households, (2) Economics, (3) Natural Environment, (4) Government, and (5) External Factors (that influence the Wellington Region). These five sectors are interconnected through the following feedback loops: (1) "Population and Households" affect "Economics" and vice versa, (2) "Economics" and "Government" are interconnected, (3) "Economics" affect the "Natural Environment" and vice versa, and lastly (4) "Population and Households" affect the "Natural Environment" which in turn affects "Economics" and therefore ultimately again the "Population and Households". In addition to these four feedback loops, the effects external factors (like for instance earthquakes) have on the regional economy, natural environment and population are also taken into account. The remainder of this section will discuss each of the five sectors. For a more detailed description of the model we refer the reader to appendix C.

The "Population and Households" sector covers the Wellington population and its households. In this sector, six types of households are considered: (1) unemployed primary industry worker households, (2) primary industry worker households, (3) unemployed worker households, (4) worker households, (5) unemployed service worker households, and (6) service worker households. Each of these households consists of householders and youngsters and/or students. Movement between the different types of households is possible and is mainly a function of changes in employment opportunities. In addition to movement between these different types of households, migration flow from and to the Wellington region are also taken into account. These flows are a function of the attractiveness of the Wellington region relative to the other regions. Finally, the potential impact of disasters like earthquakes on the households and population of the Wellington Region are included.

The sector on economics is the largest of all sectors and contains (1) economic demand, consumption and production functions, (2) inventory control mechanisms, (3) import and export, (4) output prices and price indices, (5) labour and capital (i.e., infrastructure) dynamics, (6) household income functions, and finally (7) some key indicators of the overall "performance" of the Wellington region. This sector distinguished between three types of "products": (1) food, (2) goods, and (3) services. Production is

modeled by a Cobb-Douglas type production function (in which labour, capital (i.e., infrastructure), and natural capital are taken into account) adjusted for profit expectations, changes in demand, inventory control mechanisms, and time delays in the production process. Consumption is a function of production (through inventory) and demand. Demand in turn is modeled as a function of a reference demand adjusted for (1) the interplay between output prices in the Wellington Region versus output prices outside the region (i.e., on the world market), and (2) changes in income patterns. Next, inventory control mechanisms are included in this model as production and consumption are both affected by inventory levels. Inventory control is mainly a negative feedback loop trying to assure that inventory within the Wellington region remains available. This is for instance important related to food security when disasters occur. Import and export are also taken into account in this sector. Import depends on the inventory control mechanisms and the already discussed demand and consumption functions. Export on the other hand is a function of demand, production and relative output prices. Next, this sector also contains the dynamics of labour and capital (i.e., infrastructure). The dynamics of labour is given by the labour market and captures hiring and layoff of labour based on production forecasts and population dynamics. Capital in this model is represented by infrastructure which is a function of the demand for certain types of infrastructure (which is in turn is a function of production or population) evaluated in the light of land use possibilities. In addition, the model also takes depreciation of infrastructure over time into account. Finally, this sector includes household income functions for the six types of households included in the model. Three types of income are accounted for: (1) income from labour, (2) unemployment benefits, and (3) other forms of income (not from labour). Unemployment benefits are for all unemployed labour types the same and are adjusted for growth in unemployment rates and for changes in price through the "Fisher Consumer Price Index". Average income for labour depends on the type of employment (primary industry; i.e. agriculture, mining, fisheries, forestry), industry; i.e manufactory, services; i.e. banking, government, tourism). It is a function of the industry's productivity and expected output prices adjusted for pressures emerging from changes in unemployment (i.e., price adjustment for labour due to scarcity). Average wages, however, cannot fall below the unemployment benefits. Finally, the sector on "Economics" ends with the generation of some key "economic" indicators for instance its relative attractiveness compared to other regions, its gross domestic product (GDP), the gini-coefficient, life expectancy at birth and the overall quality of food.

The sector on "Natural Environment" contains the linkages within the Wellington region between (1) land use, (2) natural capital, (3) waste and pollution, (4) available water quantity, and (5) water quality. In this sector, land use classes are defined based on whether they accommodate a certain type of infrastructure or not. Five types of infrastructure are distinguished defining five types of land use: (1) land with housing (i.e., residential area), (2) land with water infrastructure, (3) land with public and private service facilities, (4) land with factories (i.e., industrial land), and (5) land with farms (i.e., agricultural land). A sixth land class is "Natural Area" and a final one "Used Land Others" (i.e., a rest-category of land that has none of the five infrastructure types on it and not considered a natural area). Data on Agricultural land, Industrial land, Residential land and Natural area was sourced, however, the categories did not add up to the total area of the Wellington Region. Hence, a rest-category was needed For the Wellington Region it is assumed that natural capital increases through natural growth and restoration efforts. In the model natural growth is represented by an S-shaped curve, also called

'logistic' growth, if no restoration or depletion occurs. Natural capital depletes due to (1) natural decay and decay due to human induced pollution, (2) changes in land use, (3) its consumption by economic activities, and (4) disasters. This sector also takes account of waste accumulation and links it to pollution as only a fraction of the total waste adds to pollution; e.g. organic waste does not add to pollution. Production, consumption and traffic are in this model the main contributors to waste accumulation and accumulated waste can decrease through lowering the rate of 'degradation and recycling' in the model. Finally, this sector also includes both an estimate of the available regional water quantity (i.e., a function of the amount of water that human built infrastructure (i.e. reservoirs) can hold) and an estimate of the water quality (i.e., a function of natural capital and its ecosystem services) in the Wellington region.

The "Government" sector captures government demand for local production and imports of food, goods and services. Both demands are mainly a function of a historic and projected trend of government demand. The model adjusts this trend for the interplay between output prices in the Wellington Region versus output prices outside the region (i.e., on the world market).

The last sector in this model is a collection of the external factors that may significantly affect the dynamics of the Wellington region. Up till now the group determined two such factors: (1) technological efficiency (related the required space needed to build infrastructure) and (2) disasters (mainly earthquakes).

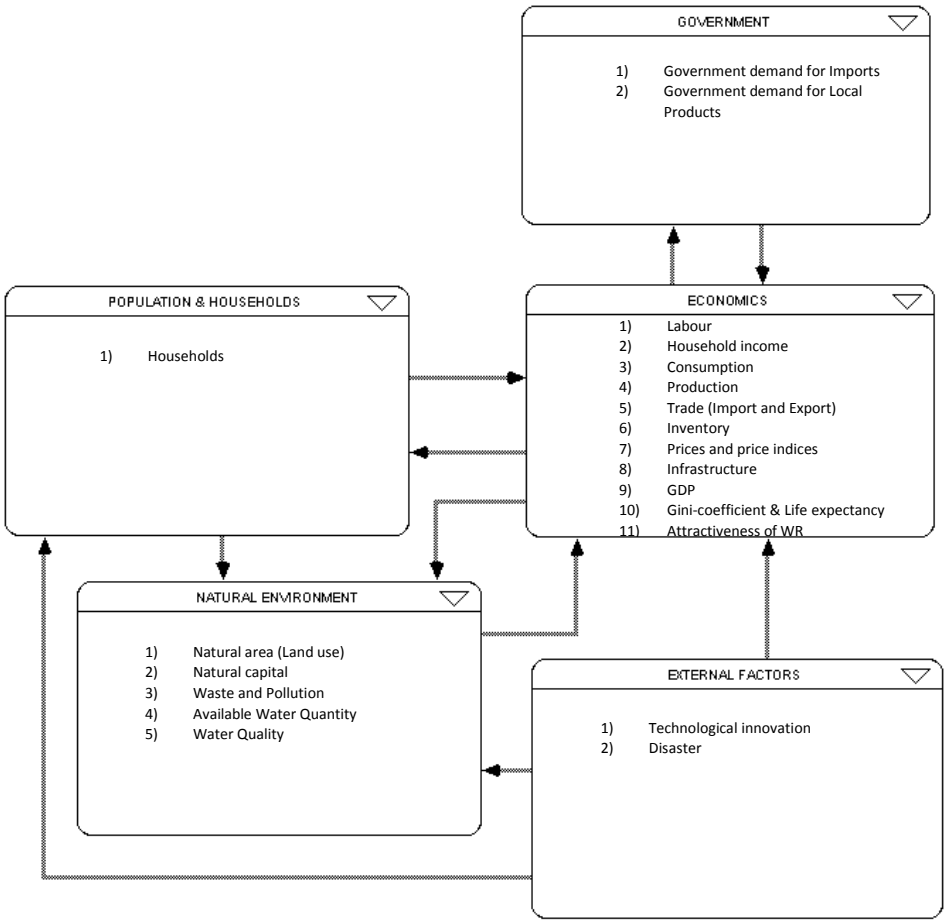


*Figure 4: The Sectors of the Wellington Regional Model and how they are interconnected*

*Table 2: Arrays in the Wellington Regional Model and how they are related*

| | | Land | Product | Working type |
|---|---|---|---|---|
| Industry | Primary industry | Land with Farms | Food | (Unemployed) Farmer |
| | Industry | Land with Factories | Goods | (Unemployed) Worker |
| | Public and Private Service industry | Land with Public and Private Service Facilities | Services | (Unemployed) Service worker |
| Housing | | Land with housing | | |
| Water infrastructure | | Land with water infrastructure | | |
| | | Natural Area | | |
| | | Used land others* | | |

* Data on land use types were sourced, however, the categories did not add up to the total area of the Wellington Region. Hence, a rest-category was needed.

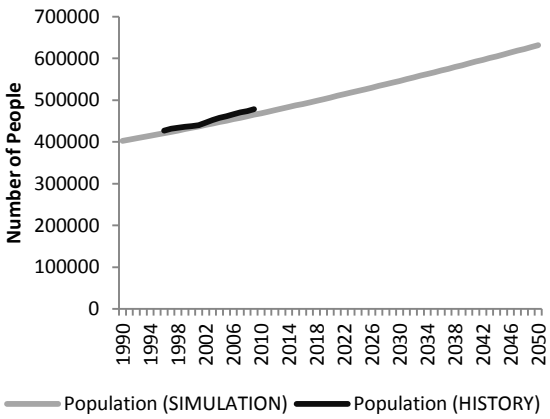
### 2.3.2. Model evaluation

The validity of the model was mainly assessed based on (1) it's capability to reproduce historic behaviour (i.e., data trends) and (2) the post-survey in which the participants of the mediated modelling workshops were asked about their perception of the model.

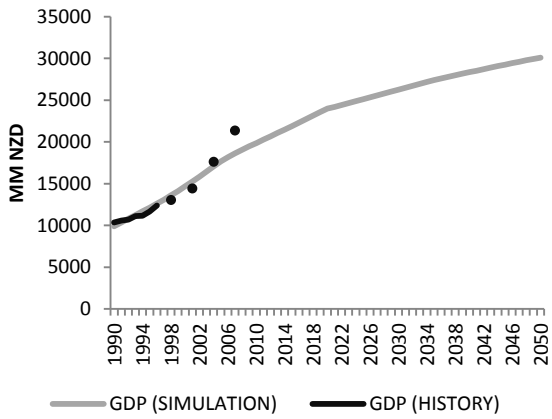
First, historic data and model fit is illustrated in Figure 5. Formal metrics were not obtained to assess the goodness-of-fit because well established data series were scarce. As a result, qualitative tests of fit were used instead of quantitative tests. Qualitative tests of fit are widely used in practice and consist of "eyeballing the magnitude, shape, periodicity and phasing of simulated trajectories and comparing to past behaviour" (Morecroft, 2008, p. 400). When eyeballing the fit for (1) the population (Figure 5.a), (2) GDP (Figure 5.b), and (3) the consumer price index (Figure 5.c) in the Wellington region, historical data points are abundant and the fit is very satisfactory. The fit for (1) natural area (Figure 5.e) and (2) yearly

waste (Figure 5.f) is more difficult to assess as for both of them there are only two historical data points available. Nevertheless, the simulation results demonstrate reasonably similar behaviour as the historical data and the fit with the two recognized data points for yearly waste is satisfactory. Finally, at first glance, the fit between the historic and simulated data for the gini-coefficient might be perceived as troublesome. However, this does not necessarily need to be the case because the behaviour of the simulation results mimic the stability in inequality also observed in the historical data. The declining behaviour prior to stabilisation in year 1998 is caused by small adjustments of the modelled Wellington regional system to some of its initial values, hence, initial parameter estimation and setting can further be improved. Also, the gini in the model is below the historical data trend, which is caused by the inability to capture all individual households (regardless of where they work) in the model. Income distribution is required when calculating the gini-coefficient and we only deal in this model with population classes (i.e., farmers. workers, services workers, unemployed farmers, unemployed workers and unemployed service workers). The richness of the distribution to calculate the gini-coefficient is limited when homogeneous classes are the basis for a distributive calculation; so instead of about 150,000 households, the model clusters them in 6 groups, which reduced the value of the gini-coefficient in the model.

(a) Population in the Wellington region

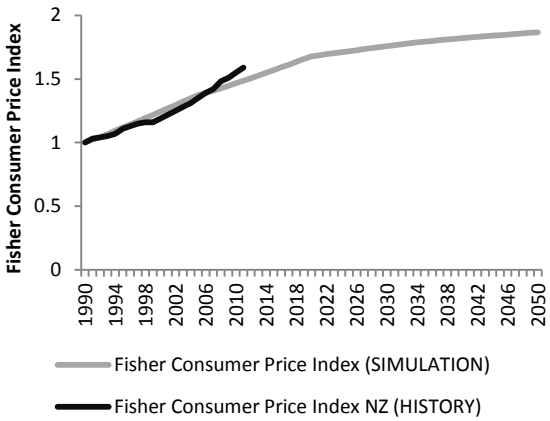


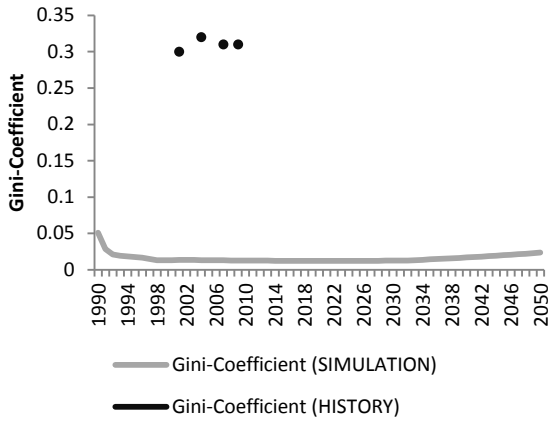

(b) GDP of the Wellington region



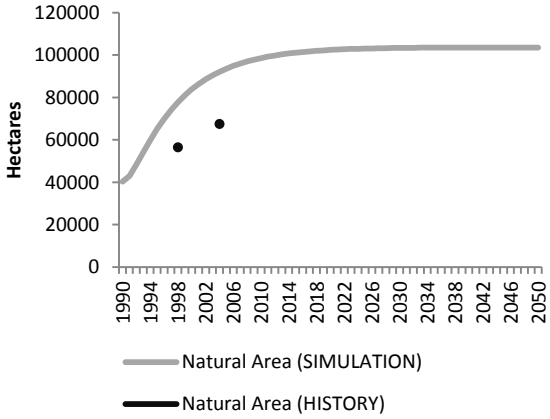

(c) Consumer Price Index of the Wellington region

(d) Inequality in the Wellington region




(e) Natural Area in the Wellington region




(f) Waste in the Wellington region

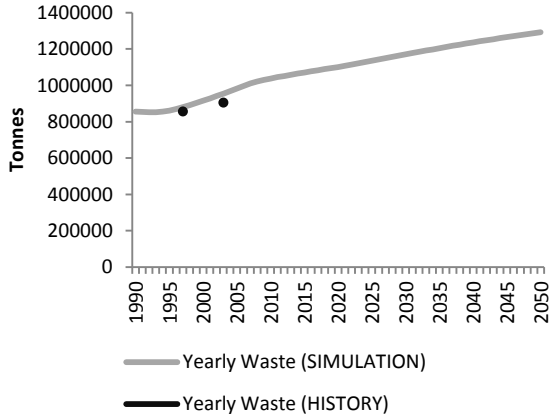



***Figure 5: Examples of the fit between simulated data and historic data for the following key variable in the model: (a) Population, (b) Gross Domestic Product (GDP), (c) Fisher Consumption Index, (d) Gini-Coefficient, (e) Natural Area, and (f) Yearly Waste.***

Secondly, the results of the surveys in which participants of the mediated modelling workshops were asked about their perception of the model validity are given in the boxplots of Figure 6. It is clear from these boxplots that the median score on all questions related to validity was high (median scores of 4) and the variance was low (except for the last question "the current model can be used as a decisions support tool for the Wellington region").

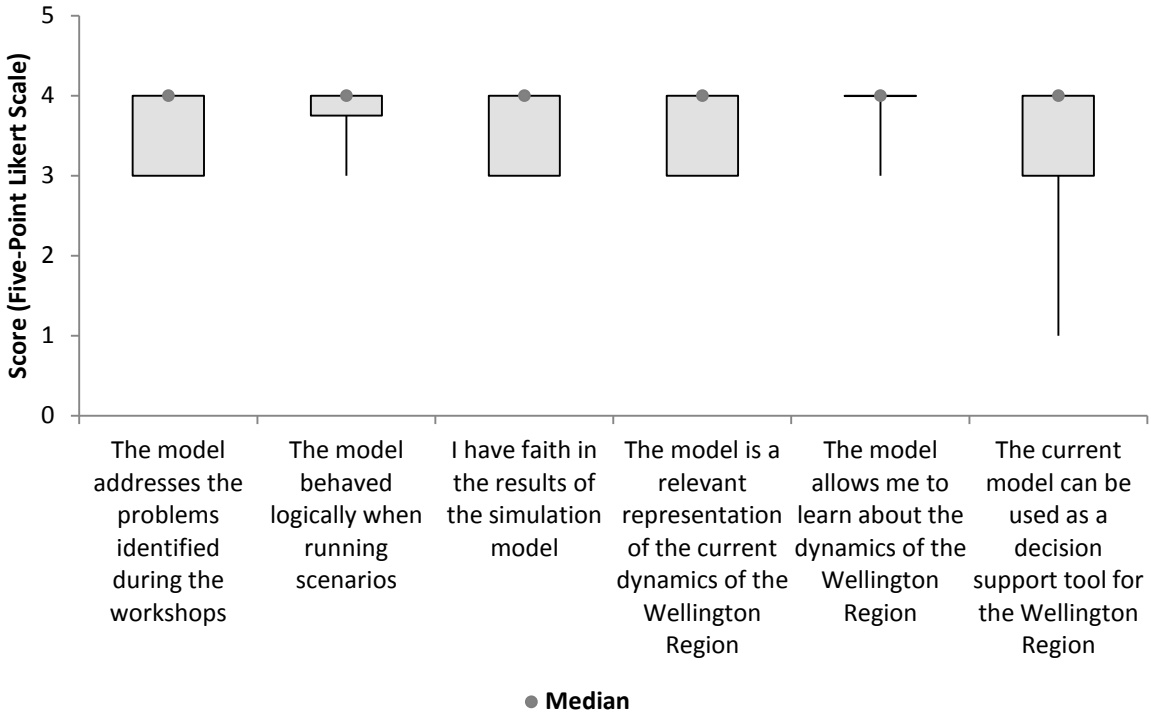



***Figure 6: Results from the post-test questionnaire on the validity of the Wellington Regional Model***

Next to these "formal" tests of model validity, the participants were also invited to discuss and evaluate the current version of the model during the last workshop. Listed here are the summarised conclusions of the general discussion related to the model:

- The model is integrated. Drilling down is what generally happens rather than looking across, e.g., transport models are detailed but not linked. Generally you need the broad level to answer questions but depth to support answers. Some people, however, need the detail (numbers) to make a model plausible.
- With the broad versus depth question it is hard to know what the actual impact will be on the model until variables are added and tested. It is therefore difficult to judge how important breadth versus depth is without being able to make comparisons. An example, was given that adding age cohorts into the model would impact on the linkages and outcomes but how this impacted was not quantified.
- The purpose of the MM process is to help determine what is important and the level of detail needed in a model. Only relevant variables that drive the system need to be included.
- Regardless of whether the model is deeper or broader the outputs still need to be communicated so that participants (and their networks) understand how the system changes. Storytelling, demonstrated using the CLD, was considered a helpful means of communicating by 6 of the 8 participants though there was reluctance to use it. .

- Timeframes are an important aspect of system dynamic models. For example, if economic growth increases the need for specific skills, adjustment of the education process has a time lag associated to develop those skills.
- When participants were asked at Workshop 3 "if we had taken a slower approach would there be more 'ownership' of the model?" the response was the need to "own" the model was not shared by everyone and the speed was felt to be about right due to the time commitment required.

In the remainder of this section we summarise additional comments made during the evaluation of the model:

- The assumptions incorporated in the model were considered acceptable.
- Urban form, transport, health and food resilience are missing from the model. Other than transport (which was not really covered) these issues were part of the MM dialogue.
- Participants have set views on what is important and what is not. We can use the simulation model to see whether the views we brought along (for example the importance of growth) are actually right.
- Unless there is buy-in from local government, people will look at the simulation model and think "ok, that's very nice" and continue on as usual. A policy question for use of the model to support the change in thinking required.
- Planners as agents of change need to be concerned with what can be changed and where local government leverage points are. There are many things in the model that a district council does not have any influence on (e.g., immigration, transport). There is a scale issue to consider – central govt -> local govt -> business. [Note: How to operate across scales to achieve change is an on-going topic for the SP2 project research.]

### 2.3.3. Scenarios and simulation

To demonstrate how system dynamic models work and test stakeholder's perceptions, 'what if?' scenarios were developed in Workshop 2 for testing in Workshop 3. The following five scenarios were decided on. Due to the time required for the modelling, data-gathering and calibration stages only the first two scenarios were demonstrated at Workshop 3.

1. What if the population changes by 10% (up or down) by 2020 then what happens to "access" and "inequality"?

   Note: *Access* was defined as able to source education, health services, jobs etc. *Inequality* was defined by participants as a lack of access and inability to achieve potential. Inequality is equated with low income, low relative income and low life expectancy. It was decided to use low income as a proxy for inequality as it is more measurable.

2. What if the relative income per person in WR changes by 10% (up or down)? How does this impact on the relative attractiveness of the WR?

   Note: *Attractiveness* is related to: housing choice and cost, sense of community, arts and culture, natural areas, compact city, robust economy, robust vibrant city centre, walkability of the central city area, commuting time (what if the travel time per car, bike or walking changes by 50% up or down?).

3. What if WR focussed on innovative niches (digital industries and comparative advantages) then what happens to resilience?

   Note: How can resilience be defined?

4. What happens to WR attractiveness if skilled labour stays on average just 1 year or up to 40 years?

   Note: Is the average length of time that skilled labour stays in the WR an appropriate indicator and how would such an indicator influence WR's attractiveness?

5. What if 50% more or less kilometres need to be travelled to deliver goods and get to workplaces? How does this impact on inequality and attractiveness?

   Note: Currently Wellington city service workers live in the Hutt where there is more affordable housing and good public transport makes this possible. The MM model does not deal with spatial location. It will be considered at the inter-linkages workshop if this is an appropriate question for the spatial model.

***Scenario 1: What if population changes by 10% (up or down) by 2020 then what happens to "inequality"?***

To address this "what-if"-question, the model was first run to see what happens if population decreases after the year 2010. To test this, four runs were performed and the results are given in Figure 7. A first run was a base run which let the model run without parameter adjustments ("full black line" in Figure 7a+b). In a second run, the birth rate in the model was decreased by 10% in year 2010 which resulted in a population trajectory situated only slightly below the base run (population is only 4.56% lower compared to the base run in 2050). This was not expected as one thought that this 10%-change in birth rate would have had at least the expected result of a 10%-change in population by 2020. The reason why population has not declined as expected is that migration to the Wellington Region increased due to job attractiveness. In addition, the gini-coefficient did not differ significantly when compared to the base run (only 1.46% lower in 2050) because of no major changes in the total Wellington population and average household income. In a third run, population decrease was aimed at by discouraging immigration through increasing the time it takes for immigrants to enter the Wellington region by 50% from 2010 onwards. Interestingly, this generates almost an identical trajectory for population as a 10% decrease in birth rate (there are only 400 people less by 2050), but now inequality is much lower (over 20% when compared to both the "-10% in birth rate"-run and the base run). The reason for this lower inequality is not related to changes in the total population. It is also not because of an increase in

unemployment as unemployment rates are even slightly higher (+4.25%) when compared to the "-10% in birth rate"-run. The reason is found in changes within the total population (i.e., the distribution of the different labour types). Indeed, the lower inequality (i.e., the gini-coefficient) is a result of having less primary industry workers (-11.26%) and unemployed primary industry workers (-12.15%) living in the Wellington region when compared to the "-10% in birth rate"-run. Although primary industry workers are still immigrating to the Wellington region, they do that at a lower rate (-26.85%) due to the increased time delay for immigration. In addition, this scarcity of primary industry workers also result in an increase of their income (+9.39% compared to the "-10% in birth rate"-run) which results in an additional effect that lowers inequality. Finally, when both policies, a 10% decrease in birth rate and a 50% increase in immigration time, are combined, it becomes clear that the increase in immigration time has the most positive impact on inequality. This is illustrated as population is lower compared to the "+50% in immigration time"-run, but this has no significant impact on inequality.

(a) Population in the Wellington region (b) Inequality in the Wellington region

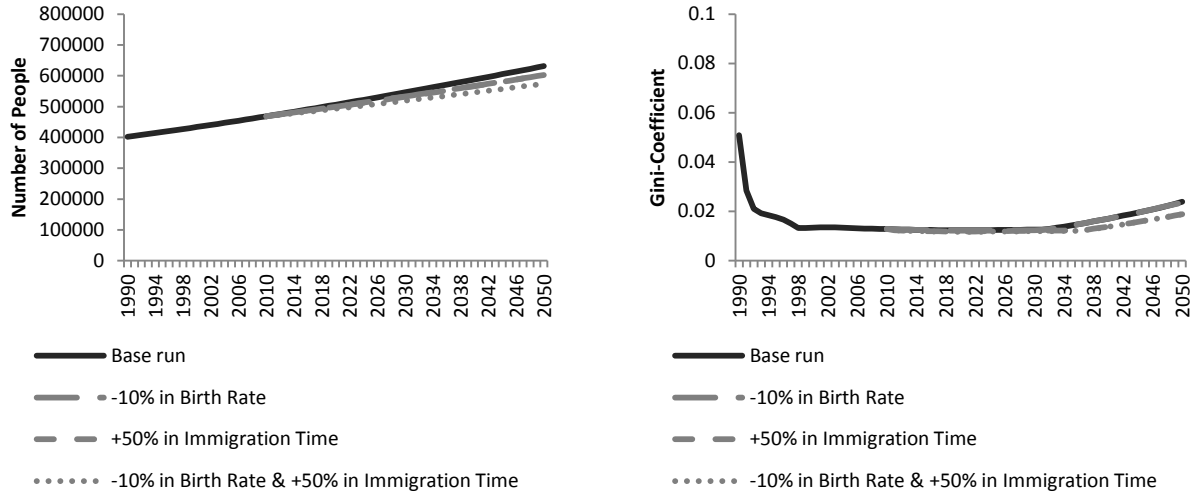
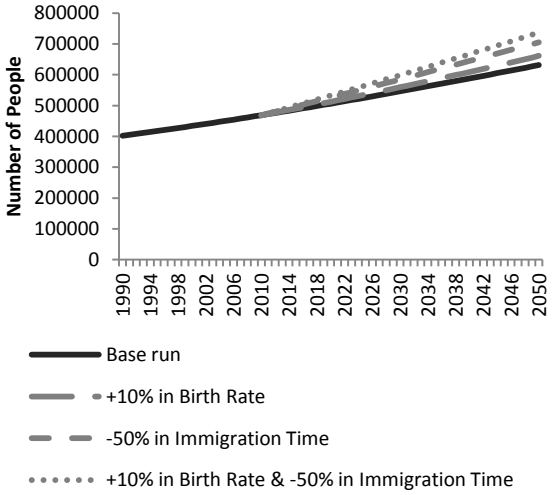



***Figure 7:.Simulation results for (a) population and (b) inequality of the Wellington region for four runs related to Wellington's concern about population decline, being: (1) a base run, (2) a 10% decrease in birth rate, (3) a 50% increase in time it takes for immigrants to enter Wellington, and (4) both a 10% decrease in birth rate and a 50% increase in immigration time.***

Figure 8 illustrates what happens to inequality if the population grows. Again four runs were performed starting with the base run which is depicted in Figure 8a+b (full black line). The second model run has, for 2010 onwards, a birth rate of 10% higher than the base run. This results in only a small increase in population (+4.69% in year 2050 compared to the base run) which was not expected. But, its effect on inequality came as an even bigger surprise for the participants as it had almost no effect at all, except for the last years (from 2045 onwards) where inequality increased instead of decreasing as participants believed it would. This delay in effect is caused by the time it takes for newborns to grow up and become a householder (i.e., approximately 20 years). The reason for the increase instead of anticipated decrease in inequality after year 2045 is due to a more than doubling of the unemployment rate. This doubling of the unemployment rate is the result of having more householders competing for the same amount of jobs. Job opportunities have not yet increased because the Wellington's economy has not yet

expanded as a response to the increase in demand. It takes time for an economy to adjust its production capacity! A third run tests what happens if immigration is encouraged through cutting the time it takes to immigrate to the Wellington region by half. Doing so is seemingly more effective at increasing the population since its trajectory lies now well above the base run (+11.71% in 2050) and also well above the "+10% in birth rate" run (+6.70% in 2050). In addition, inequality increases dramatically after approximately year 2020. In fact, in year 2050, it is almost a fourfold of the base run and it is more than twice as high as in the "+10% in birth rate" run. This increase in inequality can be mainly explained by the vast increase in unemployment rate (from approximately 2% in 2010 to almost 17% in 2050). In turn, this increase in unemployment is due to the inability of the economy to grow at a similar rate to population growth and demand for jobs. In a final run, the 10% increase in birth rate is combined with the halving of the immigration time. This results in the highest trajectories for both the population and inequality clearly illustrates that halving the immigration time has the most dramatic impact on inequality.

(a) Population in the Wellington region




(b) Inequality in the Wellington region

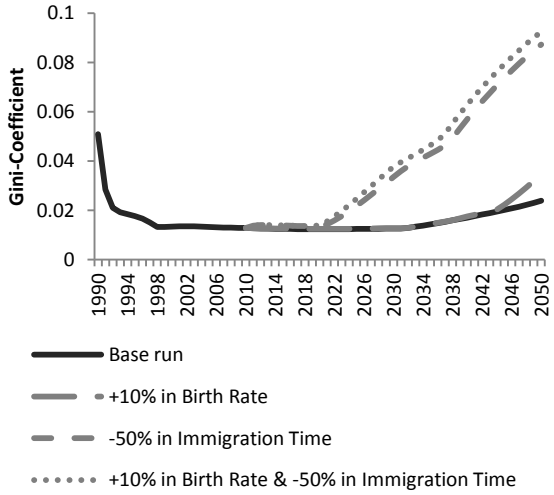



***Figure 8: Simulation results for (a) population and (b) inequality of the Wellington region for four runs related to population increase, being: (1) a base run, (2) a 10% increase in birth rate, (3) a 50% decrease in time it takes for immigrants to enter Wellington, and (4) both a 10% increase in birth rate and a 50% decrease in immigration time.***

In sum, the model results for this scenario indicate that inequality is not a big issue for the future of the Wellington region as:

- Population decline did not necessary result in more inequality as a decline in birth rate did not significantly affect the gini-coefficient. Inequality only worsened when population was declined through making it more difficult for immigrants to enter the region. However, inequality increased not because of this decline in population, but because changing the timelag for immigration altered the population distribution.
- Population growth did not decrease inequality at all.

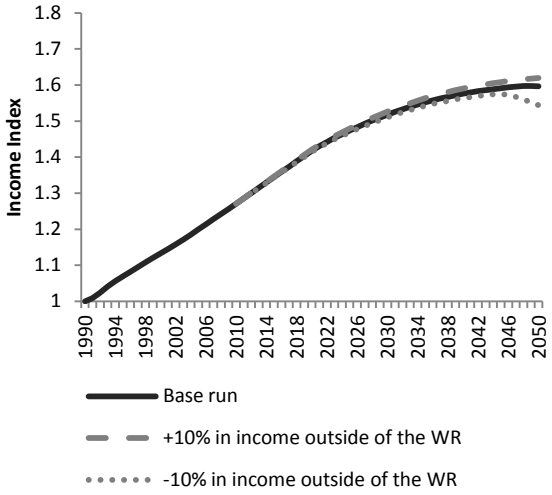
***Scenario 2: What if the relative income per person in Wellington region changes by 10% (up or down)? How does this impact on the relative attractiveness of the WR?***

The current version of the model allows changing the income per person in the Wellington region in various ways. However, the simplest and most straight forward way, for testing this scenario, is to change the income that people earn outside the Wellington region because the income in the Wellington region is relative to the incomes outside the region. Three runs were performed to see what would happen to income and the attractiveness of the Wellington region if relative income per person outside the Wellington region changed (see Figure 9). The first run was a base run and is indicated in Figure 9a+b as a full black line. In a second run, the income outside the Wellington region is increased by 10% from 2010 onwards (long dotted grey line). This 10%-increase has an interesting effect on average income in the Wellington region as income in the last simulated years is even slightly higher (+1.45%) than the base run. This can be explained by an increase in wages (especially in agriculture) as there is less labour available due to the decreased attractiveness causing people to leave the Wellington region. With less people competing for the same number of jobs there is less unemployment which pushes up wages. In addition, the region still produces the same amount of food, goods and services which increases the productivity of labour which also leads to higher average wages. When compared to the base run, the '10%-increase in income outside the Wellington region' reduces the (perceived) relative attractiveness of the Wellington region. However, this effect is small with relative attractiveness in 2050 only 4.63% lower than the base run. In addition, the converging behaviour of the trajectory towards the base run was not anticipated by stakeholders at the workshop. There are a number of reasons for this converging behaviour, the first is the relative attractiveness of a region is determined by more than just income. As this model also includes the effect of (1) job opportunities, (2) housing affordability, (3) culture, and (4) waste and pollution, the relative attractiveness of the Wellington region is a weighted average of the relative attractiveness for each of these components. The second explanation for why the effect is small is the choice of the weights for each of these components which is based on stakeholder discussions. A weight of 15 out of 100 is assigned to 'income' in attractiveness of the WR (as set out in Table 3). A third reason is related to the choice of calculating the weighted average for relative attractiveness as a harmonic mean instead of an arithmetic or geometric mean. This choice is based on the assumption that attractiveness of a region is mainly determined by all components being in "harmony". For instance, when the region performs well on all components except one, the harmonic weighted average of those components will be well below the arithmetic and geometric mean. Finally, the last but probably most important reason for the lack of a significant decrease in attractiveness is the region's ability to adjusts (in various ways) for this (sudden) increase in income external to the Wellington region (through for instance the increase in wages due to a shortfall in labour when labour moves outside the Wellington region to obtain higher wages). This last reason of system adjustment is also the reason behind the convergence of the trajectories between the "+10% in income outside the WR"-run and the base run.

The third run investigates what would happen to income and attractiveness of the Wellington region if income outside the Wellington region decreased (instead of increased) by 10% from 2010 onwards

(short dotted grey line). The external decrease results in an income trajectory below that of the base run especially after year 2045. This was unexpected as it was assumed that higher relative incomes would attract more people to the region catalyzing economic growth which would create even higher incomes. The reason income is lower can be explained by the lag time between population change and the effects on the economy. When for example, the population grows, demand for goods and services grow. However, it takes time to expand the capacity of the economy to cope with these demands. Due to this delay, at first population growth results in unemployment because the economy does not immediately adjust for population growth. With labour less scarce there is: (1) lower wages, and (2) hiring of additional labour to expand the economy. The latter causes a (at least temporal) drop in labour productivity which translates to lower wages. The relative attractiveness of the Wellington region lies slightly above the base run but it was expected to deviate more. And again, the trajectory is converging towards the base run. Similar explanations as the one for the "+10% in income outside of the WR" count for this lack of effect and converging behaviour.

(a) Average income per person in the Wellington region




(b) Attractiveness of the Wellington region

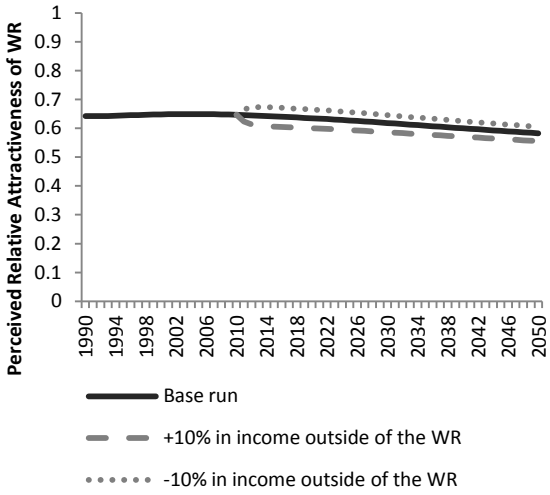



***Figure 9: Simulation results for (a) average income per person (expressed as an index in relation to its initial value) and (b) perceived relative attractiveness of the Wellington region for three runs related to Wellington's concern on income changes, being: (1) a base run, (2) a 10% increase in income outside the WR, and (3) a 10% decrease in income outside the WR.***

In sum, the model results for this scenario illustrate that:

- when relative income in the Wellington region decreases, the (modelled) Wellington region reacted to adjust for this loss limiting its effect on attractiveness
- when relative income in the Wellington region increases there is no spectacular increase in attractiveness of the region. Increased attractiveness also comes at a high cost as unemployment increases and income within the Wellington region decreases in absolute terms.

In addition to these scenarios, the sensitivity of these results to changes in the weights used to calculate the harmonic weighted average of relative attractiveness was investigated. All three scenarios were performed again for two different weight distributions. One distribution doubled the weighting for income and the other reduced it by a third in determining its effect on the attractiveness of the Wellington region (see Table 3 for the exact weights). The effect of these adjustments was that changes in the income outside the Wellington region had a larger effect when more weight was giving to income and a smaller effect when less weight was given to income. However, the deviation was not spectacular given that the maximum deviation from the base run for these trajectories was approximately 14% and that the "normal weights" scenarios deviated around 4% from the base run. In addition, the converging behaviour of the trajectories towards the base run was still observed for all sensitivity results. In conclusion, it is fair to state that varying the weights within reasonable limits has only limited effects on the behaviour of the overall relative attractiveness of the Wellington region.

***Table 3: Sensitivity analysis for the weights used in the calculation of the harmonic mean of the relative attractiveness of the Wellington region***

| | **"Normal" weight to income** | **"More" weight to income** | **"less" Weight to income** |
|---|---|---|---|
| Weight for income in attractiveness of WR | **15** | **30** | **10** |
| Weight for job opportunities in attractiveness of WR | 25 | 22 | 25 |
| Weight for housing affordability in attractiveness of WR | 15 | 11 | 16 |
| Weight for culture in attractiveness of WR | 20 | 15 | 21 |
| Weight for pollution concentration in attractiveness of WR | 15 | 12 | 15 |
| Weight for waste concentration in attractiveness of WR | 10 | 10 | 13 |
| Total | 100 | 100 | 100 |

### 2.3.4. Evaluation of the scenarios by the participants

The results of the survey in which participants of the mediated modelling workshops could evaluate the scenarios are given in the boxplots of Figure 10. They found the outcomes of the two scenarios as insightful (median score of 4 out of 5 with no deviation) and are looking forward to running additional scenarios which they believe will also be insightful (median score of 4 out of 5 with almost no deviation). Finally, most participants would like to see an improvement of the model to generate even more insightful results when running scenarios through the model (most scores between 3 and 4).

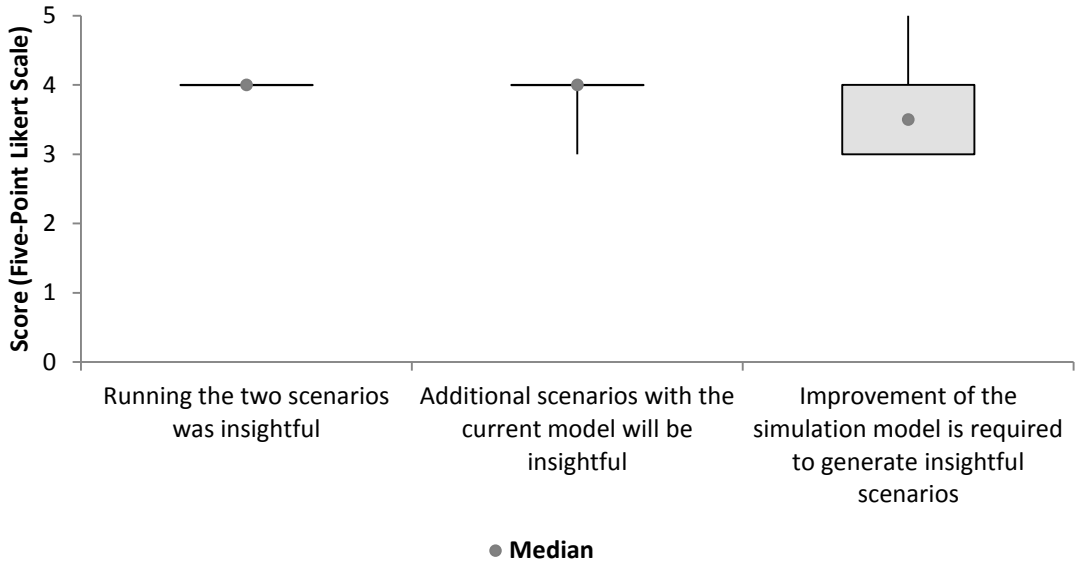



***Figure 10: Results from the post-test questionnaire on the use of scenarios***

Additional comments on scenarios were given during the workshop of which the most important are summarized below:

- Scenarios were seen by some as an enhancement to long term planning and part of the planning process rather than for other purposes.
- Economic development scenarios need to be region wide as having different scenarios for each TA in the WR would not be useful.
- Some participants felt their organisation could not use the mediated model to run scenarios on their own due to lack of capacity.
- Getting the wider picture from workshops such as the MM workshops was good due to acknowledged bias within organisations. Both the collective view and the local view are worth having.
- Scenarios would be a way to test policy. For example, the current business growth strategy is expansion not retention of business and is this best?

# 3. DISCUSSION

In the pre-assessment document what was meant by: (1) Adaptive Management, (2) Normative goal of Sustainability, (3) Scale and (4) Integration was made explicit to avoid misunderstanding. This section discusses these topics referring to the findings in the MM workshops.

## 3.1. Adaptive Management (AM)

A goal of the SP2 project is to integrate adaptive management cycles (*vision*, *integrated assessments tools*, *planning*, *implementation* and *monitoring*) into decision-making frameworks.

System dynamics modelling is a tool to assist adaptive management in the assessment stage of the AM cycle, supporting other stages of the AM cycle (noted in brackets below). The desired versus actual way of thinking provides better understanding of the horizons we are working at and when interventions are going to result in change. Small groups discussed whether the 'desired' versus 'actual' is a helpful way of thinking about an issue and noted the following.

1. When to intervene is something people were interested in finding out from the model. The desired versus actual type of thinking gives an understanding of the time horizon we are working with which helps determine the intervention (leverage) points. Issues can be relative in time, to other places, or place based (e.g. NZ flora and fauna is highly adapted to clean conditions). Closing the gap can depend on relativity with other places, science and marketing efforts. (Planning)
2. When there is a gap between reality and perception (e.g. NZ's clean green image) it is important that interventions are directed at the real state not the perceived state. (Implementation)
3. Using the desired versus actual approach with the simulation model provides the opportunity to see the down-side of decisions.(Implementation)
4. It is often difficult to determine what the desired long term outcome should be. With land use the pattern is to go for quick wins rather than long term protection. However, is protecting soils for agriculture rather than an alternative land use the desired outcome? (Vision)
5. If what we anticipate will happen is taking place, what are the required interventions and what monitoring should be put in place? Important to have this type of thinking embedded in decision-making. (Monitoring)

## 3.2. Normative goal of Sustainability

'Sustainability' was not a topic that was discussed in the workshops. The focus was more on the four well-beings (economic, environmental, social and cultural) and how these were linked.

## 3.3. Scale

In the workshops issues of scale (central government, local government (regional versus territorial) and business level) became very apparent. The systems dynamic model constructed in the 3 workshops is at the regional scale and not spatial. Some participants felt this made it unsuitable for use by territorial local authorities working at the district and city scale. A comment was made that the local authorities

contribute knowledge to the regional model, but don't get much benefit from it for local decision support, as the model levers are not within the range of decision making power at local level to change. The context of regionalization (section 1) is relevant in this respect. The model included variables that were controlled by central government which local government did not have influence over (e.g., immigration). The view was expressed that planners need to be concerned with their own leverage points to bring about change but also need to understand the relationships with other levels of government to achieve change.

Scale is important for efficiency. The MM component of SP2 allows us to both explore the scale that is most relevant to operate at and identify characteristics that will apply at all scales. No modelling scale will be perfect for all purposes. How policies and decisions are implemented at multiple scales to achieve change is a topic the SP2 project will be researching further, especially whether a spatially explicit approach can overcome this concern.

## *3.4. Integration*

Integration addresses how linkages between social and ecological systems are understood and how diverse types of knowledge are brought together when different actors are brought into governance processes to address concerns (Brown, 2009).

For workshop participants, systems thinking and system dynamics modelling was seen as a useful way to simulate how disparate elements link together to make the big picture. Public health agencies were particularly interested modelling inter-linkages as they feel they have been trying to get the message across for some time now that a multiple of factors outside the health system influence health and well-being.

While an integrated approach added value for participants it was felt that a specific practical application for systems thinking and modelling would improve the scope to contribute to strategic decision making through scenario simulations.

This goes back to the original recommendation by the Council to go for 3 workshops without a fixed topic; understanding integration takes time. For those participants who had been working on integrative approaches, the MMprocess made more sense than for those whose focus is on local issues.

## *3.5. Mediated Modelling and the Spatial model (SDSS)*

The MM workshops have been run to provide stakeholder input into the development of the more data intensive SDSS model. Based on the current scoping model/model description, a first round of recommendation will be provided to get the SDSS inter-linkages workshops off to a good start

Some of the scenarios that were suggested at the MM workshops (section 2.3.4) had a spatial scale issue associated with them. The SDSS model is being built at the regional scale at a 50x50m resolution. The view was expressed that a pixel or building level scale would be more appropriate and that the model should extend to the global level to capture external influences.[5] Also there was value in using cubic meters as a metric instead of square meters to allow scope for high-rise development. The potential "what if?" scenarios that participants were interested to explore with the SDSS model include:

1. What are the potential impacts on transport systems from climate change and sea level rise?
2. What if WR develops a compact central city?
3. What if WR develops a multi-nodal region?

## *3.6. Storytelling and communication*

The objective of the MM is to have all participants able to convey a similar insight, using the model though the starting point might be different for each individual. From a MM perspective what matters most is revealing issues. Modelling can raise issues to be considered/debated, in absence of the 'perfect model' (which doesn't exist) or all possible data gathered (which is extremely expensive). The idea is to gather relevant data and consider inter-linkages to arrive at a coherent insight which can be relayed to others in a coherent story to create momentum toward mutually desirable change.

To be able to communicate the model and outputs so people understand how dynamic systems change is an important part of the MM process. This is why time is spent with participants in the workshops and the model is built together to reflect their interests and concerns. Expert system dynamic modellers could produce a similar model in a shorter period of time but that is not the goal. However, due to the number of workshops being reduced from the ideal of seven or more, to three, this process was compromised and the model became more of an expert model developed by the SP2 team.

The system dynamics model which integrates many variables quickly becomes complex due to the number of relationships. Storytelling was considered by most of the participants to be a useful technique to communicate the model findings and show integration and connectedness to others. It was regarded by some as a means to move from ideology to logic.

[5] A number of different mapping systems exist at the detailed level (Google maps, LINZ, GNS, MED) but linking these is not one of the aims of the SP2 project.

While storytelling was regarded as a useful technique the post survey results showed that only three of the participants were interested in actually using the storytelling capacity to tell the story developed in the workshops to others. Implementation barriers therefore still need to be addressed.

## *3.7. Reflections*

In the pre-assessment report the following questions were set to reflect on when the workshops were completed. The questions and responses give an insight into the model progress.

***Did the model progress significantly from the preliminary model to the "final" scoping model after 3 workshops?***

Respondents were positive that the MM workshops helped structure thinking and discussion and the model progressed significantly over the three workshops (all respondents were positive (i.e., agree) to very positive (i.e., strongly agree)).

***What areas of the four well-beings were consistently included?***

Respondents reported that economic priorities were discussed more than the other well-beings and they saw this reflected in the model. Social and environmental issues were covered but the dialogue did not really focus on cultural concerns. A possible explanation is the workshops lacked diverse ethnic representation. The participants in the pre-assessment survey gave a low ranking to "Integrity of cultural values" which may have been a factor of the group composition. This could also be explained by the tendency to regard cultural and social well-beings as interconnected rather than separate, or, a lack of clarity as to whether cultural referred to the arts or issues related to ethnicity.

***Did the dominant areas covered in the model correspond with the areas identified in the questionnaire as priorities?***

The areas identified as priorities in the pre-workshop survey were included or not included in the model as follows:

1. Economic activity/ Jobs – well integrated into the model
2. Transport and Transport infrastructure – included as part of infrastructure but no detailed transport modelling included
3. Housing – integrated into the model
4. Population growth and location – Population change was incorporated but the specific location of population change was not as the MM is not spatial.
5. Community resilience – not included
6. Regional form/vision – this was included as "Relative attractiveness of the Wellington Region"
7. Citizen participation – not included

***What linkages are strongest and weakest?***

This will be the main topic of the interlinkages workshops to be held in April and June of 2012 to guide the development of the SDSS.

The sector which is "most" effected by other sectors is "Economics" (28 links coming in). All other sectors have only three incoming links. The sector with the most outgoing links is "Population and Households" (10 outgoing links), closely followed by the sector of "Natural Environment" (9 outgoing links). "Economics", "Government" and "External Factors" all have the least outgoing links (i.e., each has 6 outgoing links).

***Table 4: Incoming and outgoing links for each of the sectors included in the Wellington Regional Model***

| Sector | Incoming links | Outgoing links |
|---|---|---|
| Population and Households | 3 | 10 |
| Economics | 28 | 6 |
| Natural Environment | 3 | 9 |
| Government | 3 | 6 |
| External factors | | 6 |

***What was the role of data support/gathering? Is the scoping model predominantly qualitative or does it have merits as a quantitative simulation model?***

The model at the end of workshop three is quantitative. The model was populated with actual data obtained from Market Economics and/or Statistics New Zealand. When data was unavailable, "guestimates" were made based on the expert knowledge of participants and group discussions during the mediated modelling workshops. Time constraints restricted efforts to involve participants in providing data (trends).

# 4. CONCLUSION AND NEXT STEPS

In July 2011, the Wellington Region Genuine Progress Index (WR-GPI) which is a new approach to measuring the region's well-being was released to the public. The Wellington Region Genuine Progress Index framework provides four composite indices that report on the economic, social, cultural and environmental well-being of the region. For each well-being, indicators (number in brackets in Figure 11) have been established to measure the directional trend in genuine progress for people in the Wellington region.

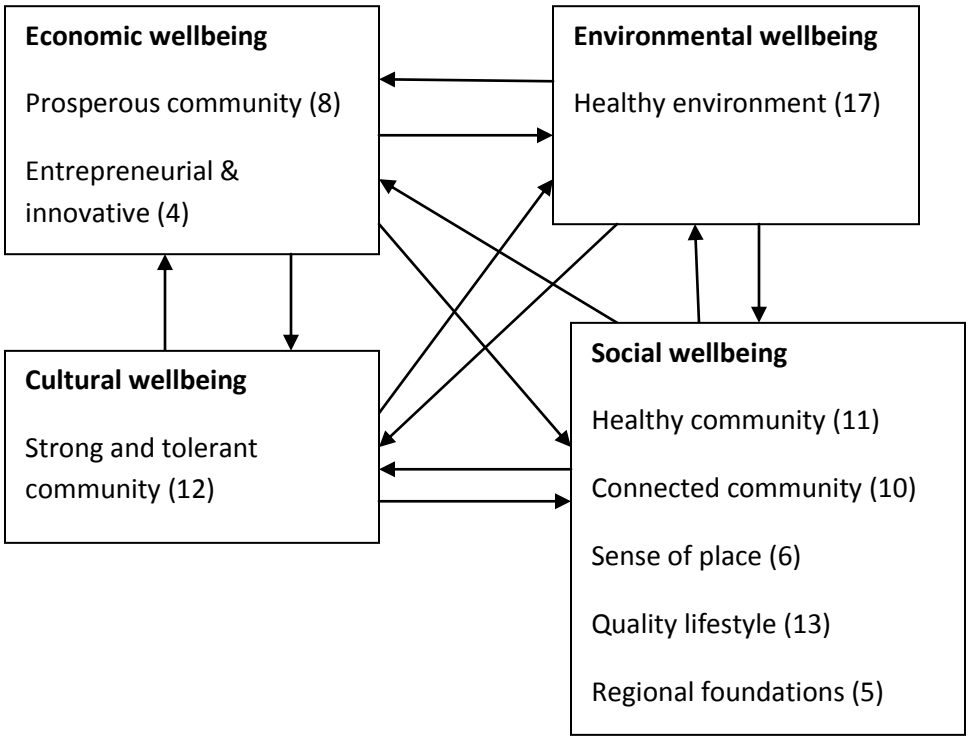



***Figure 11: WR-GPI Indictor Categories***

The GPI for the WR (WR-GPI) reports individually on the regions well-being in 4 key areas – economic, environmental, social and cultural using 86 indicators. For most indicators the desired direction of the trend to improve well-being in the GW region has been established. Comparing that direction with the indicator trend allows the community to assess whether well-being in the region is improving or declining. The interaction between indicators has not been explored as part of the WR-GPI though the scope for this is acknowledged. "The challenge in devising a framework for measuring well-being is to match the multiplicity and dynamism of what constitutes and contributes to peoples well-being with what actually gets measured (Durling, 2011, P.1). An acknowledged limitation of the WR-GPI is lack of understanding of how the indicators interact. "There is also interaction among all aspects of the framework, although we are far from knowing all the constituents and determinants of these interactions" (WR-GPI, P.9).

As a result of the mediated modelling workshops in Wellington there is a proposal to apply systems modelling to a common set of progress indicators to try and understand the interactions. Currently

indicators are selected to cover the four well-beings as shown in the boxes in Figure 11. A "dynamic GPI" (DGPI) would attempt to show the key relationships between indicators and how feedbacks between the indicators impact on outcomes overtime (the arrows in Figure 11). Genuine Progress Indicators in their present configuration report on what has happened in the past. A goal of a DGPI would be to run the model out into the future to better understand in an integrated way the likely impacts on the trends in the stocks and flows for the four capitals (built, ecological, human or social) that the indicator reports on. This would provide a more integrated picture of dynamics over time. The DGPI would build on the current system dynamics (MM) model for the Wellington Region which links economic, social and environmental well-beings – cultural aspects are not well integrated. Ideally the final output will be a DGPI system dynamics model that can be used by a number of organizations in the region as well as at different scales i.e.at district, city and regional levels?

The research question for producing a DGPI is:

*Does having a better understanding of the relationships between indictor categories allow stakeholders to have an increased understanding of policy interventions or policies required to move towards genuine progress?*

Additional questions are:

- *Is a DGPI a valid tool to track and communicate progress towards agreed outcomes in the economic, cultural, environmental and social sectors? Is it a meaningful/relevant model?*
- *Can a DGPI be used effectively (as an evidence-based planning tool) to understand the active dynamics between indicators within the four well-beings? Does use of a DGPI allow you to understand indicators better?*
- *Can you project into the future using the linked indicators and does this enhance understanding of where to intervene?*
- *What are the pros and cons of a dynamic versus static GPI? What are the reasons why you would or wouldn't utilise a DGPI?*

**Proposal**

A model that made the linkages between 86 indicators such as used in the WR-GPI would be a massive model. To build an integrated DGPI it would be necessary to reduce this number. Detail in the DGPI would, therefore, be traded for integration of the most important elements to inform possible changes

over time and identify leverage points. There are a multitude of organisations that have produced sets of indicators, detailed how they are measured and best implemented. Few of these have looked at the inter-relationships between indicators. The goal for the DGPI project is to take a selection of indictor categories (those identified as key) and link them together to see how one aspects links to another. As an example, for the indicator categories housing/education/employment/income:

> **Housing** choice/ issues mean students move from school to school -> this impacts on **education** achievement -> this impacts on ability to find work/**employment** -> which impacts on **income** -> impacts on **housing** choice/issues

The selected indicator set to be used would be determined based on methodology devised as part of the research. A possible method would be principal component analysis but others would also be investigated. The indicator sets that would be reviewed would include (but not be limited to) the following:

- NZ GPI
- NZahead report card
- The Draft Auckland Plan
- Working Towards Higher Living Standards for New Zealanders:2011
- Measuring New Zealand's Progress Using a Sustainable Development Approach:2008
- MARCO
- AnewNZ
- MfE indicator analysis
- Auckland Communities Foundation
- Wellington Region Genuine Progress Index

***Mediated Model for Wellington Region***

The Mediated modelling (MM) process undertaken in Wellington developed a system dynamics model with stakeholders to provide an integrated picture (from the stakeholder's perspective) of how key variables relate to each other in the Wellington region and how these interact overtime when time lags are taken into account. The SP2 project has scheduled further Mediated Modelling workshops and the plan is to do the MM2 workshops with a selected DGPI working group, incorporating participants from

the MM1 process interested in this topic. The proposed MM process for DGPI is to bring participants together to drill down to determine what they want to explore. This will provide the opportunity to progress thinking about the DGPI and what it can do, discuss the indicators selected and debate how they should best be interlinked. A simplified DGPI will be provided to the GPI Working Group to critique.

The GPI Working Group (part of mediated modelling (phase 2)) will be used to answer research questions such as:

a) Does the DGPI answer the questions that it has been built for well enough? What criteria should be used for measuring success? [Recognised as sufficient by eg uptake, stakeholder using]
b) Are those the right questions? (Yes/No). [Can they be answered without a spatial model?]

### Stakeholder Feedback on the DGPI Proposal

The DGPI was suggested as a topic for further exploration in the post mediated modelling (phase 1) workshop survey. All but one respondent thought this should be the recommended or accepted topic going forward. The participant who wasn't convinced doubted the WR-GPI could be refined sufficiently and agreement reached on what the best indicators to use would be if the number were reduced. Concern was also expressed that the system dynamics model while useful to indicate long term trends was not sensitive enough to reflect gradual change. Questions that need to be answered if the DGPI was to be pursued include: (i) would it be possible/necessary to have shorter timesteps for some measures if this was politically important? (ii) would it be possible to build a model able to show outputs in terms of the indicators chosen? (iii) Can indicators be projected and used to enhance understanding?

If a DGPI was to be progressed it was felt workshop participants need to align with the sectors included in the GPI (e.g. health and transport). There would also need to be a buy-in from those for whom the GPI is being developed (at both CEO/Councillor and Officer levels) and those working on the WR-GPI.

### Tentative steps and timeframe for DGPI development

1. Analyse indicator categories and indicators developed across a range of NZ organisations to determine the key indicators/indicator categories. Develop a methodology for selection of indicators/categories for the DGPI. Write up in a chapter (March-May)
2. Access datasets for the selected indicators (June/July)

3. Development of a prototype DGPI model ( Feb to June 2013)
4. Completion of 3 MM2 workshops in Wellington focused on refining the DGPI model with stakeholders (June – Dec 2013)
5. Publication of integrated MM1 and MM2 scoping model and related reports ( Sept 2015)

# Appendix A The workshops

## *Workshop 1 – 7 April 2011*

**Outline of the Day**

1. Participants introduced themselves and gave their interests in attending the workshops
2. The agenda and results from the pre workshop questionnaire were provided
3. Mediated Modelling and how it works was explained
4. The issues of concern for the region were discussed
5. The important 'stocks' or assets to be included in the model were discussed in small groups

**Pre Workshop Questionnaire Results**

External factors outside the region are important to consider as well as internally generated impacts. Participants were asked to rank the four well-beings (economic outcome, environmental sustainability, social impact on the community, integrity of cultural values) by relative importance. It was felt the low ranking of "Integrity of cultural values" could be explained by the fact that cultural and social are interconnected rather than separate; there was a lack of clarity as to whether cultural referred to the arts or issues related to ethnicity; and a diverse ethnic representation was missing from the workshop group.

The SP2 team explained that approaches had been made to iwi/Maori to attend but they were not available. Likewise environmental representation was low but we had not been able to find a suitable participant. Because there are only 3 workshops we have to proceed with the people we have here. The point was made that cities are about unplanned as well as planned actions and a spontaneous input should also be incorporated. The agent-based modelling component of Objective 2 (see below) and the ability to allow for elements of uncertainty in the Mediated Model are ways to compensate for this. There is also the option to continue workshops with different participant groups.

**Guidelines for the modelling workshops**

- Ideas belong to the group and we build on them
- People here are the right group
- Listen for possibilities and ask questions rather than judge
- Focus on what is good for all rather than interests of own organisation
- Consensus is not a requirement – can simulate different opinions with slide bars in model
- The model is not the sole objective – it is to support the dialogue
- System dynamics modelling is used for understanding not prediction

**Links between Mediated Modelling (MM) Workshops and the Spatial Decision Support System (SDSS)**

| Mediated Modelling (MM) | Spatial Decision Support System (SDSS) |
|---|---|
| The MM model being built as part of Objective 1 of the Sustainable Pathways 2 project is a systems dynamic model that uses participant knowledge to identify the key factors that need to be taken into account to link the 4 well-beings in the Wellington region. | The SDSS model being built as part of Objective 2 of the Sustainable Pathways 2 project is a large scale spatial model that links a number of existing models together. These include transport, population, economic, and landuse models. |
| The MM process aims to make linkages transparent, as perceived by the participants. | The existing models need to be linked together with feedback loops. MM scopes for the key models that need to be integrated and the best way to do this |
| The MM workshops provide the communication and understanding of what the model can do in a non-technical way. | The SDSS model is intended to be used in-house by council staff. |
| The MM model looks at changes overtime and how interventions can have unintended consequences due to feedback loops and time lags. | The SDSS model can be used to simulate perspectives from different organisations/agents to see what land use outcomes may look like overtime taking into account feedback loops |

**Scale of Model Operation**

The Mediated Model (MM) being constructed in the 3 workshops is at the regional scale and is not spatial. The SDSS model is being built at the regional scale at a 50x50m resolution. The view was expressed that a pixel or building level scale would be more appropriate and that the model should extend to the global level to capture external influences. A number of different mapping systems exist at the detailed level (Google maps, LINZ, GNS, MED) but linking these is not one of the aims of the SP2 project.

Scale is important for efficiency. The MM component of SP2 allows us to explore the scale that is most relevant to operate at and identify characteristics that will apply at all scales. No modelling scale will be perfect for all purposes.

**Systems Dynamics (SD) Modelling**

SD modelling identifies: (1) feedback loops, and (2) delays overtime which result in unintended consequences. These features make SD good for long term thinking. Stella is the SD package used in the workshops as it is the most intuitive of the SD software. It is not a statistical package that gives

probabilities and predictions. The objective for the workshop is to discuss issues impacting on the Wellington Region and what the interlinkages between these issues are. Stella uses 4 icons to interpret the conversation into a model.

Stella software can be accessed as a free run only version from **http://www.iseesystems.com/softwares/Player/iseePlayer.aspx**. This allows you to run the model but not save changes. A trial version is available free for 1 month. The SP2 research programme goal is for participants to be able to use Stella so anyone interested in using Stella please contact us.

**Disruptors**

Disruptors are catalysts for innovation, they unlock opportunities and create new on-going trends. The focus for SP2 is on the future not trying to explain the past, though it is accepted that past data does ground the model. It is difficult to predict disruptors and what they are, but important to be able to recognise them and their impact. In the past there have been disruptors such as:

- Vogel whose projects for rail and public works determined what NZ is like 150 years on. His focus on investment in infrastructure, especially railways, off a small population base encouraged regional growth. Build and they will come! The proliferation of rail led to small dairy factories and employment in rural areas. Vogel was outward looking for NZ building a nation that was a regional power in the Pacific and reliant on exports.
- WW1 and WW2
- The reforms of the 1980s
- The shift to the car after WW2. Urban design has been around the car not people. The car is a major contributor to the obesity problem
- Removal of protection for industry/agriculture
- Technological change. This drives infrastructure development, types of spatial use and distribution logistics. For example, the move from the mainframe to PCs and mobile phones have changed the way we operate
- Changes in fuel price – this provides uncertainty
- Broadband - small innovators can compete on the global market. The implication is that we might be able to reverse urbanisation with this technology.

**Leadership**

There is a tension between building a local economy and competing globally. SP2 is an opportunity for the local levels. Many systems are centralised for health reasons, such as water and sewage.

**Issues**

- Human scale – the urban environment needs to be at a scale that relates to humans rather than cars. Suburbs developed because they provided cheap housing but have resulted in congestion and obesity. The human scale needs to provide for biking and walking. Transport models don't have anything to do with humans.

- Health - is linked to infrastructure and a multiple of other factors. Has been improving in terms of the 'independent life expectancy' measure (i.e. the extent that people can live without assistance from others).
- Food - prices and food security is an increasing issue. While the price of food is increasing food is not as expensive as it was 20 years ago. People now choose to spend money on things other than food. In a global world food shocks can come from outside the system. NZ has food resources but prices paid are determined by global prices. Food shocks have the potential to reduce obesity and thereby increase well-being, as well as decrease overall living standards. Wellington's food security is being lost with loss of agricultural and horticultural land. At any one time there are 3 days of food in the city.
- Resilience - the issue is not localised self reliant communities versus the export model of international competitiveness but how to combine elements of both. We need to unlock the small scale within larger scale and realise both local and global scales are limited by the natural capital. A question is would NZ be a better provider to the world food supply if local resilience is working well? For food local resilience can be provided by growing food in the backyard and on rooftops. Loss of good agricultural land is the trade-off made for cheap housing. There is a casual loop as farmers are in the firing line because of environmental impacts but there are reservations about unrestricted conversion to urban land as agriculture land is natural capital that is not replaceable.
- Water quantity and quality - Water issues are spatially based in the Wellington Region. Different places have different needs and problems eg Kapiti, Waiararapa, Central Wellington. Good water quality is needed for healthy food, stock water and aqua-culture. Fonterra have set the standard for irrigation water close to drinking water standard so wastewater needs to be treated to a very high standard before it is an asset. There is a direct link between community well-being and the quality of water. For example, with the Ruamahunga River, iwi are concerned about using polluted water for baptisms, or if you live in a bay with poor water quality it reflects on the people who live there. People remove warning signs because they have a negative connotation. Communities see water quality as important but there is an overreliance on technology for water supply. Small communities cannot afford to pay for infrastructure. Pristine native bush is the best biofilter but in the 1990s areas restricted for water supply provision were opened up for recreation. Closing off has issues associated with possums and 1080. Opening up allows damage by hunters and recreational users. When native bush is accessible there is an increased sense of well-being so access is important from a public health point of view. It is the cultural and recreational benefits that make a place attractive to live.
- Pacific Islanders are driving population growth in NZ. Auckland has a young population base and is a hub for international rather than national migrants.

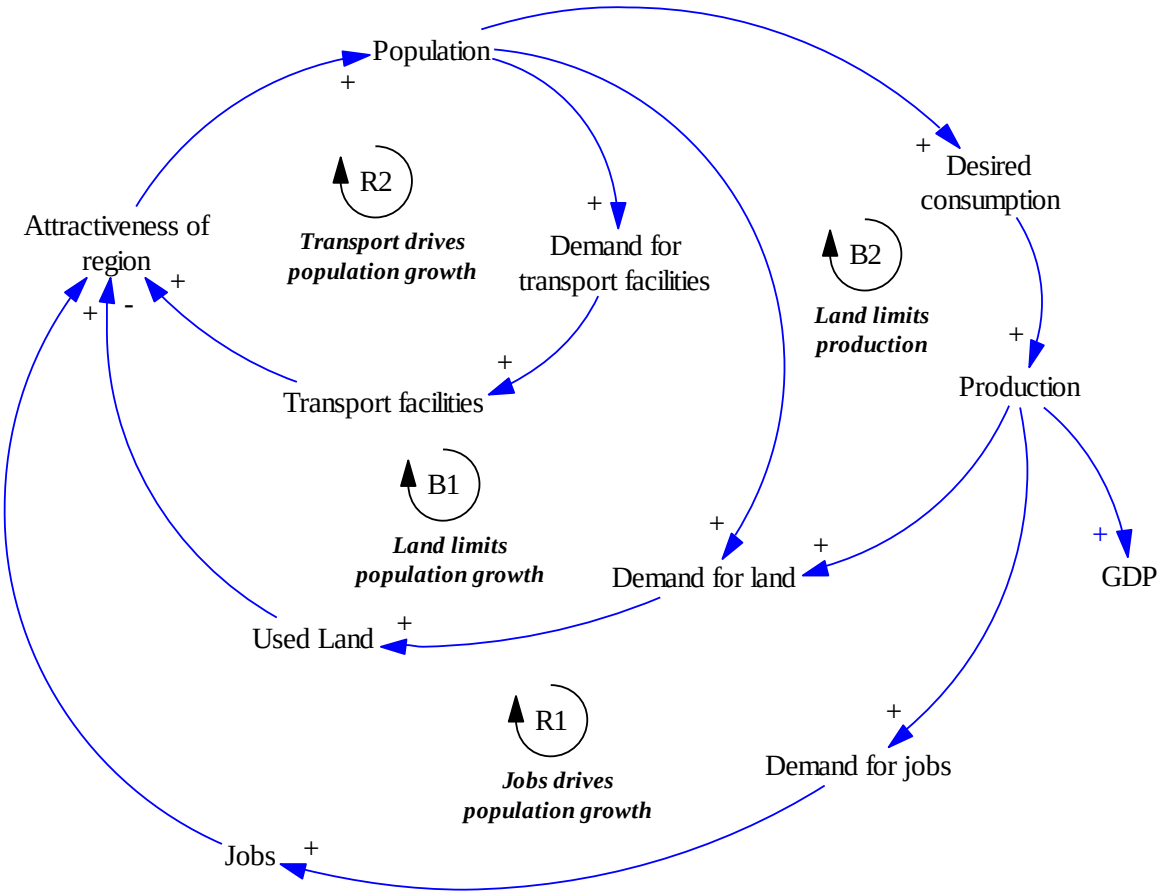
**Way forward**

The MM model was used as a tool for brain storming but moving forward we need a structure that can answer the questions we have. The MM model will allow us to anticipate outcomes not foreseen and

work out what the response might be. We can investigate putting new dynamics into the model to deal with issues that arise, for example, what impacts would permits for water trading have.

We need to take into account timeframes looking forward as well as the fact that stocks are powerful in the model. Positive feedback loops are important but even with positive feedback loops there are limits to success. If feedback loops are too successful this can cause negative impacts, such as making a place so attractive that the inflow of people causes loss of attractiveness from too many people. We want solutions where implications are understood.

**Casual Loop Diagram Presented**




Note: +/- moves in the same direction but is not necessarily a positive/negative.

**Key Discussion Points Raised**

1. GDP has a feedback loop – for example, if GDP goes down this can result in a recession with impacts.
2. There needs to be a GPI link like GDP in the system

3. Mainly economic drivers are included. Should not be advocating growth for growth's sake. The social and environmental sides are not covered.
4. Transport - diagram indicates increased population is good for region – eg public transport needs population. Population density can also make public transport work. Large numbers of people can detract from the environment. Should we be replacing transport with other structures?
5. Production does not have to lead to greater demand for land if it is not land intensive.

**Homework**

Provide 'what if' scenarios based on dialogue today and the model developed for the next Workshop on 19th May. Interested at looking at extremes as this is an opportunity the model provides not available in the real world.

## *Workshop 2 – 19 May 2011*

**Summary of Discussion at SP2 Meeting May 19th 2011 at Greater Wellington Regional Council**

Workshop 1 discussions were presented to participants summarised in a systems thinking model. This model will be further developed in workshop 2 and workshop 3. The objective of the model is to scope for change overtime to get a better idea on what is the right and wrong direction to be heading with regard to the four aspects of well-being. The mediated modelling is also scoping for critical linkages and feedbacks for the more data intensive spatial decision support system being developed for the Wellington region. The following general feedback was provided by participants on the model to date:

- It is complex
- Food has a very high status in the model at the 2nd workshop
- Transport not a big issue in the current model but is an issue for Wellington Region in reality
- The model covers what was discussed in Workshop 1

Specific comments on the model:

1. Potential immigrants are the stock of people that could come to the region.
2. The model needs more detailed demographics. Birthrate needs to be adjustable as it can be impacted by for example contraception and percentage of older mothers. Ethnicity also effects birthrate with Maori and Pacifica driving birthrates in NZ.
3. Food security (there is approximately 3 days food supply in region) is not determined by the ability to produce locally but more by the ability to pay international market prices. As WR becomes a more attractive place to live food availability declines as resources and space go to other activities. Food from the region is substituted by imported food. The price of food is not determined by local demand as local growers compete on an international market. International

drivers will determine food prices. To produce food the region will have to protect productive land and accept impacts on water quantity and quality. The model needs to link water quality in rivers to the health and well-being of people so this can be communicated to others. The Hutt Valley is built on best agricultural land in the region and how to reverse and/or stop building on high quality soils is an issue.

4. Land values are determined by urban expansion as well as informal impacts such as the film industry has had on land values in Miramar.
5. GDP is the sole determinant of 'attractiveness' in the model. This needs to be extended to cover a broader range of attractiveness factors.
6. Housing needs to link to overcrowding and health impacts. Cost and type of housing is the issue rather than supply. Apartments are the cheapest form of housing in Wellington but not popular.
7. Thinking in cubic metres is much better than square metres as this can allow for food production on roof gardens and balconies.
8. The model is not a disaster testing exercise. External factors are not drivers of the model but the impacts from these can be tested by the model.
9. The model uses available data and data ranges that can be adjusted up or down. It is a simplified version of reality and can be likened to a map of the London underground that can be used for communication. The intention is not to replicate the actual underground in all its complexity.

**Scenarios**

Between Workshop 1 and Workshop 2 participants were asked to submit scenarios for events likely to impact the Wellington region. For the scenarios provided causal loop diagrams were prepared. There were strong cross links between the scenarios provided. For example, housing and transport link to inequality and health, and infrastructure links to health and transport options such as biking/walking. The model is run to understand how things are interconnected and what happens when feedback loops and time lags are introduced. A goal of the workshops is to refine the evolving model and establish the "what-if" scenarios for the final model in August.

The scenarios were discussed by the group and the following comments made:

*Scenario 1: Population Decline and Increase in Low Income Households*

Loss of employment opportunities results in people leaving the region. **If those leaving are high paid, high skilled workers this could increase the number of low income households in the region.** Recent reduction in manufacturing opportunities in WR has resulted in people moving to Auckland, Australia and back to Europe with a subsequent loss of skilled people. Assumptions made regarding education need to be explicit as often it is not university degree but trades people leaving. Also, the loss of employment in Crown Research Institutes impacts on a range of spin-off industries. The mobility assumption needs to be checked. The assumption on population decline is that people leaving are not the low income families. Low income families are actually highly mobile as they rent rather than own their homes.

*Scenario 2: Oil Price Shock*

Fossil fuel availability will fluctuate in the future which will introduce more unpredictability and issues around fuel security which will force looking for alternatives. Government infrastructure funding predominantly goes to the road network. This may reflect short term thinking rather than what is best for the long term. A different mode of thinking is needed to get people to use public transport and the same applies for high density living. For both to be effective requires a critical mass of people. While more dense urban living may be needed if fuel prices increase urban consolidation is not popular in NZ. The public is resistant to high density living with lack of amenity control a common reason given. Therefore, high quality urban design that considers how amenity is impacted is essential. Past changes to the RMA allowed growth in inner city living but not planning at the large urban block scale.

The relationship between live-work is important. In European cities you can have mixed use within a courtyard block. As a result of petrol prices it may be logical to relocate places of work. Instead of providing public transport allow work closer to residential living. This may impact on the benefits associated with agglomeration for business. As there are time delays between costs and benefits incentives need to be provided to bring about change.

Is the private cars the right thing to have in the model as kilometres travelled is the important aspect? Currently the only feedback loops are for vehicles but there needs to be links with the rest of the economy, food and inequality.

*Scenario 3: Urban form and Innovation*

In Groningen (The Netherlands) there was no demand for a certain type of mixed use housing. A development was built by a Public Private Partnership and within 10 years demand was generated. A drop in the traditional industrial base provides an opportunity to unlock a new type of industrial capacity such as GNS and IRL (which are CRIs) based in Lower Hutt.

Government seed funding has to be linked into a source. This will need to come from somewhere such as increased tax take. It is questionable as to whether government input achieves the desired results. Agricultural productivity has increased since the government withdrew. Funding sources should be wider than central government. There needs to be a feedback loop that stimulates research and development and investment to unlock funding.

Are there physical limitations or shocks such as earthquake risks that need to be incorporated in the model?

*Scenario 4: Health*

Health will be an issue by 2035 when the baby boomers are elderly. Inequality should really be low income. Obesity was considered to be related to levels of income. Inequality impacts on both high and low incomes levels and in NZ relate to ethnicity as much as income. High income Maori have poor health. The Deprivation Index maps show inequality spatially. The crudest measure of inequality is life expectancy. We should be aiming to narrow the inequity gap over the next 40 years. What needs to come out of the model is the impact changes will have on inequality.

**What Makes Wellington Attractive**

- Education which provides job opportunities
- GDP/person or Income/person
- Compact city which is accessible, has a core centre (which provides a good heart), a functioning central centre with jobs in one place. This allows efficiencies eg public transport
- Housing choice
- Intellectual hub (provider of education)
- Topography of central city – fosters residential communities
- Sense of community
- Robust/vibrant regional economy
- Public housing in centre of city
- Relative attractiveness compared to other centres
- Knowledge industry that attracts students to Wellington and allows engineering companies to export knowledge
- Trade deals with China allow skills and knowledge to be exports
- Lots of manufacturing in the region but it is a different type of manufacturing now

**What Makes Wellington Unattractive**: The region has the highest level of inequality in New Zealand.

**Summary of Workshop 2 'what if' scenarios to be tested by the model in Workshop 3 to see what stories are told:**

1. What if the population changes by 10% (up or down) by 2020 then what happens to "access" and "inequality"?

   Note: *Access* was defined as able to source education, health services, jobs etc. *Inequality* is equated with low income, low relative income, low life expectancy. Inequality was defined by participants as a lack of access and inability to achieve potential. It was decided to use low income rather than inequality as it is more measurable.

2. What if the relative income per person in WR changes by 10% (up or down)? How does this impact on the relative attractiveness of the WR?

   Note: *Attractiveness* is related to: housing choice and cost, sense of community, arts and culture, natural areas, compact city, robust economy, robust vibrant city centre, walkability of the central city area, commuting time (what if the travel time per car, bike or walking changes by 50% up or down? )

3. What if WR focussed on innovative niches (digital industries and comparative advantages) then what happens to resilience?

Note: What is resilience?

4. What happens to WR attractiveness if skilled labour does stays on average between 1 and 40 years?

   Note: Is the average length of time that skilled labour stays in the WR an appropriate indicator and how would such an indicator influence WR's attractiveness?

5. What if 50% more or less kilometres need to be travelled to deliver goods and get to workplaces how does this impact on inequality and attractiveness?

   Note: Wellington city service workers live in the Hutt where there is more affordable housing and good public transport makes this possible.

**What if scenarios for the SDSS model**

1. What are the potential impacts on transport systems from climate change and sea level rise?
2. What if WR develops a compact central city?
3. What if WR develops a multi-nodal region?

**Conclusion of Meeting**

The general agreement was we would not set up to do simulation of the final model on individual computers at the next workshop to be held on August 18th

## *Workshop 3 – 18 August 2011*

**Summary of Mediated Modelling Workshop 3 Discussion 18 October, 2011**

**Workshop Goals**

1. To show the model that has been produced and how it can be used
2. Model evaluation and comparing wish-list with model capabilities
3. Decide future options for utilising mediated modelling (MM) to keep the dialogue on complex decisions integrated
4. Findings and recommendations from the 3 Workshops held

**Scenarios provided**

The strength of the simulation model comes from users in different organisations using the same structure when telling their story. To show the simulation model and how it could be used two different scenarios were presented using story-telling. These were: (1 ) If the population increases or decreases by 10% what happens to inequality? (2) If the income for the Wellington region increases or decreases relative to other parts of New Zealand what happens to the region's attractiveness?

**Mediated Model Evaluation and Comments from Participants on Story-telling**

1. The assumptions incorporated in the model were discussed and considered acceptable.
2. Urban form, transport, health, food resilience are missing. Other than transport these were part of the MM dialogue.
    a. We can add in transport BUT we need a discussion on the goals of public versus private transport before this is done. An alternative is to change the model and then have the discussion. It is possible to include time spent in traffic as a slider for regional attractiveness. This will feed into the need for new roads. Transport in Wellington has national as well as local/regional implications.
    b. For food resilience could have an inventory of food/goods which can be increased to provide more resilience.
    c. The wider impacts of urban form were discussed but how this can be incorporated in the simulation model is not obvious.
3. At the start of the MM process participants had set views on what was important or not important. Now we need to test using the simulation model to see whether the views we brought along (for example the importance of growth) are actually right.
4. Unless there is buy-in from local government, people will look at the simulation model and think "ok, that's very nice" and continue on as usual. What is needed is a policy question written up and presented using the model to support the change in thinking required.
5. Planners as agents of change need to be concerned with what can be changed and where local government leverage points are. There are many things in the model that a district council does not have any influence on (eg immigration). There is a scale issue to consider – central govt -> local govt -> business. How to operate across scales to achieve change is a topic for the SP2 project research.
6. Storytelling is a useful technique to explain model findings and show integration and connectedness. Story telling is a way to move from ideology to logic.

**Model evaluation and comparing wish-list with model capabilities based on Model simulation**

a) Is the model at the right level or is more depth or breadth required?

- Drilling down is what generally tends to happen rather than looking across, eg transport models are detailed but not linked. Need broad level to answer questions but depth to support answers.
- Some people need the detail (numbers) to make a model plausible.
- With the broader vs deeper question it is hard to know what the impact is on the model. Adding age cohorts into the model will impact on outcomes.

- Often don't know something is important till added. The purpose of the MM discussion is to determine what is important and to decide how deep to go.
- Regardless of whether deeper or broader still need to be able to communicate the model and outputs so people understand how the system changes. Storytelling was useful.
- Only relevant variables that drive the system need to be included. For example, birth rate by type of worker is less important than ethnicity.
- Timeframes are important. For example, if growth increases the need for specific skills the education process takes time.

b) Are scenarios useful?
- Scenarios are an enhancement to long term planning generally provided at the end of the planning process.
- Economic development scenarios need to be region wide. Don't want 10 different scenarios for GW.
- Some participants felt their organisation could not do scenarios on their own due to lack of capacity. Getting the wider picture from workshops such as the MM workshops was good due to bias within organisations. Both the collective view and the local view are worth having.
- Scenarios would be a way to test policy. For example, the current business growth strategy is expansion not retention of business and is this best?

c) Mediated modelling experience
- The objective is to have all participants able to tell the same story using the model though the starting point might be different for each individual. What matters most is revealing issues. Even if not 100% right modelling can raise issues to be considered/debated.
- In response to the question "if we had taken a slower approach would there be more 'ownership' of the model?" the response was the need to "own" the model was not shared by everyone and the speed was felt to be about right due to the time commitment.
- Phase 2 of SP2 project is how to inform people. Who is going to use the MM decision support tool going forward? Gaps in the MM process include who is the audience (for who are we doing this) and how do you communicate the model to them?

**Sensitivities in the model and feedback on the "gap analysis between desired and actual"**

The desired versus actual way of thinking provides better understanding of the horizons we are working at and when interventions are going to result in change. The simulation model can be used to look at when and where interventions should take place. Small groups discussed whether the 'desired' versus 'actual' is a helpful way of thinking about an issue and noted the following.

1. When to intervene is something people were interested in finding out from the model. The desired versus actual type of thinking gives an understanding of the time horizon we are working with which helps determine the intervention (leverage) points. Issues can be relative in

time, to other places, or place based (e.g. NZ flora and fauna is highly adapted to clean conditions). Closing the gap can depend on relativity with other places, science and marketing efforts.

2. When there is a gap between reality and perception (e.g. NZ's clean green image) it is important that interventions are directed at the real state not the perceived state.
3. Using the desired versus actual approach with the simulation model provides the opportunity to see the down-side of decisions.
4. It is often difficult to determine what the desired long term outcome should be. With land use the pattern is to go for quick wins rather than long term protection. However, is protecting soils for agriculture rather than an alternative land use the desired outcome?
5. If what we anticipate will happen is taking place what are the required interventions and what monitoring should be put in place? Important to have this type of thinking embedded in decision-making.

**Future Options for Utilising MM**

For the three introductory workshops for GW (Greater Wellington Regional Council) choose not to address a specific issue and to bring a wide group together. Now you have had experience with MM how do we deploy this tool into the future? Suggestions:

**Health Option**

- From a public health point of view it is a struggle to get across that health is a system (4 well-beings). Public health participants would like a tool able to do this. For last 20 years have tried to show you cannot solve health problems in the health sector. Conversations about the system and connections with other decision-makers are important. Would like to increase these connections into additional spheres of decision-making. Health participants would like a tool to help communicate and influence decisions. Such a tool would need a level of credibility such as the ability to predict what happens now from 10 years back.
- For long term health improvements investment in health for first 2 years is much more important than in final years of life.
- Health sector cannot cope with the growth 85+ age group in next years. Local government can influence outcomes by actions such as changing district plans to allow the elderly to be independent in homes on the flat.
- Drilling down to look at health would be good as this links with the Genuine Progress Indicator (GPI). Would it be possible to link the GPI working group with the MM? Need a dynamic framework with more systems thinking and integrating health. This would provide a mechanism for GW to have an advocacy role for health
- A model that shows the health benefits of different transport options would be useful to have alongside the transport model. Transport needs to be managed from the demand side so people do not have to travel so far. Currently transport modelling is related to travel to work rather than other activities which account for most of the distance travelled. Ageing population need to be linked with transport.

- The current pattern of energy use projected into the future will result in big increase in inequality according to a PCE report and this will impact on health.
    a. If health and transport is to be the focus going forward do we need to involve wider groups? We need guidance on where we can add the most value going forward.
    b. As the SDSS does not have a health component might be good to have health in simulation model.

**Others Options**

- Currently Grow Wellington is driven by export growth rather than filling office space. Should the focus be on retaining/growing existing business or attracting new business?
    a. A model is only as good as the data, assumptions and the way has been constructed so first would need to determine if the simulation model is suited to this use.
- Spatial planning is the new buzz word. If GW needs a spatial plan can the modelling be used and filter down into the District Plan? The Auckland Spatial Plan was initially tasked with looking ahead. There is now interest in connectivity.
- Irrigation project in Wairarapa is a possibility. Freshwater issues need to be connected eg irrigation, natural capital, health, economic development.

**What the next steps are for SP2**

The SP2 project has 4 years to go and participants were asked where they would like to see the project heading in this time. While some participants recognised the value of having a model to run to understand the underlying structure of the system better no firm agreement was reached.

The following points are from the group activity report back and discussion on future work areas:

1. Need a clear practical application for Wellington. Statistics NZ are doing sustainable development reporting at the national level which is similar to the Genuine Progress Indicator (GPI) approach. Can we use the MM tool box with the indicators already developed? Can the simulation model show what the key relationships are? Can the simulation model take the GPI indicators for the Wellington region and show the interrelationships between those indicators. From there is it possible to identify key touch points where GW can make most effective (for all wellbeings) intervention. Such a model bringing all the well-beings together would have a much bigger impact and potentially more use for decision-support.
2. The common use of indicators is to report past events. Ideally we want indicators that can help us understand future possibilities. Therefore indicators need to link to impacts in a dynamic way.
3. How to place the simulation model into a GPI framework would be a good development. Could use a GPI lens to cluster and interlink indicators in the simulation model to see what impacts on each indicator. Would then be able to work out the GPI leverage points and where can they best be changed.
4. Buy-in needs to come from people who use the simulation model at a regional level. Model needs to be upper level so that at a district level all are doing integrated planning. The modelling can compare regional and national patterns to see how variables interact. What points are

controlled at a national level and what is controlled at the local level? What level is the simulation model most appropriate for: national or regional? The SP2 team is keen to include this when planning beyond the 3 workshops.

5. Predicting the future is impossible but the model could be run when key decisions need to be made involving DHB, WCC, GW to look at future in a systematic way. Currently rely on gut-feel or ideology.
6. Model could be used for next round of LTP in 3 years time. Looking at the prioritisation of a specific project in Annual Plan could be a good use of the decision support tools.
7. Participants recognised the need to refine the model by using it and also build capacity to use the model at the same time.
8. Apply model to a case study, ideally where a traditional cost/benefit analysis or environmental impact assessment has already been undertaken. This should highlight the benefit of a broader more holistic approach. As an example, local councils could use the model to look at issues in an integrated way for growth management.
9. Working with individuals or small groups might be the best option going forward in Phase 2 of SP2.
10. Use the simulation model to support a planning process that goes beyond short term funding strategies and quick wins by showing the longer term implications of decisions based on a better understanding of under lying system.
11. Potential work programme for SP2 from participants:
    a. Now to March 2012 – develop current model plus integrate transport and health
    b. March/ April 2012 – GPI linkages.
    c. Model communication.

**Other information the SP2 team wanted to find out about**

If we document the model and data trends, write a post-report and ask for feedback how can this best be used? The final report would need to be endorsed by participants to have credibility. The report would need to document the model limitations as well as how it was developed. Would a video or automated powerpoint communicate better than a report?

With MM different groups of participants end up with different models. Do we continue with this group or bring together new participants for future work?

Workshop Action Points

- Post workshop surveys
- Post workshop assessment report
  Model need to be communicated effectively

# Appendix B Post-survey Analysis and Interviews

Of the 15 participants surveyed and interviewed before the workshops (pre-survey), nine attended the last workshop and eight completed a post-workshop survey by phone.

The pre-survey was in part to establish a topic to explore using the MM approach. The post-survey sought to understand if individual participants thought their topic was sufficiently addressed, evaluate the use of MM, and establish the extent to which progress was made on their topic during the joint discussions.

The post-survey first summarized: 1) the issue of concern 2) the causes of that issue of concern, and 3) the implications of the issue of concern, as previously outlined by the participant in the Pre-survey.

1. After a reminder of their original issue of concern, the participants were asked to indicate their strength of agreement (on a five-point likert-scale from “strongly disagree” to “strongly agree”) for a number of statements related to their issue.

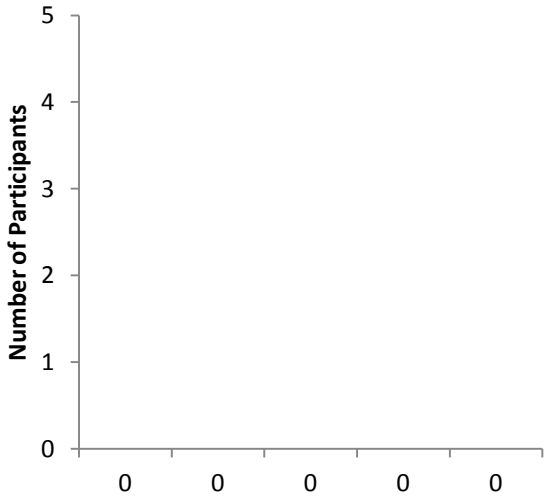



*Figure 12: My issue was addressed during the workshops*

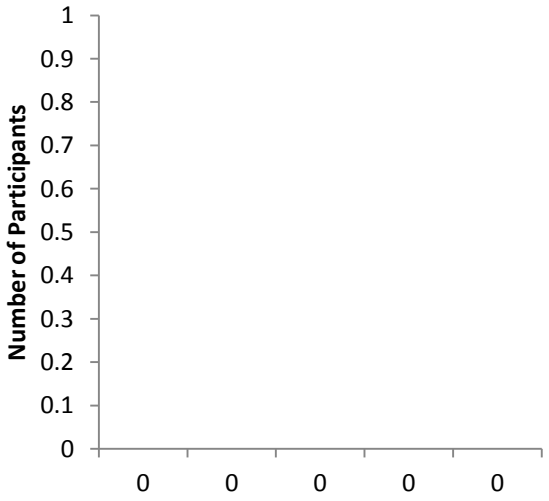



*Figure 13: My issue was part of the integrated picture that has emerged through the workshops*

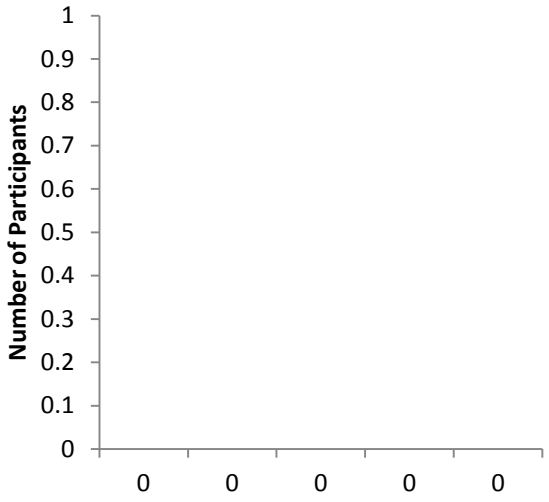



***Figure 14: My issue has been modified through the mediated modelling workshops.***

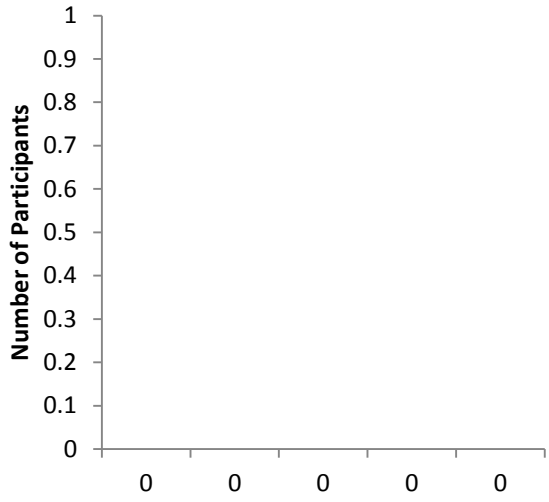



***Figure 15: My issue can benefit from an extended mediated modelling process.***

2. After the mediated modelling workshops and based on the **actual** participants do you perceive that within this group there is currently **consensus** on:

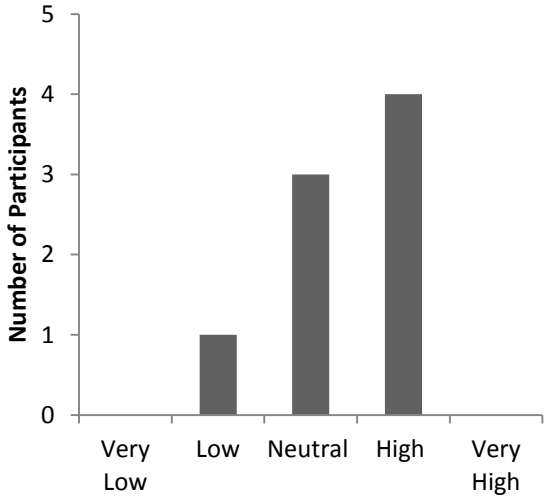



***Figure 16: An appropriate topic for the Wellington Region***

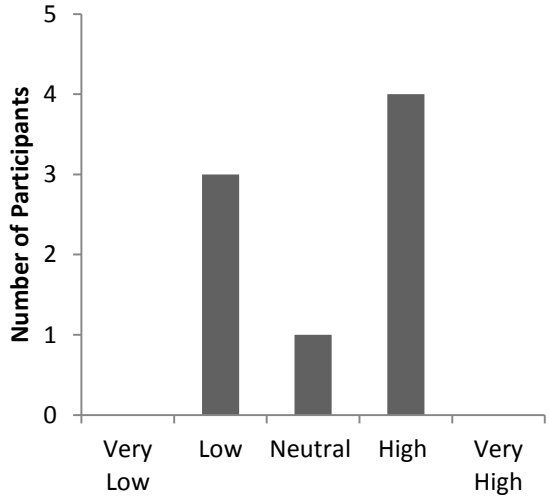



***Figure 17: The long term goal/vision for the Wellington Region.***

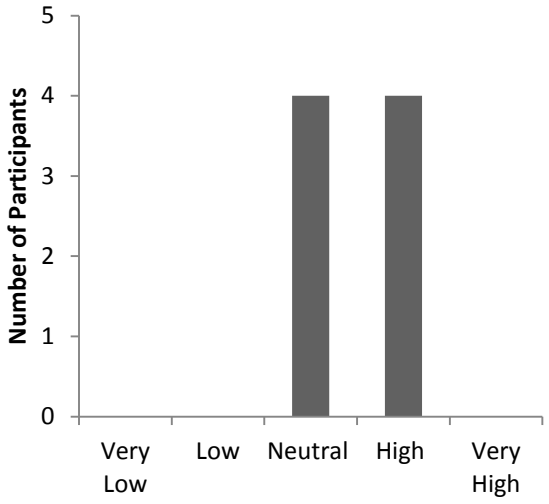



***Figure 18: The implementation process toward future goals/vision for the Wellington Region.***

3. Reflecting on the discussion during the mediated modelling workshops, please rank the relative importance of the 4 aspects of well-being for the stakeholder group you represent. Rank in order of priority for your stakeholder group from 1(highest) to 4 (lowest):

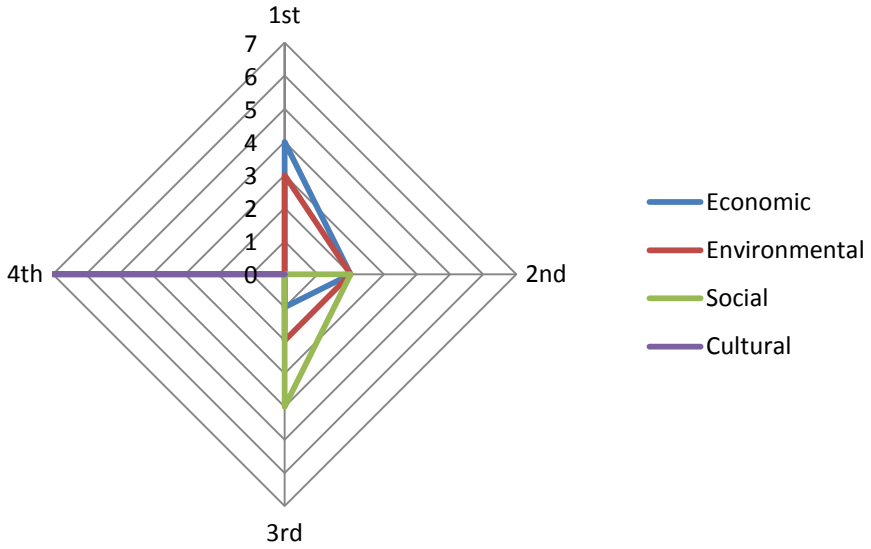



***Figure 19: Reflecting on the discussion during the mediated modelling workshops, please rank the relative importance of the 4 aspects of well-being for the stakeholder group you represent. Rank in order of priority for your stakeholder group***

4. Please rank the relative importance by which each of the 4 aspects of well-being was discussed in the mediated modelling workshops. Rank in order of priority from 1(highest) to 4 (lowest):

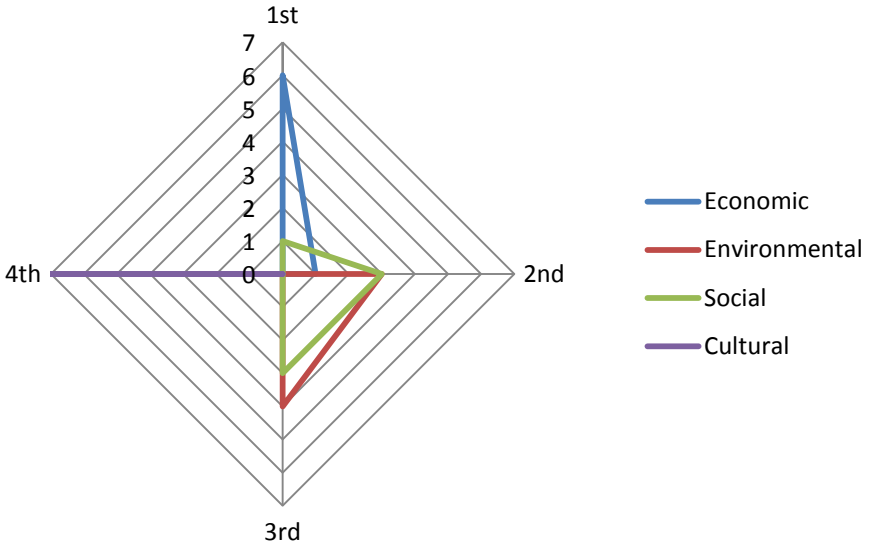



***Figure 20: Please rank the relative importance by which each of the 4 aspects of well-being was discussed in the mediate modelling workshops***

5. Reflecting on the **actual** workshop participants, how do you think the group rated overall in terms of the following criteria (Please mark you answer with an "x")?

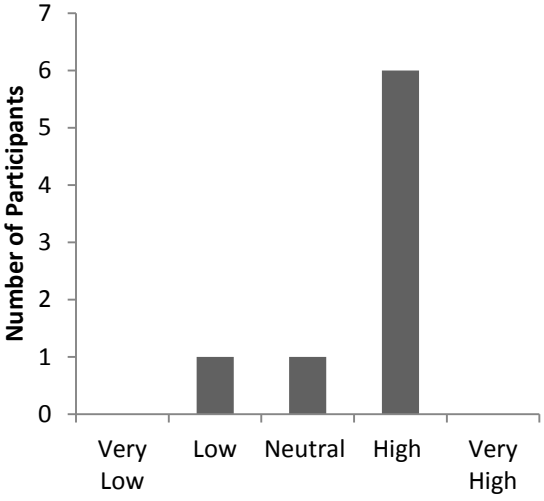



***Figure 21: Inclusiveness: i.e. the level of inclusiveness of different perspectives***

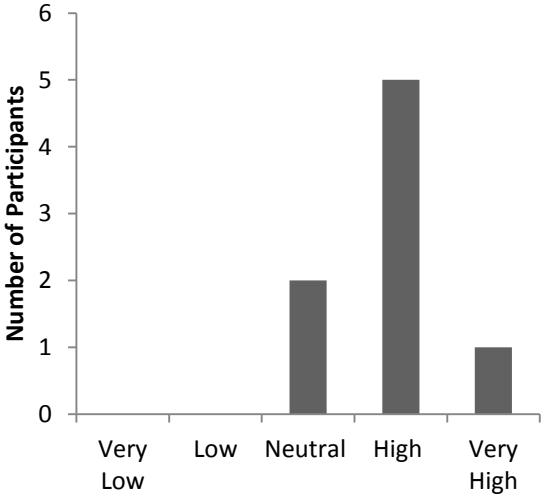



***Figure 22: Long Term Time Preference: i.e. a strategic, long term emphasis***

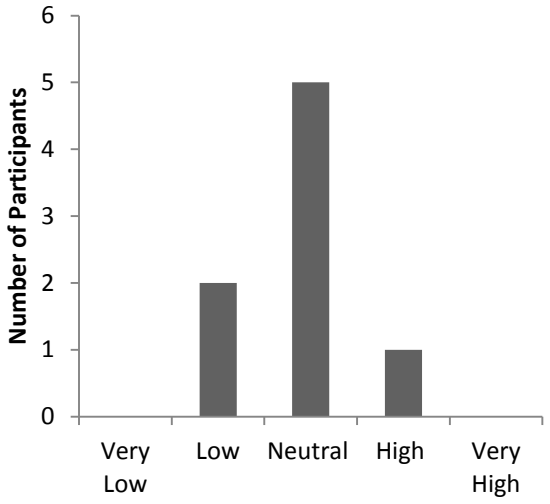



***Figure 23: Leadership: i.e. the ideas developed in this group will be implemented***

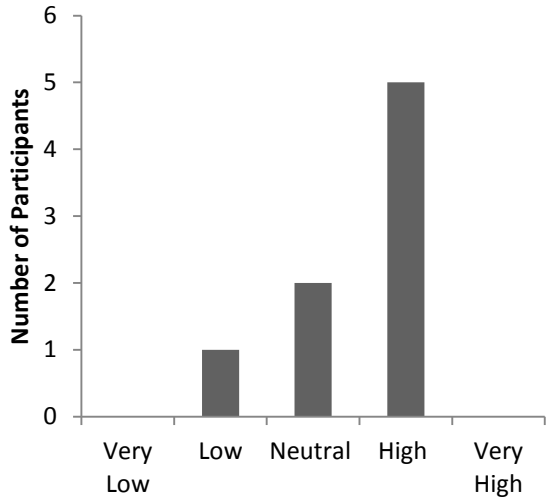



***Figure 24: Creativity: i.e. this group developed innovative ideas***

6. With how many of the participants do you intend to interact on a regular basis in the future?

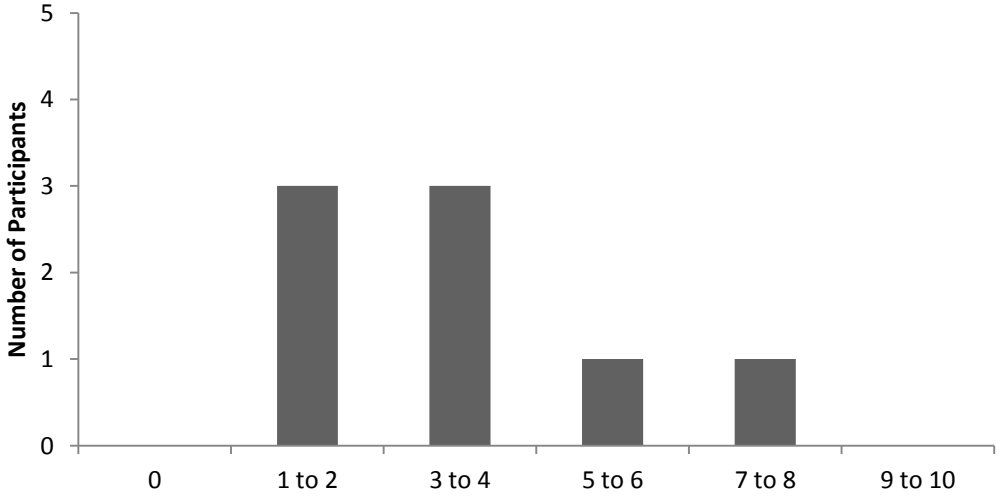



***Figure 25: With how many of the participants do you intend to interact on a regular basis in the future?***

7. Please mark with an "x" the answer that best indicates your agreement or disagreement with each of the following statements related to the **mediated modelling process** in which you were involved.

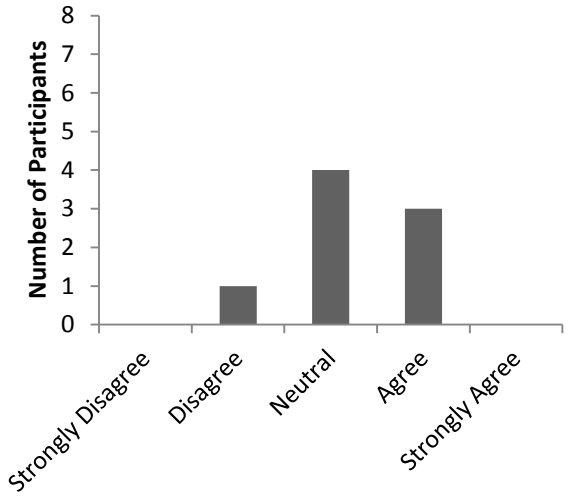



***Figure 26: My expectations about the workshops were met***

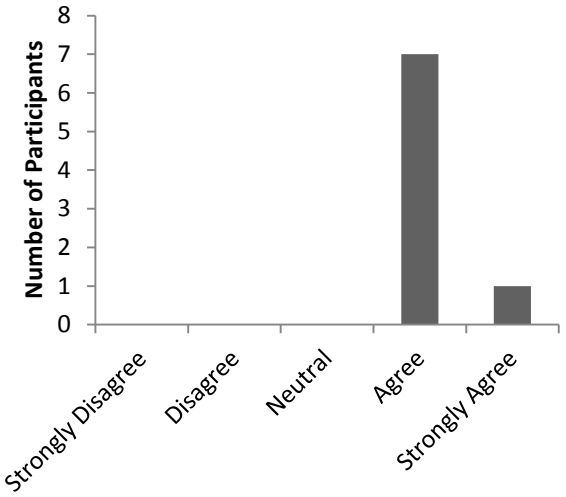



***Figure 27: The mediated modelling workshops helped in structuring the thinking***

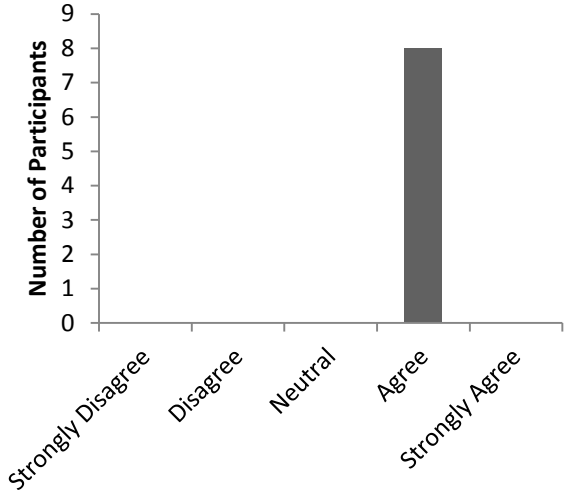



***Figure 28: The mediated modelling workshops helped in structuring the discussion***

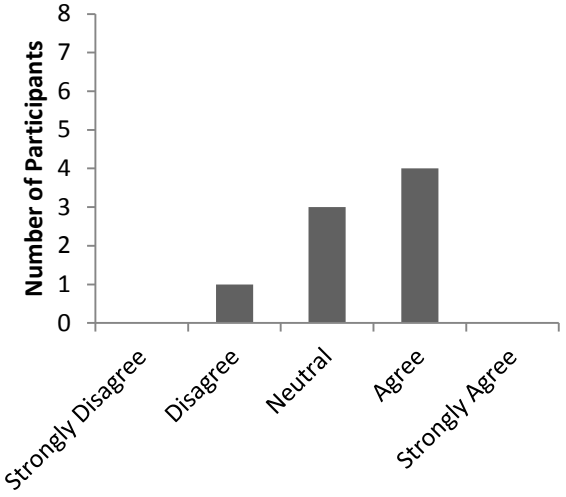



***Figure 29: I discovered more linkages with other sectors and stakeholders than before the workshops***

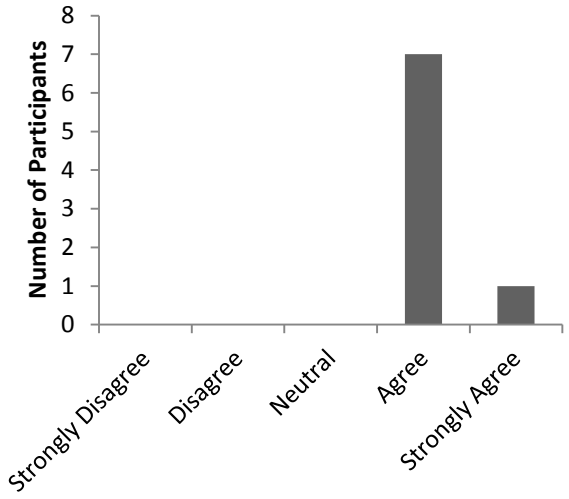



***Figure 30: The model progressed significantly over the three workshops***

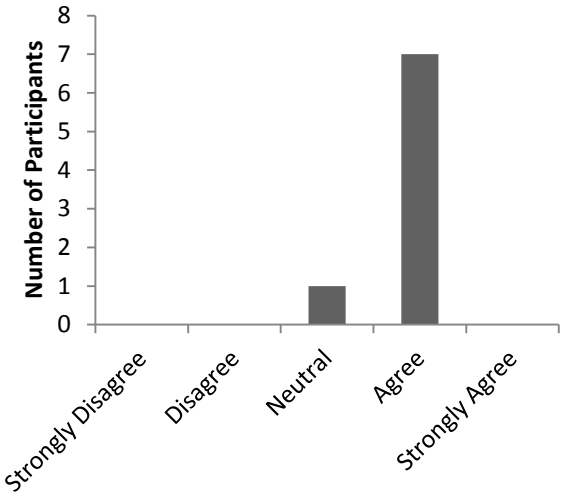



***Figure 31: My concerns were addressed during the dialogue at mediated modelling workshops***

8. Please mark with an "x" the answer that best indicates how much you agree or disagree with each of the following statements related to the final version of the **causal loop diagram**.

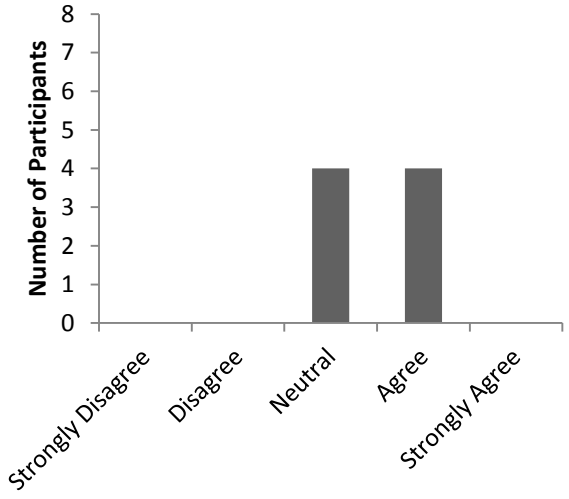



***Figure 32: The causal loop diagram represents well the problem the group set out to investigate***

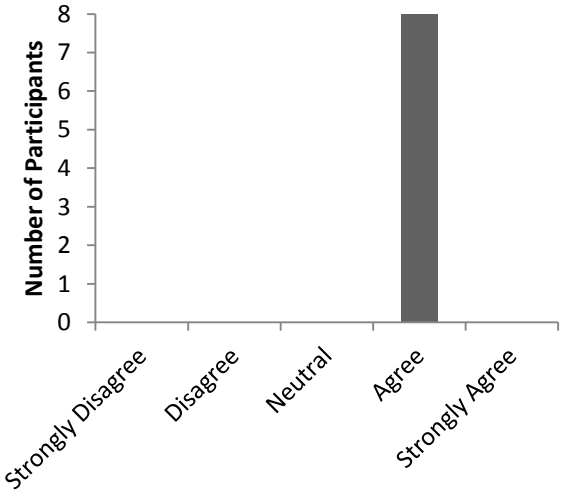



***Figure 33: This causal loop diagram is a good representation of the group discussions***

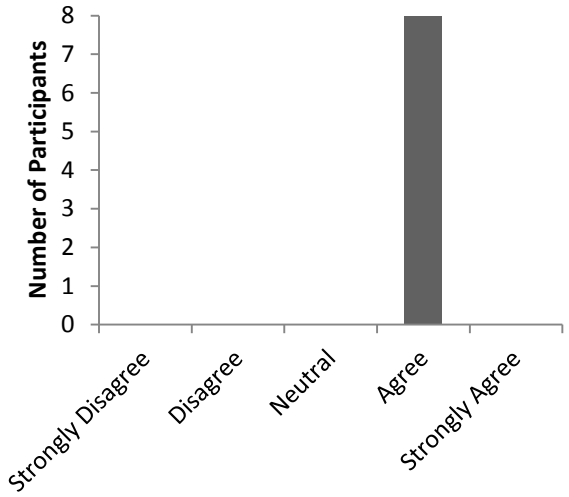



***Figure 34: I contributed to the design of this causal loop diagram.***

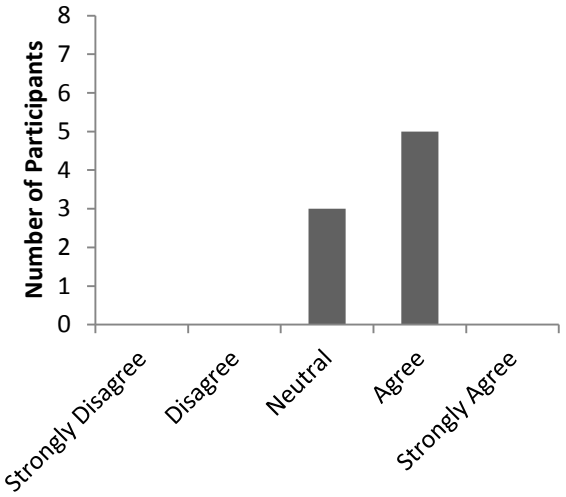



***Figure 35: This causal loop diagram is of enough interest to show to others***

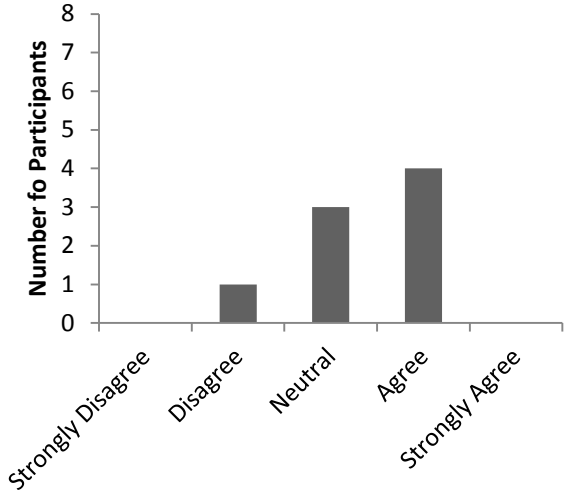



***Figure 36: This causal loop diagram is a helpful tool for me in communicating problems facing the Wellington Region to others***

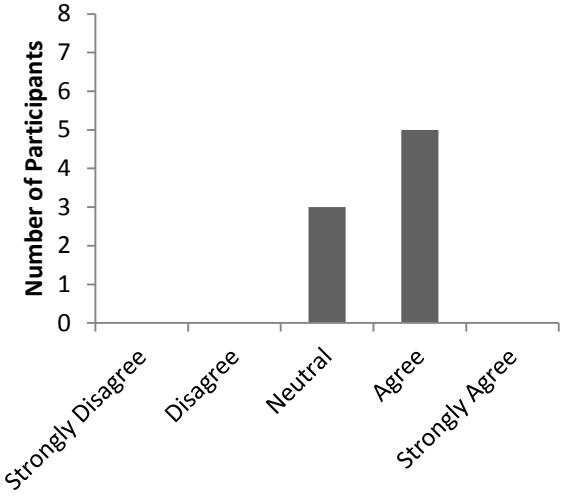



***Figure 37: It is useful to continue developing the causal loop diagram***

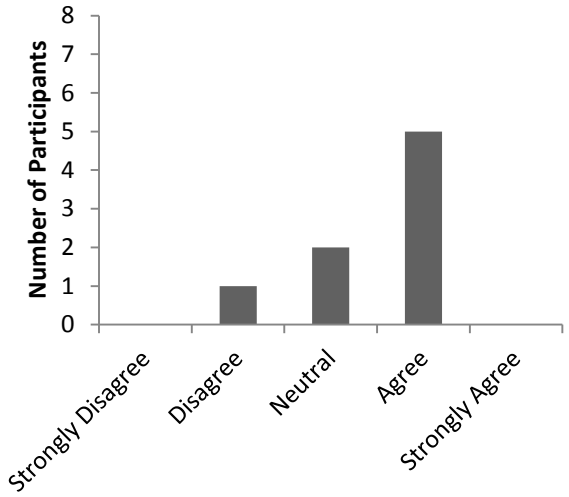



***Figure 38: I will explain this causal loop diagram to others***

9. **Storytelling** was used in the last workshop to guide you through the final version of the causal loop diagram. Please mark with an "x" the answer that best indicates how much you agree or disagree with each of the following statements related to storytelling.

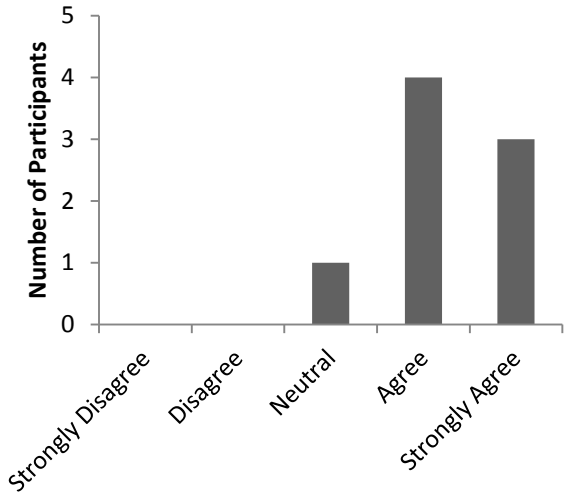



***Figure 39: I could follow the stories that were presented to me during the workshops***

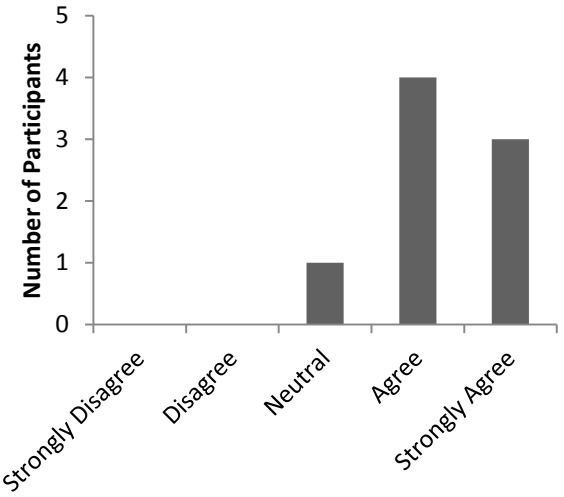



***Figure 40: Storytelling helped me understand the causal loop diagram***

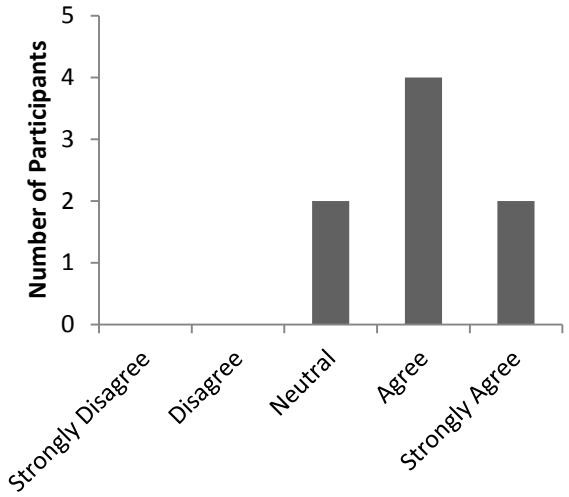



***Figure 41: Storytelling is a helpful tool for me in communicating problems facing the Wellington Region to others***

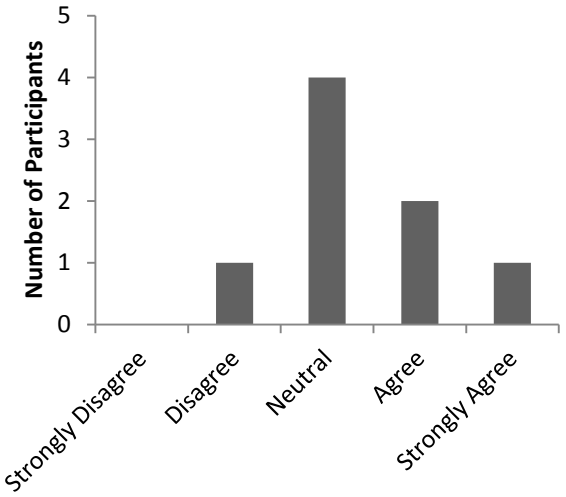



***Figure 42: I intend to tell the developed story to others***

10. A **STELLA-model** was presented at the last workshop. Please mark with an "x" the answer that best indicates how much you agree or disagree with each of the following statements related to this STELLA-model.

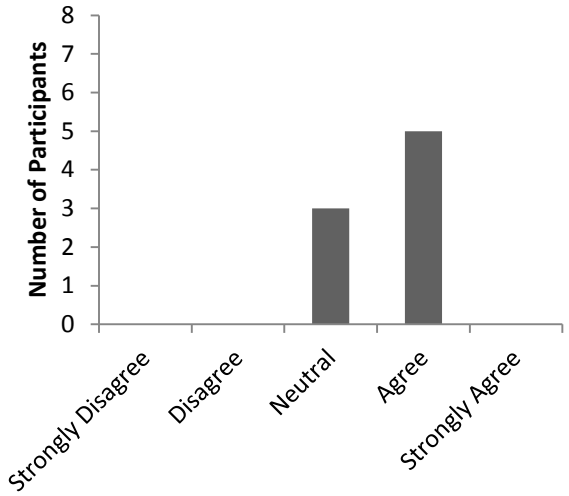



***Figure 43: The model addresses the problems identified during the workshops***

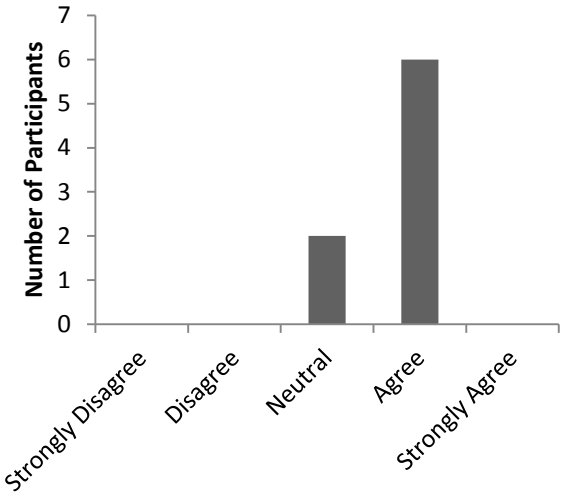



***Figure 44: The model behaved logically when running scenarios***

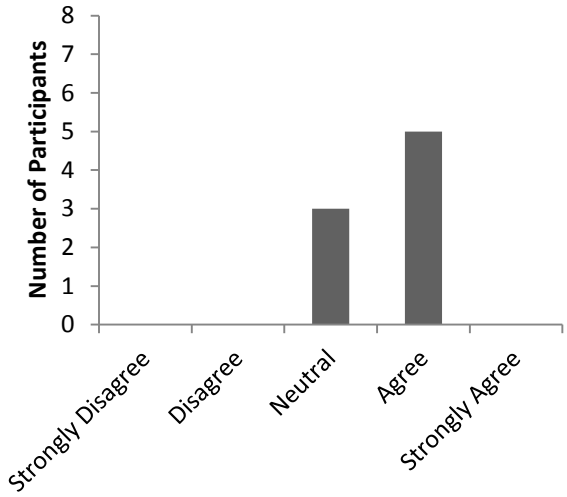



***Figure 45: I have faith in the results of the simulation model***

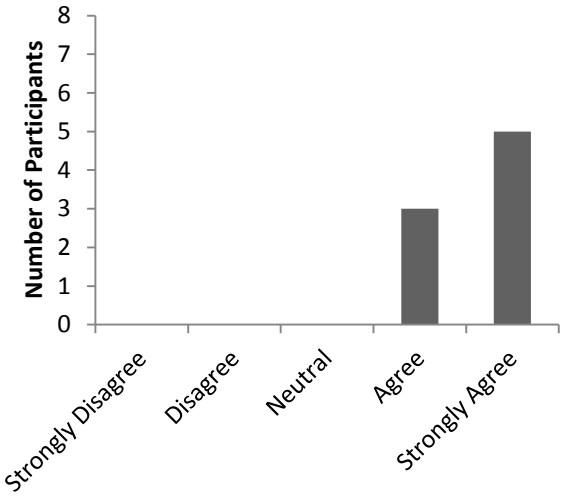



***Figure 46: The model is a relevant representation of the current dynamics of the Wellington Region***

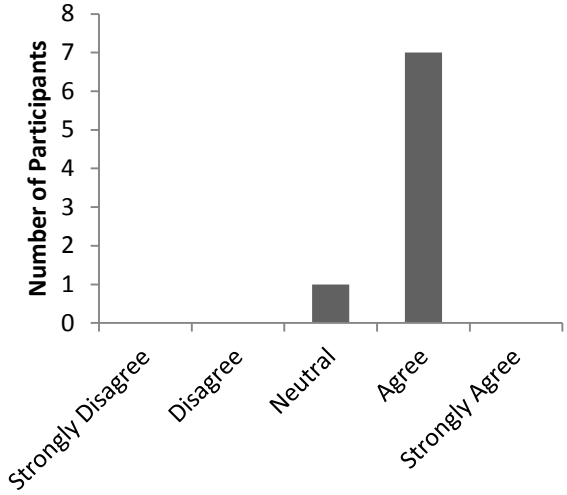



***Figure 47: The model allows me to learn about the dynamics of the Wellington Region***

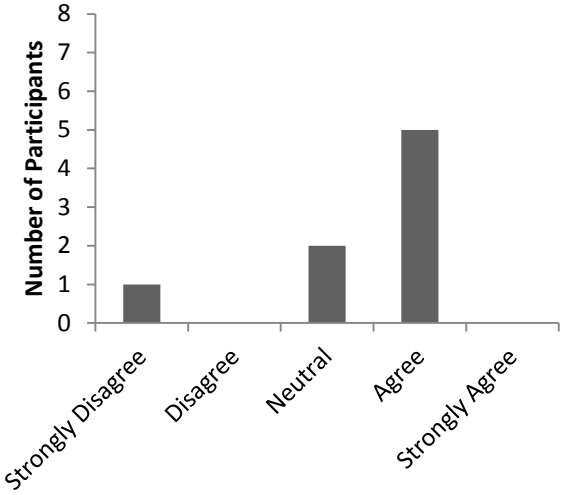



***Figure 48: The current model can be used as a decision support tool for the Wellington Region***

11. Please mark with an "x" the answer that best indicates how much you agree or disagree with each of the following statements related to the scenarios that were run though the STELLA model.

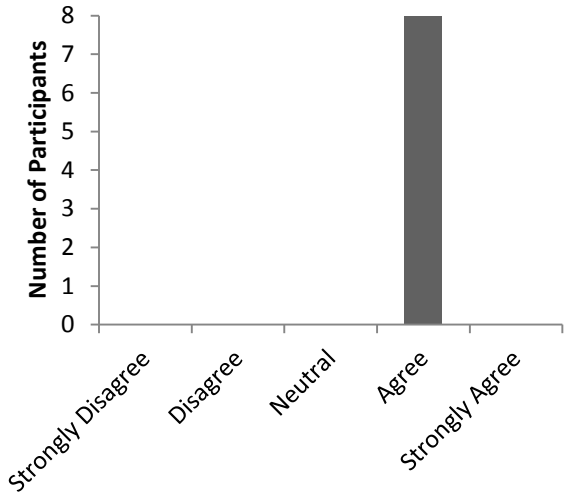



***Figure 49: Running the two scenarios was insightful***

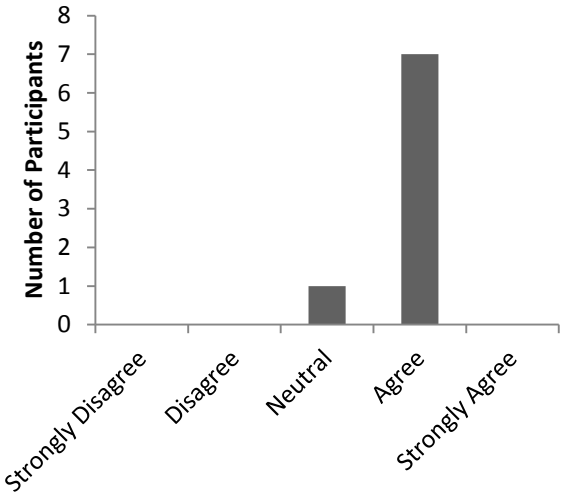



***Figure 50: Additional scenarios with the current model will be insightful***

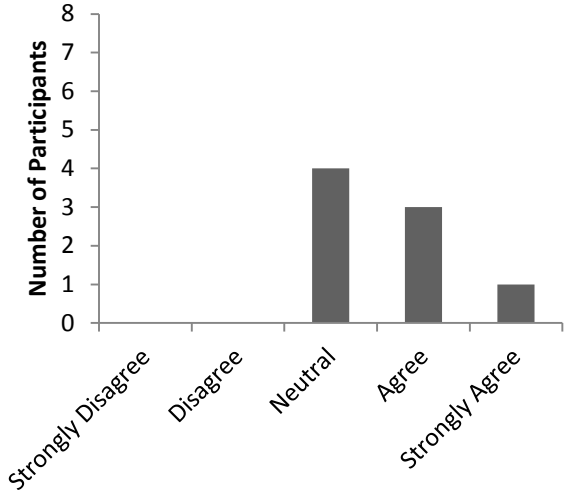



***Figure 51: Improvement of the simulation model is required to generate insightful scenarios***

12. What should be the purpose of the mediated modelling process going forward?

- *I think that systems thinking and modelling is a useful way to simulate how disparate elements link together to make up the big picture. As I said at the last workshop this is something we have been trying to do in public health when we refer to the wider determinants of health and how they influence health and well-being. Therefore systems thinking and modelling can make an important contribution to strategic decision making through scenario simulations*
- *The 'health option' was one I would like to pursue, particularly because of the links with the GPI and the indicators around health*

- *Move it to something useful for organizations*
- *To help inform the Regional Policy Statement and Regional Plan and therefore also inform/influence District Plan's across the Wellington Region*
- *Linkages between well-being, needs practical application*
- *No view, the process is closely aligned with GPI, it will have to be a massive model (versus time and resources)*
- *It needs to tie in with the WR strategy*
- *I believe the tool should be used by planners and policy makers to evaluate the impacts of suggested changes in the council's LTCCP*

13. Reflecting on the three mediated modelling workshops, what was the **best** outcome for you?

- *The best outcome was to see how the Stella software works and how scenarios can be considered*
- *Having everyone in the same room and the range of ideas discussed*
- *See STELLA model working*
- *Getting a range of opinions/view points from the diverse range of participants, to feed into the model was the best outcome for me.*
- *Gaining an understanding of MM and system approach*
- *Interesting academic, theoretical process, learned more about it and how it works*
- *Seeing the scenarios, see where it could be useful*
- *The Story telling*

14. Reflecting on the three mediated modelling workshops, what was the **worst** outcome for you?

- *I still find it a challenge to see the interconnection and linkage with spatial planning*
- *Because of the time between the workshops and the time before the notes etc come out, I think that some momentum is lost*
- *Lost urban form aspects perhaps due to the loss of Chris*
- *I'm not clear on what we achieved in terms of the final outcome (the model). While we identified an issue and ran it through the model to show different scenarios (10% population change) I am not sure that I could take the model away and use it to test scenarios for issues within the Kapiti Coast district.*
- *Missing second workshop, missing practical application*
- *Struggle to see a practical application (vs lot of time and resources), value proposition is not clear*
- *The early workshops. Too hard to get your input in. Too many people talking or doing something else. Difficult to being heard.*
- *Did not have one. But believe that technical people and non technical people should attend workshops which reflect their interests.*

15. At the end of the workshops the participant group arrived at the following suggestion (derived from the summary notes made available on the SP2 website):

***To use this mediated modelling process to progress toward a dynamic GPI (Genuine Progress Indicator) for the Wellington Region.***

*Seven of the eight respondents agreed that the above statement was a good way forward. The participant who wasn't convinced that the GPI is the way forward thought: "I am not sure whether GPI's can be refined sufficiently to agree what the best indicators will be. Also the model seems to be a very good long term indicator but changes will be gradual. Thought should be given to shorter term timeframes for some measures but the model will need to be able to show that there has been a result of the measured outputs."*

16. If we continue this mediated modelling process toward a dynamic GPI (Genuine progress indicator) or follow your suggestion, whom should be included in the subsequent workshops?

- *Unfortunately participation in the group has dropped off. I would like to see more of the cultural perspective and also vulnerable groups*
- *Same people, but we may need to relook if we have all stakeholder groups/types covered*
- *Iwi, service delivery (NGOs, city mission (salvation army like))*
- *Our group, Maori, DOC, people with environmental interests*
- *Need for involvement of pure planning person out of his organisation?*
- *Representatives of the sectors in GPI (health and transport)*
- *Believe that there will need to be a buy in initially from those for whom the GPI is being developed for and those that are creating the GPI's. This will be both at CEO/Councillor levels and at Officer levels.*

17. Have you used STELLA (= the modelling software used in this project) to run the developed simulation model outside the Mediated Modelling workshops (Please mark you answer with an "x")?

*None of the participants used STELLA to run the model. Some participants tried to download STELLA but their organizations IT systems fire-walled this.*

18. Is there any scenario under which you can see yourself use STELLA?

*Five participants can see a scenario where they themselves would use STELLA. Three did not see this happening for various reasons.*

19. Would your organisation (but not you) be interested in using STELLA in the future?

*Five participants thought that, if not themselves, their organizations would be interested in using STELLA in the future. One didn't know. This question doesn't make sense if the answer of Q18 is YES.*

20. How many times have you visited the project website (www.sp2.org.nz) during the workshops?

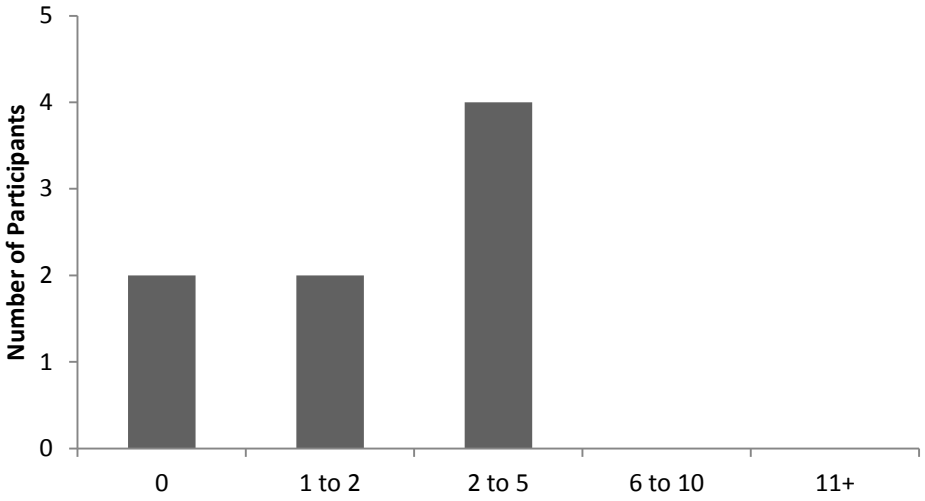



***Figure 52: How many times have you visited the project website***

21. Do you want to stay involved in the mediated modelling workshops?

*Four participants wanted to stay actively involved. Four were either not sure but wanted to receive updates on phase 2 and one wants to receive updates because workload prevents prioritizing active participation in phase 2.*

22. Any other thoughts, observations, suggestions, recommendations?

- *Interested in Stella with respect to the fresh water quality and allocation*
- *No*
- *Do not let people get into the process "COLD" (i.e., without expectations). Important in this process is that we need robust info so you do not worry about it afterwards. Question of output versus process.*

*Hope it does go forward, but we cannot be involved because lack of capacity*

- *Missed one and a half sessions. Enjoyed it for what it was.*
- *Less representatives needed allowing to be heard more*
- *No*

# Appendix C Detailed Wellington Regional Model Description:

The Wellington Regional model currently contains five sectors: (1) Population and Households, (2) Economics, (3) Natural Environment, (4) Government, and (5) External Factors (influencing the Wellington Region). Figure 53 illustrates how these sectors are interconnected through the following feedback loops: (1) population and households affect economics and vice versa, (2) economics and government are interconnected, (3) economics affect the natural environment and vice versa, and lastly (4) population and households affect the natural environment which in turn affects economics and therefore ultimately again the population and households. In addition to these four feedback loops, the effects external factors have on economics, natural environment and population and households are also taken into account.


***Figure 53: The sectors of the Wellington Regional Model and how they are interconnected***

In what follows, we discuss each these sectors more in depth.

***Sector Population and Households***

This sector is all about the Wellington population and its households and is given in Figure 54. Six types of households are considered: (1) unemployed primary industry worker households, (2) primary industry worker households, (3) unemployed worker households, (4) worker households, (5) unemployed service worker households, and (6) service worker households. Each of these households consists of householders and youngsters and/or students. Movement between the different types of households is possible and is mainly a function of changes in employment opportunities. Next to movement between these different types of households, migration flow from and to the Wellington region are also taken into account. These flows are a function of the attractiveness of the Wellington Region relative to the other regions. Finally, disasters like earthquakes can have a devastating effect on the population of the Wellington Region and are therefore taken into account in this model by the outflows "Loss of youngsters and students due to disaster" and "Loss of householders due to disaster" (disasters are in this model conceptualised as external factors influencing the Wellington). Based on this narrative, the formulas for the stock of "households" (Equation 1) and "youngsters and/or students" (Equation 2) are:

*Householders[Household Type](t) = Householders[Household Type](t - dt) + (Immigration_Rate_Householders[Household Type] + Rate_at_which_Youngster_and_Students_become_new_Householder[Household Type] - Emmigration_Rate_Householders[Household Type] - Loss_of_Householders_due_to_Disaster[Household Type] - Death_Rate_Householders[Household Type] - Net_Movement_Rate_of_Householders_between_Households[Household Type]) * dt* (1)

*INITIAL VALUES: Householders[Farmer] = 4452 {People}, Householders[Worker] = 27288{People}, Householders[Service_Worker] = 237403 {People}, Householders[Unemployed_Farmer] = 330 {People}, Householders[Unemployed_Worker] = 2022 {People}, Householders[Unemployed_Service_Worker] = 17595 {People}*

*Youngsters_and_Students[Household Type](t) = Youngsters_and_Students[Household Type](t - dt) + (Birth_Rate[Household Type] - Death_Rate_Youngsters_and_Students[Household Type] - Loss_of_Youngsters_and_Students_due_to_Disaster[Household Type] - Net_Movement_Rate_of_ Youngsters_and_Students _due_to_Moverment_of_Householders[Household Type] - Rate_at_which_* (2)

*Youngsters_and_Students _become_Householders[Household Type]) * dt*

*INITIAL VALUES: Youngsters_and_Students[Farmer] = 1741 {People}, Youngsters_and_Students[Worker] = 10671 {People}, Youngsters_and_Students[Service_Worker] = 92837 {People}, Youngsters_and_Students[Unemployed_Farmer] = 129 {People}, Youngsters_and_Students[Unemployed_Worker] = 791 {People}, Youngsters_and_Students[Unemployed_Service_Worker] = 6881 {People}*

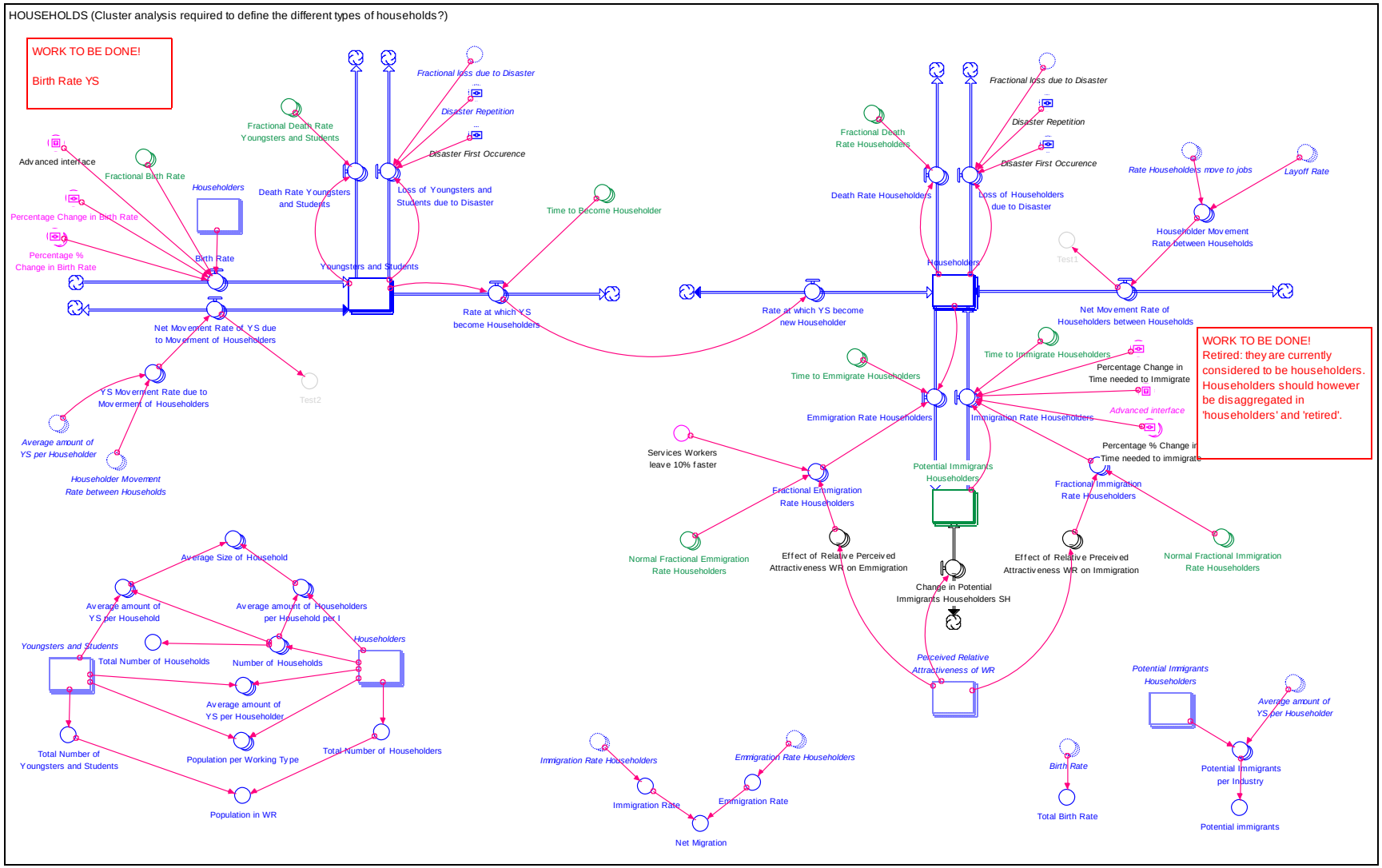



***Figure 54: Sector Population and Households***

***Sector Natural Environment***

The sector on natural environment is build up around five subsectors: (1) Natural Area, (2) Natural Capital, (3) Waste and Pollution, (4) Available Water Quantity, and (5) Water Quality.

The subsector "Natural Area" is given in Figure 55 and captures changes in land use due to changes in infrastructure. Five types of infrastructure define the following five types of land use: (1) land with housing on (i.e., residential area), (2) land with water infrastructure on, (3) land with public and private service facilities on, (4) land with factories on (i.e., industrial land), and (5) land with farms on (i.e., agricultural land). A sixth land type is "natural area" and a final one is "used land others". The latter is a rest-category of land that has none of the five infrastructure types on it and it is also not considered to be natural area. "Natural area" is calculated as follows:

$$Natural\_Area = Wellington\_Region\_in\_Ha - Used\_Land\ \{Ha\} \tag{3}$$

Where:

$$Wellington\_Region\_in\_Ha = 813005\ \{Ha\} \tag{4}$$

$$Used\_Land(t) = Used\_Land(t - dt) + ((\text{Used\_Land}) * dt + Used\_Land\_Others) - \text{Used\_Land}) * dt \tag{5}$$

$$INITIAL\ VALUE: Used\_Land\_Others\ \{Ha\} + Used\_Land\_Others\ \{Ha\}$$

In equation 5, Land_with_infrastructure_on[Infrastructure Type] is calculated as:

$$Land\_with\_Infrastructure\_on[Infrastructure\ Type] = Infrastructure[Infrastructure\ Type] * Land\_Needed\_per\_10000xM3\_of\_Infrastructure[Infrastructure\ Type] / 10000\ \{Ha\} \tag{6}$$

And "Used land others" is a placeholder set at 50000 Ha.

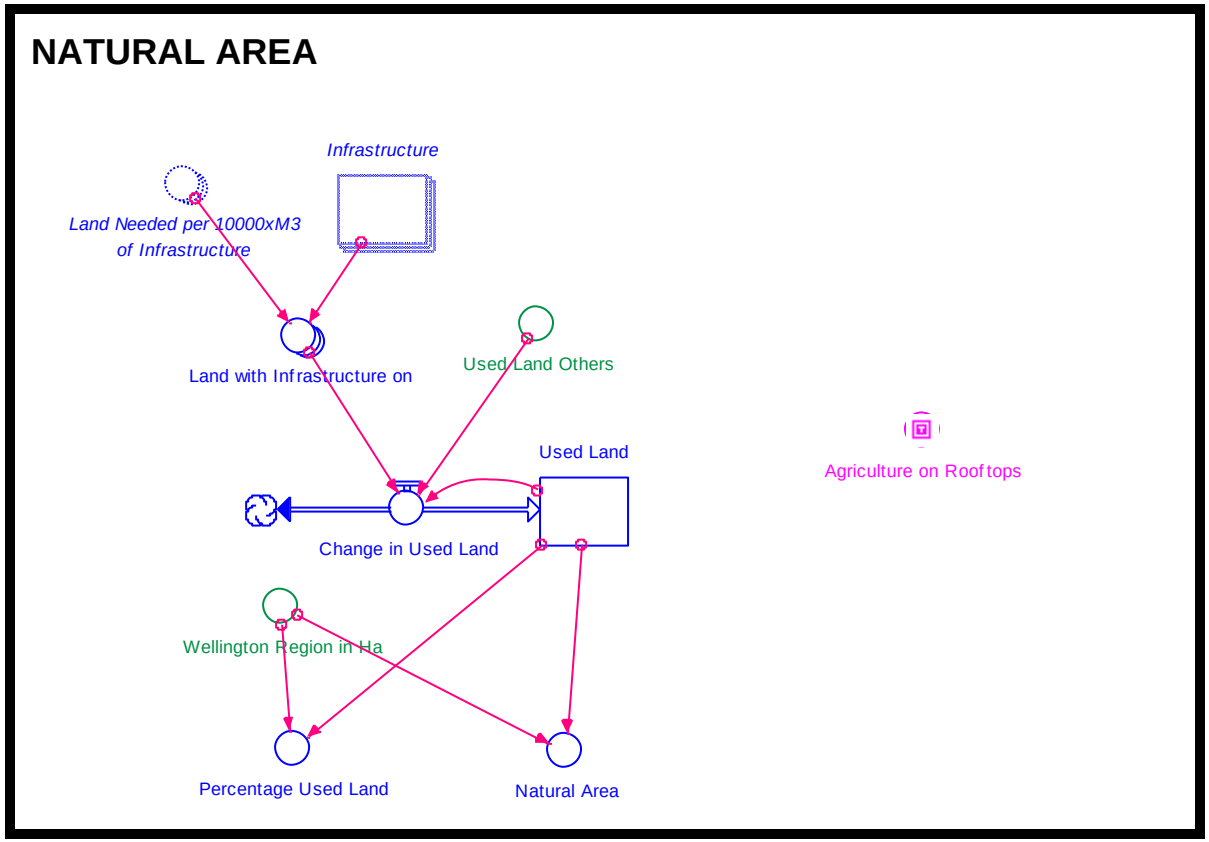



***Figure 55: Subsector Natural Area which is part of the sector Natural Environment***

The subsector on Natural Capital captures the dynamics of natural capital within the Wellington Region and is given in Figure 58. Natural capital increases through (1) a yearly natural capital growth rate (i.e., "New rate of new natural capital") and (2) a yearly restoration rate (i.e., "Yearly new natural capital due to restoration of ecosystems"). The yearly natural capital growth rate is a function of the density of the natural capital (e.g., trees in a forest, fishing in a fish stock, flowers in a national park, etc.) as illustrated in Figure 56.

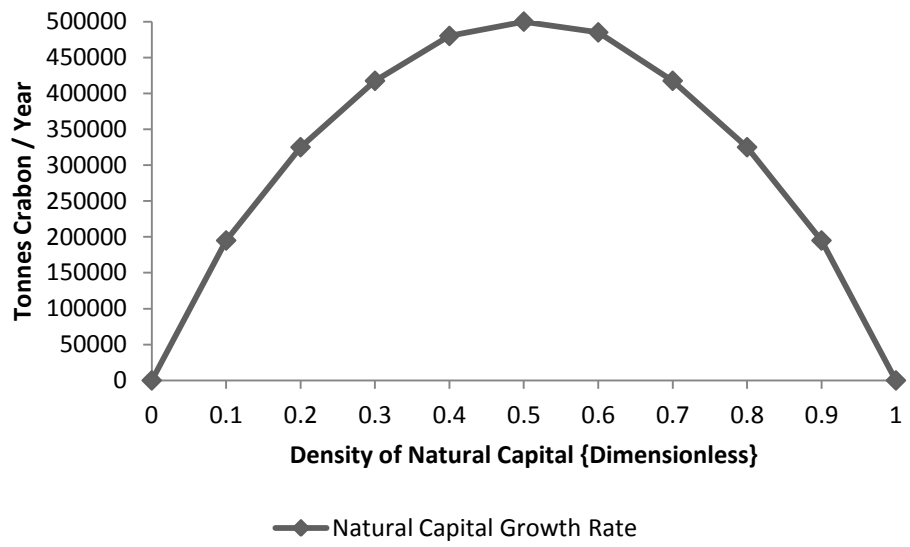



***Figure 56: Natural capital growth rate as a function of the density of the natural capital***

In turn, the density of the natural capital is calculated by comparing the amount of natural capital against its carrying capacity. Carrying capacity is determined by the available natural area and pollution as expressed in equation 7.

*Carrying_Capacity = Normal_Carrying_Capacity * (1 - Effect_of_Pollution_on_Carrying_Capacity) {Tonnes Carbon}* (7)

Yearly new natural capital due to restoration of ecosystems differs whether there is collaborative governance for natural capital or not. If there is, then the restoration goals of natural capital are assumed to be higher but the time to implement restoration decisions will be longer compared to if there is no collaborative governance for ecosystems. Next, natural capital decreases due to (1) consumption of natural capital, (2) decay due to pollution, (3) destruction of natural capital due to loss of natural area, and (4) loss of natural capital due to a disaster. Consumption of natural capital is the sum of the consumption of natural capital by the (economic) production process and consumption of natural capital by the population outside the (economic) production process (e.g., recreational activities like sport fishing). Decay of natural capital due to pollution is a function of the pollution concentration within the Wellington Region (See Figure 57).

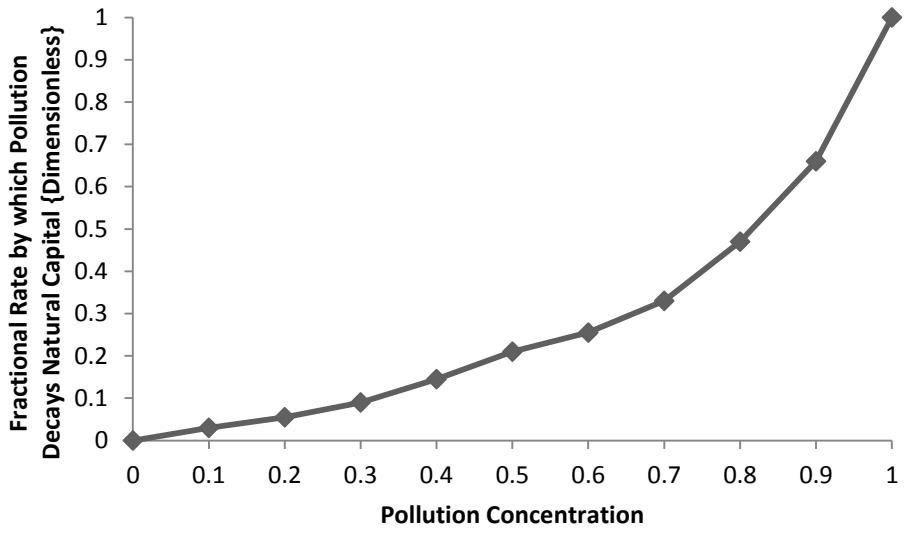



***Figure 57: Fractional rate by which pollution decays natural capital expressed as a function of pollution concentration***

Destruction of natural capital due to loss of natural area happens when the total size of infrastructure in the Wellington Region expands taking up more land. Finally, natural area can also be directly lost after a disaster. In sum, natural capital can be expressed as the following equation:

*Natural_Capital(t) = Natural_Capital(t - dt) + (Net_Rate_of_New_Natural_Capital + Yearly_New_Natural_Capital_due_to_Restoration_of_Ecosystems - Distruction_of_Natural_Capiltal_due_to_New_Land_Use - Loss_of_Natural_Capital_due_to_Disaster - Consumption_of_Natural_Capital - Decay_of_Natural_Capital_due_to_Pollution) * dt* (8)

*INITIAL VALUE: Carrying_Capacity * 0.70 {Tonnes Carbon}*

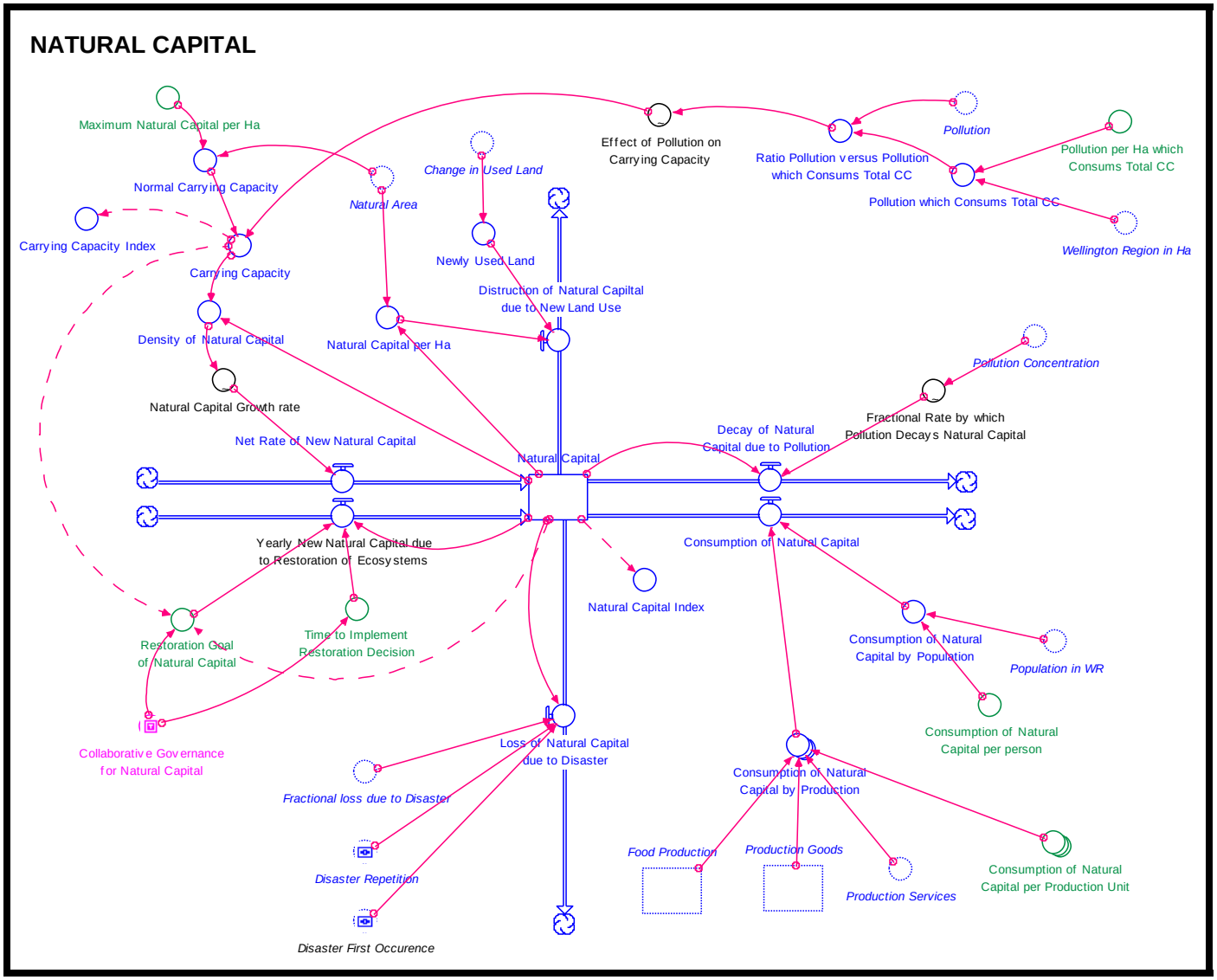



***Figure 58: Subsector Natural Capital which is part of the sector Natural Environment***

The subsector on Waste and Pollution is given in Figure 59 and captures waste accumulation over the years and how waste is linked to pollution. Production, consumption and traffic are in this model the main contributors to waste accumulation and accumulated waste only decreases through degradation and recycling (see equation 9 to 11).

$$Accumulated\_Waste(t) = Accumulated\_Waste(t - dt) + (Total\_Yearly\_Waste\_Flow - Rate\_of\_Waste\_Degradation\_\&\_Recycling) * dt \quad (9)$$

*INITIAL VALUE: 213000 {Waste Unit}*

Where:

$$Total\_Yearly\_Waste\_Flow = Total\_Waste\_Flow\_due\_to\_Traffic\_Volume + \quad (10)$$

*+*

*{Waste Unit}*

and

$$Rate\_of\_Waste\_Degradation\_\&\_Recycling = Accumulated\_Waste / Time\_to\_Reclycle\_or\_Degrade\_Waste \ \{Waste\ Unit\} \quad (11)$$

The speed at which waste is recycled is a function of the comparison between the waste concentration in the Wellington Region and the waste concentration outside the Wellington Region. It is assumed that if the waste concentration in the Wellington Region is higher (lower) compared to the one outside the Region then Wellington will speed up (slow down) its recycling speed. Finally, waste is linked to pollution as only a fraction of the waste cause pollution (see equation 12).

$$Pollution = Accumulated\_Waste * Fraction\_of\_Waste\_that\_is\_Pollution \quad (12)$$

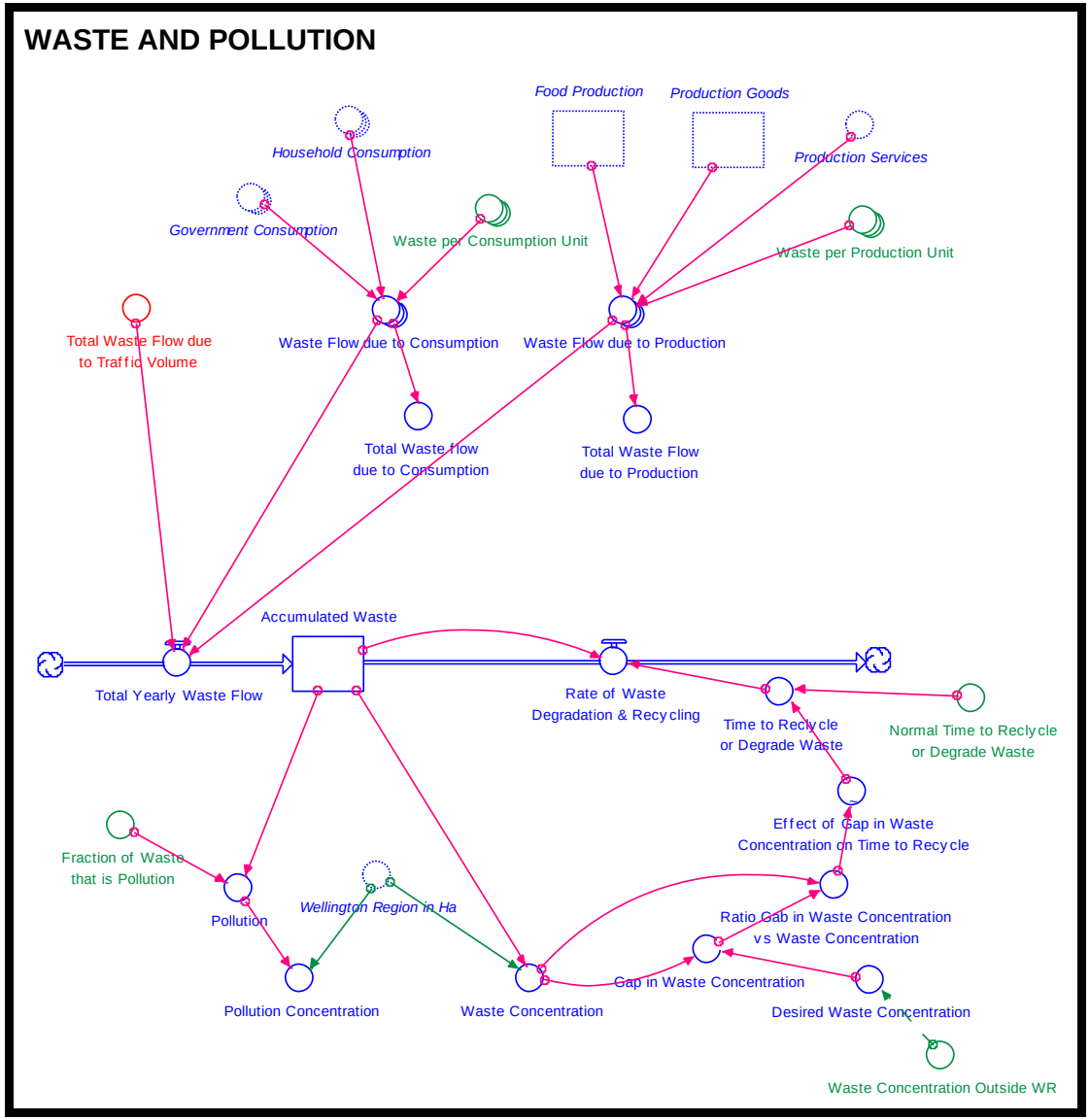



***Figure 59: Subsector Waste and Pollution which is part of the sector Natural Environment***

The subsector on Available Water Quantity is given in Figure 60 and calculates the amount of available water in the Wellington Region by multiplying the amount of water infrastructure with the maximum amount of water this infrastructure can hold. Available water quantity is given by both a real quantity and an index (i.e., water quantity now compared to the initial water quantity at the beginning of the simulation).

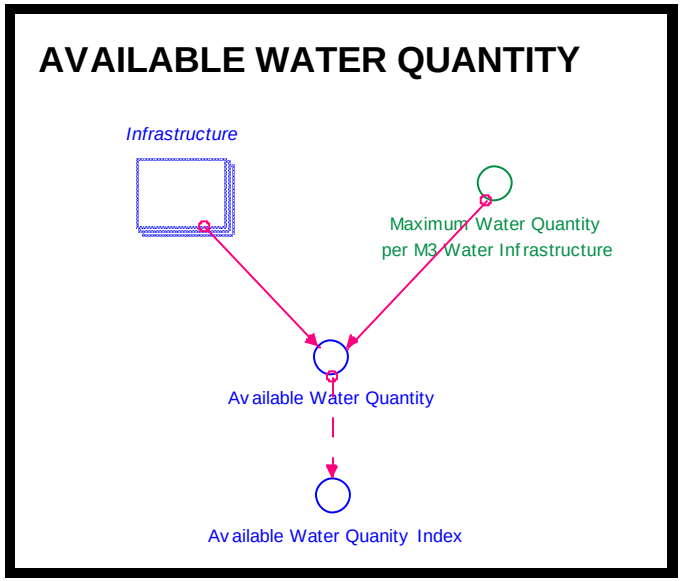



***Figure 60: Subsector Available Water Quality which is part of the sector Natural Environment***

Figure 62 illustrates the subsector on Water Quality which calculates water quality as a function of natural capital (see equations 13-14). Natural capital determines in this subsector the maximum level of water quality possible as water quality is mainly a function of ecosystem services derived from natural capital. However, a change in natural capital will not immediately affect water quality captured by this subsector through the delay "time needed for biomass to change water quality". Finally, water quality itself is represented in the form of an index ranging from 0 to 1.

$$Water\_Quality(t) = Water\_Quality(t - dt) + (Change\_in\_Water\_Quality) * dt \quad (13)$$

*INITIAL VALUE: Maximum_Water_Quality_Given_Natural_Capital {Dimensionless}*

Where:

*Change_in_Water_Quality = (Maximum_Water_Quality_Given_Natural_Capital - Water_Quality) / Time_needed_for_Biomass_to_Change_Water_Quality {Dimensionless}* (14)

"Maximum water quality given natural capital" is a graph function:

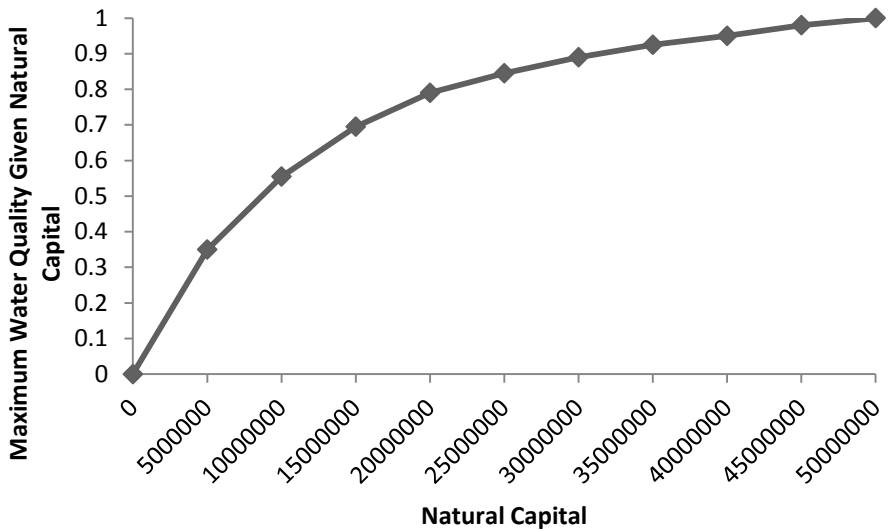



***Figure 61: Maximum water quality given a certain amount of natural capital***

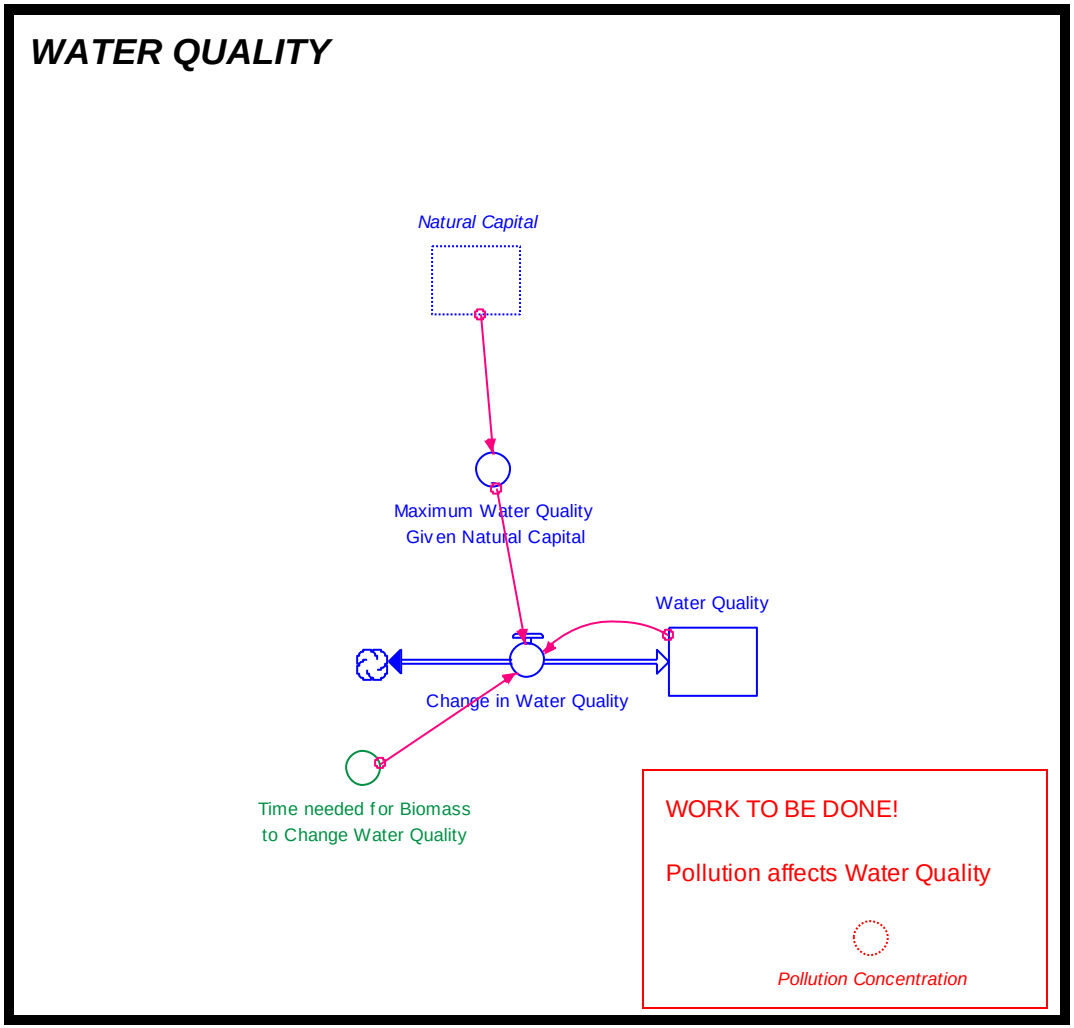



***Figure 62: Subsector Water Quality which is part of the sector Natural Environment***

***Sector Economics***

This sector on economics contains 17 subsectors: (1) Production, (2) Household Demand for Import, (3) Import, (4) Demand for Export, (5) Export, (6) Output Prices, (7) Price Indices, (8) Consumption, (9) Inventory, (10) Labour, (11) Household Income, (12) Infrastructure, (13) Relative Attractiveness of the Wellington Region, (14) Gross Domestic Product, (15) Gini-coefficient, (16) Life Expectancy, (17) Food Quality.

The subsector of production contains three parts: (1) household demand for production, (2) desired production and (3) production itself.

Household demand for production in the Wellington Region as given in Figure 63 is divided into household demand for (1) food, (2) goods from industries and (3) services. Household demand for production in the Wellington Region is conceptualized as a stock accumulation as given by equation 15:

*Household_Demand_for_Local_Products_&_Services[Industry Type](t) =*
*Household_Demand_for_Local_Products_&_Services[Industry Type](t - dt) +*
*((Indicated_Demand_for_Local_Production[Industry Type]-*
*Household_Demand_for_Local_Products_&_Services[Industry*
*Type])/Demand_Adjustment_Delay_for_Local_Production[Industry Type]) * dt* (15)

*INITIAL VALUE: Reference_Demand_for_Local_Production[Industry Type] {Tonne Food}*

These levels of these demands vary based on the prices of those products and services relative to their “world market prices” (see equation 16). In addition, total demand for products and services is limited by (1) household income (more specifically “Expected Long-Term Household Income” which also captures consumption smoothing), (2) the desired fraction of household income you want to spend on local products and services, and (3) the amount of households.

*Indicated_Demand_for_Local_Production[Industry Type] =*
*MIN(Maximum_Consumption_of_Local_Production[Industry Type] ,*
*Reference_Demand_for_Local_Production[Industry Type]) * MAX(0,1 +*
*Demand_Curve_Slope_for_Local_Production[Industry Type] * (Output_Price_in_WR[Industry Type] -*
*Output_Price_outside_WR[Industry Type] ) / Reference_Demand_for_Local_Production[Industry Type]) {Tonne Food}* (16)

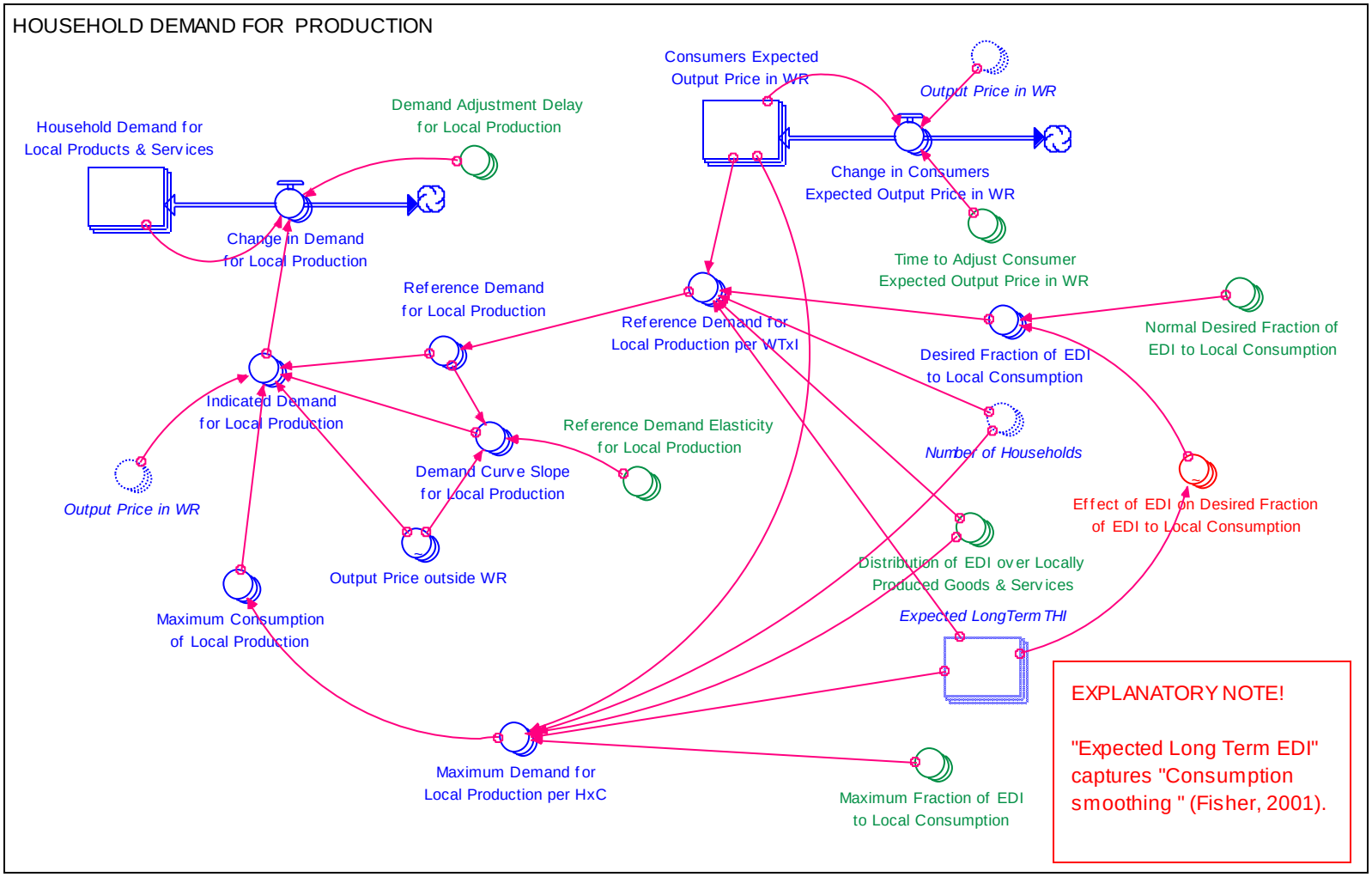



***Figure 63: Subsector Household Demand for Production which is part of the sector Economics***

The “Desired production”-sector is given in Figure 66 and captures the desired production of food, goods and services from the producer’s point of view. It distinguishes between short- and long-run desired production. Both are a function of expected demand for production in the Wellington Region adjusted for producers expected profits as given by equations 17 and 18.

$$\begin{gathered}\textit{Producers\_Desired\_LongRun\_Production\_in\_WR[Industry Type]} = \\ \textit{Producers\_LongRun\_Expected\_Aggregated\_Demand\_for\_Production\_in\_WR[Industry Type]} * \\ \textit{Effect\_Producers\_LR\_Expected\_Profit\_on\_Desired\_Production[Industry Type]} \ \ \{\#\}\end{gathered} \tag{17}$$

$$\begin{gathered}\textit{Producers\_Desired\_ShortRun\_Production\_in\_WR[Industry Type]} = \\ \textit{Producers\_ShortRun\_Expected\_Aggregated\_Demand\_for\_Production[Industry Type]} * \\ \textit{Effect\_Producers\_SR\_Expected\_Profit\_on\_Desired\_Production[Industry Type]} \ \ \{\# \ / \ Year\}\end{gathered} \tag{18}$$

Expected demand is an aggregation of the demand for production by the households and the government. Expected demand also takes into account a constant inventory requirement within the Wellington Region for food (e.g., food security) and goods. As long as producers expect to be profitable given their level of production, they will adjust production capacity following the aggregated demand for products and services. However, if they are unprofitable, they will produce less than the desired aggregated demand. How much less depends on their expected profitability which is a comparison between expected unit costs and output prices. The exact relationship between expected profit and the effect it ahs on desired production is given in Figure 64 and Figure 65.

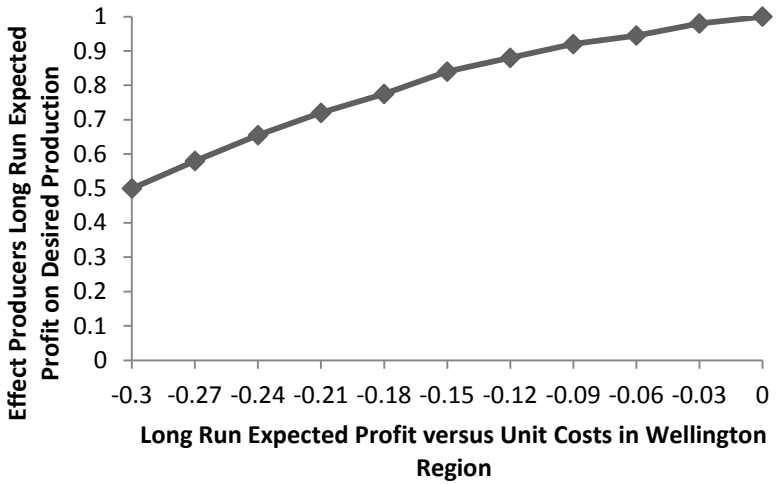



*Figure 64: Relation between expected profit and its effect on producer's long run desired production.*

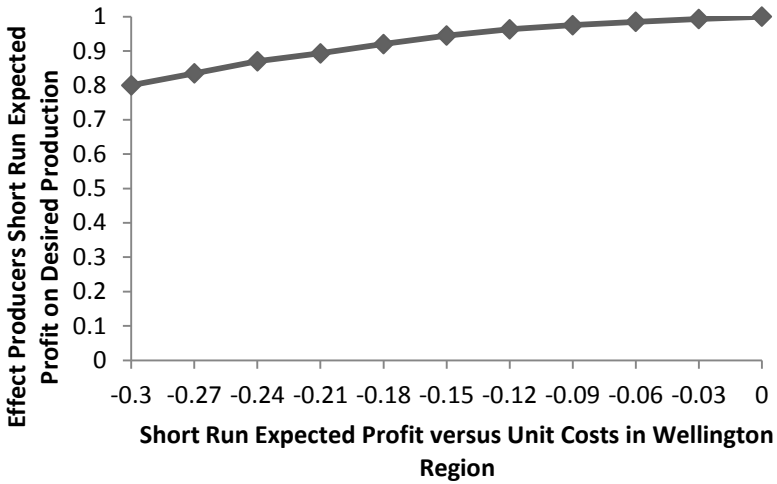



*Figure 65: Relation between expected profit and its effect on producer's short run desired production.*

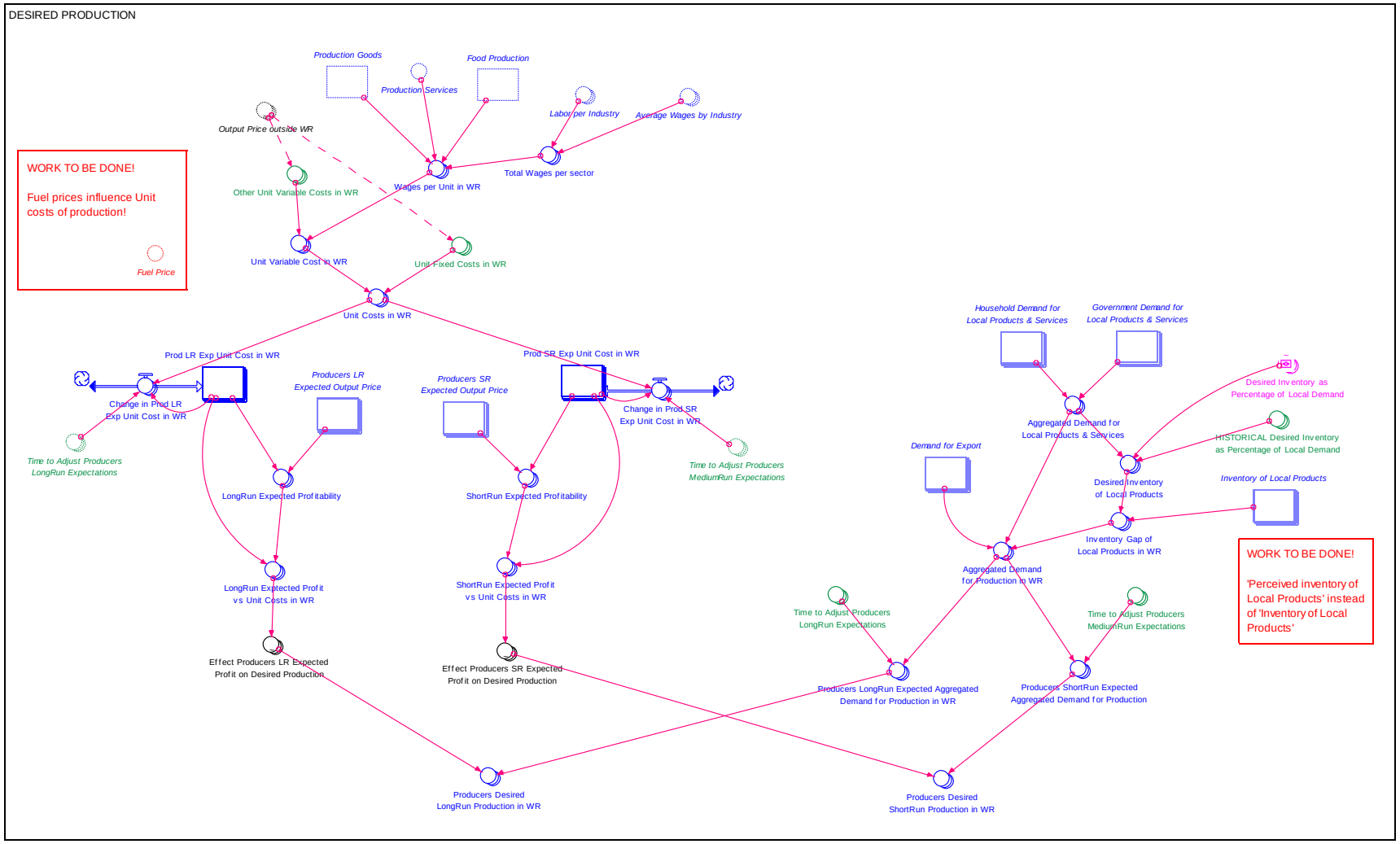



***Figure 66: Subsector Desired Production which is part of the sector Economics***

The last part of the “Production”-subsector is production itself and is given in Figure 67. Three types of production are taken into account in this model: (1) food, (2) goods and (3) services. Production is limited by a Cobb-Douglas maximum production function consisting of (1) labour, (2) capital (i.e., infrastructure), and (3) natural capital (see equation 19). Available water quantity is also taken into account as a separate production input to the production process for food.

*Maximum_Production_Capacity[Industry Type] = Total_Factor_Productivity[Industry Type] * (Labour_Hours_per_Industry[Industry Type] ^ Elasticity_of_Production_to_Labor[Industry Type]) * (Infrastructure[Factories] ^ Elasticity_of_Production_to_Infrastructure[Industry Type]) * (Natural_Capital ^ Elastisity_of_Production_to_Natural_Capital[Industry Type]) * (Available_Water_Quantity ^ Elasticity_of_Production_to_Available_Water_Quantity[Industry Type]) {# Tonnes Goods / Year}* (19)

However, maximum production is in many cases not desirable as the desired production can be well below the maximum production. Hence, the minimum between the maximum production and de desired production results in a production objective. Production is then adjusted towards this production objective over time (see equation 20, 21 and 22).

*Food_Production(t) = Food_Production(t - dt) + (Change_of_Food_Production - Loss_of_Food_Production_due_to_Disasters) * dt* (20)

*INITIAL VALUE: Production_Objective[Primary Industry] {# Tonnes Food / Year}*

*Production_Goods(t) = Production_Goods(t - dt) + (Change_of_Production_Goods - Loss_of_Production_of_Goods_due_to_Disasters) * dt* (21)

*INITIAL VALUE: Production_Goods = Production_Objective[Industry] {# Tonnes Goods / Year}*

*Production_Services = MIN(SMTH1(Production_Objective[P&P_Services] , Time_to_Adjust_Production_of_Services) , Aggregated_Demand_for_Production_in_WR[P&P_Services]) {# 1000 x Services / Year}* (22)

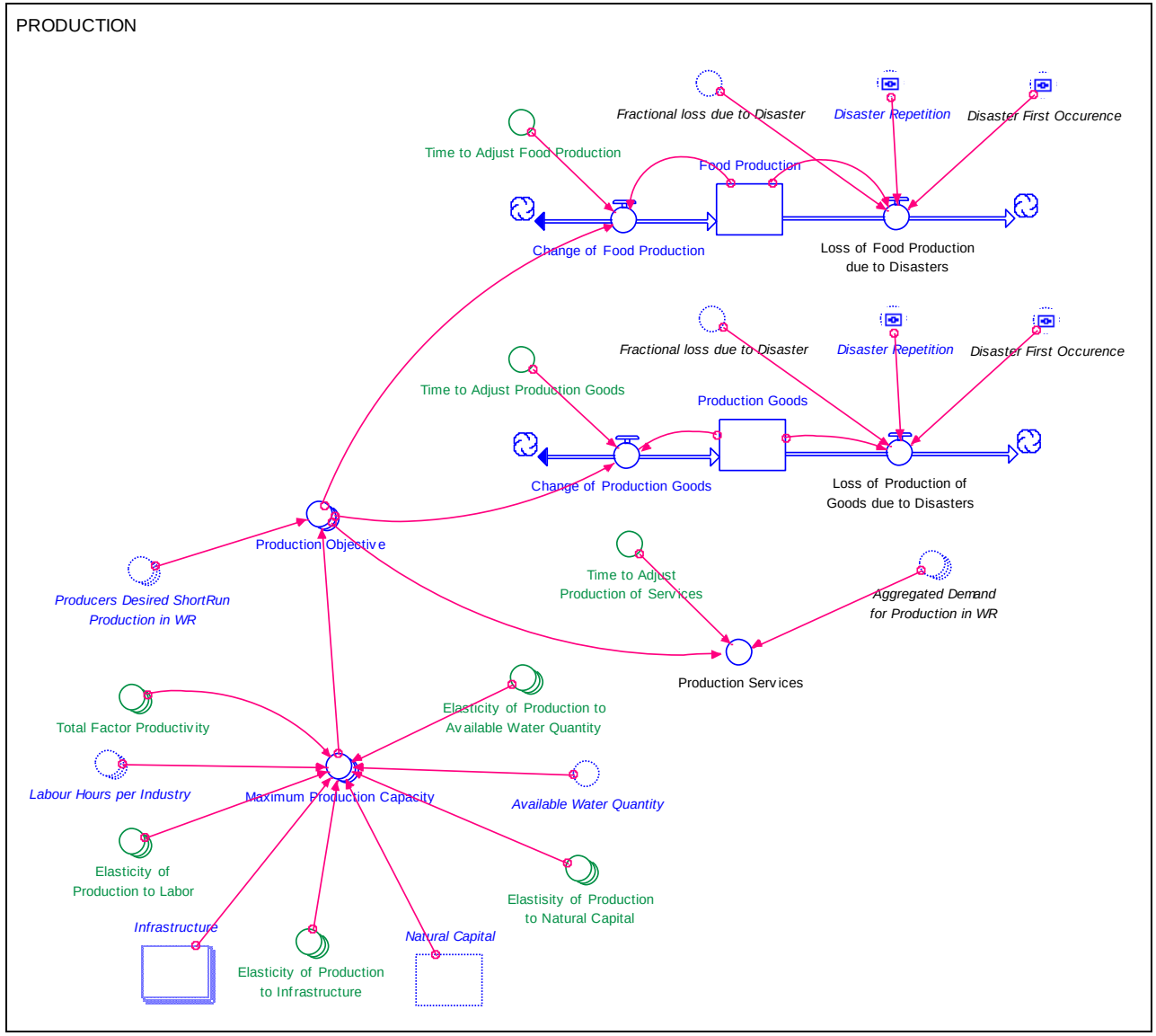



***Figure 67: Subsector Production which is part of the sector Economics***

The subsector on “Household demand for Import” is given in Figure 68. Household demand for import is divided into household demand for (1) food, (2) goods from industries, and (3) services. These demands are in this model heavily tied to the interplay between local prices for local products and services and the “world market prices”. In addition, total demand for imports is limited by household income (more specifically “Expected long term household income” capturing consumption smoothing), the desired fraction of that income households want to spend on imports, and the amount of households. It structure and equations are similar to “Household demand for production in the Wellington Region”.

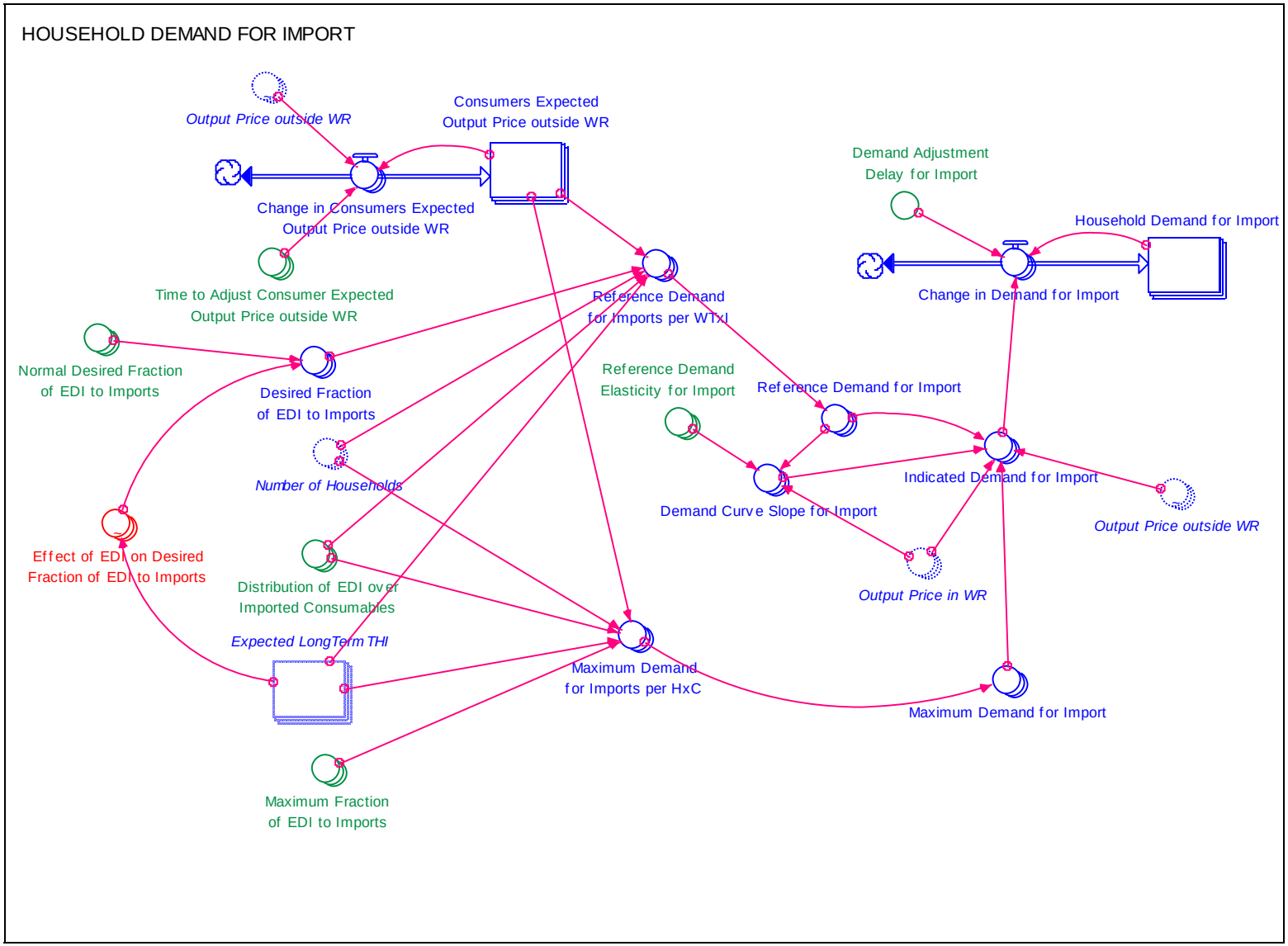



***Figure 68: Subsector Household Demand for Import which is part of the sector Economics***

The subsection “Import” is given in Figure 69. Import of food and goods depend on the demand for imports (from both households and government) and the inventory of imports available in the Wellington Region.

*Aggregated_Demand_for_Imports[Industry Type] = MAX(Household_Demand_for_Import[Industry Type] + Government_Demand_for_Import[Industry Type] - Inventory_Gap_of_Imports[Industry Type] , 0) {# / Year}* (23)

In turn, this inventory is not fixed over time as it is set to a percentage of the local demand for imports. Inventory can also structurally change when new inventory-goals are defined (i.e., new percentage of local demand is chosen as a desired level of inventory). Import of services does not depend on any inventory as services are not inventoried. Hence, they equal to the sum of household and government demand for imports. Finally, this subsector also determines the total import value in NZD.

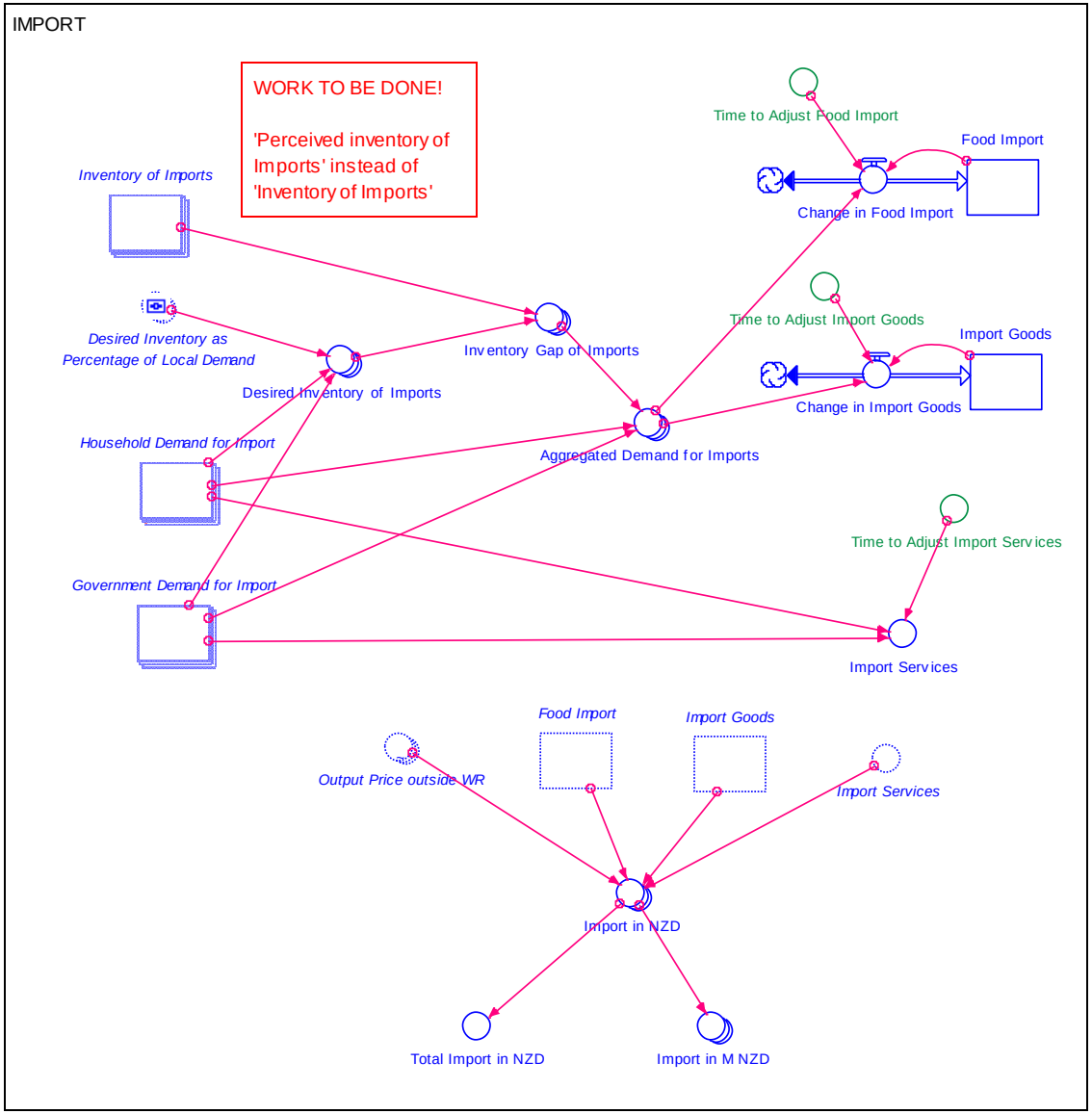



***Figure 69: Subsector Import which is part of the sector Economics***

The subsector dealing with export is given in Figure 70. Export equals the demand for export if production can both support local demand and the demand for export. If not, then export is only a fraction of the demand for export. This faction is determined by comparing the demand for export to the total demand for products produced in the Wellington Region (i.e., export demand and local demand from households and government). So, export is given by the following equations:

*Export[Primary Industry] = MIN(Food_Production * (Demand_for_Export[Primary Industry] / Aggregated_Demand_for_Production_in_WR[Primary Industry]) , Demand_for_Export[Primary Industry]) {# Tonnes / Year}* (24)

*Export[Industry] = MIN(Production_Goods * (Demand_for_Export[Industry] / Aggregated_Demand_for_Production_in_WR[Industry]) , Demand_for_Export[Industry]) {# Goods / Year}* (25)

*Export[P&P_Services] = MIN(Production_Services * (Demand_for_Export[P&P_Services] / Aggregated_Demand_for_Production_in_WR[P&P_Services]) , Demand_for_Export[P&P_Services]) {# Services / Year}* (26)

Finally, this subsector also calculates the value of the exports in NZD.

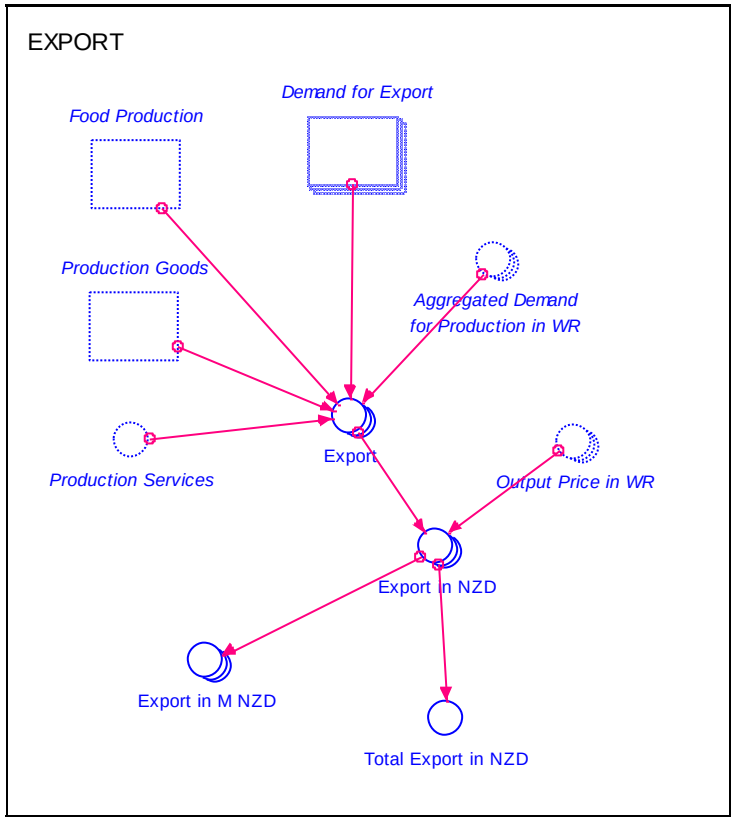



***Figure 70: Subsector Export which is part of the sector Economics***

The subsector on the demand for export is given in Figure 71. Demand for export is mainly a function of a reference demand for export adjusted for the interplay between output prices in the Wellington Region and output prices in the world. It structure and equations are similar to "Household demand for production in the Wellington Region".

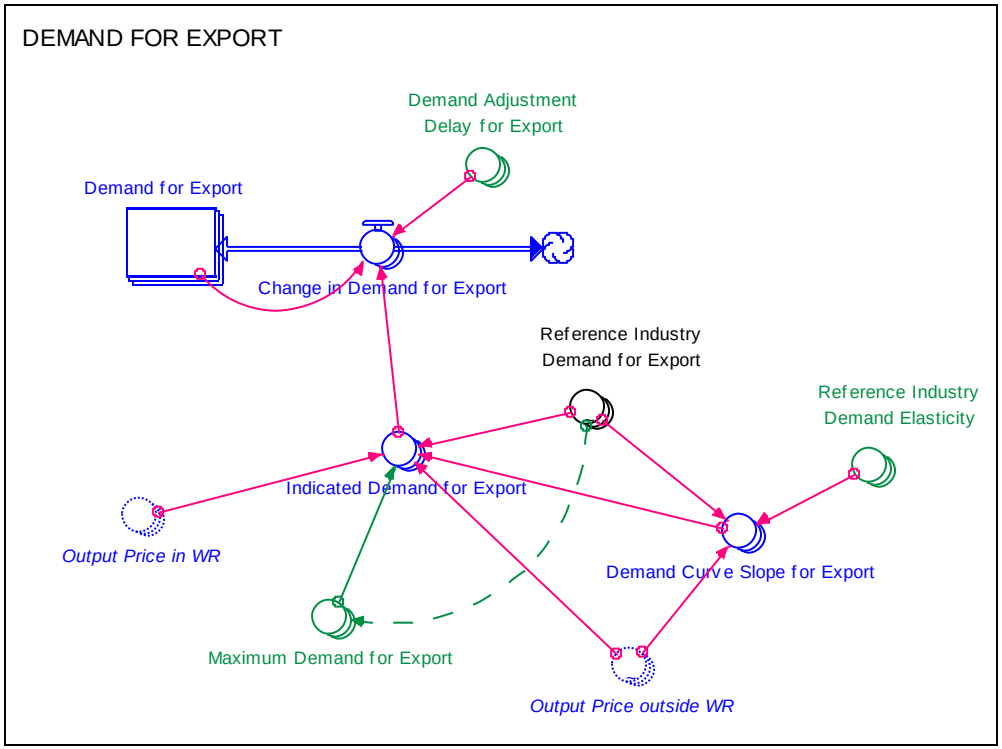



***Figure 71: Subsector Demand for Export which is part of the sector Economics***

The subsector on output prices for products in the Wellington Region (see Figure 72) is based on Sterman's (2000: 816) model capturing price dynamics. It assumes that nobody knows the optimal price that clears the market. Hence, producers try to adjust their prices towards that optimal taking into account (1) their (short run) expectation about the price, (2) their production costs, (3) demand and supply, and most importantly (4) the output prices on "the international market" (as New Zealand is a price taker) (equation 27-). In addition, this subsector also ensures that output prices cannot fall below a minimum price which is the unit variable costs for producing the goods or services. Finally, a difference is made between the producer's long- and short run price expectations.

*Output_Price_in_WR[Industry Types] = Producers_SR_Expected_Output_Price[Industry Types] * Effects_of_Costs_on_Output_Price[Industry Types] * Effect_of_Coverage_on_Output_Price[Industry Types] * Effect_of_Output_Price_outside_WR_on_Output_Price_in_WR[Industry Types] {NZD / #}* (27)

Where:

*Producers_SR_Expected_Output_Price[Industry Types](t) = Producers_SR_Expected_Output_Price[Industry Types](t - dt) + (Change_in_Producers_SR_Expected_Output_Price[Industry Types]) * dt* (28)

*INITIAL VALUE Output_Price_outside_WR[Industry Types] {NZD / #}*

And:

*Effects_of_Costs_on_Output_Price[Industry Types] = 1+ Sensitivity_of_Output_Price_to_Costs[Industry Types] * ((Prod_LR_Exp_Unit_Cost_in_WR[Industry Types] / Producers_SR_Expected_Output_Price[Industry Types]) - 1) {Dimensionless}* (29)

*Effect_of_Coverage_on_Output_Price[Industry Types] = Relative_Coverage[Industry Types] ^ Sensitivity_of_Output_Price_to_Coverage[Industry Types] {Dimensionless}* (30)

*Effect_of_Output_Price_outside_WR_on_Output_Price_in_WR[Industry Types] = Ratio_Output_Price_outside_WR_vs_Prod_Exp_Output_Price_in_WR[Industry Types] ^ Sensitivity_of_Output_Price_in_WR_to_Output_Prices_outside_WR[Industry Types] {Dimensionless}* (31)

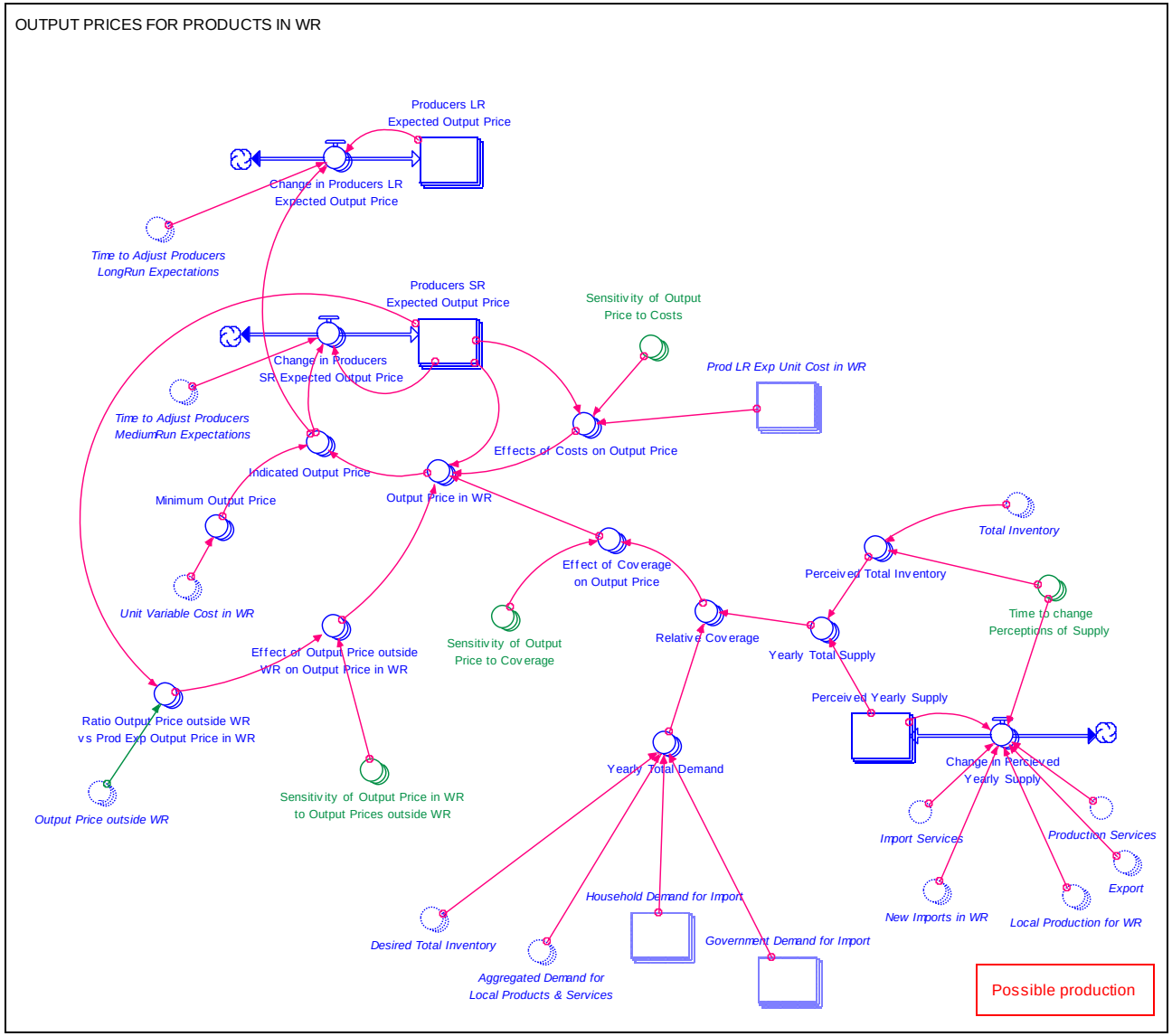



***Figure 72: Subsector Output Prices for Products in WR which is part of the sector Economics***

The subsection on price indices as illustrated in Figure 73 captures the consumer price index and food price index both calculated following three methods: (1) Paasche, (2) Laspeyres and (3) Fisher. All three calculations are based on the output price of the goods and services in the Wellington Region and the aggregated consumption of local products in the Wellington Region.

The Paasche ($CPI_{Paasche}$), Laspeyres ($CPI_{Laspeyres}$) and Fisher Index ($CPI_{Fisher}$) are calculated as follows:

(32)

(33)

(34)

Where: and presents respectively the price and quantity sold of *c* in period *t*.

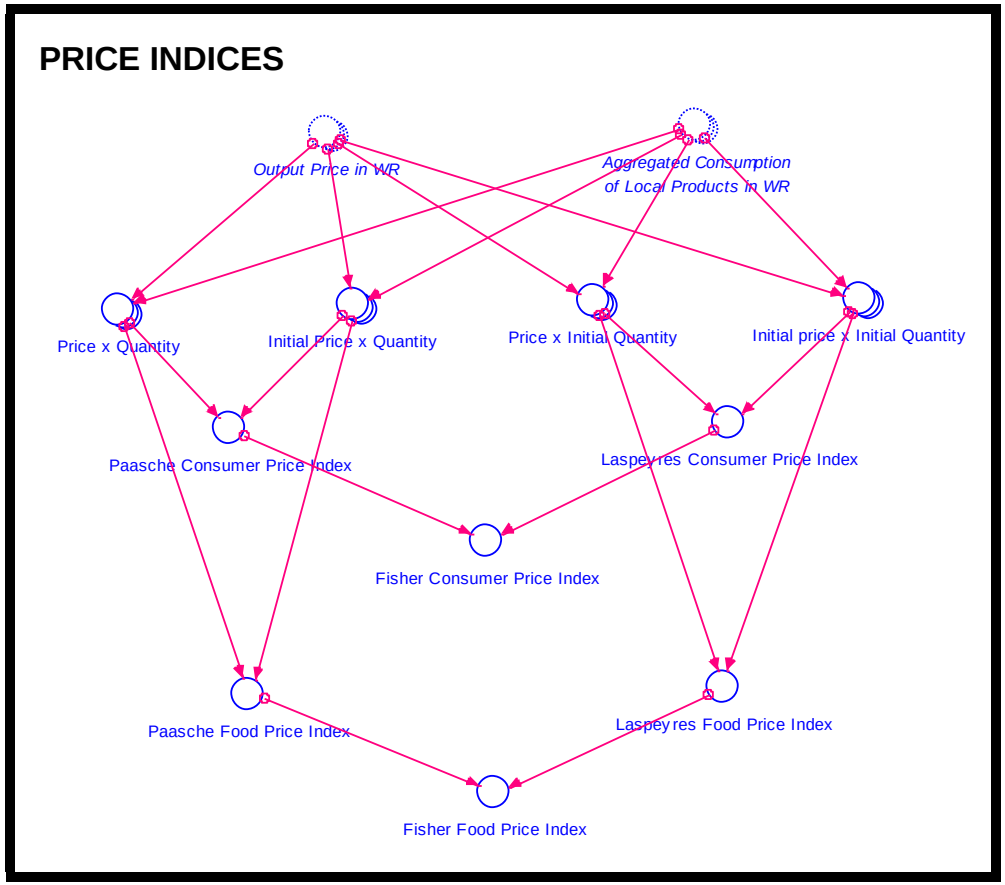



***Figure 73: Subsector Price Indices which is part of the sector Economics***

The subsector capturing consumption is given in Figure 74 and captures both household and government consumption in quantities and monetary values. The same calculations are made for both household and government consumption of food, goods and services. Consumption (of households or the government) is the sum of consumption of local products or services and consumption of imports. Consumption of local products or services equals the minimum between the demand for local products and the actual production of local products for the local

market (i.e., local production minus export) increased with the inventory of these products. A similar calculation is performed for consumption of imports as this equals the minimum between the demand for imports and the actual imports increased with the inventory for these products.

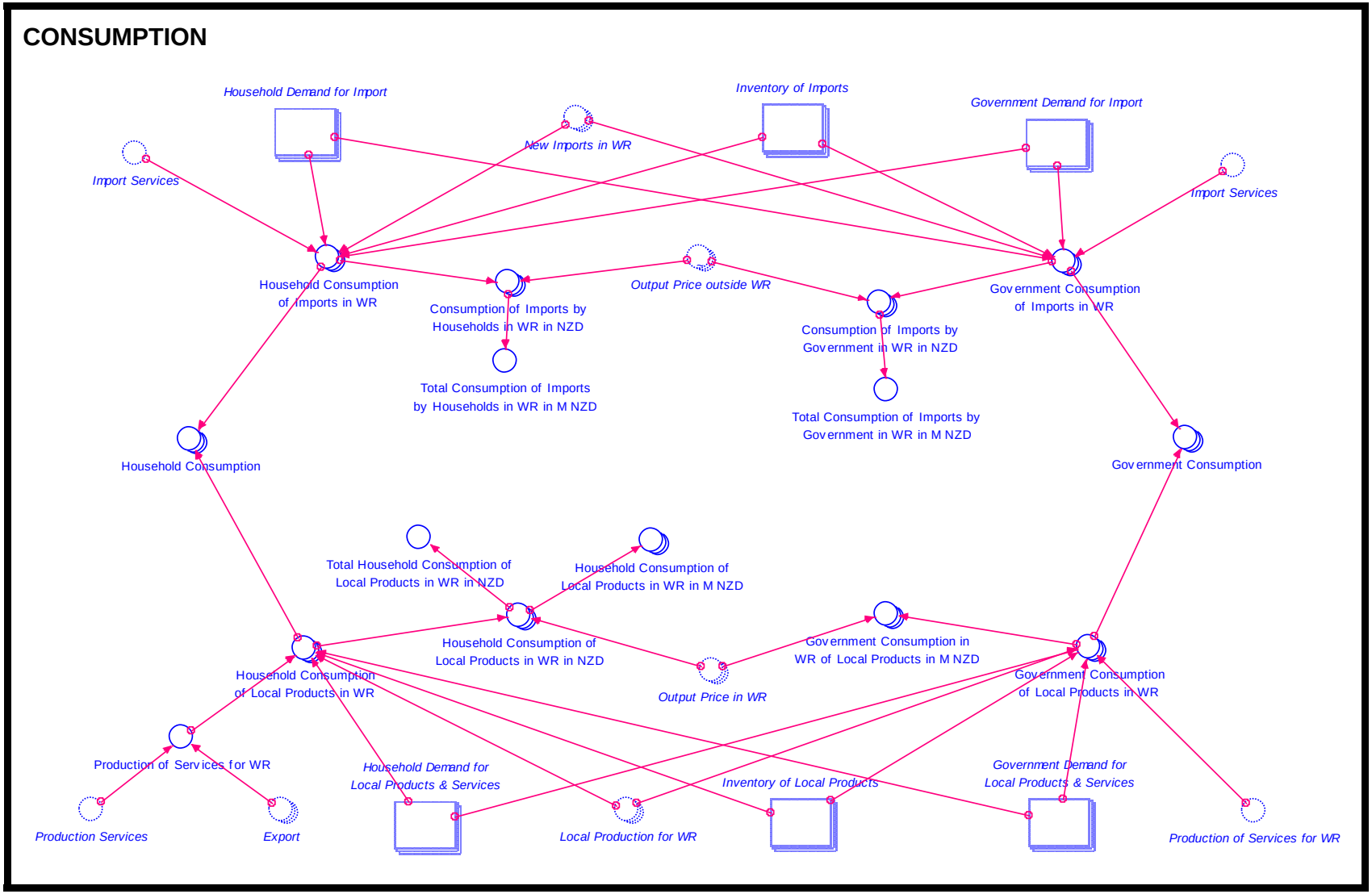



***Figure 74: Subsector Consumption which is part of the sector Economics***

The subsector on Inventory is given in Figure 75. It keeps track of the inventories of both local and imported products. The inventory of imports increases due to new imports into the Wellington Region and decreases when households and government consumes these imports (see equation 35).

*Inventory_of_Imports[Industry Type](t) = Inventory_of_Imports[Industry Type](t - dt) + (New_Imports_in_WR[Industry Type] - Loss_of_Inventory_of_Imports_due_to_Disaster[Industry Type] - Aggregated_Consumption_of_Imports_in_WR[Industry Type]) * dt* (35)

*INITIAL VALUES: Inventory_of_Imports[Primary Industry] = (Household_Demand_for_Import[Primary Industry] + Government_Demand_for_Import[Primary Industry]) * (Desired_Inventory_as_Percentage_of_Local_Demand[Primary Industry] / 100) {Tonnes Food}*

*Inventory_of_Imports[Industry] = (Household_Demand_for_Import[Industry] + Government_Demand_for_Import[Industry]) * (Desired_Inventory_as_Percentage_of_Local_Demand[Industry] / 100) {Tonnes Goods}*

*Inventory_of_Imports[P&P_Services] = 0 {# x 1000 Services}*

A similar structure is used for the dynamics of the inventory of local products. This inventory increases due to local production aimed at the local market and decreases when households and government consume those local products. Finally, disasters can have a loss of products in both inventories as a result. “Inventory of Local Products” is then given by the following equation:

*Inventory_of_Local_Products[Industry Type](t) = Inventory_of_Local_Products[Industry Type](t - dt) + (Local_Production_for_WR[Industry Type] - Loss_of_Inventory_of_Local_Products_due_to_Disaster[Industry Type] - Aggregated_Consumption_of_Local_Products_in_WR[Industry Type]) * dt* (36)

*INIT Inventory_of_Local_Products[Primary Industry] = (Household_Demand_for_Local_Products_&_Services[Primary Industry] + Government_Demand_for_Local_Products_&_Services[Primary Industry]) **

*(Desired_Inventory_as_Percentage_of_Local_Demand[Primary Industry] / 100)  {Tonnes Food}*

*Inventory_of_Local_Products[Industry] = (Household_Demand_for_Local_Products_&_Services[Industry] + Government_Demand_for_Local_Products_&_Services[Industry]) * (Desired_Inventory_as_Percentage_of_Local_Demand[Industry] / 100)  {# Tonnes Goods}*

*Inventory_of_Local_Products[P&P_Services] = 0  {*1000 Services}*

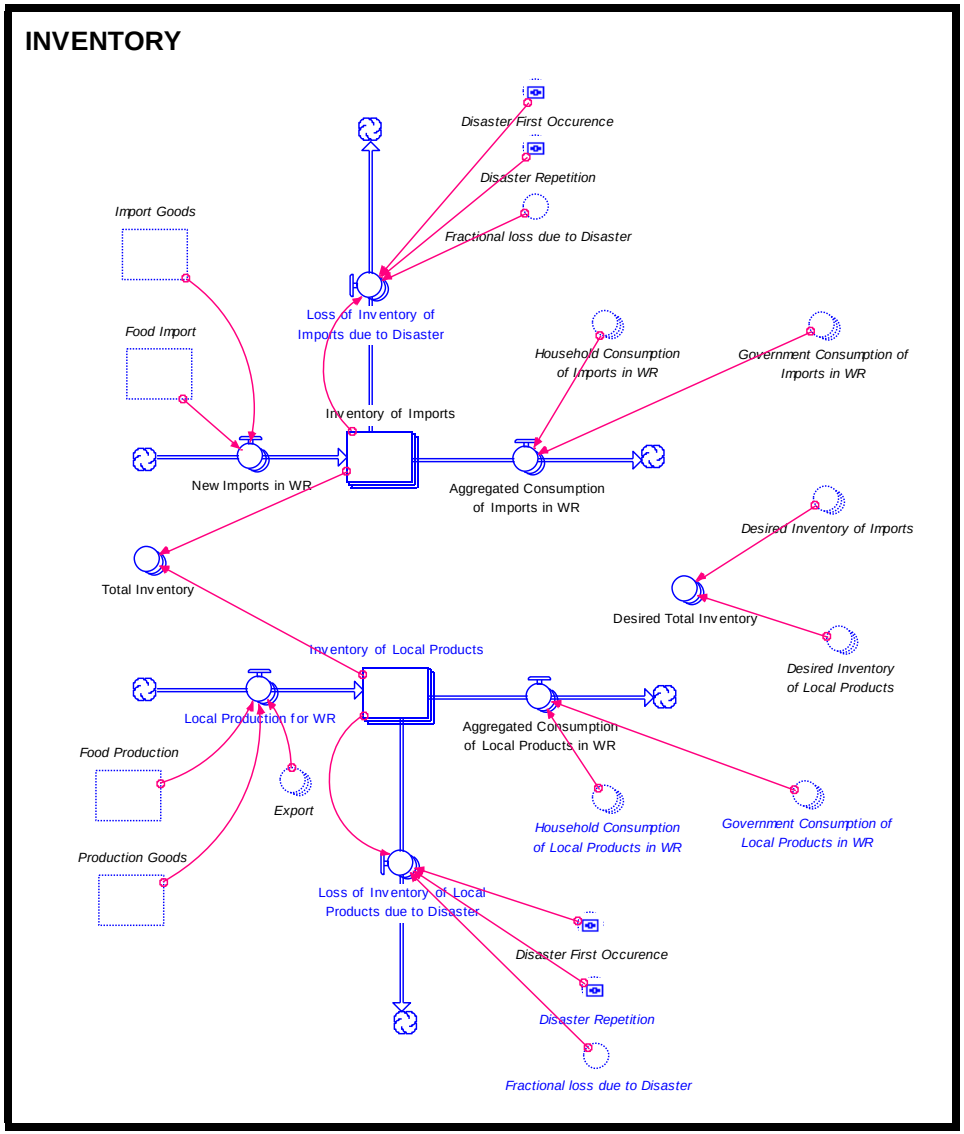



***Figure 75: Subsector Inventory which is part of the sector Economics***

The subsector of labour is given in Figure 76 and captures the dynamics of the labour market. Hiring labour depends on vacancies which in turn depend on the producer's desired short-run production targets (equation 18) and the marginal productivity of labour (equation 37).

*Marginal_Productivity_of_Labour_Hours[Primary Industry] = Total_Factor_Productivity[Primary Industry] * Elasticity_of_Production_to_Labor[Primary Industry] * (Labour_Hours_per_Industry[Primary Industry] ^ (Elasticity_of_Production_to_Labor[Primary Industry] - 1)) * (Infrastructure[Farms] ^ Elasticity_of_Production_to_Infrastructure[Primary Industry]) * (Natural_Capital ^ Elastisity_of_Production_to_Natural_Capital[Primary Industry]) * (Available_Water_Quantity ^ Elasticity_of_Production_to_Available_Water_Quantity[Primary Industry]) {Tonnes Food / Year / People}* (37)

*Marginal_Productivity_of_Labour_Hours[Industry] = Total_Factor_Productivity[Industry] * Elasticity_of_Production_to_Labor[Industry] * (Labour_Hours_per_Industry[Industry] ^ (Elasticity_of_Production_to_Labor[Industry] - 1)) * (Infrastructure[Factories] ^ Elasticity_of_Production_to_Infrastructure[Industry]) * (Natural_Capital ^ Elastisity_of_Production_to_Natural_Capital[Industry]) * (Available_Water_Quantity ^ Elasticity_of_Production_to_Available_Water_Quantity[Industry]) {# Goods / Year / People}* (38)

*Marginal_Productivity_of_Labour_Hours[P&P_Services] = Total_Factor_Productivity[P&P_Services] * Elasticity_of_Production_to_Labor[P&P_Services] * (Labour_Hours_per_Industry[P&P_Services] ^ (Elasticity_of_Production_to_Labor[P&P_Services] - 1)) * (Infrastructure[Private_&_Public_ServiFacilities] ^ Elasticity_of_Production_to_Infrastructure[P&P_Services]) * (Natural_Capital ^ Elastisity_of_Production_to_Natural_Capital[P&P_Services]) * (Available_Water_Quantity ^ Elasticity_of_Production_to_Available_Water_Quantity[P&P_Services]) {# *1000 Services / Year / People}* (39)

Hiring labour is limited by the amount of unemployed householders. Laying-off people on the other hand happens when the demand for labour per industry is below the required labour per industry and one cannot fire more people then there are people employed in each of these industries. Hiring and firing people affect the amount of householders within each of the different household-types (See sector "Households") which allows us to derive the total supply of labour, total labour and unemployment rates.

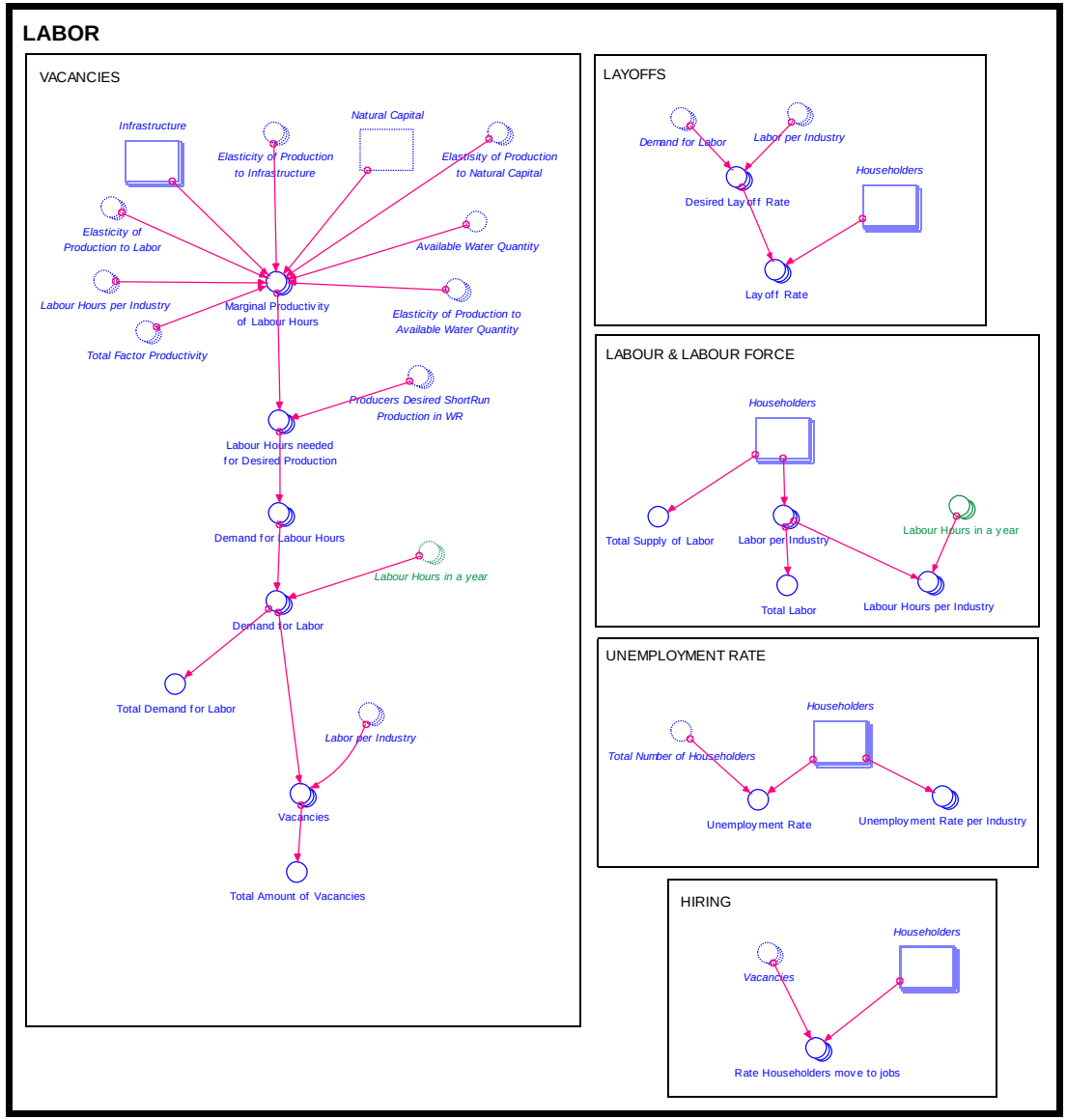



***Figure 76: Subsector Labour which is part of the sector Economics***

Figure 77 illustrates the subsector on household income which determines the average income for the six "labour-type" included in the model: (1) unemployed primary industry worker, (2) primary industry worker, (3) unemployed worker, (4) worker, (5) unemployed service worker, and (6) service worker. Average income for the unemployed is the total of average unemployment benefits and other forms of income (not from labour). Unemployment benefits are for all the unemployed labour types the same. They are adjusted for growth in unemployment (i.e., the assumption that unemployment benefits will decrease (increase) if unemployment rates increase (decreases)) and for changes in price through the "Fisher Consumer Price Index" (see equation 40).

*Average_Unemployment_Benefits = (IF TIME<2010 THEN HISTORICAL_Normal_Unemployment_Benefits ELSE Normal_Unemployment_Benefits) * SMTH1(Fisher_Consumer_Price_Index , Time_to_adjust_Unemployment_Benefits_to_Price_Index * (1 + (Change_in_Time_needed_to_Adjust_UnemployBenefits_to_Price_Index / 100))) * SMTH1(Effect_of_Unemeployment_Rate_on_Unemployment_Benefits , Time_to_adjust_Unemployment_Benefits_to_Unemployment_Rate * (1 + (Change_in_Time_needed_to_Adjust_UnemployBenefits_to_Unemploy_Rate / 100))) {NZD / Year / Person}* (40)

Average income for the employed labour types is the total of their average wages earned through labour and other forms of income (not from labour). Average wages depends on the type of industry you are in. It is a function of the industry's productivity and expected output prices adjusted for pressures emerging from changes in unemployment. By the latter is meant that the model assumes that average wages will decrease when unemployment is high and increase when unemployment is low (i.e., price adjustment for labour due to scarcity). Average wages however cannot fall below the unemployment benefits. This narrative is mainly captured in the following five equations:

*Average_Wages_by_Industry[Industry Type] = MAX(Normal_Average_Wages[Industry Type] * SMTH1(Effect_of_Unemployment_Rate_on_Average_Wages[Industry Type] , Time_to_adjust_Wages_to_Unemployment_Rate[Industry Type]) , Minimum_Wages[Industry Type]) {NZD / Year / Person}* (41)

Where:

*Normal_Average_Wages[Industry Type] = SMTH1(Actual_Productivity_per_Labor[Industry Type] * Producers_LR_Expected_Output_Price[Industry Type] * MIN(Normal_Fraction_of_Productivity_to_Wages[Industry* (42)

*Type] * (1 + (IF TIME<2010 THEN 0 ELSE Percentage_Change_in_Productivity_to_Wages / 100) , 1) , Time_to_Change_Wage_to_Perceived_Productivity[Industry Type] * (1 + (IF TIME<2010 THEN 0 ELSE Percentage%_Change_in_Time_needed_to_Adjust_Wages_to_Productivity[Industry Type] / 100))) {NZD / Year / Person}*

*Actual_Productivity_per_Labor[Primary Industry] = Food_Production / Labor_per_Industry[Primary Industry] {Tonnes Food}* (43)

*Actual_Productivity_per_Labor[Industry] = Production_Goods / Labor_per_Industry[Industry] {# Tonnes Goods}* (44)

*Actual_Productivity_per_Labor[P&P_Services] = Production_Services / Labor_per_Industry[P&P_Services] {*1000 Services}* (45)

Finally, this subsector on household income also translates average income per “labour-type” into “Total Household Income”, “Expected Long Term Total Household Income”, and “Equivalised Disposable Household Income”.

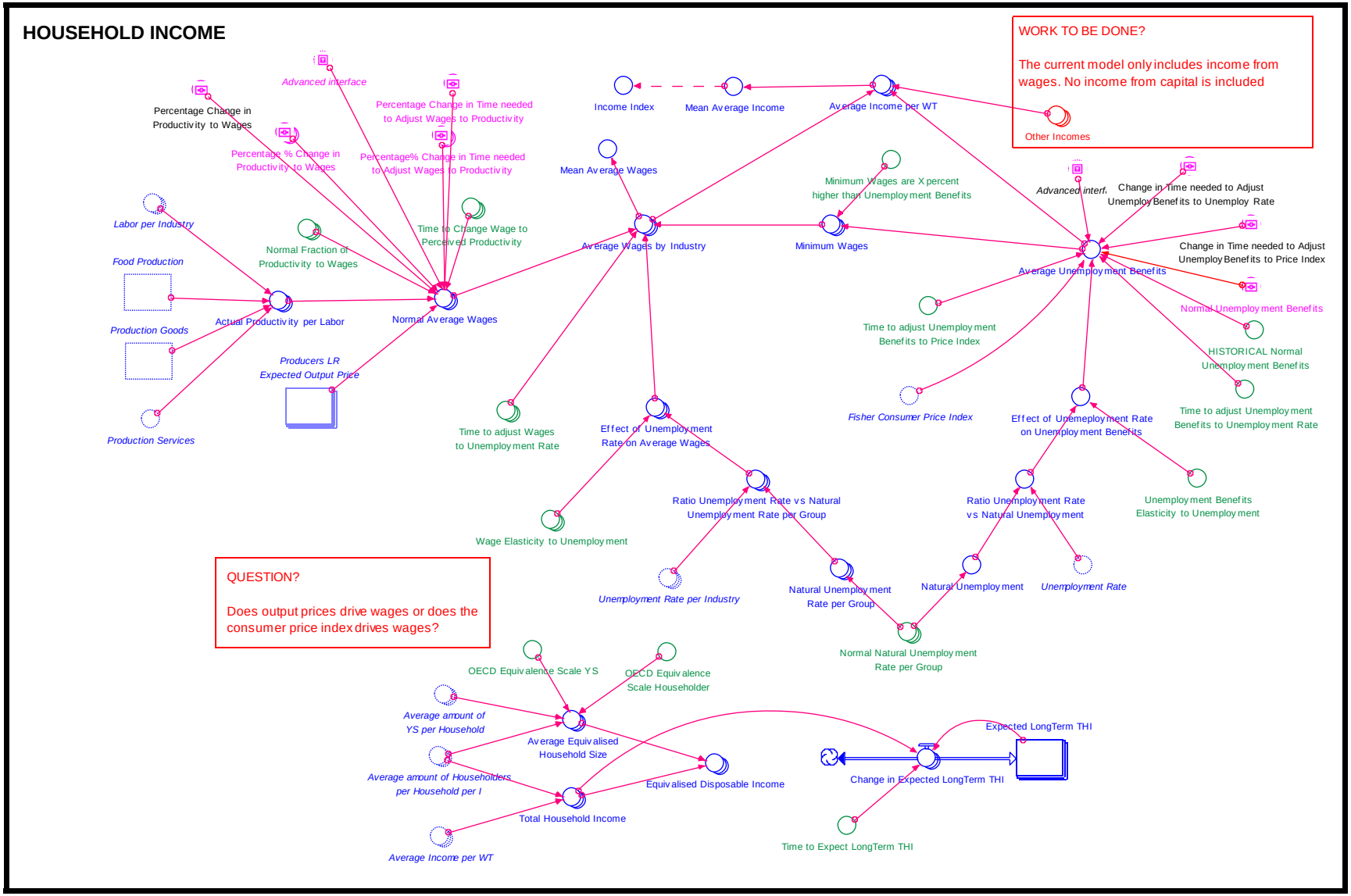



*Figure 77: Subsector Household Income which is part of the sector Economics*

The subsector on infrastructure is given in Figure 78 and captures the change in infrastructure due to changes in the demand for infrastructure that in turn is affected (except for housing) by changes in desired long-run production (see equation 17) in relation to the marginal productivity of infrastructure (in the production process) (equation 46 - 48). Demand for housing is a function of the number of households in the Wellington Region and the desired "amount" of housing per household.

*Marginal_Productivity_of_Infrastructure[Primary Industry] = Total_Factor_Productivity[Primary Industry] * Elasticity_of_Production_to_Infrastructure[Primary Industry] * (Demand_for_Labour_Hours[Primary Industry] ^ Elasticity_of_Production_to_Labor[Primary Industry]) * (Infrastructure[Farms] ^ (Elasticity_of_Production_to_Infrastructure[Primary Industry] - 1)) * (Natural_Capital ^ Elastisity_of_Production_to_Natural_Capital[Primary Industry]) * (Available_Water_Quantity ^ Elasticity_of_Production_to_Available_Water_Quantity[Primary Industry]) {Dimensionless}* (46)

*Marginal_Productivity_of_Infrastructure[Industry] = Total_Factor_Productivity[Industry] * Elasticity_of_Production_to_Infrastructure[Industry] * (Demand_for_Labour_Hours[Industry] ^ Elasticity_of_Production_to_Labor[Industry]) * (Infrastructure[Factories] ^ (Elasticity_of_Production_to_Infrastructure[Industry] - 1)) * (Natural_Capital ^ Elastisity_of_Production_to_Natural_Capital[Industry]) * (Available_Water_Quantity ^ Elasticity_of_Production_to_Available_Water_Quantity[Industry]) {Dimensionless}* (47)

*Marginal_Productivity_of_Infrastructure[P&P_Services] = Total_Factor_Productivity[P&P_Services] * Elasticity_of_Production_to_Infrastructure[P&P_Services] * (Demand_for_Labour_Hours[P&P_Services] ^ Elasticity_of_Production_to_Labor[P&P_Services]) * (Infrastructure[Private_&_Public_ServiFacilities] ^ (Elasticity_of_Production_to_Infrastructure[P&P_Services] - 1)) * (Natural_Capital ^ Elastisity_of_Production_to_Natural_Capital[P&P_Services]) * (Available_Water_Quantity ^ Elasticity_of_Production_to_Available_Water_Quantity[P&P_Services]) {Dimensionless}* (48)

Demand for infrastructure should however be evaluated in the light of land use as pressures for natural area limit the potential expansion of infrastructure (see equation 49).

*Possible_New_Land_to_Infrastructure[Infrastructure Type] = IF Total_demand_for_New_Land_to_Infrastructure < Available_Land_for_Infrastructure THEN Desired_New_Land_to_Infrastructure[Infrastructure Type] ELSE Desired_New_Land_to_Infrastructure[Infrastructure Type] * (Available_Land_for_Infrastructure / MAX (Total_demand_for_New_Land_to_Infrastructure , 1)) {Ha}* (49)

Finally, infrastructure decays over time and potential disasters also affect infrastructure through potential infrastructure loss. The equation that tract the amount of infrastructure over time is given by:

*Infrastructure[Infrastructure Type](t) = Infrastructure[Infrastructure Type](t - dt) + (Change_in_Infrastructure[Infrastructure Type] - Decay_Rate_of_Infrastructure[Infrastructure Type] - Loss_of_Infrastructure_due_to_Disasters[Infrastructure Type]) * dt* (50)

*INITIAL VALUES: Infrastructure[Farms] = 5900000000 {$m^3$}*

*Infrastructure[Factories] = 20000000 {$m^3$}*

*Infrastructure[Private_&_Public_ServiFacilities] = 500000000 {$m^3$}*

*Infrastructure[Water_Infrastructure] = Infrastructure[Farms] * Water_Infrastructure_needed_per_M3_Farm {$m^3$}*

*Infrastructure[Housing] = ARRAYSUM(Desired_Housing[*]) {$m^3$}*

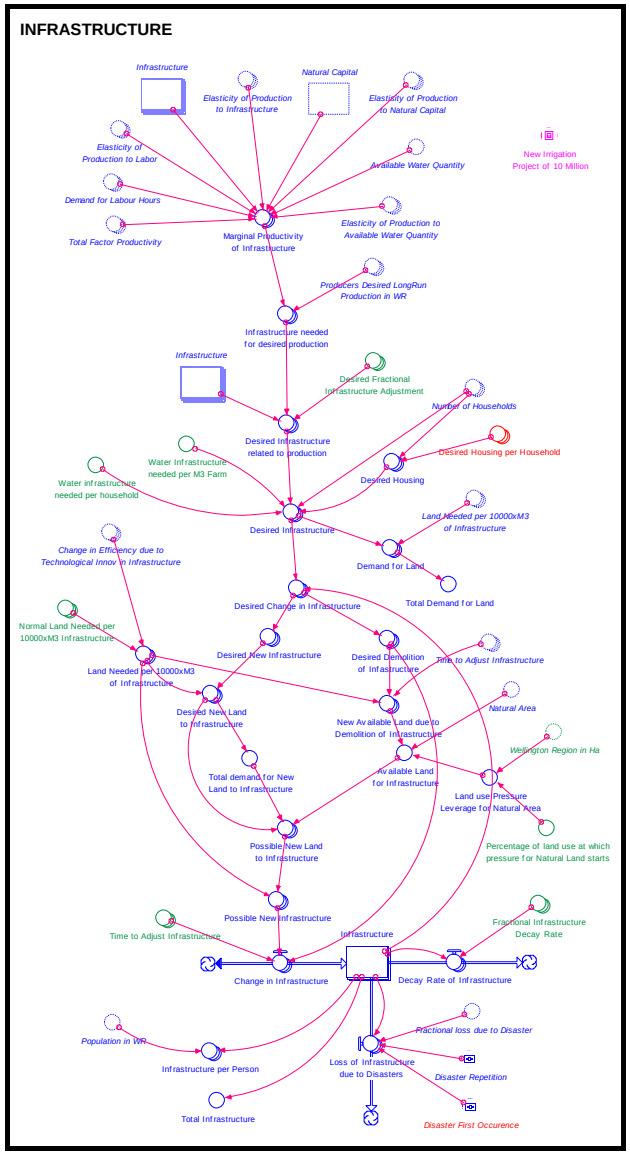



***Figure 78: Subsector Infrastructure which is part of the sector Economics***

The subsector on the relative attractiveness of the Wellington Region is given in Figure 79 and calculates the relative attractiveness of the Wellington Region basically as a (harmonic) weighted average of (1) relative income attractiveness, (2) relative job attractiveness, (3) relative waste and pollution concentration attractiveness, (4) relative housing affordability attractiveness, and (5) relative cultural attractiveness (see equation 51-57). Attractiveness of the Wellington Region is relative as it needs to be compared to the attractiveness of "the outside world".

*Relative_Attractiveness_of_WR[Household Type] = (Weight_for_Housing_Affordability_in_Attractiveness_of_WR + Weight_for_Income_in_Attractiveness_of_WR + Weight_for_Job_Opportunities_in_Attractiveness_of_WR + Weight_for_Waste_Concentration_in_Attractiveness_of_WR + Weight_for_Pollution_Concentration_in_Attractiveness_of_WR + Weight_for_Culture_in_Attractiveness_of_WR) / ((Weight_for_Housing_Affordability_in_Attractiveness_of_WR / Relative_Housing_Affordability_Attractiveness_of_WR) + (Weight_for_Income_in_Attractiveness_of_WR / Relative_Income_Attractiveness_of_WR[Household Type]) + (Weight_for_Job_Opportunities_in_Attractiveness_of_WR / Relative_Job_Attractiveness_of_WR[Household Type]) + (Weight_for_Waste_Concentration_in_Attractiveness_of_WR / Relative_Waste_Concentration_Attractiveness_of_WR) + (Weight_for_Pollution_Concentration_in_Attractiveness_of_WR / Relative_Pollution_Concentration_Attractiveness_of_WR) + (Weight_for_Culture_in_Attractiveness_of_WR / Relative_Cultural_Attractiveness_of_WR)) {Dimensionless}* (51)

Where:

*Weight_for_Culture_in_Attractiveness_of_WR = 20 {Dimensionless}* (52)

*Weight_for_Housing_Affordability_in_Attractiveness_of_WR = 15 {Dimensionless}* (53)

*Weight_for_Income_in_Attractiveness_of_WR = 15 {Dimensionless}* (54)

*Weight_for_Job_Opportunities_in_Attractiveness_of_WR = 25 {Dimensionless}* (55)

*Weight_for_Pollution_Concentration_in_Attractiveness_of_WR = 15 {Dimensionless}* (56)

*Weight_for_Waste_Concentration_in_Attractiveness_of_WR = 10 {Dimensionless}* (57)

Finally, there is a distinction made in this subsection between the "actual" relative attractiveness of the Wellington Region and the "perceived" relative attractiveness of this region. This distinction is important as migration flows (see the "population and Household"-sector) will depend on perception of a region instead of its actual state.

*Perceived_Relative_Attractiveness_of_WR[Household Type](t) = Perceived_Relative_Attractiveness_of_WR[Household Type](t - dt) + ((Relative_Attractiveness_of_WR[Household Type] - Perceived_Relative_Attractiveness_of_WR[Household Type]) / Time_to_Change_Perception_of_Attractiveness_WR[Household Type]) * dt* (58)

*INITIAL VALUE: Relative_Attractiveness_of_WR[Household Type] {Dimensionless}*

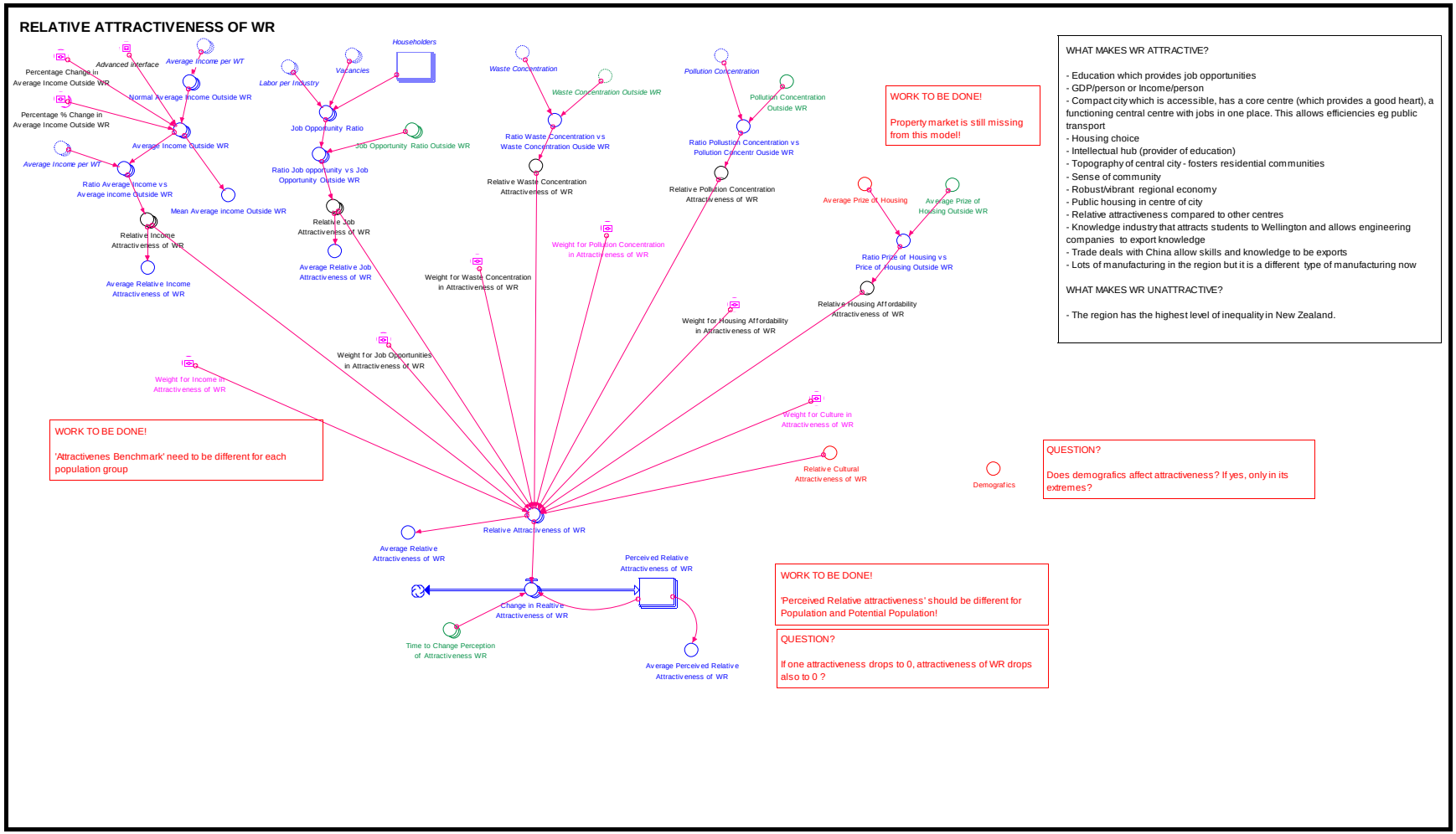



***Figure 79: Subsector Relative Attractiveness of WR which is part of the sector Economics***

The subsector on Goss Domestic Product (GDP) is given in Figure 80 and calculates GDP from an expenditures approach. Household consumption, government consumption, net capital formation (in this case change in product inventory), and export (minus import) are

summed generating GDP (see equation 59). From GDP, GDP per capita and a GDP index (Current GDP/initial GDP in the first time step) are derived.

$$GDP\_Expenditure = Total\_Household\_Consumption\_of\_Local\_Products\_in\_WR\_in\_NZD + Total\_Government\_Consumption\_in\_NZD + Net\_Capital\_Formation\_in\_NZD + Total\_Export\_in\_NZD - Total\_Import\_in\_NZD \ \{NZD / Year\} \quad (59)$$

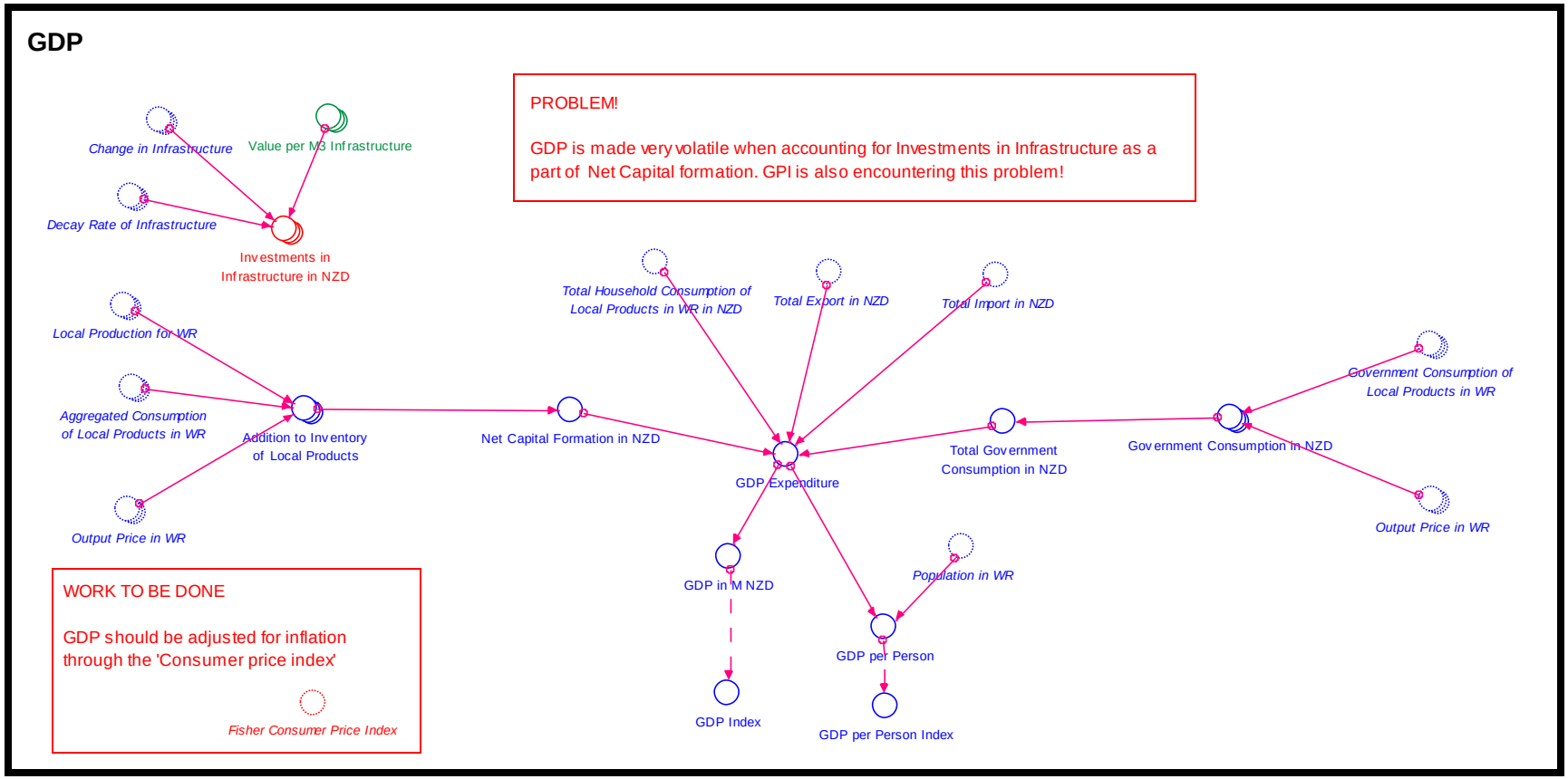



***Figure 80: Subsector GDP which is part of the sector Economics***

The gini-coefficient is calculated in a separate subsector which is given in Figure 81. The gini-coefficient in this model looks at the distribution of "Equivalised Disposable Household Income" (i.e., total household income adjusted for equivalised household size) amongst households. Next to the gini-coefficent, this subsector also generates the percentage of households having a low household income. The model does however not endogenously specify what a low household income is as its value can be adjusting based on perceptions of where a low household income starts.

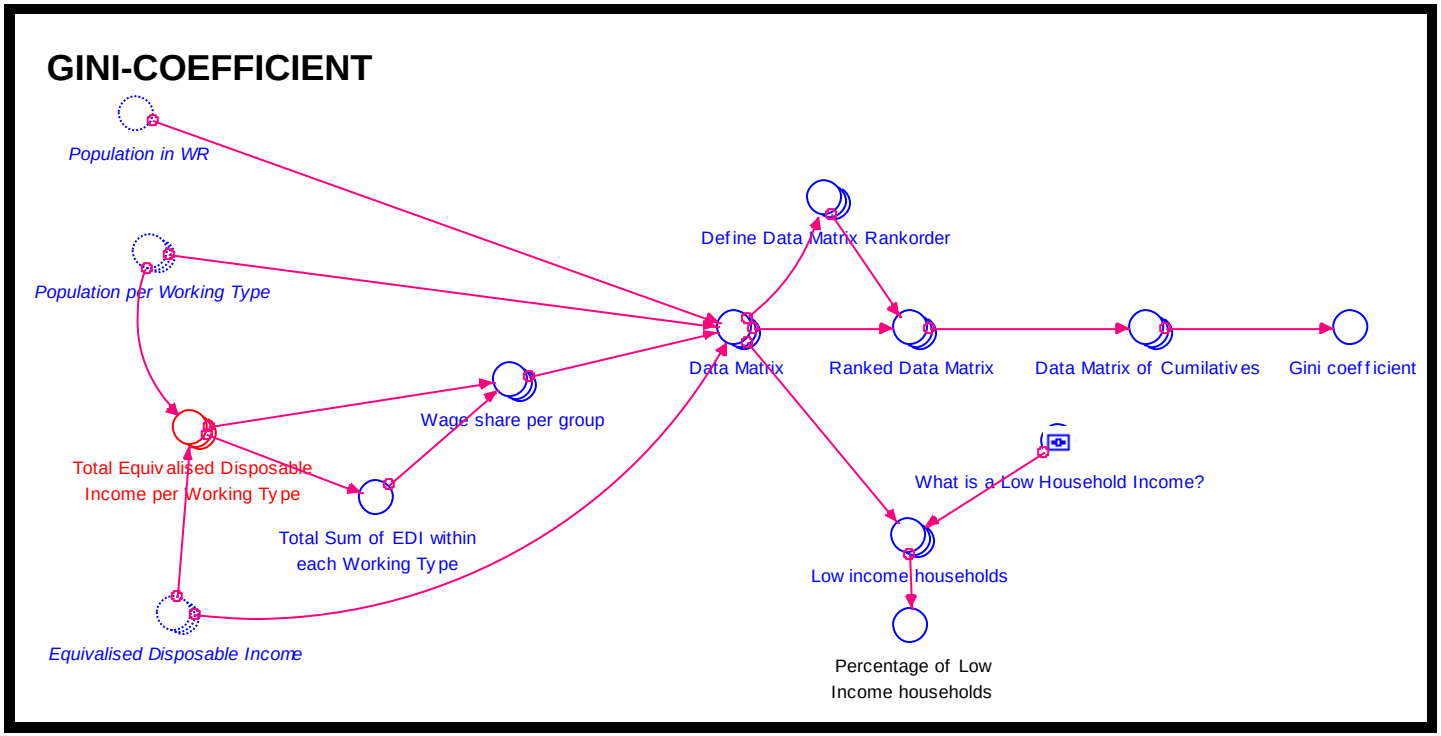



***Figure 81: Subsector Gini-Coefficient which is part of the sector Economics***

The subsection on life expectancy determines a "Life Expectancy at Birth Index" as illustrated in Figure 83. At the moment, life expectancy is only a function of inequality (i.e., the gini-coefficient) as given in equation 60.

$$Life\_Expectancy\_at\_Birth = Normal\_Life\_Expectancy\_at\_Birth * (1 + Effect\_of\_Inequality\_on\_Life\_Expectancy\_at\_Birth) \ \{Dimensionless\} \quad (60)$$

Where the effect of inequality on life expectancy at birth is the following graph function:

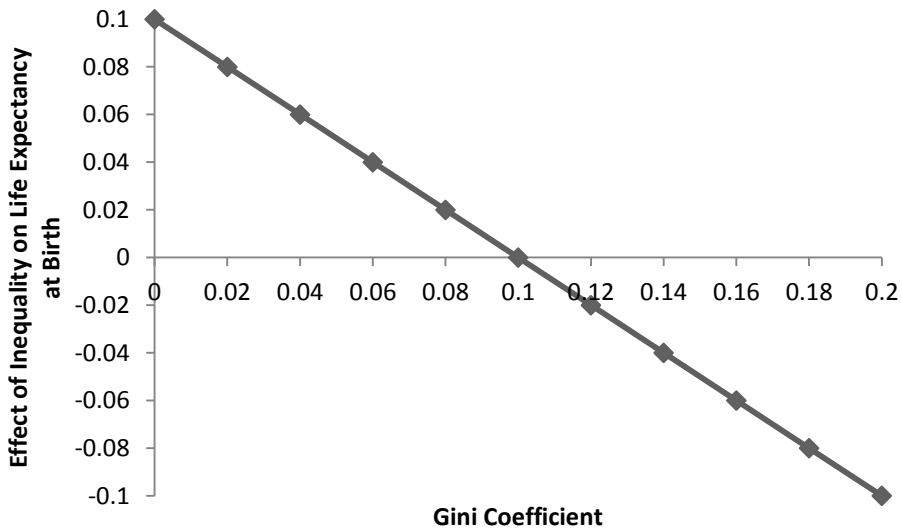



***Figure 82: The effect of Inequality on life expectancy at birth***

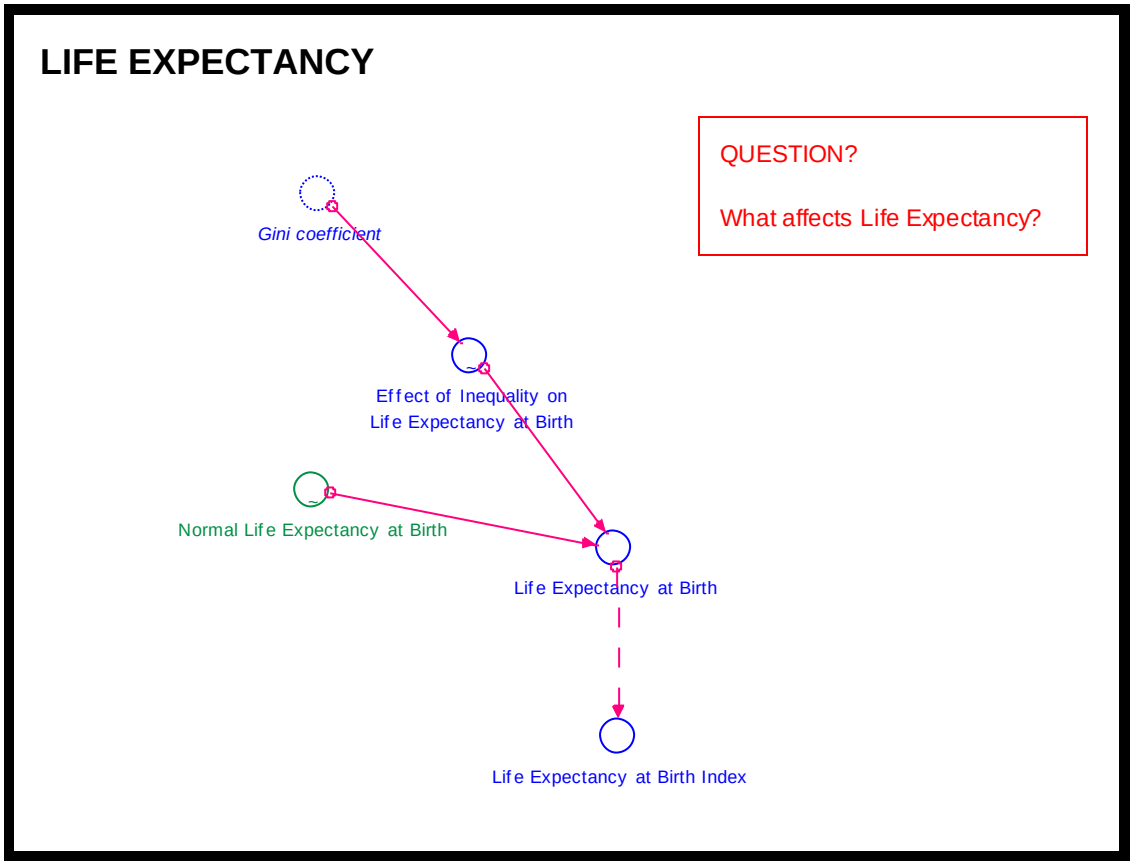



***Figure 83: Subsector Life Expectancy which is part of the sector Economics***

The subsector on food quality is given in Figure 84 and is still underdeveloped. Food quality of the local products is currently only determined by the quality of the water in the Wellington Region. As water quality changes, so does the quality of food taking into account that there is a delay between the two.

*Quality_of_Food_Produced_in_WR(t) = Quality_of_Food_Produced_in_WR(t - dt) + ((Food_Quality_Maximum - Quality_of_Food_Produced_in_WR) / Time_to_Change_Food_Quality) * dt* (61)

*INITIAL VALUE: Food_Quality_Maximum {Dimensionless}*

Where:

*Food_Quality_Maximum = Water_Quality {Dimensionless}* (62)

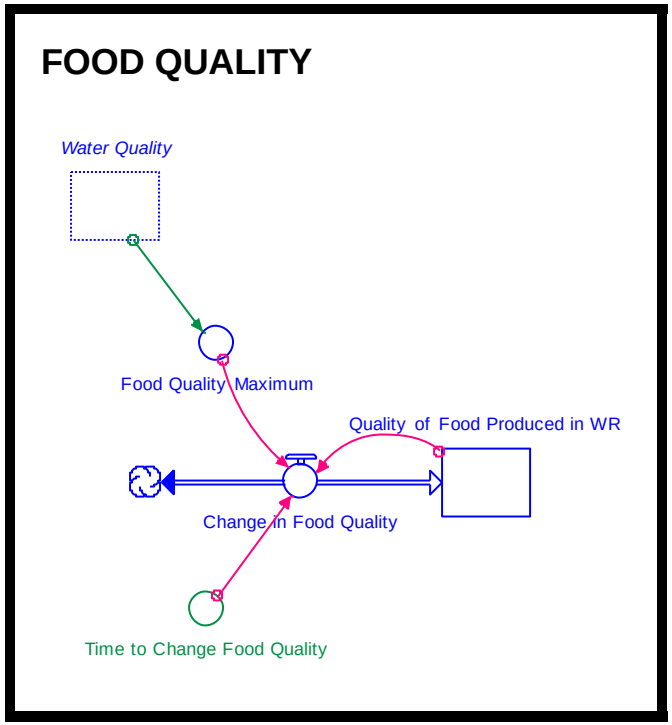


*Figure 84: Subsector Food Quality which is part of the sector Economics*

**Sector government**

The government sector consists of four subsectors (see Figure 88): (1) Government demand for local production, (2) Government demand for import, (3) Government income, and (4) Government expenses. The last two are however not yet developed.

Government demand for local production is mainly a function of a reference government demand for local products and services adjusted for the interplay between output prices in the Wellington Region versus output prices in the world (structure and equations are similar to "Household demand for production in the Wellington Region"). Government demand for import is determined similarly by a reference government demand for import adjusted for the interplay between output prices in the Wellington Region versus output prices in the world. The reference government demand graphs used in this sector are:

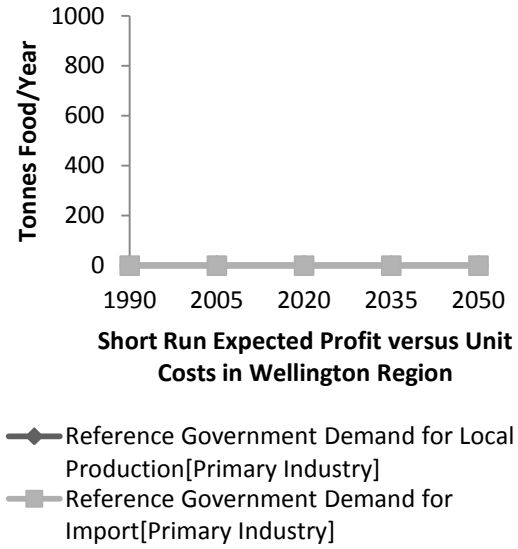



*Figure 85: Reference government demand for (1) local production and (2) import for the primary industry*

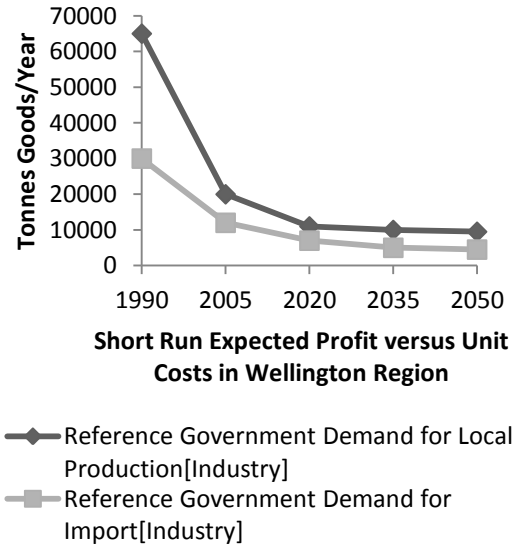



*Figure 86: Reference government demand for (1) local production and (2) import for the industry*

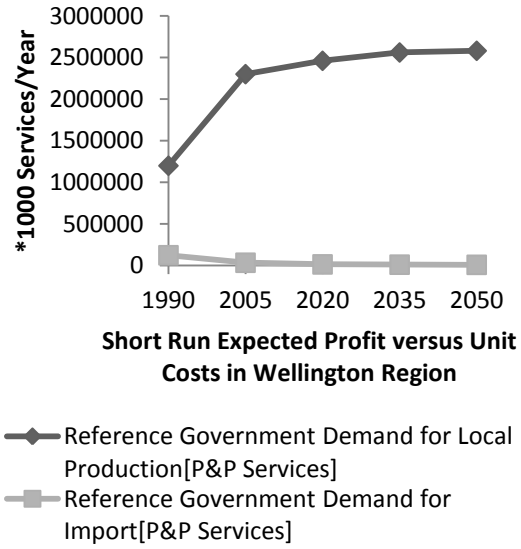
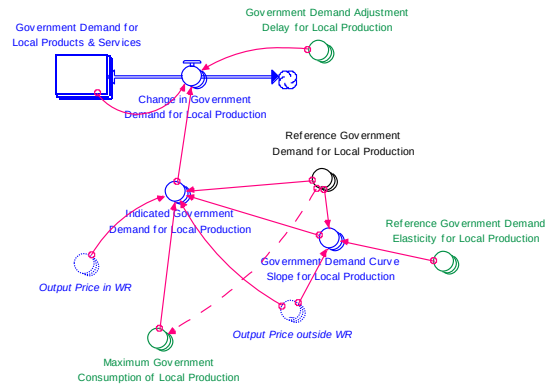



*Figure 87: Reference government demand for (1) local production and (2) import for the private and public*

GOVERNMENT

## GOVERNMENT INCOME

## GOVERNMENT DEMAND FOR LOCAL PRODUCTION




## GOVERNMENT EXPENSES

## GOVERNMENT DEMAND FOR IMPORT

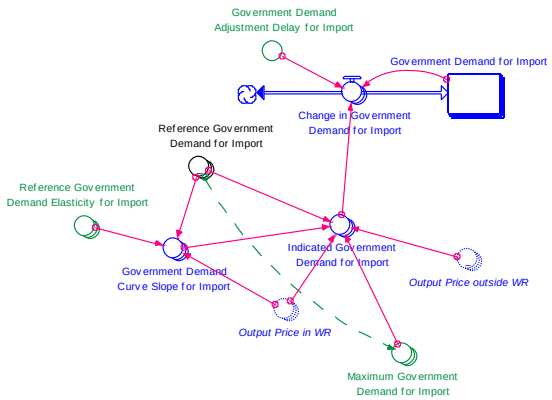


*Figure 88: Sector Government*

**Sector external factors**

This sector contains two subsectors (see Figure 89): (1) technological efficiency and (2) disaster. The subsector of technological efficiency allows for changing the required space needed to build a similar infrastructure unit. This is done through changing the value of the variable "Change in efficiency due to technological innovation in infrastructure". Next, this sector also allows for testing what if Wellington faces disasters like earthquakes. To test this, the subsector of "Disaster" requires three inputs: (1) the percentage of loss due to the disaster, (2) when the disaster (first) occurs, and (3) the time intervals between disasters (i.e., disaster repetition).

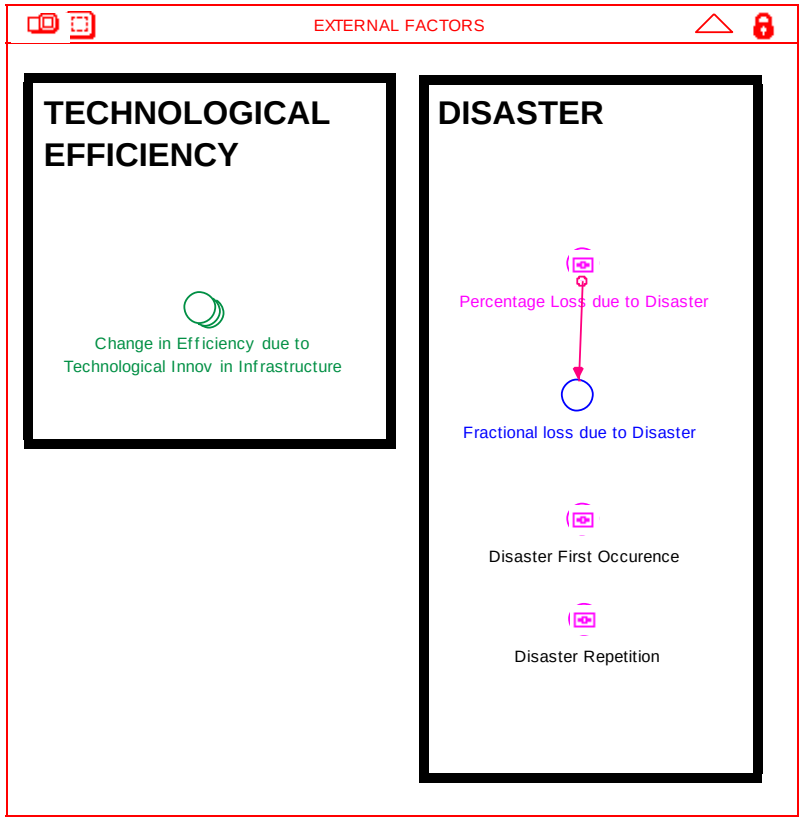


*Figure 89: Sector External Factors*

# List of figures

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# REFERENCES

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