



**Infrastructure under one roof:
standardising how we think about
the shared services around us**

Discussion Document

Foreword

Kupu takamua

Our wellbeing depends on our infrastructure

E whakawhirinaki ana tō tātou ora ki ā tātou hanganga

Our wellbeing depends on our infrastructure. Whether it's taking kids to school, moving freight from a to b, keeping our homes warm or connecting our businesses to the world, there are few parts of our life that don't rely on the shared experience of infrastructure.

For this reason, we need to take a strategic view of the planning, building and investing of infrastructure in this country, making sure that the decisions we make now contribute to the success of future generations. The significance of this task is reflected in the Māori name for the New Zealand Infrastructure Commission, Te Waihangā, which means the cornerstone.

Te Waihangā was formed to give New Zealand this strategic view, and we're working on a 30-year strategy for New Zealand infrastructure. This paper is an early step in this work, setting out our thinking about infrastructure as an integrated system of networks.

Over the coming months, we'll also be releasing a series of "State of Play" reports that take a close look at the key sectors that make up this system. By building a picture of New Zealand's current infrastructure, we start our journey in identifying the key challenges and opportunities that we all face. Considering these against major structural changes, such as our changing climate, rapidly growing cities or evolving global technologies will help get the best wellbeing outcomes for New Zealanders, both today and in the future.

We're keen to receive your feedback on the definition of infrastructure and integrated management framework set out in this paper, and look forward to hearing from you as our State of Play reports are released and we continue to work to develop the infrastructure strategy for New Zealand's future.



Ross Copland
Chief Executive

Executive Summary

He whakarāpopototanga

The New Zealand Infrastructure Commission, Te Waihangā is working to improve New Zealanders' lives through better infrastructure. A major part of this work is the development of a 30-year Infrastructure Strategy that will be presented to the Minister for Infrastructure by September 2021. This strategy will look ahead to 2050, and consider how infrastructure will support environmental, social, cultural and economic wellbeing for New Zealanders.

E mahi ana a Te Waihangā ki te whakapai ake i te kōunga o te ora o ngā tāngata o Aotearoa mā ngā hanganga kōunga ake. Ko te whakawhanake i tētahi Rautaki Hanganga 30-tau tētahi wāhanga nui o tēnei mahi, ā, ka tāpaetia tēnei ki te Minita Hanganga hei te marama o Mahuru i te tau 2021. Ka tiro takamua tēnei rautaki ki te tau 2050, me te āta whakaaro ka pēhea ngā hanganga e tautoko ai i te ora ā-taiao, ā-pāpori, ā-ahurea, ā-ōhanga hoki, o ngā tāngata o Aotearoa.

As an initial step in developing this strategy and to help define the perimeter of the work programme ahead, we've developed a working definition of infrastructure. Our definition places wellbeing outcomes at the core, while recognising commonalities, including the use of capital such as financial and environmental resources; the interconnectedness of physical structures; and the delivery of shared services, as well as the wellbeing benefits we get from those shared services. In short, Te Waihangā defines infrastructure as follows:

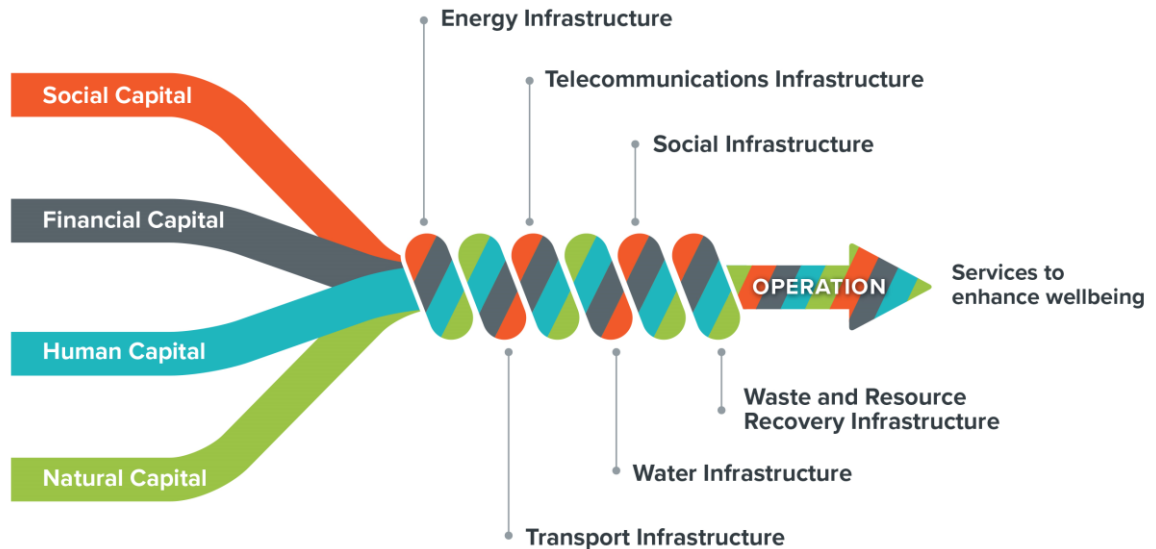
Hei tepe tuatahi ki te whakawhanake i tēnei rautaki, hei āwhina hoki ki te tautuhi i ngā tepenga o te hōtaka mahi e tū mai nei, kua whakawhanaketia e mātou tētahi tautuhinga hohe o tēnei mea te hanganga. E whakamātāmua ana tā mātou tautuhinga i ngā paetae ora, me te tautohu hoki i ngā ōritetanga, me te whakamahi i te haupū rawa pērā i ngā rawa ōhanga, taiao hoki; te whakahonongatahi o ngā hanganga ōkiko; me te tukunga hoki o ngā ratonga tūhonohono, tae atu hoki ki ngā patanga e whiwhi ana tātou katoa i ngā ratonga tūhonohono. Nō reira, anei tā Te Waihangā tautuhi i ngā hanganga:

“A system of inter-connected physical structures that employ capital to provide shared services to enhance wellbeing.”

“He pūnaha o ngā hanganga tūhonohono e whakamahi ana i ngā haupū rawa hei whakarato ratonga tūhonohono e kōunga ake ai te ora.”

Figure 1: Te Waihanga's definition of infrastructure

Hoahoa 1: Tā Te Waihanga tautuhinga o te hanganga

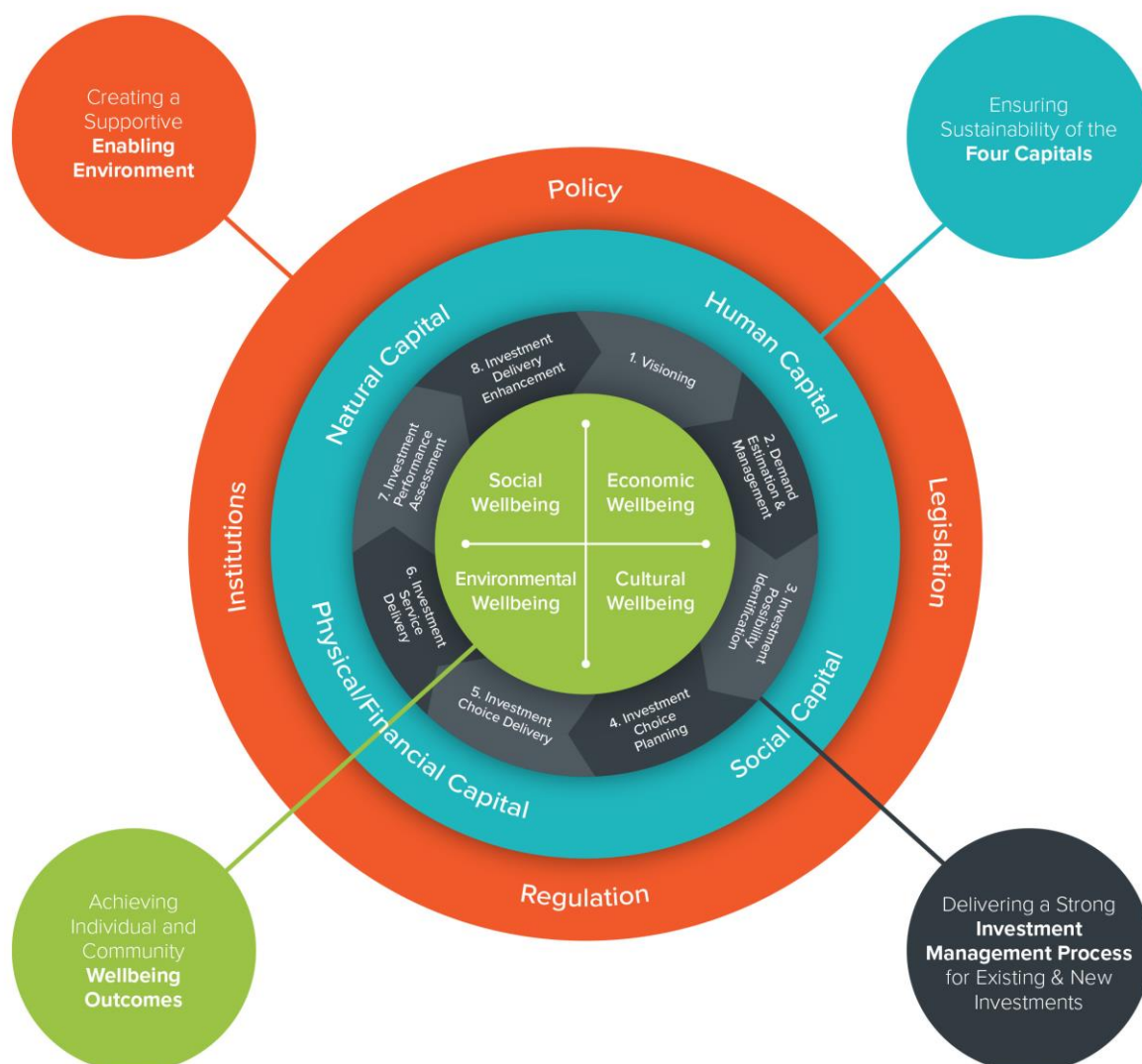


By defining infrastructure in this way, we are able to develop a common framework to think about the integrated management of infrastructure. This considers the relationship between the enabling environment for our infrastructure, the sustainable use of the capitals employed in its development, the investment management process and the wellbeing benefits created by infrastructure services.

Mā te tautuhi pēnei i te hanganga, e āhei ana i a mātou te whakawhanake i tētahi anga pātahi e whakaaro ai ki tētahi momo whakahaere tōpū i te hanganga. E whakaaro ana tēnei ki te hononga o te taiao whakaahei mō tā tātou hanganga, te whakamahinga toitū o ngā haupū rawa e whakamahi ana i tana whakawhanaketanga, te tukanga whakahaere whakangao pūtea me ngā patanga ora e whakaputaina mai ana i ngā ratonga hanganga.

Figure 2: Integrated Infrastructure Management Framework

Hoahoa 2: Anga Whakahaere Hanganga Tōpū



These four components integrate to support decision making across all sectors and asset classes in the infrastructure ecosystem. Analysis of these components can also help us to understand the root cause of infrastructure challenges, identify strategic priorities for change and maximise the social return on our collective dollar invested in infrastructure.

E mahi ngātahi ana ēnei mea e whā ki te tautoko i te whakatakotoranga whakaaro huri noa i ngā rāngai katoa me ngā momo rawa i te rauwiringa kaiao hanganga. Mā te arohaehae i ēnei mea mātou e āwhinatia ai ki te mārama i ngā pūtakekanga o ngā whakapātaritari hanganga, me te tautohu i ngā whakaarotau rautaki mō te panoni me te whakanui ake i ngā painga pāpori i tā tātou whakangao moni ā-rōpū ki ngā hanganga.

As we work towards our strategy, we want to hear from you – starting now. Tell us what you think about our working definition of infrastructure and our integrated infrastructure

management framework. Have we got it right or do you see gaps? We will refine and assess our work based on the feedback we receive.

I a tātou e mahi ana ki te whakatutuki i tā mātou rautaki, kei te hiahia whakarongo mātou ki a koe – ināia-tonu-nei. Whākina mai ōu whakaaro ki tā mātou tautuhinga hohe me tā mātou anga whakahaere hanganga tōpū. Kua tika tā mātou, kua kite rānei koe i tētahi hapa? Ka whakatōtika me te aromatawai hoki mātou i tā mātou mahi i runga tonu i ngā whakahoki kōrero.

Context

Horopaki

Who we are and what we do

Ko wai mātou, he aha tā mātou mahi

The New Zealand Infrastructure Commission, Te Waihangā is working to improve New Zealanders' lives through better infrastructure. It aims to lift the level at which infrastructure is planned and delivered, taking a strategic approach so that we can maximise the social return on our collective dollar, and stand well prepared in the face of an uncertain future.

Our Māori name, Te Waihangā, means the cornerstone, or to make, create, develop, build, construct, generate. Te Waihangā therefore indicates the significance of long-term planning in shaping New Zealand's future.

A major part of this work is the development of a 30-year Infrastructure Strategy. The strategy will look ahead to 2050, and consider how infrastructure might support environmental, social, cultural and economic wellbeing for New Zealanders. This will be delivered to the Minister for Infrastructure by September 2021 and will set out how we can make sure our investment in infrastructure delivers what we need, where we need it and at the right time.

Our plan to develop the 30-year Infrastructure Strategy

Tā mātou mehere ki te whakawhanake i te Rautaki Hanganga 30-tau

Our plan is to work with New Zealanders between now and September 2021 to develop the recommendations in the 30-year Infrastructure Strategy and the evidence base that sits behind it. To develop a credible and compelling strategy, it is essential that Te Waihangā works broadly along the infrastructure value chain – including policy, regulation, planning, investment, procurement and delivery. It also means getting input from the customers of infrastructure, such as iwi, businesses and communities. This will help us build consensus on a long-term vision for infrastructure and the outcomes New Zealand wants to achieve.

This document is designed to be a “conversation starter”, introducing how we are defining infrastructure, and how we are thinking about it as a system-of-systems that supports wellbeing. We understand that our infrastructure works together as part of an inter-connected whole. Our roads carry pipes and power lines; rail lines connect us to homes, workplaces and schools; telecommunications connect our businesses to the world, support world class healthcare and enable remote learning.

But we cannot understand what is required in the future without first understanding what we have now, and the contribution infrastructure makes to the everyday lives of New Zealanders today. Therefore, over the coming months we'll be releasing sector-based “State of Play” reports for each of the following infrastructure sectors:

1. **Telecommunications:** Broadband, fixed line and mobile
2. **Energy:** Electricity, Oil, Gas, Hydrogen and other fuels
3. **Water:** Three-waters, flood protection, storage and irrigation
4. **Resource Recovery and Waste:** Landfill and recycling facilities
5. **Transport:** Land, aviation and maritime
6. **Education, Skills and Research**
7. **Health and Aged Care.**

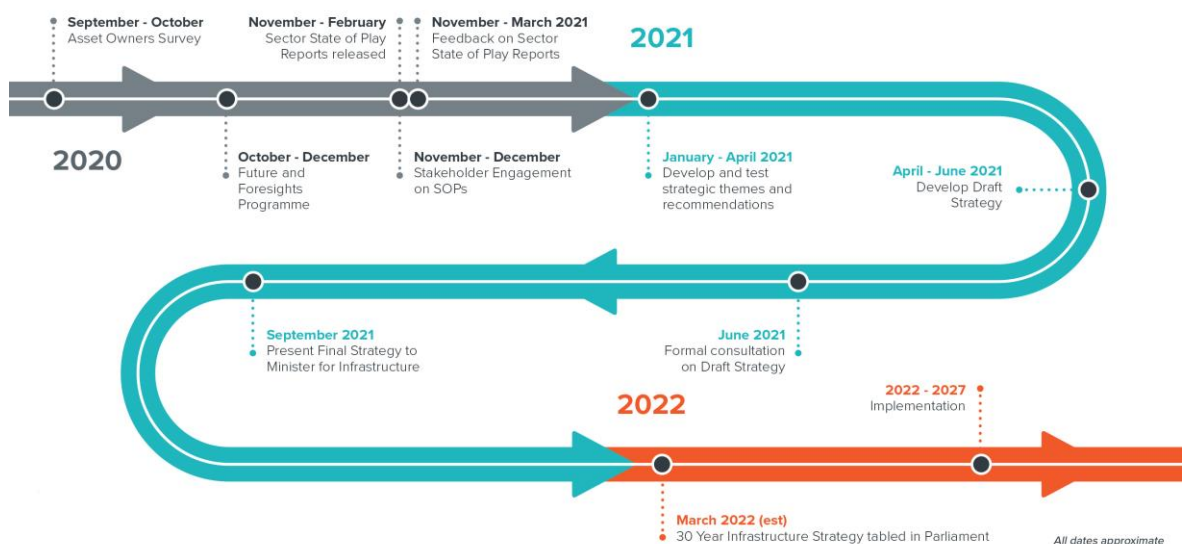
The sector reports are the result of desktop research, augmented by insights from a survey of infrastructure asset owners, and engagement with sector experts. These reports will be updated over time as better information and data becomes available.

As well as continuing to build on our picture of the state of play, next steps include building our understanding of future trends and likely challenges, including climate change, incorporation of Mātauranga Māori, demographic change and the role of technology. We will look at what our way of life might be 30 years from now and, based on the available evidence, begin to form recommendations that will help us get the most out of our shared infrastructure assets.

Figure 3, below, sets out the road map for delivering the strategy. We'll be publishing the State of Play reports over the coming months and we'll regularly share our thinking on what will be included in the strategy, focusing on the cross-cutting themes, the opportunities and challenges that are on the horizon, and a flavour of the recommendations as they emerge.

This will be followed by a draft strategy in mid-2021 which we will consult widely on.

Figure 3: The timeline for delivering the 30-year infrastructure strategy



Have your say

Kōrero mai

We'll share our work as we go and are keen to hear what you think, starting now. Tell us what you think about our definition of infrastructure and the integrated infrastructure management framework. Have we got it right or are there issues, information or ways of looking at things we've missed?

You'll also have the opportunity to comment on the next stages of our work, the Sector State of Play reports and on the draft strategy. We'll be continually refining and assessing our work based on the feedback we get from you and others.

Infrastructure under one roof: standardising how we think about the shared services around us

Te hanganga i raro i te tuanui kotahi: e whakaauraki ana i tā tātou whakaaro ki ngā ratonga tūhonohono huri noa i a tātou

Our Definition of Infrastructure

Tā mātou tautuhinga o te Hanganga

“A system of inter-connected physical structures that employ capital to provide shared services to enhance wellbeing.”

While most people have an instinct for what core infrastructure is, a precise definition is more difficult. Roads, pipes and wires are all obviously in scope but there are shades of grey. For many, social infrastructure is equally important, and includes housing, education, health and civic infrastructure. For others, more out-of-sight shared assets, such as community and social networks and digital infrastructure might be included.

In developing an infrastructure strategy for New Zealand, there is a need to bring together the common characteristics of infrastructure.^{1,2,3} These are the employment of capital, the interconnectedness of physical structures, the delivery of shared services and the wellbeing outcomes derived from those services.

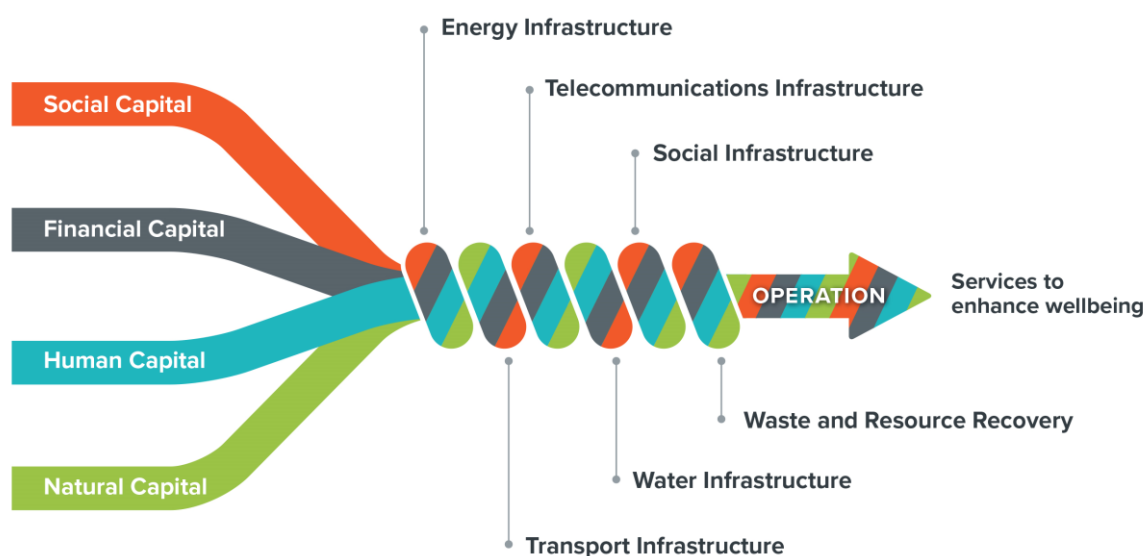
Figure 4 illustrates the components of our working definition, showing how they are related to one another in delivering wellbeing services.

¹ Walter Buhr “What Is Infrastructure?” Volkswirtschaftliche Diskussionsbeiträge, (2003).
<https://www.econstor.eu/handle/10419/83199>.

² Remy Prud’Homme. “Infrastructure and Development.” In *Annual World Bank Conference on Development Economics*, (2005)153–89,

³ Gianpiero Torrisi, “Public Infrastructure: Definition, Classification and Measurement Issues.” *Economics, Management, and Financial Markets* 4, no. 3 (2009): 100–124.

Figure 4: Te Waihangā's definition of infrastructure



These three components are further described below:

1. Infrastructure employs capitals ...

The four capitals (natural, human, social, and physical/financial capital) are central and scarce ingredients to the process of delivering infrastructure. Natural capital provides services to infrastructure in the form of land and raw materials like cement, aggregate, water and steel.⁴ Human capital provides people who have the skills, education and experience necessary to build and operate infrastructure. Social capital refers to the ties that help make the most of human capital across networks of people, such as the role organisations play in planning, developing and maintaining infrastructure. Finally, physical and financial capital provides the finance and funding necessary to bring all the other elements together.

2. To create a complex system of inter-connected physical structures ...

Although infrastructure sectors have often operated separately, infrastructure is a collection of interdependent systems - networks connecting to networks. Despite this, infrastructure has often been organised in terms of sectors, such as transport, energy or health. In recent years there has been recognition of infrastructure as a complex network of interconnected elements.^{5,6,7,8} Convergence across these systems - such as the increasing blend between digital, energy and transport infrastructure - increasingly underscores the importance of thinking in systems.

⁴ We acknowledge that, for some, parts of our environment such as rivers are regarded as systems of "natural infrastructure".

⁵ Adrian Hickford, "Creating an Ensemble of Future Strategies for National Infrastructure Provision." *Futures* 66 (February 2015): 13–24.

⁶ Jim Hall, Robert Nicholls. *The Future of National Infrastructure*. Cambridge University Press, 2016.

⁷ Hall *et al*, *The Future of National Infrastructure: A System-of-Systems Approach*. Cambridge University Press, 2016.

⁸ Ralitsa Hiteva, Jim Watson. "Governance of Interdependent Infrastructure Networks." In *the Future of National Infrastructure: A System-of-Systems Approach*, edited by Jim Hall, Martino Tran, Adrian Hickford, Robert Nicholls, 294–309. Cambridge University Press, 2016.

The following extract from an analysis of infrastructure in cities highlights how traditional infrastructure sectors are rapidly converging:

“Looking back over the last century, it is fair to say that the layers of ... infrastructure took form ... in response to discrete civic needs and at different times – for streets and clean water in the nineteenth century, for efficient transport at the dawn of the twentieth, for speedier means of trade by the middle of that century. It is not surprising, then, that the systems portrayed here operate almost entirely independently of one another and share little or nothing in the way of physical infrastructure.

As we look to the future, however, it is likely that connections between forms of infrastructure will become more routine ... Telecom lines may well run through sewers, solar power will be used at sewage plants, wastewater can replace freshwater for industrial uses, and garbage may be among the fastest growing rail freight commodities.”⁹

Kate Ascher, The Works: Anatomy of a City

Converging infrastructure is known as “sector coupling”^{10,11} and is associated with a further phenomenon known as “distributed infrastructure”. This is infrastructure embedded in households or communities, such as electricity generating rooftop solar panels. These and other technologies mean consumers will increasingly be producers of shared infrastructure services too. Infrastructure is transforming in complex ways that require more nuance than a sector-siloed approach. Collaboration across infrastructure sectors will become paramount.

3. That provide shared services to enhance wellbeing

Our way of life and our wellbeing depends on infrastructure.¹² Most homes and businesses are connected to mains water, waste and stormwater discharge pipes, electricity and gas reticulation, and telecommunications connections. Their properties are connected to a road, footpath and other forms of transport. These connections provide water, energy and communication services that people use in a variety of ways to serve their lives and businesses.

In measuring infrastructure’s contribution to wellbeing, we are guided by the New Zealand Treasury’s Living Standards Framework (LSF)¹³, which balances the four capitals with twelve “domains” of wellbeing outcomes. We are also guided by the Local Government Act 2002 (LGA), which provides for four wellbeings¹⁴ (social, environmental, economic and cultural wellbeing), and He Arotahi Tatauranga, which incorporates Māori perspectives on wellbeing.

For the purposes of the first strategy, we are focusing on a particular set of infrastructure sectors: transport, three waters, energy, telecommunications, waste and resource recovery, health and

⁹ Kate Ascher. *The Works: Anatomy of a City*. Penguin Books, 2005, 205.

¹⁰ Rinaldi *et al.* “Identifying, Understanding, and Analyzing Critical Infrastructure Interdependencies.” *IEEE Control Systems*. Institute of Electrical and Electronics Engineers, January 1, 2002.

¹¹ Robinius *et al.*, “Linking the Power and Transport Sectors—Part 1: The Principle of Sector Coupling.” *Energies* 10, no. 7 (July 21, 2017): 956.

¹² Angela Walters “Flourishing Systems - Re-Envisioning Infrastructure as a Platform for Human Flourishing.” University of Cambridge, May 12, 2020. <https://www.cdbb.cam.ac.uk/news/flourishing-systems>.

¹³ “Our Living Standards Framework,” The Treasury. December 12, 2019. <https://treasury.govt.nz/information-and-services/nz-economy/higher-living-standards/our-living-standards-framework>.

¹⁴ Local Government Act 2002, s 3.

education. This set is only a starting point - as the work of Te Waihanga continues to evolve, we expect the perimeter to widen.

Standardising how we think about the shared services around us

E whakaauraki ana i tā tātou whakaaro ki ngā ratonga

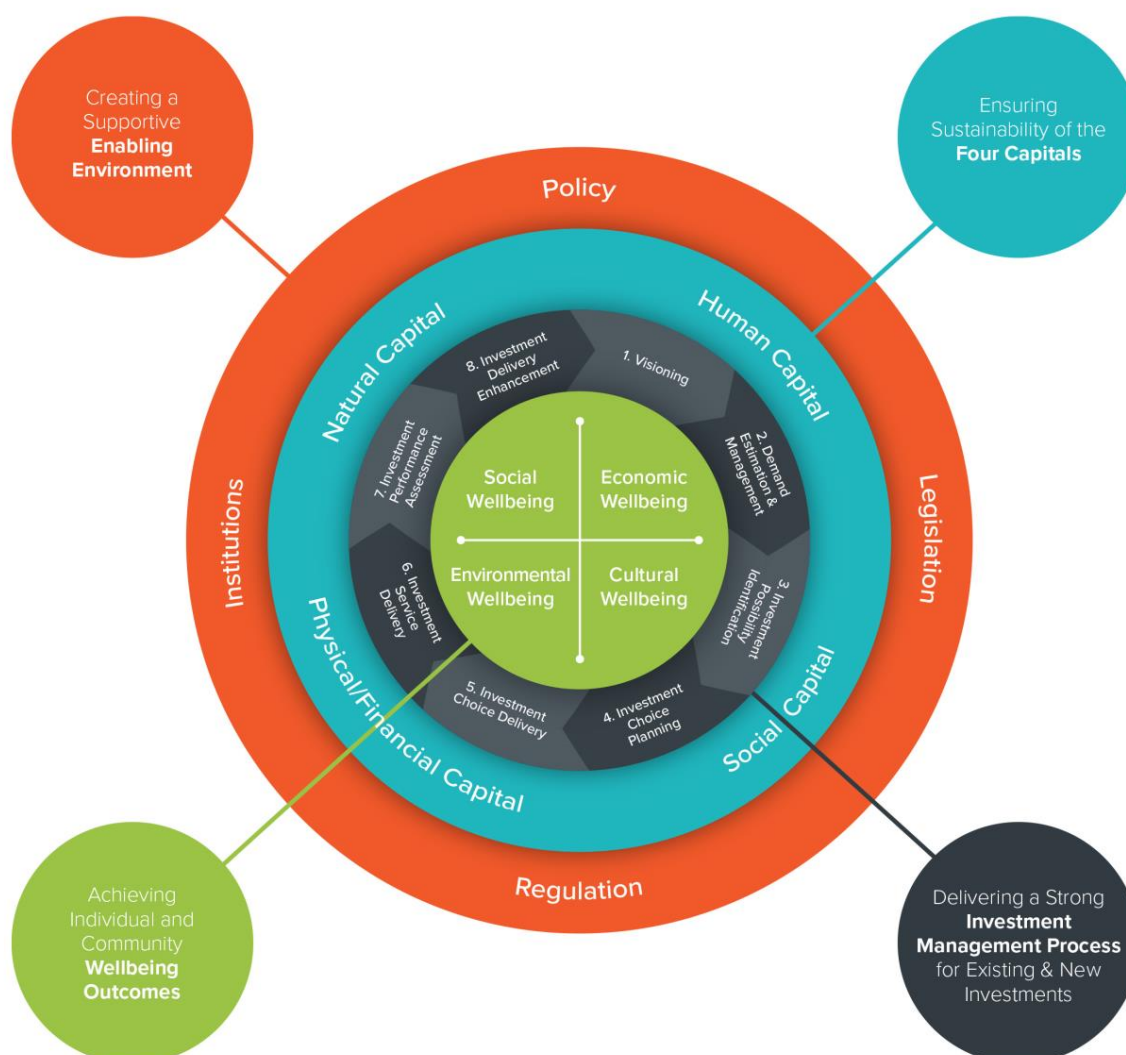
tūhonohono huri noa i a tātou

With a definition in place, we can begin to establish a standardised framework for thinking about infrastructure that categorises the tools and process available to create value from shared community assets. This is shown in Figure 5, and brings together the enabling environment, sustainability of the four capitals, the investment management process and wellbeing outcomes.

This approach highlights that the greatest benefit from infrastructure will come when we optimise the quality of policies, legislation, regulation and public institutional arrangements (the enabling environment)¹⁵. The quality, experience and maturity of each part of this enabling environment is key to how well the country's infrastructure is supported. Systemic problems affecting the performance of infrastructure service delivery can often be traced back to parts of the enabling environment that need strengthening.

¹⁵ "Measuring the Enabling Environment for Public-Private Partnerships in Infrastructure." The Economist. Accessed August 2020. <https://infrascope.eiu.com/>

Figure 5: Integrated Infrastructure Management Framework



This framework has four components:

1. Balancing policy settings, legislation, regulation and institutions to create a supportive enabling environment
2. Ensuring sustainability of the four capitals
3. Delivering a strong investment management process for existing and new infrastructure investments
4. Achieving individual and community wellbeing outcomes – this sits at the heart of the integrated infrastructure management framework.

These four layers integrate to support decision making across all sectors and types of asset in the infrastructure ecosystem, whether these decisions relate to anticipating peoples' needs, delivering shared services or adapting to change. Decisions made about infrastructure need to create a balance between social, sustainable and secure outcomes for New Zealand.

The infrastructure investment management process is a major determinant of infrastructure outcomes. A strong enabling environment for infrastructure includes having clear and transparent processes for selecting, planning, developing, managing and improving infrastructure choices, whether they be built or non-built options.

As shown in Figure 5, above, and drawing heavily on the New Zealand Treasury's Investment Management System (IMS)¹⁶, an infrastructure investment process has eight distinct parts, as follows:

1. Visioning - The starting point for infrastructure investment planning is building a sense of the range of futures New Zealand might face and which of these possibilities are preferred. Assessing preferred futures helps establish a vision for the future through which an infrastructure lens can be applied.
2. Demand Estimation - Interpreting preferred futures for infrastructure helps when it comes to estimating the demand for future infrastructure services. Demand can be met through a combination of demand side and supply side measures.
3. Investment Possibilities – Involves building on the first two steps to state the compelling economic case for change, identifying investment options that optimise value for money, assessing commercial viability and affordability of the service, and examining delivery options.
4. Investment Choices – This means choosing the investment option that is most strategically aligned, represents the best value for money, and is achievable. Investments can involve built and non-built solutions, the second of which can lead to less employment of the capitals.
5. Investment Implementation - Irrespective of the delivery model selected, whether public or commercial, ensuring the investment is implemented on time, to budget and specification.
6. Investment Service Delivery - Delivery of the services that respond to the demand estimated as part of the case for change.
7. Investment Performance Assessment - Reviewing how well the investment is performing against key performance indicators.
8. Investment Service Enhancement - Responding to opportunities to improve performance as identified in investment performance reviews.

We can refer to the Investment Management System to understand, for example, whether infrastructure decision-makers are adequately considering non-built solutions or assessing demand. This will help us identify some of the underlying causes for high or low performance across infrastructure sectors.

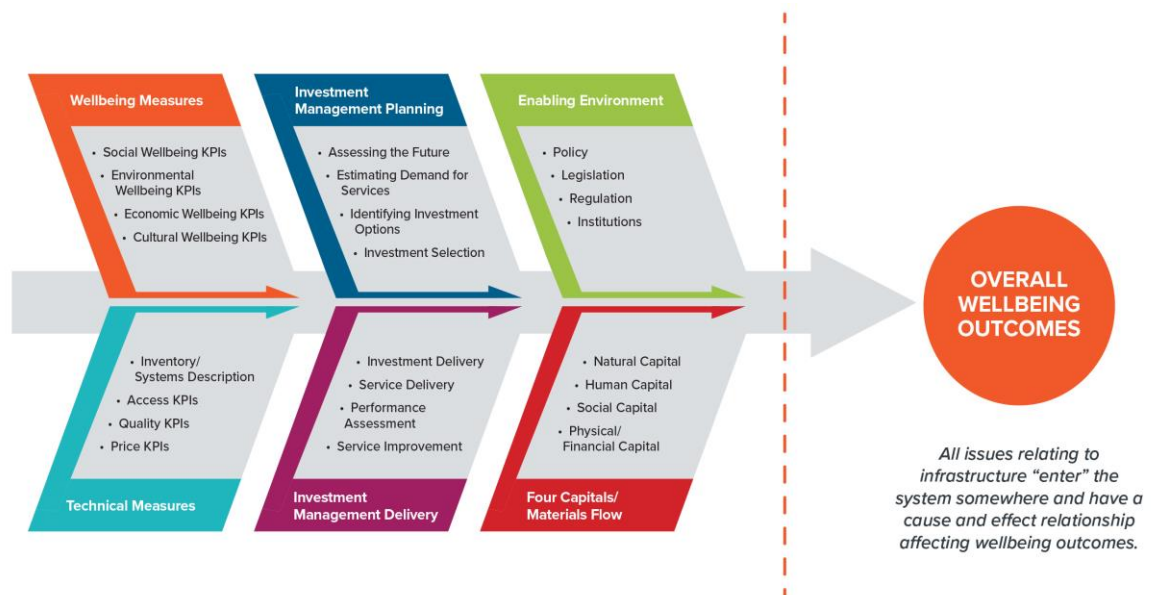
¹⁶ "Investment Management System," The Treasury. March 1, 2018. <https://treasury.govt.nz/information-and-services/state-sector-leadership/investment-management-system>.

A diagnostic tool for identifying strategic priorities

Tētahi taputapu tātari tiro whānui ki te tautohu i ngā whakaarotau rautaki

When identifying strategic priorities for infrastructure, a complete diagnostic is required. To do this, Te Waihanga has developed an infrastructure performance cause and effect diagnostic tool, shown in Figure 6, below. This is based on the integrated infrastructure management framework described in Figure 5

Figure 6: Infrastructure performance cause and effect diagnostic tool



When investigating challenges or issues with infrastructure, a first step is to assess technical and wellbeing measures to understand performance. Technical measures refer to the services or outputs of the infrastructure provider, for example the quantity or reliability of electricity generated. Wellbeing measures help us to understand the issue from the consumer's perspective, for example an inability to heat their homes or to live the way they would expect.

When shared services do not meet these standards, we can use the infrastructure performance cause and effect diagnostic tool to determine causes and identify actions and priorities that improve outcomes.

These building blocks bring together common elements of infrastructure and help provide a standardised way for considering, evaluating and solving infrastructure problems.

Example: Delivering clean water

Tauira: te tuku i te wai mā

As an example of how these concepts can be used in practice, consider a council water utility that is receiving complaints from customers and issuing 'boil water' notices frequently. Investigation of community **Wellbeing Measures** shows consumers are having to buy more water than usual from their local supermarkets, some health indicators are unfavourable and

complaints have increased. Closer inspection of **Technical Measures** shows the utility's distribution network is losing more than thirty percent of the water coming from the treatment station. Pathogens are in the system and maintenance of the network is problematic because the utility is receiving less income than is needed to manage the network.

The challenge has become a capital problem because major system upgrades are necessary but being implemented slowly. A quick-fix plan with two options was put to local councillors. The

procurement of consultants was rushed, and so the **Investment Management Planning** process was flawed. The best option was not chosen because the council and utility do not have the **Financial Capital** due to many competing demands. In part, this is because of a policy decision that rates should not exceed inflation and do not consider other water revenue options, and so the **Enabling Environment** is not fit-for-purpose. In the meantime, the contractor undertaking the quick-fix upgrade project has gone into liquidation and the project has stalled, suggesting a problem with **Investment Management Delivery**. At a central government level, the **Enabling Environment** also needs strengthening. Reviews of service delivery could have picked up the problems earlier so some **Institutional** strengthening is required to improve outcomes.

Overall, rather than simply responding to the community's call to "fix the pipes", the solution lies in making difficult decisions about whether the right technical solution was identified and whether revenue policies need revisiting for a more enduring outcome.

Conclusion

Hei whakatepe

Infrastructure is a system of networks that supports our way of life, both now and in the future. Defining it by its characteristics – rather than through a sector – is useful, especially since the interconnectedness between shared services is increasing in response to technological change, population growth and climate change. Infrastructure is fundamentally about consuming capitals like financial and natural resources to deliver shared services, such as power or drinking water, to enhance wellbeing.

We have also developed a common framework to think about the integrated management of infrastructure. This shows the relationship between the enabling environment, the sustainability of the four capitals, the investment management process and the wellbeing benefits created by infrastructure services.

This allows for a standardised approach to analysing infrastructure problems to develop strategic recommendations. This analytical framework is useful for addressing infrastructure questions through a holistic, integrated, logical lens.

Subject to ongoing feedback, Te Waihangā will use this definition and common framework in future work. This will come through in the State of Play reports, to be released over the coming months, and in the New Zealand 30-Year Infrastructure Strategy.

Appendix One: References

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