External Research Report ER56 [2020]

Digital Product Data for Lifting Productivity

Nick Allison and Gary Hartley

Project LR12038

GS1 New Zealand, funded by the Building Research Levy

About BRANZ

A multi-faceted, science-led organisation, BRANZ uses independent research, systems knowledge and broad networks to identify practical solutions for improvement of New Zealand's building system performance. BRANZ is driven by the knowledge that to thrive as a society, New Zealand needs a built environment which is safe and healthy, and which performs well in all key respects.

The 2019 BRANZ Inc. prospectus sought research that would enhance understanding of technologies available globally that could feasibly be used in New Zealand to improve the productivity and performance of this country's construction work force. This research report undertaken by GS1 New Zealand looks at the potential to improve productivity through a trusted source of digital product data.

About GS1 New Zealand

GS1 is a global family of not-for-profit, nationally owned organisations which provide help for organisations and people to trade and exchange information. While GS1 is known most for barcodes and barcoding technologies, it is also a global expert in supply chain data exchange. GS1 NZ is an incorporated society owned by more than 8,000 New Zealand members who span most sectors and industries including food and grocery, healthcare, building and construction, agribusiness and government. GS1 NZ is governed by a volunteer board with representation from the healthcare, government, building and construction, food and grocery and primary sectors.

Contributors

Name	Role
Nick Allison	Lead author, GS1 New Zealand
Gary Hartley	Co-author & reviewer, GS1 New Zealand
Dr Peter Stevens	Reviewer, GS1 New Zealand
Michael Bealing	Reviewer and author, NZIER contribution
Dermott Ferris	Design graphics, GS1 New Zealand
Jonathan Howard-Clarke	Solutions architecture reviewer and advisor

Disclaimer

Table of contents

List of Tables

List of Figures

Glossary of terms

Term	Definition
Building information modelling (BIM)	An intelligent 3D model-based process that gives architecture, engineering and construction (AEC) professionals the insight and tools to more efficiently plan, design, construct and manage buildings and infrastructure.
Building Control Authority (BCA)	A Territorial Local Authority must perform the functions of a BCA for its own city or district. This includes building consents where the consent is subject to a waiver or modification of the Building Code, inspections and compliance or acceptance certificates.
Capital productivity	Capital productivity measures the units of output produced per unit of capital (variable or fixed assets) utilised, including financial capital.
Construction object	A data template can only be a common data structure for a specific set of similar products. This set of similar products is what is called a construction object.
Economies of scale	Economies of scale occur when the average production cost per unit of output decreases with the increase in output.
GDP	Gross domestic product.
Gross value added	An estimate of the value of goods and services produced after deducting the cost of the intermediate inputs of goods and services consumed in the production processes throughout the entire supply chain.
Infostructure	An organisational structure used for the collection and distribution of information; the information technology infrastructure comprised of hardware, networks, applications etc. used by a society, business or other group. *https://www.lexico.com/definition/infostructure*
ISO	International Organization for Standardization.
CEN	European Committee for Standardization.
Labour productivity	Labour productivity measures the units of output produced per unit of labour worked – for example, construction GDP per hour of construction labour input.
Metadata	Metadata is "data that provides information about other data". In other words, it is "data about data". Many distinct types of metadata exist, including descriptive metadata, structural metadata, administrative metadata, reference metadata and statistical metadata. https://en.wikipedia.org/wiki/Metadata
Multi-factor productivity	Multi-factor productivity measures the productivity that cannot be accounted for by changes in inputs of quality-adjusted labour and capital. In practice, changes in multi-factor productivity reflect the effect of technological progress, economies of scale, changes in management techniques and business processes.
Network effect	When the value of a good to a consumer changes because the number of people using it changes. For example, technological innovations, such as the internet, may have large positive network effects, which make possible much higher productivity.

Term	Definition
Standardised data template	A common data structure defining the properties (essential and non-essential product characteristics – for example, fire rating and colour) that describe any type of product in a standardised way so that it and product data can be traced to a credible source. Such credible sources are product standards declaring the performance characteristics of products and the methods they should be tested against. There is a specific hierarchy of credible data sources taken into account in the data template structure.

Acknowledgements

We wish to express our sincere appreciation to the members of the Research Reference Group who generously provided their time, insights and guidance to the research.

Jason Bardell
Managing Director
Independent Building Supplies

Janet Blake
Manager, Building Industry Systems
Ministry of Business, Innovation and Employment

Ruth Brash
General Manager, Merchandise
PlaceMakers and Mico

Matthew Duder
Managing Director
EBOSS

Mark Fairburn
National Sales and Marketing Manager
Masterspec

Teena Hale Pennington
Chief Executive
New Zealand Institute of Architects

Derek Heard
General Manager - Trade
Mitre 10

John Jamieson
Technical and Development Manager
Winstone Wallboards

David Kelly
Chief Executive
Registered Master Builders Association

Julien Leys
Chief Executive
New Zealand Building Industry Federation

Ross McCarthy
Strategic Engagement Manager
Wellington City Council

Andrew Minturn
Manager Capability
Auckland City Council

Gavin Shaw
General Manager - Project Strategy & Delivery
Beca

Murray Robinson
Executive General Manager
Hawkins

We also wish to thank the many other industry leaders interviewed, who provided insights into construction industry issues and the development of this report.

1 Executive Summary

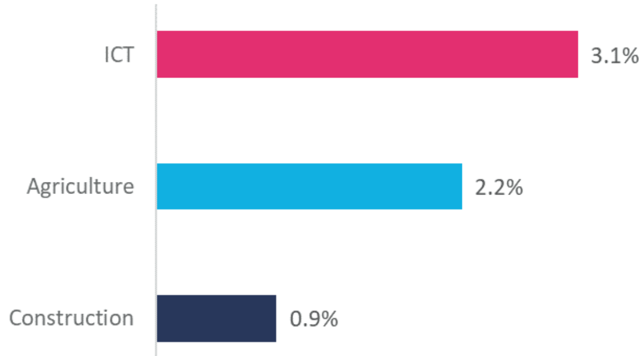
This report is about how *standardisation, structured product data and associated infostructure* can support the digital transformation of the construction sector and how this can be achieved.

The industry is important for the wellbeing of New Zealanders in many ways. It contributed $18.54 billion to the nation's Gross Domestic Product in 2018, representing 7% of that year's total GDP. The value of the construction industry's economic output in 2018 was $64 billion, or 11.5% of total economic output.

However, when it comes to productivity, the industry is a poor performer compared to other key industry sectors in New Zealand.

Figure 1 Average multi-factor productivity growth

Average growth per year 1994–2019



Source: NZIER based on Stats NZ (2020).

McKinsey Global Institute indicates that digital transformation in the construction industry globally could result in productivity gains of 14 -15% and cost reductions of 4 - 6%.

How standards and technology adoption will lift multi-factor productivity

Multi-factor productivity is lifted when firms combine technologies, human capital skills and processes to produce more without significant new capital or growth in staffing. It is about how businesses change processes and apply technologies and skills to produce more outputs. When *open global* standards are used, productivity gains can spill across industry boundaries and create network effects. Open global standards also help prevent market failure by addressing information asymmetries, and by enabling innovation and competition.

Our focus is on construction industry product data exchange

Our focus is on one part of the technology stack, namely structured digital product information which can effectively create 'digital twins' for physical construction products. Product data flows into numerous use cases and technology applications. For example, it can flow across processes from building information modelling ('BIM'), into consent applications and on to whole-of-life building management and maintenance systems.

A common industry-agreed set of product 'metadata', including unambiguous product identification based on global standards, could be digitally shared across sectors (retailers, suppliers, designers and regulators) and be used in many interoperable systems and applications.

There is now industry and government consensus emerging on the importance of standardised, structured product master data. This is evident in:

- Recent government research and industry consultation on proposed regulatory reforms which identified the need for improved product information.
- International research, a literature review and industry interviews, which have all identified numerous use cases and sector-wide benefits that would arise from the use and implementation of standardised product master data.
- Wide support among industry participants for legislative reforms to provide a minimum level of product information, with these reforms now before the New Zealand Parliament.

Many of the submitters on these reforms, including Councils, said a national product library or register is required for government proposals to work. Councils said this would reduce the effort required to assess the quality of building products. The idea of a building products register however, was not supported by the government. The reform Cabinet paper raised reasonable concerns about how a product library could be kept up to date?

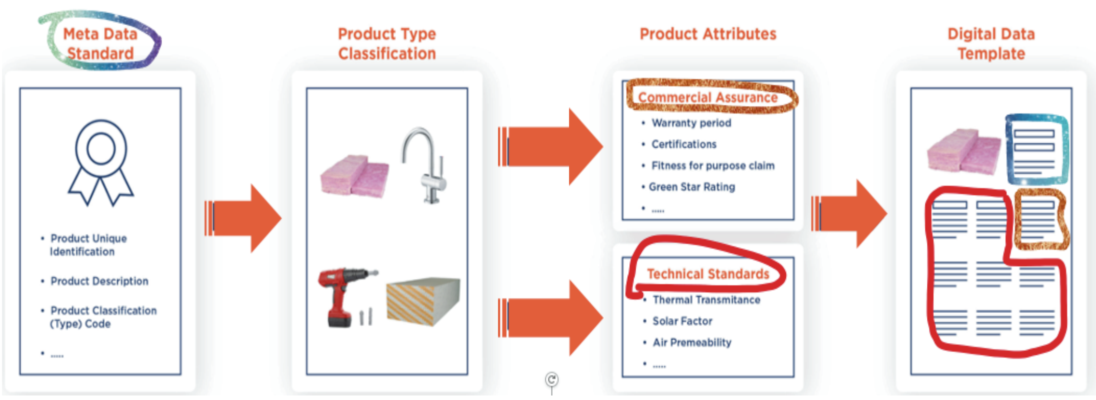
The starting point: standardised identification and structured product data

Industries which have virtual 'lakes' of 'unstructured data' might be data rich, but they are information poor in the sense that they lack the ability to transform data into meaningful information which will enable process automation.

Extensive literature research and feedback sourced from construction industry stakeholders worldwide reveal that this industry generally faces time consuming information search and rework costs. Unstructured data is a root cause of this because it is not easily accessible, searchable or exchangeable between manufacturers, suppliers and trading partners, or between these entities and regulatory authorities.

Taking our lead from European Union initiatives for the structuring of construction product data,[1] we have created a conceptual schema for a Product Data Template, as shown in Figure 2.

Figure 2 Product Data Template for construction sector products or objects



[1] We have used the same definition of a product the DSCiBE User Group (2019) used: where a product equates to a construction object, which can be defined as an object of interest in the context of the construction process (ISO 12006-2:2015 *Building construction – Organization of information about construction works – Part 2: Framework for classification*). Therefore, a construction object can be used to denominate a product, system, assembly, space, building etc. However, we have chosen to use the term product to avoid the confusion with 3D CAD objects.

Metadata is the set of data that describes and gives information about other data. In the context of a building product, metadata might include information about a product's unique identifier that unlocks other important contextual information so that the reader or a digital system which is ingesting data knows what the product is and its function.

Commercial assurance attributes, such as a product's certifications and fitness for purpose claims, are critical to guiding construction design and procurement choices. Also critical is trusted identification of the data supplier.

We recommend that a 'product library' begin with a thin core set of data attributes that adds quantifiable sector-wide (including government) value and utility, and that can be extended easily.

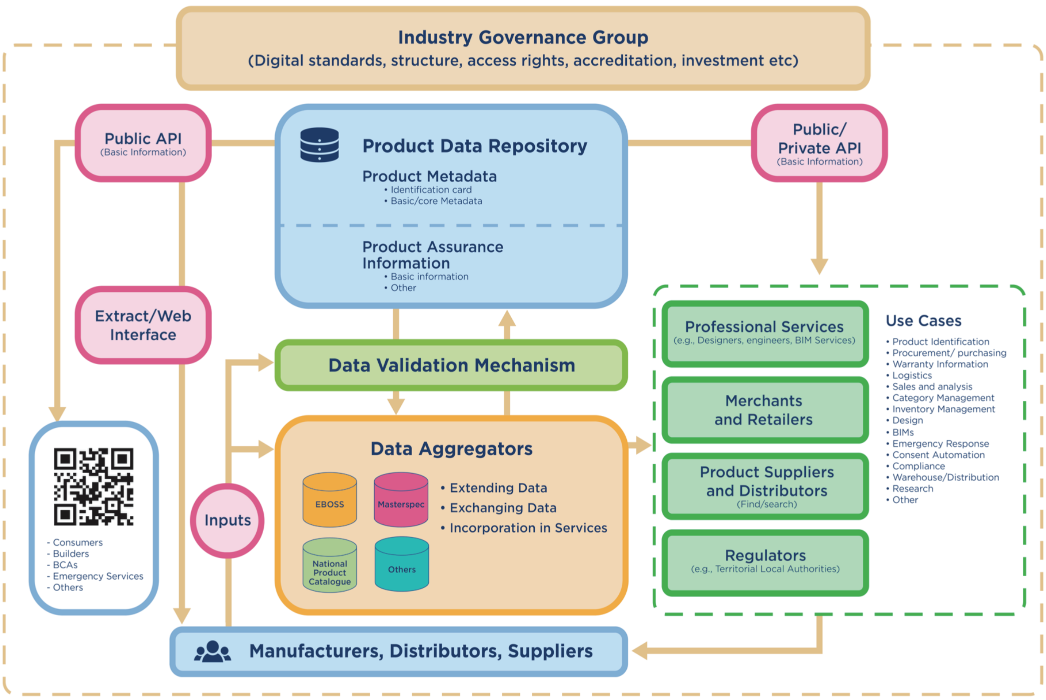
Product data related solution providers or data aggregators can then extend this information set by adding supplementary information such as proprietary data or industry technical standards. We recommend that international technical standards are used in recognition that many products are traded globally, unless there is a compelling reason to use or develop a New Zealand standard.

Industry infostructure for a Product Library implementation

Once data is structured and standardised to industry-agreed requirements, it can be shared across an interoperable industry ecosystem. The term '*infostructure*' is used to describe the soft infrastructure of information creation and exchange. Today it is being used to describe the acceleration of 5G broadband deployment. The initiative of the Australian and New Zealand Governments to implement standardised e-invoicing is another example of investment in infostructure.

We have designed a model of how a product data infostructure could work, outlined in Figure 3 below. We recommend that a not-for-profit, cross-sector governance-group oversee this infostructure, rather than have a Product Data Repository ('PDR') operated by a business unit within an agency.

Figure 3 Product data infostructure system



Our research highlights that cross-sector/cross-industry engagement is essential in driving the adoption and implementation of standardised, structured data. We document a wide range of research findings and cite initiatives by governments, industry groups and global standards bodies to support the development of industry-wide 'digital twin' data exchanges. One of the most promising examples highlighted, is the Sweden BIM Alliance collaboration that brings together retailers, suppliers and construction industry participants to adopt and implement agreed data standards.

We need to develop an infostructure that is fit-for-purpose in the particular New Zealand context. Given the potential support a PDR would give to building consent automation, it would be logical for TLAs to be part of any industry collaboration.

Operating design principles

In the context of a fragmented and competitive industry - and in addition to adopting a not-for-profit model - we propose that the infostructure operate in accord with the following principles:

- Use of open-source international product standards, wherever possible.
- Provide public visibility of basic product data and the identity of the data supplier.
- Be market neutral in data provision and pro-competitive (enables data integration service competition), thereby supporting innovation in many forms.
- Be the agreed source of truth for product data with robust data validation to ensure integrity, trust and confidence.
- Enable one-to-many and many-to-one interoperable data exchanges, designed to mitigate data and system error while supporting systems scalability and feature enhancements.

Enabling one-to-many data exchanges and keeping the amount of metadata to a minimum (given that such data rarely changes) would help keep data in the PDR accurate and up to date.

Overcoming the barriers to collaboration

We explored the barriers to industry collaboration on standards by sector stakeholders. In essence, the problem is about coordination among many participants, often competitors, who would benefit from network effects over time but who would also have to meet up-front collaboration costs. We conclude that leadership is required from a cornerstone stakeholder/s if this infostructure establishment is to succeed.

Ongoing *incentives* for collaboration are needed to maintain the infostructure. Product suppliers have incentives to participate as they would avoid duplicative, non-standardised data entry costs since validated data would be populated in the PDR only once and then made available throughout the ecosystem for purchasing, procurement and other purposes. Solution providers and/or data aggregators who offer specialist services to construction sector stakeholders, could avoid costly data collection and compilation costs, while adding value and utility through extended use of data attributes or data analytics in ways that are designed to better serve customer needs.

The technology, benefits, costs and sustainability

There is nothing revolutionary about the PDR technology proposed. It is used widely in global supply chains today. By using modern Application Program Interfaces ('APIs') and internet technologies, data can be exchanged easily and synchronised between multiple parties.

This research was initiated in the context of earlier BRANZ research which found that a lack of trusted digital product assurance data was a factor contributing to the use of non-conforming products in construction projects with costs of approximately $232 million per year arising from product failures.

The research estimated that if making better product assurance information widely available resulted in a reduction of only 6% in the use of non-compliant products, then the investment would pay-back.[2]

NZIER explored the potential benefits, including network benefits, that might arise from the infostructure. Table 1 summarises estimates of benefits from case studies and economic modelling of comparative studies of problems and infostructure investments. Realisation of benefits in each example rely on standards, structured data and/or systems that build infostructure. Even if the infostructure could achieve only 10% of these benefits, the economic payback would be substantial.

Table 1 NZIER summary of indicated benefits

Benefit	Indicative comparative values	Importance of digital product infostructure
20% uptake in digital tools	$120m–$220m p.a.	Critical to deliver interoperability
Product compliance	$23m p.a.	Important to deliver interoperability, standardisation and readily updatable information
More complete product inspection documentation	$33m p.a.	Provides standardisation and mobile retrieval
Enable BIM for construction and assets management in local government	Millions annually in savings for local government	Critical for interoperability, standardisation and independence quality assurance

Source: NZIER (2020)

It was outside our research scope to undertake a detailed assessment of costs and benefits. The technology component would likely require less than $1.0-1.25 million investment, but other establishment costs, such as industry co-ordination, pooling and initial collection of data would be likely to cost more. Ongoing financial sustainability would require 'demand side' users such as solution providers, regulators and commercial users to pay a small access fee. We recommend a detailed business case be developed to evaluate and expand on these findings.

Conclusion

The construction industry lacks consensus on specific standards and structured product data, but it does share a view that making progress with these concepts is fundamental and of high priority if productivity growth is to be achieved. However, because of industry fragmentation and co-ordination challenges, this might be difficult to achieve. The industry does run a risk of forfeiting future productivity gains that are available through digitisation.

Pleasingly, several global standards bodies are pushing forward with work in this area, and there are now industry collaborations emerging around the world which could spur wider adoption.

[2] Dowdell, D, Page I, Curtis M. Electronic traceability of New Zealand construction products: Feasibility and opportunities. Building Research Association of New Zealand (BRANZ). SR365 [2017]. Wellington. 2017.

Our research has outlined a feasible approach for New Zealand's construction industry to move forward on. There is plenty of industry goodwill and interest. We hope these are sufficient to overcome barriers to collaboration, especially given the opportunities which are clearly on offer.

Recommendations

It is recommended that:

1. The New Zealand construction sector take the lead from its European counterparts (and others) and initiate collaboration initiatives in driving the digital agenda.
2. Implement a 'Product Library' with the focus on an initial thin, core set of data attributes that adds quantifiable, sector-wide (including government) value and utility and is easily extensible.
3. The product library includes basic product metadata and product assurance data.
4. A detailed business case be developed to evaluate and expand on these findings.
5. A not-for-profit, cross-industry governance-group model be adopted, rather than having the Product Data Repository (PDR) operate as a business unit within an agency.
6. International technical standards be adopted, as products are globally traded, unless there is a compelling reason to use or develop a New Zealand standard.

2 Introduction

There has been considerable discussion in the industry, media and public policy circles on the idea of a building products library. The main problem the building and construction industry and territorial local authority advocates for a digital library are trying to solve is making trusted product master data, readily accessible to users, including standardised structured product assurance information, safety data sheets, BIM data and other technical information.

A common thread is clear: the sector-wide need for a trusted source of digital product data.

A 2017 BRANZ report into electronic traceability of New Zealand construction products[3] found that the cost incurred to New Zealand Inc. for non-conforming product is estimated at up to $232 million and that a data synchronisation platform such as the GS1 National Product Catalogue (NPC) offered a means of addressing this problem. The research was aimed at offering an approach for widespread technology adoption and implementation via a government/industry collaboration model rather than deploying a particular service.

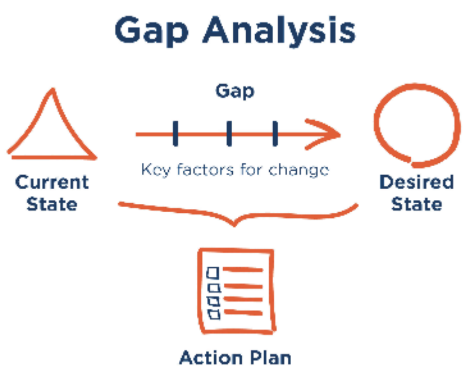
2.1 Research objectives and method

The research examined:

- How to facilitate adoption of established and proven product data capture and data exchange technologies to improve construction sector productivity.
- Indicative costs and benefits and appropriate distribution of costs among private and public stakeholders for accessing and using trusted product master data.

To achieve these objectives, we framed research questions and interview questions used with stakeholders and our industry reference group.

The research method used a gap analysis approach. This involved assessing and understanding the gaps between the current state and desired end state to enable broad adoption and implementation of standardised data to enable both data and systems interoperability.



The research employed desk research and in-depth face-to-face interviews with key sector stakeholders. A system review analysis was completed, as was an indicative cost-benefit analysis. An industry-based reference group was used to discuss, review and critique findings.

An overview of the current state of digital capabilities both globally and in New Zealand is provided and includes commentary on the New Zealand Government's regulatory changes and local building industry reforms. A needs assessment for more efficacious product data throughout the sector is discussed, supported by use case examples. An analysis of benefit realisation opportunities is provided and a discussion on a roadmap for a future state is advanced.

[3] Dowdell, D., Page, I. & Curtis, M. (2017). *Electronic traceability of New Zealand construction products: Feasibility and opportunities*. BRANZ Study Report SR365. Judgeford, New Zealand: BRANZ Ltd.

3 Why digital transformation of the construction sector?

The key points and concepts in this section:

- Construction sector multi-factor productivity lags behind other sectors of the economy.
- Digital infostructure is important for lifting productivity.
- Structured and accurate product data is a key component of infostructure.
- Data standardisation can help lift productivity through network effects.

3.1 The importance of infostructure for innovation and productivity

Innovation is a key driver of productivity. To support innovation, an infostructure must be created to ensure that ideas are continuously produced, information is shared, and innovations are adopted across commercial and social networks.

While there is no generally agreed definition, the term 'infostructure' is commonly used to describe the soft infrastructure of information production and exchange. It is cited in relation to government initiatives to: Accelerate broadband 5G; adopt standardised e-invoicing economy-wide; and other sector-specific initiatives such as improving service quality and efficiency in health delivery.[4]

Johannessen[5] suggests that infostructure has the same importance in the knowledge society as infrastructure had in the development of industrial society and will be a decisive factor in success or failure in the fourth industrial revolution.

The five major productivity benefits of using digital tools and infostructure recognised in the literature are:

- Increased multi-factor productivity.
- Improved accuracy of information.
- Enhanced flexibility and mobility.
- More time to focus on business.

3.2 Structured data is fuel for building industry infostructure

Unstructured data is not organised in a pre-defined fashion or it lacks a specific data model. Most data on building products is unstructured data - it is comprised of information that is not easily searchable, including in soft copy formats, containing different measurement units, the same words with different meanings and a wide variety of technical standards pertaining to the same performance feature.

Industries with 'lakes' of unstructured data are data rich but information poor, without the ability to transform their data into process automation or gain valuable insights.

[4] See, for example, *https://www.canada.ca/en/health-canada/services/health-care-system/ehealth/canada-health-infostructure.html*

[5] Johannessen, J-A. (2019). *The workplace of the future: The fourth industrial revolution, the precariat and the death of hierarchies.* Abingdon, UK: Routledge.

Extensive research and feedback from construction industry stakeholders worldwide tells us the industry faces enormous information search and rework costs, which we cover in this report. One of the root causes is because of data that is unstructured and not easily accessible or exchangeable.

> The lack of use of well-structured data in the construction industry stands in sharp contrast to the food industry where, today in New Zealand, supermarket chains ingest from their suppliers up to 150 structured data attributes for each packaged product instore into their enterprise systems. Standardised product master data is used to automate numerous business processes both throughout the logistics supply chain, in point of sale applications as well as electronic product recall networks. This has been achieved through industry collaboration on standards development and agreed formats to create structured data.

Structured data

Structured data has clear definable relationships between standardised data points, with a pre-defined model or template containing it. Structured data is far easier for 'big data' or machine learning programs to digest, while the myriad formats of unstructured data create a greater challenge.[6] Also, by its very nature, unstructured data is not easily validated even if machine learning can be deployed. Once structured and interoperable data can be shared across an industry ecosystem, it helps build the infostructure essential for supporting innovation and lifting productivity.

3.3 What's the problem and opportunity?

We have outlined above the importance of industry infostructure for innovation and productivity and that structured product data is part of the infostructure.

> The contribution of the construction industry to New Zealand GDP was $18.54 billion in 2018, which represents 7.0% of total GDP for that year. The total output of the construction industry was $64 billion in that same year, or 11.5% of New Zealand's economic output.

So how is construction sector productivity tracking? We focus on multi-factor productivity in answering this question because this kind of productivity is lifted through firms combining technologies, human capital skills and business processes to produce more without investing in significant new capital or adding staff. In part, it is about leveraging infostructure.

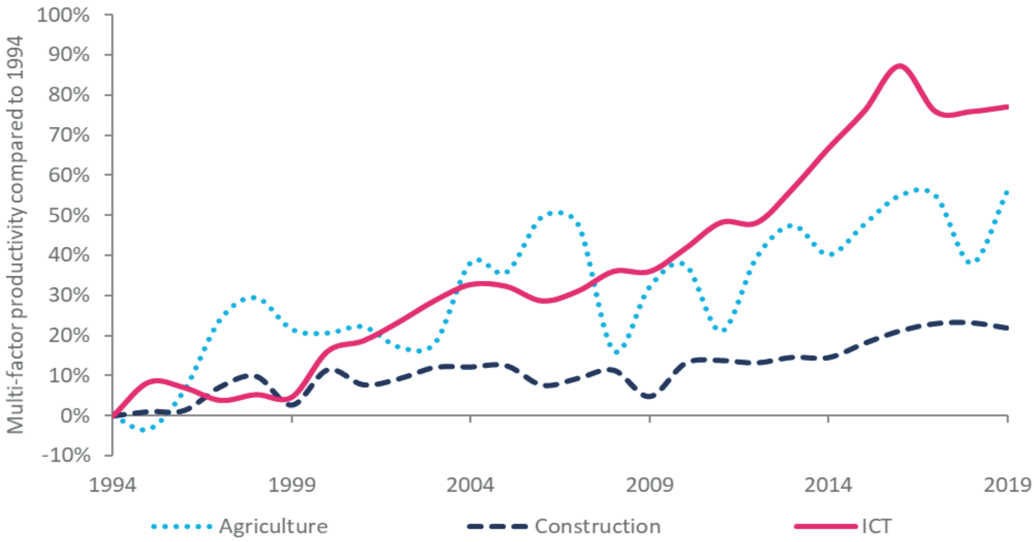
Between 1994 and 2019, multi-factor productivity in the construction industry in New Zealand increased by 22%.

This represents an annual average increase of 0.9% per year. In comparison over the same period, multi-factor productivity in agriculture increased by 56% (an average 2.2% p.a.) and in ICT it increased by 77% (an average of 3.1%).

Annual growth in multi-factor productivity in the ICT industry then, was over three times higher than that of the construction industry. Agriculture's annual multi-factor productivity growth was more than twice that of the construction industry.

[6] https://www.datamation.com/big-data/structured-vs-unstructured-data.html

Figure 4 Long-term multi-factor productivity growth – the big picture



Source: NZIER based on Stats NZ (2020)

There are many potential reasons behind these productivity divergences. The development, deployment and mass adoption of new technologies is a way of life in the ICT industry. Agriculture is an interesting case study, because the removal of almost all government support for agriculture forced the industry to compete globally based on efficiency gains. Competition on an international scale encourages the consistent adoption on new technology in agriculture, whereas construction does not face this same pressure. What is clear from our research is that there is considerable opportunity to address the industry productivity problem through better provision of open standards and digital infostructure.

3.4 The productivity prize of standards for digital infostructure transformation

A decade ago, BERL[7] estimated that standards used in the construction industry increased total factor productivity by 0.1% per year and 1% over 10 years. Using a computable general equilibrium model of the economy, they estimated that standards would increase GDP in 2021 by 1% or $3.1 billion over 10 years in today's dollars. While adoption of building standards can have an impressive economic payback, the construction sector's use of digital standards and infostructure that we investigated can have a much broader reach.

While our focus is on one part of the technology stack - i.e., structured digital product information, this flows into numerous other technology applications via network effects. For example, data could flow across processes from building information modelling (BIM) into resource consent applications and on to whole-of-life building management and maintenance, or a small common set of product metadata could be digitally shared across sectors (retailers, suppliers, designers and regulators). Even if structured digital product information made only a small difference to the productivity gap, this could create significant value for the economy.

New technologies in the digital space will not only improve productivity and reduce project delays but it can also enhance the quality of buildings and improve safety, working conditions and environmental compatibility.[8]

[7] Stokes, F., Dixon, H., Generosa, A. & Nana, G. (2011). *The economic benefits of standards to New Zealand.* Wellington, New Zealand: BERL.
[8] World Economic Forum. (2016). *Shaping the future of construction: A breakthrough in mindset and technology*. Geneva, Switzerland: World Economic Forum.

Research by the McKinsey Global Institute indicates that digital transformation in the construction industry could result in productivity gains of 14 - 15% and cost reductions of 4 - 6%.[9] The economic prize of building industry digital infostructure is potentially very large.

3.5 Institutional barriers, standardisation and networks matter for digital uptake

Institutional network barriers can hinder the way industry collaboration is shaped, including:

- Lack of agreement on the rules for shaping standardisation.
- A lack of trust in the information and information security.
- A lack of alignment, agreement and accountability for maintaining and updating the infostructure and information.
- A lack of agreement on the terms of engagement and access to the infostructure.

The standardisation and interoperability offered by the infostructure presented in this project cannot be easily realised with single proprietary investments. Rather, any solution requires coordination across the industry and arguably other industries, such as construction procurement and retail. A lack of standardisation across the construction industry has been a leading factor in slow technology adoption rates in general.[10] The construction industry in New Zealand has a valuable opportunity in generating potential productivity gains by adopting a common approach and avoiding the pitfalls of fragmented standardisation. However, this will require cross-industry collaboration.

Network effects and benefits

A network effect is where an additional user of a service has an impact on the value of the service to others. 'Network effects are a special type of externality in which consumers' utility and/or firms' profits are directly affected by the number of consumers and/or producers using the same (or a compatible) technology. Loosely speaking, network effects are generated by increasing the adoption rate (popularity) of a good or a service'[11]. When a network effect is present, the value of a product or service increases according to the number of others using it. Think of transport networks or a telephone system where the number of users matter.

Given the potential financial gains could be significant, some may say that the Private Sector should be left to invest and secure whatever benefits it can from standardised and structured data.

Our focus is on the uptake of open standards for product identification and associated structured product data. This creates a level playing field where firms can compete to offer digital applications. In the next section, we look at what is happening internationally to support the infostructure needed to lift construction sector productivity.

[9] Barbosa, F. et al. (2017). *Reinventing construction: A route to higher productivity*. Brussels. Belgium: McKinsey Global Institute.
[10] FIEC. (2016). Smarter construction, stronger economy, inclusive society: The European construction industry manifesto for digitalisation. Brussels, Belgium: European Construction Industry Federation.
[11] Shy, Oz (2010): A short survey of network economics, Working Papers, No. 10-3, Federal Reserve Bank of Boston, Boston, MA

4 Digital transformation – international developments and initiatives

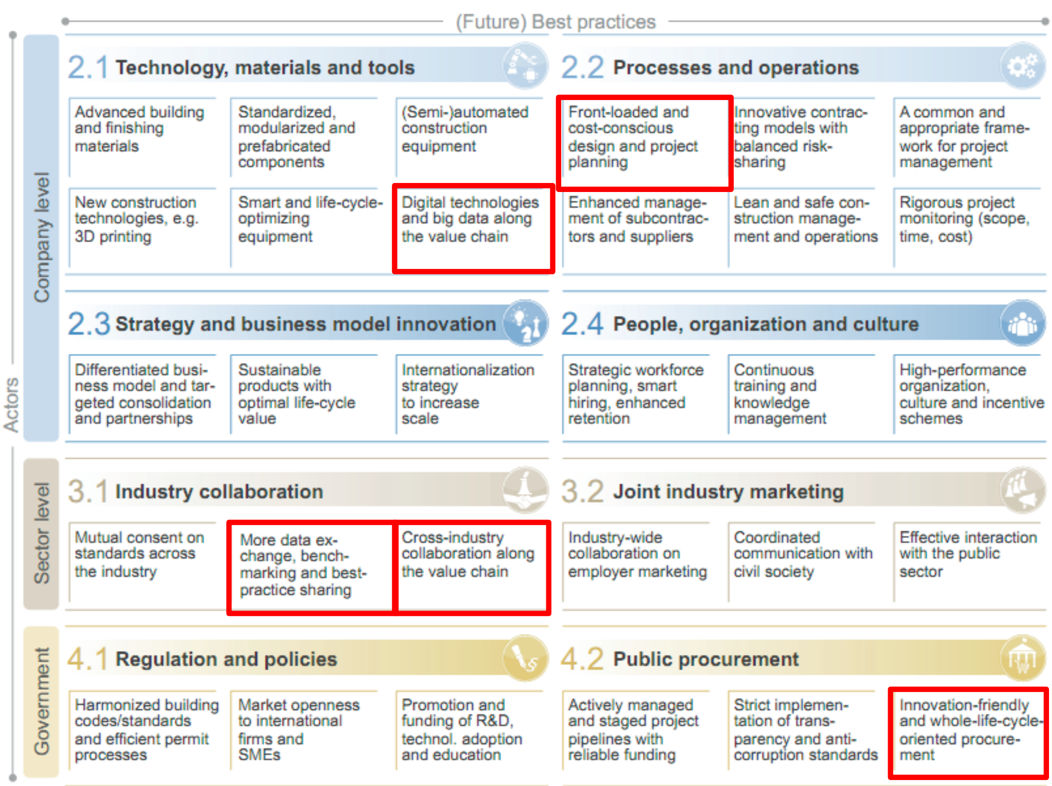
The key points and concepts in this section:

- Around the world, there is a clear focus on digital transformation in the construction sector, as this is seen as one of the most promising ways of lifting productivity performance.
- If the vision of using BIM or other information management systems throughout the building design, build, operation and demolition life cycle is now realised, we need to identify and track product life cycles.
- Industry and government attention is turning to establishing interoperable data and standards for digital product data – sometimes referred to as 'digital twins'.
- New Zealand needs to leverage international standardisation efforts to establish structured technical performance data for products in digital formats.
- A range of innovative cross-sector (manufacturing, retail and construction) collaborations and government initiatives are emerging to support and deploy product digitisation and standardisation.
- New Zealand needs to find its own fit-for-purpose implementation pathway.

4.1 Global coordination to support digital transformation

A World Economic Forum report[12] rallies a call for action for digital transformation of the construction industry tackling a wide range of practices to lift productivity (see Figure 5).

Figure 5 World Economic Forum transformation framework



[12] See footnote 8.

In Figure 5, we have highlighted in red where structured digital product or object information could make a substantial contribution to advancing the transformation strategy.

The Forum calls on the industry as whole to agree on a common approach:

- **Standards in software systems**, interfaces and communication protocols to facilitate the digitalisation of the industry as a whole. In particular, companies should establish standards in machine code for robots and automated construction equipment and in interfaces between different systems such as BIM.
- **Standard interfaces** between prefabricated modules and components will enhance system compatibility, provide economies of scale for suppliers and act as a powerful productivity driver accelerating the industrialisation of the sector overall.
- **The standardised definition of costs, classifications and measurements** along the whole life cycle will lead to greater comparability and compatibility among projects.

GS1 and buildingSMART signed a Memorandum of Understanding in October 2018 to advance the use of global standards in the construction sector. The aim is to support standardised product instance identification and exchange of open, interoperable product data to help with digitising the construction industry by seamlessly connecting supply chain product information into design, build and maintenance processes.

With approximately one-third of construction cost attributed to building materials, the scope for applying improved advanced building materials is considerable.

The Forum argues that, for optimal innovation and better uptake, what is needed is a concerted effort on the part of the industry as a whole for instance, via industry-wide standards and certification, as well as an active role played by governments in establishing innovation-friendly policies and procurement processes.

4.2 Putting things into practice – European Union

The European-based Digital Supply Chains in the Built Environment Work Group (DSCiBE) brings together major industry stakeholders involved in the built environment supply chain by developing processes for digital exchange of data and information based on global data standards. Their initial focus is on product/material master data enabling real-time synchronisation of a physical object with its digital twin through the product's life cycle.

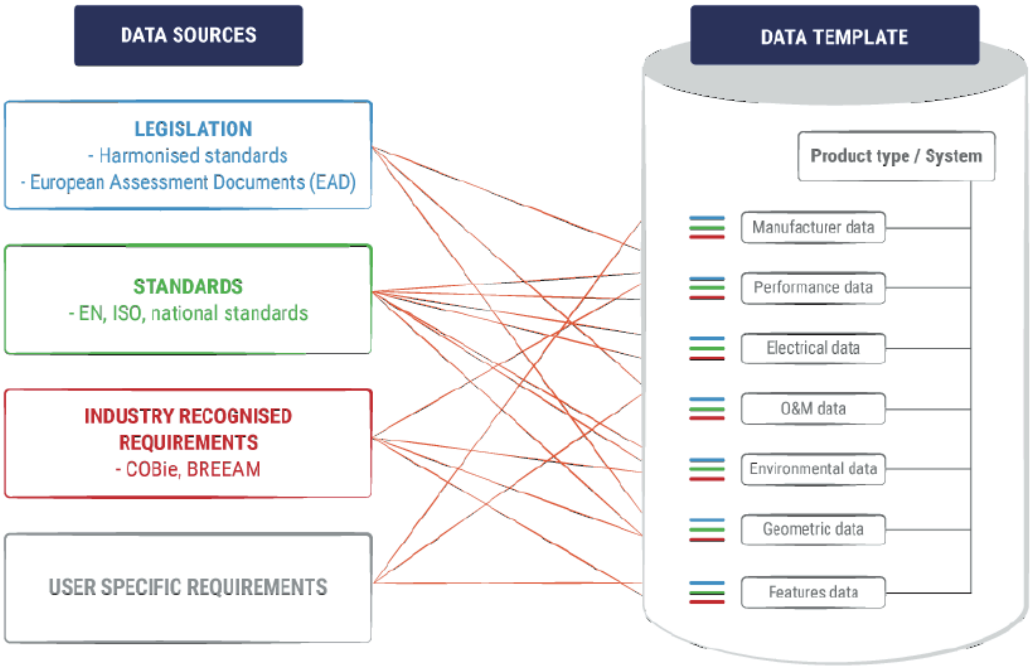
A published white paper[13] outlines DSCiBE's definition of structured product master data and the potential benefits on offer if the European construction sector harmonised on its use and implementation. DSCiBE defines a data template as a common data structure containing the properties, measures, units and values for a product stored in a data dictionary. Data templates describe any type of object for construction works and building services in a way that can be traced to a credible source, such as standards declaring the performance characteristics of construction objects or products.

The group's analysis details standardisation efforts (mainly by European standards bodies such as ISO, CEN and IFC) that are designed to align the European construction industry. Foundational to the group's focus of creating digital supply chains is the widespread adoption,

[13] DSCiBE User Group. (2019). *Digital supply chains: Data driven collaboration.* https://www.gs1.org/sites/default/files/digitalsupplychainsdatadrivencollaboration.pdf

implementation and use of global data standards for the identification of construction products, assets, documents, logistics consignments and relationship identifiers, based on GS1 ISO-compliant standards.

Figure 6 DSCiBE illustration of a data template



While many, if not most of the product technical performance standards are international and could be adopted in New Zealand, a template for structured product master data is context dependent. It would need to take into account New Zealand's legislative requirements, including the Building Code and industry requirements that emerge out of local practices.

4.3 United Kingdom

The UK BIM Alliance Product Data Working Group outlined seven key areas of focus for the UK construction sector with regards to structured data and data standards, including the following:[14]

- **Structured data definitions** to gain universal sector-wide agreement on a definition of structured data to enable interconnected dictionaries, structured data creation and approvals.
- **Product data standards** because there are no commonly agreed standards for digital product data in the UK or in Europe and given the landscape is both fluid and complex, common data standards need to be developed and agreed to by all stakeholders.
- **Product data journey** – there is no 'golden thread' of product information for most projects. "Because the data journey involves information provided at different times by different stakeholders, any system to manage that information may need to be connected to/merged with each other at different points in the journey. The way in which information moves through the construction supply chain needs to

[14] Product Data Working Group. (2018). *A fresh way forward for product data.* London, UK: UK BIM Alliance.

be significantly improved if we are to truly benefit from efficient and effective digital workflows".

- **Product data naming and product identification** – implementing a unified methodology to produce data templates in the UK is considered long overdue, unlike Europe, so the UK needs to align with European and international standards in a collaborative manner throughout the data journey.

The UK BIM Alliance report recommends the formation of a funded cross-industry Product Data Steering Committee to provide a coordination and guidance role in the above areas.

4.4 Scandinavian countries

Scandinavian countries have a long history of successful digital standardisation. For example, Denmark began to implement standardised e-invoicing in the 1990s, followed by the EU and now the Australian and New Zealand Governments have just begun in the last year.

Government as driver of standardisation in Norway

While there is no legislation in Norway (or other Scandinavian countries) we are aware of, implementation of standardised product data for e-procurement and for identification purposes is pushed by government agencies that are applying GS1 identification standards. This follows on from the fact that around 200 Norwegian municipalities have adopted GS1 standards for the identification of delivery locations for e-procurement purposes.

The first step towards this is to require the GS1 Global Trade Item Number (GTIN) to be used for item identification purposes and to extend this to procurement processes that align product identification with the BIM models in the construction phase.[15]

Statsbygg is Norway's directorate of public construction.[16] It recently required GTINs to be used in its BIM. Norway starts in a different place from New Zealand since most building products in that country are already identified with GTINs. GS1 Norway has been asked to work with the industry on product classification. Liquid concrete, for example, is available in 7,000 - 9,000 different recipes, and recipes need to be grouped to create a better data structure.

The Statsbygg policy rationale for GTIN use in BIM is for better whole-of-life asset building management. Between 70 - 80% of the expenses in the life of a building involve maintenance, demolition and recycling of building stock. Better identification of a building's components will help plan maintenance schedules and maintenance procurement and enable better management of whole-of-life building risks.[17]

[15] GS1 Norway – https://www.gs1.no/vare-bransjer/bygg

[16] The Norwegian Directorate of Public Construction and Property provides construction and property management services on behalf of the Norwegian Government. This includes 2.7 million square metres in 2,350 buildings, of which 115 are located abroad.

[17] https://www.gs1.no/vare-bransjer/nytt-om-bransjene/statsbyggs-nye-bim-manual-stiller-krav-til-gtin

Cross-sector industry collaboration in Sweden

In Sweden, while there are no official requirements, all major construction companies, several retailers and the BIM Alliance Sweden asked sector suppliers to use GTINs for product identification to streamline procurement processes and enhance sector-wide traceability outcomes.[18] But there is now a collaborative industry group where construction product suppliers, contractors and logistics players are represented together to be able to map construction products for an entire industry.

In 2018, the five biggest construction companies together with the industry retail organisation formed the largest manufacturing organisation and BIM alliance in Sweden and asked the entire supplier base to identify all building products with a GTIN. Two years on, most retail products are now identified by a GTIN, and GTINs are being introduced in procurement systems in order to increase transparency and traceability outcomes. As a result of the success of the 2018 initiative, the industry User Group was set up to look at how GTINs could be configured for building industry products or objects.

[18] GS1 Sweden – https://www.gs1.se/din-bransch/bygg/

5 New Zealand situation

The key points and concepts in this section:

- Government research and industry consultation has identified the need for improved product information.
- Legislative reforms to provide a minimum level of product information are widely supported by the industry.
- Research has identified numerous use case opportunities and sector-wide benefits through improved product master data.
- Benefits most commonly cited by industry participants in interviews are outlined in section 5.3.

5.1 Regulatory information reform proposals

In April 2019, the Ministry of Business, Innovation and Employment (MBIE) released the Building System Legislative Reform Programme Discussion Paper[19] for public consultation. The reform proposals aim to lift the quality of building work.

One proposal promoted is to require product manufacturers and suppliers to provide enhanced information about their building products, the rationale being that:

- Building products are central to safe and durable buildings, yet information about products is not required until engagement in the consenting process.
- Building consent authorities frequently request information about specified products to ensure compliance with Building Code requirements, which causes costly delays for building owners.
- An increasing range of complex building products and building methods, coupled with the availability of cheaper alternatives, increases the risk of products not meeting Building Code requirements through the use of unsafe products.[20]

The reform document proposes a minimum set of product information, including:

- Supplier details and contact information.
- Information on the scope and limitations of use for the product.
- Design, installation and maintenance requirements.
- A declaration of whether the product is subject to any warnings or bans.

Required information will be set by regulation and subject to a consultation and development process. Close to 90% of submitters supported the need for mandatory information requirements. The majority of submitters said the proposal needed to go further to include more information. This included information on:

- How the product complies with the Building Code.
- Sustainability of the product.
- Verification that the product will be durable and meet the intended life of the building.

[19] https://www.mbie.govt.nz/dmsdocument/5009-building-system-legislative-reform-discussion-paper
[20] https://www.building.govt.nz/assets/Uploads/getting-started/building-law-reforms-factsheet-2-product-information.pdf

- Who can undertake installation and construction projects.
- Associated risks of the products and methods.

National product registry or product library

The majority of submitters said a national product library was required for reform proposals to work. Councils were unified in their support for change, and many noted the need for a national product library saying it would reduce the effort required to assess the quality of building products. A number of key stakeholders made submissions in support of a register of building products – an idea not supported by government.

The Cabinet paper on the reform outlined, that "while a national register could make it easier to find information about building products, it would need to be up-to-date to deliver real benefits. Given the number of building products available (estimated to be over 600,000), it would be very costly to ensure that the register is regularly updated".[21] Regular updating of information is a legitimate concern. Our infostructure ecosystem model (see section 6) has been designed for dynamic data synchronisation where data updating happens through the use of structured and coordinated vendor-managed data repositories. Sector-designed incentives should ensure data is efficacious.

5.2 Needs assessment – better product data

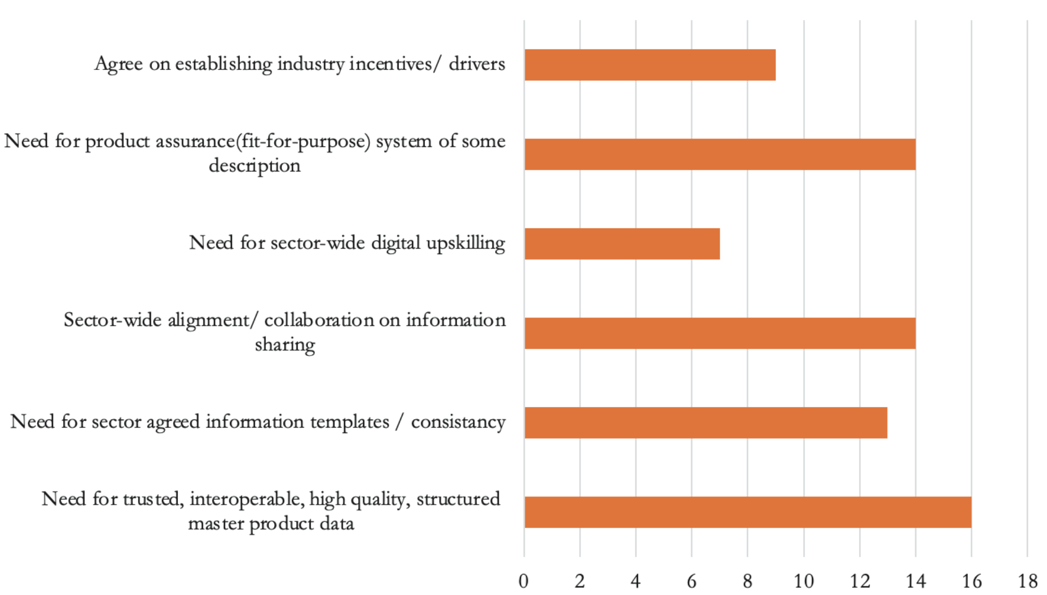
The World Economic Forum report into shaping the future of the global construction sector[22] stressed that the industry as a whole should enhance coordination and cooperation across the value chain and agree on common goals and standards. A lack of commonly agreed standards and low interoperability among companies that comprise the global construction sector represents an obstacle to digital change.[23] Our research into sector needs aligns closely with the report's findings. Additional needs include:

- Galvanising the industry around agreed goals such as driving sector-wide alignment and enhanced collaboration through the use of trusted, structured and interoperable product information and agreed data templates. The use and implementation of one reliable source of information was also encouraged.
- The need for a product assurance system ranked prominently.
- Sector-wide digital upskilling and recruiting young people with technical and managerial digital talents was emphasised.
- Government's role as regulator and key project owner should be to create a fertile environment for sector transformation.

We summarise below the main needs identified from our interviews.

[21] https://www.mbie.govt.nz/dmsdocument/7020-lifting-the-efficiency-and-quality-of-the-building-system-overview-paper-a-proactive-release-pdf
[22] ibid.
[23] Sategna, L. G, Meinero, D, Volonta, M. (2019). *Digitalising the construction sector: Unlocking the potential of data with a value chain approach.* Brussels, Belgium: Committee for European Construction Equipment.

Figure 7 Needs cited by interview respondents



5.3 What industry said on use cases and benefits

Research from Sategna et al.[24] identifies that the adoption of digital technologies will positively impact the construction sector in many ways including increased efficiency and improved productivity. Our interviews reveal use cases (Figure 8) and benefits (Figure 9) that are available to the construction industry and include the following use cases:

- Improved product specification and design services.
- Improved product recall outcomes.
- Improved product due diligence capability though enhanced supply chain visibility and procurement processes.
- Enhanced asset management and whole-of-life traceability, especially in the context of BIM developments.
- Streamlined management and automation of consent applications, compliance and variation processes.

These use cases lead to a wide range of benefits and beneficiaries including:

- Confidence in product assurance.
- Compliance certainty for councils, retailers, designers and specifiers.
- Reduced consent variation times.
- Reduced information search and rework costs for many activities.

[24] ibid.

Figure 8 Use cases most commonly cited

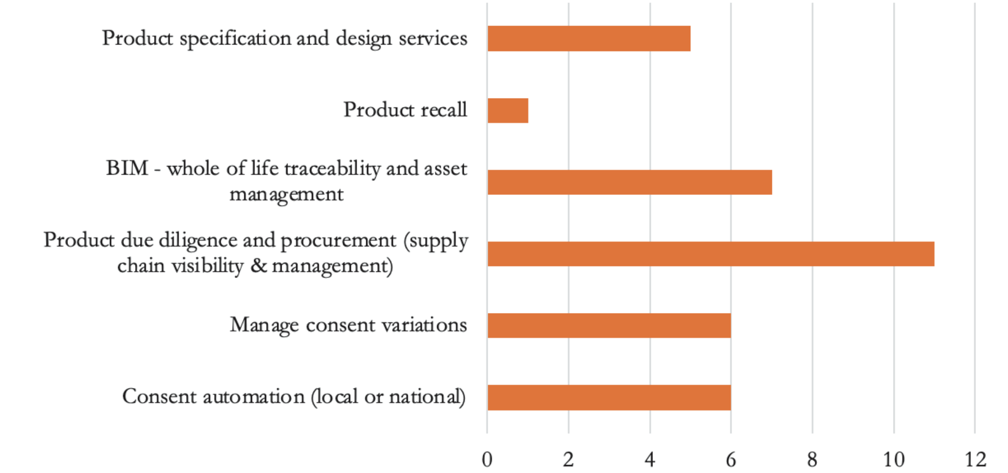
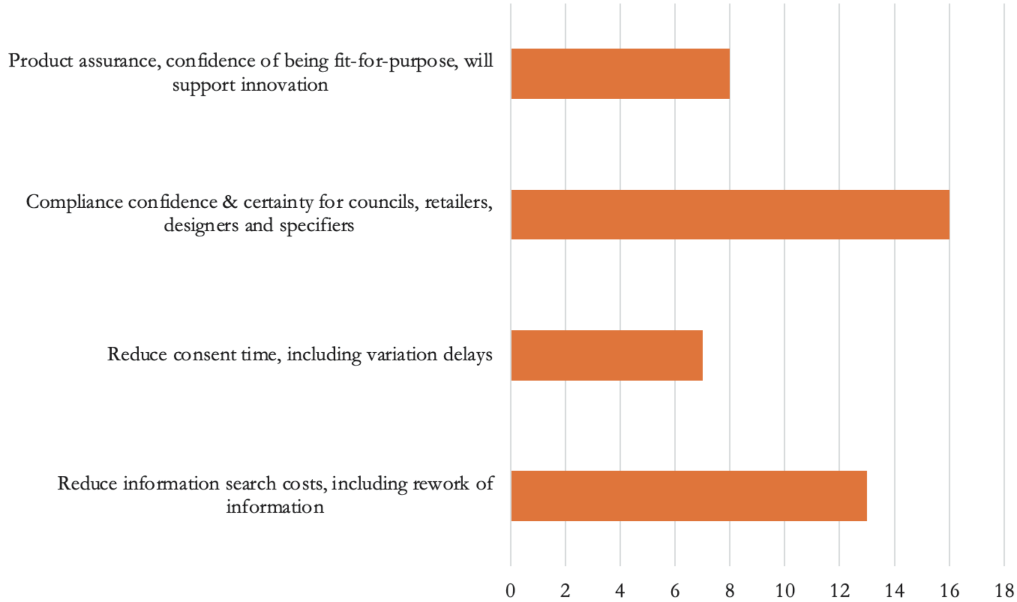


Figure 9 Benefits most commonly cited



5.4 The barriers to digital uptake

Barriers to digital uptake outlined by Sategna et al.[25] are relevant in the New Zealand context given their focus on impacts for SMEs. Identified barriers include the following:

- SMEs fear of potential drawbacks resulting from the adoption of digital equipment because they lack the skills and competencies to oversee the maintenance of fully digitised equipment.
- Digital transformation can be relatively high cost and particularly burdensome for construction SMEs because of the cost of initial investments in equipment and technologies. This element is relevant when the potential of digitisation is also not immediately evident and return on investment is not clear.

[25] ibid.

- Large companies tend to be slow in taking decisions because of the size and complexity of decision making, but they can act as a trendsetter in a future digital scenario.
- Lack of commonly agreed standards and low interoperability represent an obstacle to digital change.

Barriers to uptake – New Zealand findings

With such large productivity opportunities, why is the sector not responding in New Zealand?

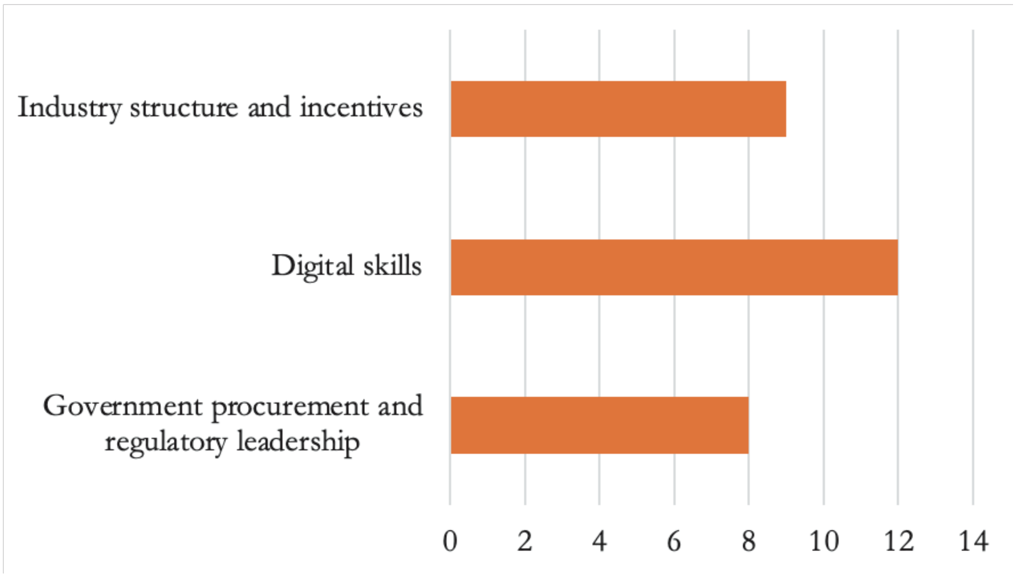
NZIER[26] outlines that barriers to digital uptake fall into two categories:

- Institutional network barriers affect the extent of collaboration between agents and the realisation of network benefits.
- Private barriers are costs or changes that the individual or organisation face in relation to adopting the tools and accessing the infostructure network.

In our industry stakeholder interviews, we asked about the constraints and barriers to digital uptake in New Zealand. Recognising that constraints and barriers differ depending on a stakeholder's function in the industry, three barriers were cited most prominently:

- Poor, industry-wide digital skills.
- Fragmented industry structure and incentives.
- Lack of government procurement and regulatory leadership.

Figure 10 Barriers most commonly cited



Poor, industry-wide digital skills

- The sector is practically oriented and not technically savvy – an indication of where the sector is positioned on the technical maturity curve. This compares unfavourably with other industry sectors such as food and grocery and agriculture.
- There is no entity in New Zealand driving the digital skillset agenda in the sector.

[26] NZIER. (2020). *Digital data productivity*. Report to GS1. Refer Appendix B.

- The industry has a significant number of small to medium-sized business that lack the technical skills to use product information effectively.

Fragmented industry structure and incentives

- A lack of sector-wide direction, maturity, coordination and alignment on data standards and data sharing where value can be identified, and benefits quantified for the whole sector. Sector-wide leadership and collaboration on data standards, data use and the 'digital story' is required to drive sector-wide value.
- Industry rivalry, low trust, IP protection and the hyper-competitive 'zero-sum game' environment were highlighted as issues where a sector-wide discussion might result in removing these barriers.
- There's a requirement for an industry-aligned, shared and governed information platform where the data can be easily populated into computer systems and it can be made readily accessible and usable in order to drive sector-wide value.

Lack of government procurement and regulatory leadership

- A lack of product-specific regulation including product information disclosure requirements.
- An untapped opportunity for government agencies to use procurement mechanisms to drive digitisation and digital adoption including interoperable, open standards such as open BIM.
- A lack of government-to-sector collaboration.

A key to overcoming the barriers to collaboration around construction industry infostructure will be the identification of the appropriate leadership body or organisation to create a neutral space to agree on the terms of collaboration. This could involve the development of a neutral forum formed by government, industry associations and/or BRANZ to facilitate.

6 The roadmap to the future state: digital product twins

The key points and concepts in this section:

- The aim is to provide a basic product information system – a product library.
- Infostructure is designed as neutral to support innovation and be pro-competitive.
- Public access is free.
- Cornerstone stakeholder(s).
- Plan the progressive implementation steps needed to structure data.

6.1 Future state infostructure – vision and operation principles

Based on our research and discussions with industry and government, a future state is achievable using existing technology so that basic descriptive product data, safety data (where needed) and assurance information on most construction industry products is:

- Searchable and visible to users using, for example, a website or smartphone that renders search results using barcode scanning (e.g. QR Codes).
- Downloadable and exchangeable via modern application programme interfaces (APIs).

- Integrated into public and private sector services.
- Extensible with other data sources for proprietary use purposes.

To achieve this outcome, a cross-industry collaboration would be needed to build a sustainable infostructure. Through our interviews with suppliers, central and local government officials, construction industry retail executives, construction professional service companies and other construction industry segments, we conclude that collaboration is possible and desirable. However, given current industry rivalry and competition, any collaborative endeavour in building the infostructure would need to be driven by agreed operational principles, including:

- A not-for-profit model designed to implement construction industry product standards and trusted, structured product data in an accessible digital format.
- Use of open-source international product standards, wherever possible.
- Provide public visibility of basic product data and identity of the data supplier.
- Be market neutral in data provision and pro-competitive (enables data integration service competition), thereby supporting innovation in many forms.
- Be the agreed source of truth for product data with robust data validation to ensure integrity, trust and confidence.
- Enable one-to-many and many-to-one interoperable data exchanges designed to mitigate data and system error while supporting systems scalability and feature enhancements.

Before we look at how such a future infostructure could be designed and operate, we turn to how the standardised and structured data to feed such a system could be developed.

6.2 The starting point - development of a structured product data repository

If the development of an infostructure ecosystem relied on the development of an extensive standardised dataset, nothing would happen. The task is far too big but also unnecessary. A more logical starting point is deploying a minimal product dataset, that provides value to as many stakeholders as possible from the outset but is extensible.

New Zealand construction product data template

Leveraging EU initiatives to structure construction product models,[27] we have designed a conceptual schema for a product data template illustrated in Figure 11.

Figure 11 Data template for construction industry products or objects

Metadata is the set of data that describes and gives information about other data. It provides important contextual information so that, at a glance, the reader or a digital system ingesting data knows what the product is. The data attributes used in the GS1 Global Product Registry Platform are:

- Global Trade Item Number (GTIN providing globally unique identification):
  - Brand name.
  - Product description.
  - Product image URL.
  - Global Product Classification (GPC) schema.
  - Net content and unit of measure.
  - Target market(s).
- New Zealand Business Number (NZBN).

The data attributes highlighted in grey shading above are mandatory attributes required in order to provide sufficient product information to begin the development of the digital data template. Brand name and product description are essential for product identification.

[27] A product equates to a construction object, which can be defined as an object of interest in the context of the construction process (ISO 12006-2:2015 *Building construction – Organization of information about construction works – Part 2: Framework for classification*). Therefore, a construction object can be used to denominate a product, system, assembly, space, building etc. However, we have chosen to use the term product to avoid the confusion with 3D CAD objects.

The other two attributes are also necessary, alongside the GTIN, in order to add value to industry and government parties:

- The GPC schema or coding is essential for applications such as product search to find, view, procure or use for market research. Analogous to other classification schemas such as the United National Standard Products and Services Code (UNSPSC[28]), the GPC adds value to all participants in the ecosystem of users. A GPC schema is also important for structuring or nesting other data elements. For example, insulation products will have a different set of technical standards than electrical products, whereas many of the commercial assurance attributes will have elements in common such as warranty periods and certification claims. However, these may differ by type of product and manufacturer or brand owner market position.
- The NZBN provides globally unique identification of the product supplier. The GS1 Global Location Number (NZS ISO/IEC 6523.1:2019 *Information technology – Structure for the identification of organizations and organization parts – Part 1: Identification of organisation identification schemes*) can be digitally checked, validated and ingested into enterprise management systems and used to support electronic procurement. Its currency can be automatically updated using public APIs available from MBIE (New Zealand Companies Office) – for example, if a company goes into liquidation. The need for unambiguous supplier identification is part of a minimum product data requirement anticipated by MBIE in regulator reforms discussed. The NZBN also provides a match into business customer resource management systems as more businesses adopt the NZBN to manage procurement and customer processes.

The simple starting point for a product library is to begin with metadata and a selected set of common, product assurance information. There is widespread use of these type of data attributes defined for products in supply chains (GTIN is also a BIM standard), and it is common for manufactures to provide basic product assurance and compliance data such as certifications.

The set of technical data standards is extensive and varied, with many different international standards bodies (ISO, CEN, buildingSMART International) leading digitalisation for these technical standards. It is important that New Zealand leverages this work and progressively adopts these data templates rather than going it alone.

6.3 Product library infostructure system, operation and costs

As outlined above, we recommend the product library starts with basic product metadata and product assurance data.

These core data attributes would add value across the supply chain very quickly and would provide a link to safety data sheets that could be provided for hazardous products for example. There may be an advantage in having a central repository of such information, which is currently in development for the grocery sector. This would mean manufacturers and suppliers loaded this data once, resulting in immediate savings.

[28] https://www.unspsc.org/

Why not a bigger product data set?

Our interviews uncovered a clear need from industry stakeholders for a more comprehensive dataset but key reasons for minimising the dataset as a starting point are:

- Feasibility - the basic data we have recommended is readily available and its use would add utility to all stakeholders quickly.
- Technical standards are dynamic in nature and can take significant development time to build and incorporate in digital templates.
- Data management - limiting the dataset to static attributes initially, simplifies the data input, validation and synchronisation processes.
- Supports the infostructure operational principles, namely:
    - To maintain market neutrality in standards and data provision.
    - To ensure the infostructure is pro-competitive to support innovation.

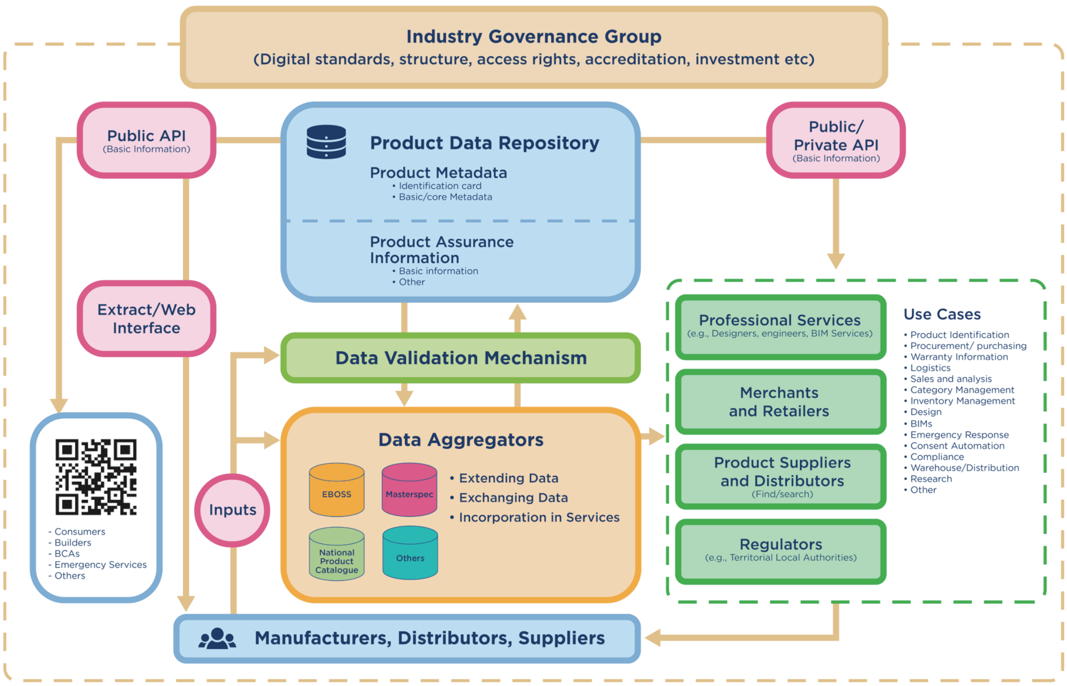
Numerous stakeholders today extend or add to this basic dataset - for example, retailers and data aggregators for proprietary purposes. Data aggregators clean and validate data and sometimes incorporate it into a service offering for a specialist industry segment. They are close to customer needs and in the best position to extend and regularly update extended datasets. Incorporation of additional, standardised data can also be developed in line with an agreed industry standard on structured technical data standards to support interoperability objectives.

Overview of proposed infostructure system

While there is no standard or agreed definition, the term infostructure is commonly used to describe the infrastructure of information.

Figure 12 depicts a product library infostructure highlighting the network stakeholders, APIs, data providers, users and governance.

Figure 12 Product data infostructure system



- **Industry Governance Group (IGG)** – a governing body established to provide system-wide oversight performance and accountability, defining, monitoring and maintaining core digital data standards, stakeholder access rights and funding. The IGG might be a functional unit within a government ministry or agency, an industry-based association or a sector-appointed body.
- **Product data repository (PDR)** – a repository of standardised core product data elements and structures (a dataset) used for data searching, sharing, reporting and analysis and product assurance information. The PDR is extensible as required and as determined by the IGG based on stakeholder needs.
- **Data validation mechanism** – A data validation mechanism to check data accuracy and quality prior to importing and processing - based on agreed validation rules.
- **Data aggregators** - IGG-approved repositories of product and assurance master data that populate the PDR with standardised validated data. Data aggregators have data relationships within a user community for a myriad of use cases.
- **Manufacturers, distributors and suppliers** (MDS) - a community of industry stakeholders who share/input product master data and product assurance data into data aggregator repositories where data-sharing relationships exist. Product master data and product assurance data is also shared with a community of users (professional service organisations, merchants and retailers, regulators etc.) through existing data-sharing arrangements. MDS that do not have a data-sharing relationship with a data aggregator may provide product master data and product assurance information to the PDR intermediated through the data validation mechanism.
- **Public/private API** – an application programming interface (API) that controls and manages access and interactions between the PDR and public and/or private stakeholders. The API defines the kinds of requests that can be made, how to make them, the data formats that should be used and the standards to follow.
- **Use of automatic data capture technology** – product master data and product assurance data may be accessed using technologies such as barcodes (QR code or DataMatrix) or radio frequency identification (RFID). Within the context of the infostructure ecosystem, scanning a barcode or RFID tag queries an API linked to the PDR for a relevant, managed data response.

This infostructure model is a significant departure to that proposed by BRANZ.[29] The BRANZ model positioned GS1 New Zealand's National Product Catalogue (NPC) as a central product registry to support traceability outcomes. GS1 NZ's NPC is a membership service that enables suppliers and retailers to exchange master product and price data. While the NPC is the largest industry repository, GS1 New Zealand does not have the discrete relationships with other user segments of the industry (specifiers, designers, engineering companies) that data aggregators have, nor are the circa 80 NPC data attributes tailored to the specific needs of other user segments despite there being many common attributes.

Most importantly, the infostructure needs to be a neutral and pro-competitive construct to support innovation and encourage stakeholder participation.

[29] Dowdell, D, Page I, Curtis M. Electronic traceability of New Zealand construction products: Feasibility and opportunities. Building Research Association of New Zealand (BRANZ). SR365 [2017]. Wellington. 2017.

6.4 Governance and participation incentives – what's the business case?

Our research findings suggest the main obstacle for industry and government to realise the payback from using accurate and structured product data is a lack of industry coordination around standards and core and common data needs (product metadata and product assurance data). This is an ongoing problem and will not be resolved without a circuit breaker.

The circuit breaker would need to include three elements:

- Industry governance, ownership and leadership.
- Direct, sector-wide benefits of infostructure use to align with overall industry interests.
- Investment and a sustainable funding model.

As outlined previously in this report, a governing body would be established to provide system-wide oversight and performance monitoring and could be a functional unit within a government ministry or agency, an industry-based association or a sector-appointed body.

Direct benefits of infostructure use

Despite the promise of sector-wide economic benefit on offer through the use and sharing of standardised data, this may not provide sufficient incentive to stimulate industry collaboration. Industry stakeholders will only be encouraged to participate in the infostructure opportunity if they can see tangible and quantifiable benefit accruing. Earlier in the report, we outlined many potential uses cases such as BIM use, managing building consents and e-procurement opportunities. However, use cases such as these may not be available or hold any utility or value for all stakeholders in the sector. What is common to all participants however, is the need for accurate, validated product master data that has currency and efficacy in terms of access to an extensive range of products and product systems. The challenge in securing this, however, is sector desire, collaboration and coordination.

If the construction sector in New Zealand is serious about raising productivity outcomes as we have outlined, it can't be a zero-sum game. All stakeholders must benefit from participation, not only suppliers who load data for industry consumption or regulatory authorities who process data but also the numerous other stakeholders involved in both bricks and mortar environments and online marketplaces.[30]

Investment and sustainable funding

Development of a detailed investment and funding model would require industry engagement to develop a business case which is beyond the scope of this research. However, the research has provided useful insights into what a strong business case would need to cover in order to move forward with infostructure development:

- **Estimation of overall establishment and operating costs:** While significant, the technology is unlikely to be the largest infostructure establishment cost. The registry technologies, associated APIs and user interfaces are all proven technologies and to design and build these, we estimate a cost of $0.75 - $1.25 million. The potentially larger costs involve:
    - Data migration and validation.

[30] Indeed, a somewhat thinner layer of metadata is used by such retailers, electronically accessing GS1 registries in marketplaces outside of New Zealand. It is technically feasible, proven and easily scalable, but extension of data fields to include an expanded set of attributes requires sector-wide coordination and agreement.

- Project management of industry engagement.
- Coordination, including agreement on structured data standards and user education.

Much of this cost is not financial but rather it is in-kind contributions as participants volunteer resources. Notwithstanding, it does represent real costs and there will be ongoing support and coordination costs – and likely administrative overhead (up to two FTEs).

- **Source of investment funds and other resources:** This is one of the most problematic issues when network benefits are distributed, and when establishment investment and benefits may fall unevenly across the stakeholder community. Sources of investment could come from any combination of the following:
  - "Cornerstone investors" kick off the investment process. These could be, for example, a group of direct beneficiaries such as BCAs, or government grant seed funding.
  - Data aggregators who contribute core seeding metadata and in-kind expertise in systems and data validation support.

- **Ongoing operational funding:** Committed system use from demand-side beneficiaries is critical to success. It is envisaged in the PDR model that some data would be free for public use cases, including for example, consumers and emergency service providers as 'read only' data. Data used for private or public agency application would attract a small fee, so different access/use arrangements would apply.

Development of a detailed business case covering the above issues is beyond the scope of this report.

6.5 The economic and social payback

Importance of standards for the functioning of markets

A 2011 BERL economics review[31] on standards, concluded that open standards prevent market failure by preventing or addressing information asymmetry and allowing and encouraging innovation.

This aligns closely with our research findings. The successful deployment of the infostructure we have proposed would directly address both these features of market failure. Industry, including the private and public sectors, consistently report their frustration and difficulty in accessing high quality, accurate, trusted and interoperable product information to support productivity outcomes and innovation. Given this, the government's role should be in providing leadership and resources to support the development of the infrastructure we have outlined because it too stands to be one of the beneficiaries. Government leadership to help the market function better could be a game changer for innovation and productivity.

Productivity gains

BERL's review also concluded that standards improve efficiency by creating economies of scale, allowing network externalities and reducing transaction costs.

Again, this aligns with our research findings where we have documented the extensive search, rework and transaction costs around accessing product data.

[31] See footnote 7.

As we have outlined, the technology component of the infostructure is affordable and scalable as long as a few common structured data standards are agreed. Scaling in this way using standards, provides the network benefits we have outlined, including the value of having suppliers enter metadata into the system once for it to be made available to all stakeholders.

NZIER on potential benefits of digital product data

Table 2 summarises indicative comparative estimates of benefits from case studies on economic modelling to provide insights into the potential economic value of standardised and structured product data. Realisation benefits in each example rely on standards, structured data and/or systems that build infostructure.

The first example concerns the uptake of digital tools in work done for Xero on the economic benefits of cloud computing. Xero's digital accounting software is directly comparable in the sense that it is based on tax and accounting standards and so uses structured data and is accessible through the internet. Also, at least in the United States market, Xero uses GS1 product identifiers for inventory management purposes. The standardised infostructure we propose would enable SMEs to load information into such inventory systems using scanning technologies or data feeds.

Table 2 NZIER summary of indicated benefits

Benefit	Indicative comparative values	Importance of digital product infostructure
20% uptake in digital tools	$120m–$220m p.a.	Critical to deliver interoperability
Product compliance	$23m p.a.	Important to deliver interoperability, standardisation and readily updatable information
More complete product inspection documentation	$33m p.a.	Provides standardisation and mobile retrieval
Enable BIM for construction and assets management in local government	Millions annually in savings for local government	Critical for interoperability, standardisation and independence quality assurance

Source: NZIER (2020)

More focused research has also identified such benefits directly associated with one use case for product data. BRANZ[32] found that a lack of trusted digital product assurance data is a factor contributing to the use of non-conforming products costing circa $232 million a year in product failures. A 2019 MBIE Cabinet Paper[33] states that a lack of product information creates building consent delays of up to 21 days, costing applicants $3,000 per consent.

Estimating the specific benefits of multi-factor productivity gains achieved through the use of digital product data would require the kind of bespoke and sophisticated economic modelling undertaken in the two reports cited above. Despite this, they do provide useful comparators. These results indicate that productivity improvements in the construction industry specifically and small business generally, will yield significant improvements in GDP and wellbeing for the New Zealand economy and New Zealanders.

[32] See footnote 3.
[33] See footnote 21.

Appendix A: Literature review

Productivity performance and opportunities for improvement

The construction sector is one of the largest in the world economy, with about US$10 trillion spent on construction-related goods and services annually, equivalent to 13% of world GDP.[34] Construction matters.

Construction has suffered from poor productivity relative to other industry sectors for many decades, and there is a US$1.6 trillion opportunity to close the gap. That would meet about half of the world's annual infrastructure needs or boost global GDP by 2%.

Globally, construction sector labour-productivity growth averaged 1% a year over the past two decades, compared with 2.8% for the total world economy and 3.6% for manufacturing.

Figure 13 Productivity in construction

Source: Barbosa et al., 2017 (see footnote 9).

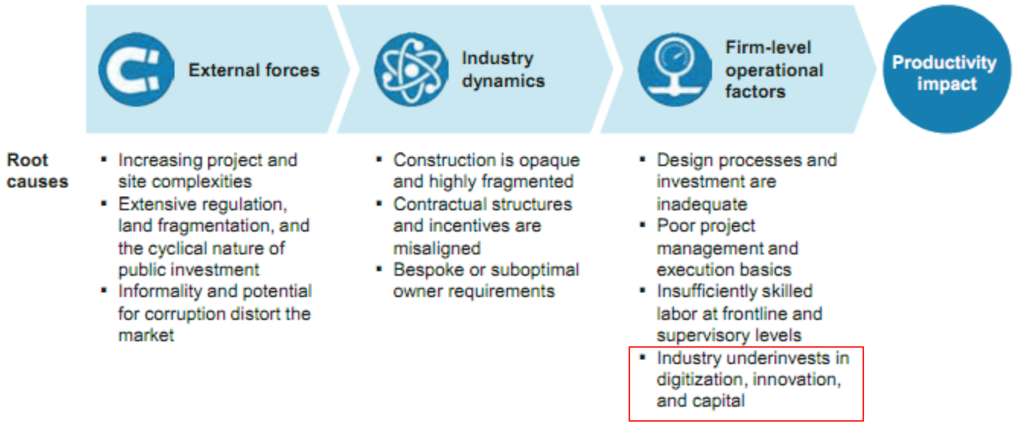
Sectors such as retail have transformed themselves to boost productivity, and many of the larger global retailers refine their global supply chains and embrace digital technologies to achieve improved performance outcomes. In manufacturing, lean principles and aggressive automation have been transformative.

Similarly, global healthcare has transformed itself over the past two decades through the adoption of interoperable global data standards. A worldwide healthcare industry analysis undertaken by McKinsey & Company[35] highlighted the significant potential benefits to all sector stakeholders from adopting global standards and enabling business processes if a critical mass of channel partners adopt the same standards. In other words, global standards adoption is not a 'zero-sum' game in healthcare: benefits could be shared across the value chain, given sufficient adoption and standardisation.

The cause for low productivity outcomes are numerous as outlined in Figure 14, but underinvestment in digitisation and innovation are specifically cited, as is limited standardisation. Investing in these areas is highlighted as a key enabler in raising productivity.[36]

[34] See footnote 9.
[35] Ebel, Y. et al. (2012). *Strength in unity. The promise of global standards in healthcare.* New York, NY: McKinsey & Company. https://www.gs1.org/docs/healthcare/McKinsey_Healthcare_Report_Strength_in_Unity.pdf
[36] See footnote 9.

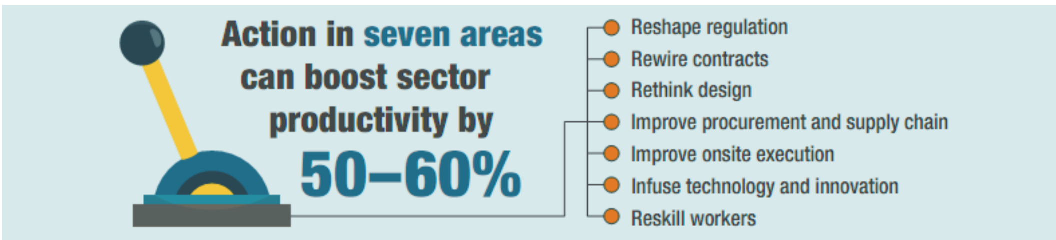
Figure 14 Root causes for low construction productivity



Source: Barbosa et al., 2017 (see footnote 9).

Industry commentators outline that productivity performance could be improved significantly by focusing on several main areas (Figure 15). These include such things as improving design processes and improving the overall level of skills in the sector, but specifically highlighted was the need for improvement in procurement and supply chain management, the infusion of digital technologies and need for advanced automation. Crucial for successful outcomes is a need for widespread adoption in all areas. However, adoption of just a few of them would also be transformative. Focusing on just two areas, procurement and supply chain management, and technology, could lift productivity 21–23% and produce cost savings of 7–11%.

Figure 15 Productivity opportunities in construction



Source: Barbosa et al., 2017 (see footnote 9).

The construction sector in the United Kingdom has consistently performed in a way that is thought to be wasteful compared to other industries. There is a general impression that it does not deliver good value for its customers.[37] In 1994, the final report of the government/industry review of procurement and contractual arrangements in the UK construction industry investigated the problems in the sector, which were described as ineffective, adversarial, fragmented and incapable of delivering for its customers.[38] The report proposed that the client should be at the centre of the construction process and that the industry should move away from its adversarial structure, adopting a more integrated approach with greater partnering and teamwork. Highlighted in the report was a recommendation for the establishment of common standards for the exchange of electronic data, which was seen to be highly desirable, and that further consideration should be given to this issue.

[37] https://www.designingbuildings.co.uk/wiki/Home
[38] Latham, M. (1994). *Constructing the team*. London, UK: Department of the Environment. http://constructingexcellence.org.uk/wp-content/uploads/2014/10/Constructing-the-team-The-Latham-Report.pdf

There were a significant number of recommendations in the report including:

- Greater standardisation and better integration of contract documents.
- Publication of a number of codes of practice and guidance documents to clarify, coordinate and standardise practices across the industry.
- A specified duty to deal fairly with each other and the supply chain in an atmosphere of mutual cooperation.
- Interrelated documentation clearly defining roles.
- Partnering, including teamwork between supplier and client in a process of total and continuous improvement.
- Openness between parties, ready acceptance of new ideas, trust and perceived mutual benefit.

The report suggested that, if the full suite of recommendations were adopted, savings of 30% could be achieved over five years.

Twenty-five years after the report was published, industry commentators asked whether it changed the industry in the UK.[39] This resulted in the immediate creation of the Construction Industry Board to implement its findings. Some 39 of the recommendations are considered to have been achieved, with the UK construction industry now in a better position than it was in 33 of those areas. Of the recommendations implemented, the following are cited as significant:

- Government has committed to be a best-practice client through new procurement routes.
- Various government guidance has been published including government established procurement models that focus on early partnering involvement.

A 2017 BRANZ report[40] described the feasibility of a sector-wide national traceability system based on the use and implementation of existing interoperable GS1 data standards (GTIN and NZBN) and infrastructure for New Zealand for the purposes of reducing product substitution on construction sites and the deliberate use of non-conforming products. The BRANZ analysis estimated a cost incurred to New Zealand annually when non-conforming product is detected and requires replacement or repair of $95 million (residential construction) and $232 million for both residential and commercial construction.

The report posited that a modest 6% reduction in non-conforming building products would realise savings of at least $5.7m annually through the use and implementation of a sector-wide product catalogue based on GS1 global data standards.

Other benefits cited in the report included fewer accidents and injuries from product failure and potential for faster design and consenting though a database/product catalogue easily accessed by designers, consenting authorities (and others). Enhanced tracking and tracing of building and construction products providing for product authentication and chain of custody options was mentioned as was the opportunity for a broad community of sector stakeholders to use real-time data for analytical purposes and robust decision making.[41]

[39] Gardiner, J. (2014). *Latham's report: Did it change us?* Retrieved from https://www.building.co.uk/focus/lathams-report-did-it-change-us/5069333.article
[40] See footnote 3.
[41] BRANZ. (2017). *Electronic traceability: feasibility*. BRANZ Research Now: Traceability #1. Judgeford, New Zealand: BRANZ Ltd. https://www.branz.co.nz/pubs/research-now/traceability/1-electronic-traceability/

In terms of leading the development of a traceability system for New Zealand, the research emphasised that sector bodies and trade associations are considered best placed to manage such a service. Notwithstanding clearly identified benefits, a lack of resources and the potential administrative burden were seen as important potential barriers to adoption.

Digital supply-chains and procurement management improvement

Embracing best practices as other industry sectors have (retail, manufacturing, healthcare) such as standards-based procurement disciplines and increased sector-wide interoperability would likely drive economies of scale for certain products. Digitising procurement and supply-chain workflows would enable more sophisticated logistics management. Sector-wide standardisation of product and entity identification and data management processes would streamline purchasing and procurement processes, speed up consenting processes, enhance product assurance outcomes and provide improved sector-wide analytics by aligning the sector around a common language of business. Sector-wide harmonisation around data standards enables adoption of more sophisticated technologies such as RFID and the Internet of Things (IoT) unlocking the benefits these technologies offer, such as digital collaboration and systems interoperability across multiple sectors.[42]

The World Economic Forum has published a comprehensive transformation framework that is designed to unlock the potential benefits technology adoption promises[43] and outlines steps they consider must be taken as an industry collaboratively to improve the current state. Within the context of industry collaboration, three key initiatives were identified:

- Mutual consent on standards across the industry.
- More data exchange, benchmarking and best-practice sharing.
- Cross-industry collaboration along the value chain.[44]

However, within the context of regulation and policies, harmonised building codes/standards and efficient permit processes are also highlighted.

Digital libraries in the building and construction sector

There are numerous digital libraries, catalogues and databases for building and construction products, specifications, architectural information etc. available throughout the world. Many are available online and many are subscription based. A simple online search query (product catalogues for the building and construction industry) demonstrates that there is a proliferation of material available online.

However, there appears to be no implementation in the world of a national product catalogue or digital library of building and construction products. This is likely to force sector stakeholders to be judicious about what information is sourced and from where and how it is stored and broadly shared easily and efficiently.

Industry collaboration

Mutual consent on standards across the industry, including data standards, is considered very desirable for many different reasons. Standards implementation aids in ensuring products are safe and data and systems are interoperable and good for the environment.

[42] The construction sector ranks in the lower range of sophistication in the McKinsey Procurement Practice Global Purchasing Excellence Survey.
[43] See footnote 8.
[44] Castagnino, S., Buehler, M. & Odeh, I. (2017). 8 ways the construction industry can rebuild itself for the 21st century. Retrieved from https://www.weforum.org/agenda/2017/05/construction-industry-recruit-talent.

Harmonising technical specifications and identifiers of products and services can make industries more efficient and can break down barriers to trade.[45]

A literature review indicates widespread and general agreement that the construction industry lacks robust global arrangements on standards. Consequently, it has forfeited and continues to forfeit productivity gains that modernisation of the industry could secure. Alarmingly, the global construction industry runs the risk of forfeiting future potential inherent in digital technologies if sector-wide fragmentation prevails, unable to agree on enabling broadly defined standards. Further, the opportunity for influencing beneficial cross-industry standards will also be thwarted.

The World Economic Forum[46] rallies a call for action along a number of lines, but within the context of this research assignment, the following are relevant:

- Affiliate and organise – the industry as a whole should define key areas to work on and should agree on a common perspective:
    - Standards in software systems, interfaces and communication protocols will facilitate the digitalisation of the industry as a whole. In particular, companies should establish standards in machine code for robots and automated construction equipment and in interfaces between different systems such as BIM.
    - Standard interfaces between prefabricated modules and components will enhance system compatibility, provide economies of scale for suppliers and act as a powerful productivity driver accelerating overall industrialisation of the sector.
    - The standardised definition of costs, classifications and measurements along the whole life cycle will lead to greater comparability and compatibility among projects.
- More data exchange, benchmarking and best-practice sharing. In the past, for many industry sectors, proprietary standards and knowledge was the key differentiator (and supposed source of competitive advantage) of companies. Today, the pressure is increasingly on companies to join forces and share common global standards.
- Increased knowledge sharing and aligning on standards among peers can help to close the gap between technological development and application. For this purpose, the industry should establish a platform – perhaps a formal association – comprising top engineering and construction firms across all regions. That platform, from its neutral and respected position, could encourage the regular sharing of best practices, benchmarking across peers and could optimise data by ensuring its availability, comparability and protection. If offered the right incentives, companies will readily share knowledge and advice.

A study of the Norwegian architecture, engineering and construction industry into sector-wide collaboration outlines concerning collaboration challenges – more specifically, technical aspects of collaboration.[47]

---

[45] See footnote 44.
[46] See footnote 8.
[47] Bråthen, K. (2015). Collaboration with BIM – learning from the front runners in the Norwegian industry. *Procedia Economics and Finance*, *21*, 439-445.

Given many projects have heavy reliance on ICT and in particular with the emergence of BIM, a lack of standards or the proprietary nature of software are considered obstacles for seamless exchange of data and information across organisations. Further, it was pointed out that the low technical compatibility (or technical interoperability) across organisational boundaries will cause extra work because of the need to re-enter already existing data as well as the possibility of loss of data and information.

While there is no legislation or regulations in Norway (or other Scandinavian countries) for the use and implementation of standardised product data for procurement, supply chain and identification purposes, there is a push from some government agencies for GS1 standards. The first step towards this is to require the GTIN to be used for documentation purposes and to extend this to procurement processes that align product identification with the BIM model in the construction phase.

In Sweden, while there are no official requirements, all major construction companies, several retailers and the BIM Alliance Sweden are asking sector suppliers to use GTINs for product identification to streamline procurement processes and enhance sector-wide traceability outcomes.

Having outlined the above however, information about construction products is heavily regulated at the European level,[48] the goal being to harmonise construction product information using data dictionaries. However, while standardisation work is being undertaken in Europe around the data story in the building and construction sector, there is still confusion regarding issues such as a standard way to define and structure construction object data (product, system, assembly, space, building etc.) in order to make it suitable for digital use.[49]

Ideally, a data dictionary would hold the complete diversity of concepts and relations between them. However, because data dictionaries do not single out all concepts and relations about a product, the content credibly sourced from EU and international standards is stored in data templates. The methodology to create data templates is under development within the European standards body CEN.[50] They are being billed as the pillars of interoperability as they set out common formats, structures, concepts and relations for effective and efficient data exchange. Figure 6 illustrates the process of sourcing product characteristics from credible sources.

A report on the digitisation of the German construction industry[51] is unequivocal on the criticality of digitisation and insistence for the German construction sector to catch up. The authors highlight similar areas of technical development and approaches to others that would powerfully affect the business of construction industry players to yield genuine benefits including digital data, digital access, automation and connectivity, electronic tendering systems, electronic procurement platforms and data catalogues.

The European-based Digital Supply Chains in the Built Environment Work Group (DSCiBE) aims to bring together major industry stakeholders involved the built environment supply chain by developing processes for digital exchange of data and information based on global data standards. Their initial focus is on product/material master data enabling real-time

[48] EC 305/2011 Construction Products Regulation (CPR) – https://ec.europa.eu/growth/sectors/construction/product-regulation_en

[49] Cobuilder. (2019). *Standardising construction object data for digital use*. Oslo, Norway: Cobuilder.

[50] CEN TC/442 WG 4.

[51] Roland Berger. (2016). *Digitization in the construction industry. Building Europe's road to "Construction 4.0"*. Munich, Germany: Roland Berger.

synchronisation of a physical object with its digital twin through the product's life cycle. The introduction of BIM is the group's first step towards a collaborative digital communication.

A published white paper[52] outlines DSCiBE's definition of structured product master data and the potential benefits on offer if the European construction sector harmonised on its use and implementation. The group's analysis details standardisation efforts (mainly by European standards bodies such as ISO, CEN and IFC) that are designed to align the European construction industry.

Foundational to the group's focus of creating digital supply chains is the widespread adoption, implementation and use of global data standards for the identification of construction products, assets, documents, logistics consignments and relationship identifiers based on GS1 standards.

Technology and digitalisation of the construction sector

There is global recognition that demand in exploiting technology to overcome challenges with productivity, costs and quality achievement are endemic in the building industry. Within the New Zealand context, the construction sector appears to be a low-technology performer when compared to all-industry averages.[53] The New Zealand building and construction sector, similar to other countries, continues to face pressures to improve productivity performance and lower construction costs.[54] The use of new technologies that embrace systems, tools and equipment used in the process of design/construction to digitise the sector is cited as a major focus area for New Zealand Government agencies.[55]

A review of digital technologies to improve productivity of the New Zealand construction industry outlines a significant number of references to technologies that could be and are being exploited to aid sector-wide productivity including electronic commerce, barcode technology[56] and the use of mobile devices, big data and analytics to name a few. An article by Chowdhury et al.[57] outlines corroboration in the use of these technologies as key enablers to productivity improvements enabled through the synergistic application of digital technologies that make information through interconnected automated systems achievable. Diffusing digital technology is cited as leading to significant productivity improvements but the impacts are poorly understood. The analysis concludes that the array of international studies into digital technologies demonstrate great potential for productivity gains and profit margins and a few emerging functions in particular such as BIM, RFID, cloud computing, GPS and mobile computing. This is seen as a significant resource to encourage digitisation in the New Zealand building industry despite concerns of the revealed barriers such as financial, technological, process, organisational and governmental concerns.

Making BIM universal within companies and combining this with digital collaboration tools (IoT, product catalogues, mobile apps loaded on smart devices) will establish widespread transparency in areas such as data quality and data sharing, productivity analytics, equipment

---

[52] See footnote 13.
[53] Stats NZ. (2013). Research and development survey 2012. Retrieved from http://archive.stats.govt.nz/browse_for_stats/businesses/research_and_development/ResearchandDevelopmentSurvey_HOTP2012.aspx#gsc.tab=0
[54] NZIER. (2014). *Bespoke residential housing demand and construction innovation*. Wellington, New Zealand: NZIER.
[55] https://www.buildingbetter.nz/
[56] Referring specifically to automating the acquisition of data, cost and schedule tracking and improving the speed, reliability and accuracy of data can be integrated with GIS for construction progress monitoring.
[57] Chowdhury, T., Adafin, J. & Wilkinson, S. (2019). Review of digital technologies to improve productivity of New Zealand construction industry. *Journal of Information Technology in Construction*, *24*, 569–587.

and materials tracking. Importantly, the opportunity is created to ensure the right data is shared with the right people in a timely manner – big data has a significant role to play.

Some governments are now addressing the poor productivity of the construction sector front on and are attempting to break the deadlock by deploying tools to achieve this based on new materials but specifically by deploying digital technologies and transformation.

Any action to boost performance needs to apply across the entire supply chain as has been evidenced in other industry sectors, especially manufacturing, retail and healthcare.[58]

Digitisation of the economy is a priority for the European Union (EU) with its strategy for a digital single market. The development of digital platforms and standardisation are emphasised as foundational pillars to enable this, and its aim is to "maximise the growth potential of the digital economy in Europe and to ensure European industries are at the forefront of developing and exploiting digital technologies of the markets of the future".[59]

In a manifesto published in 2018,[60] the European Construction Industry Federation (FIEC) along with other major European construction industry associations acknowledged the role of digital technologies in improving productivity, reducing project delays, improving safety, offering better working conditions, providing affordable homes and enhancing the quality of buildings and infrastructures. Importantly, the manifesto called for strong EU leadership in the digitisation of the construction sector by developing a regulatory framework on data policy and investing in IT infrastructure. The use of BIM, big data analytics and artificial intelligence in particular were cited as important considerations.

Several EU initiatives (such as the BIM task group) have been implemented, and some Member States have made the use of BIM mandatory for public works and design contests. The directive and the existing initiatives at both EU and national level focus on the use of BIM, recognising that full potential of BIM requires combining it with other digitalisation technologies such as IoT.

Given the construction industry's societal, environmental and economic importance, even small improvements in performance will have a strong effect in all three key domains according to the World Economic Forum:[61]

- **Societal:** A mere 1% reduction in construction costs would save society about $100 billion annually. In fact, the ambitions go far beyond that. The vision formulated by the UK Government for 2025 is of a 33% reduction in the initial cost of construction and the whole-life-cycle costs of built assets.
- **Economic:** The global shortfall in infrastructure capacity is expected to reach $15–20 trillion by 2030. Closing this gap could create up to 100 million additional jobs and generate $6 trillion a year in economic activity in the long run. Up to 30% of this boost could come from improvements to construction projects and to asset operations.

[58] McKinsey & Company. 2012.
[59] European Commission. (2015). *A digital single market strategy for Europe*. Brussels, Belgium: European Commission. https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:52015DC0192&from=FR
[60] FIEC. (2016). Smarter construction, stronger economy, inclusive society: The European construction industry manifesto for digitalisation. Brussels, Belgium: European Construction Industry Federation. http://www.fiec.eu/en/library-619/joint-manifesto-on-digitalisation-from-the-construction-industry.aspx
[61] See footnote 8.

- **Environmental:** By harnessing the capacity of the building sector, many countries can cut emission rates cost-effectively and achieve energy savings of more than 30%, according to the United Nations Environment Programme.

The WEF considers that all this potential is ready to be unlocked. New opportunities are emerging as transformative developments reshape the building and construction industry, from innovative technologies to revolutionary construction techniques. Productivity and efficiency will surge. Despite the promise on offer, it is up to the industry to embrace the new opportunities aggressively and change the way it has traditionally operated. Construction companies need to act quickly and decisively.

The circular economy

A Circular Economy can be said to be one 'that is restorative and regenerative by design and aims to keep products, components and materials at their highest utility and value at all times' and aims to decouple economic growth from resource consumption.[62] By maintaining the value of materials and keeping them in circulation, the Circular Economy is seen as a way to reduce reliance on material extraction and as a condition for the continuation of our current way of life.

FIEC is the European Construction Industry Federation representing via its 32 National Member Federations in 28 countries (25 EU, Norway, Ukraine and Turkey) construction enterprises of all sizes. FIEC has published a position paper outlining their action plan on the Circular Economy where one of the key principles and priorities is to position digitisation as an enabler for all the EU policy goals and this applies in particular to the Circular Economy. In the context of digitisation, FIEC specifically outlines:

- A recognition that digital technologies will not only accelerate circularity but also the dematerialisation of the economy.
- That public administration in the EU must keep pace with technological progress in the private sector and ensure that adequate research and innovation funds are allocated for fostering digitisation in the construction sector.
- Support for promoting digital technologies for tracking, tracing and mapping resources and gathering important data about materials.
- Support for the development of EU Digital Log Books for buildings that will facilitate a common interface and linking to other sources of information to enable accurate, thorough and constantly updated records of materials used in new buildings. The log books are also seen as vital for the CE as it will facilitate future recycling and reuse when a building is renovated or disassembled.

Industry transformation framework

WEF considers that the construction industry should take action in several key areas as outlined in the industry transformation framework shown in Figure 5.

The framework structures the various areas of action according to responsibility. Initially, the transformation relies on the initiatives at individual company level and includes the adoption of new digital technologies, big data processes, business model innovation, refinements to corporate culture and organisation. Again, a recurring theme in the literature is that individual action is insufficient in what is a highly fragmented and horizontal industry. Collective industry-

[62] Hart, J, Adams, K, Giesekam, J, Densley Tingley, D, Pomponi, F, (2019). *Barriers and drivers in a circular economy: the case of the built environment.* 26th CIRP Life Cycle Engineering (LCE) Conference. ScienceDirect. Available at: www.sciencedirect.com

wide collaboration action along the value chain is required - especially more data exchange, benchmarking and best-practice sharing. Governments, too, have a large part to play in their dual role as regulators and clients.

Standardisation and interoperability are crucial for digitalisation, and various organisations are active in this area (ISO, CEN, GS1, buildingSMART International). Recognising the importance of this, GS1 and buildingSMART[63] signed a Memorandum of Understanding in October 2018[64] to advance to use of global standards in the construction sector. Both organisations see the use of standardised product instance identification and exchange of open, interoperable product data as a critical 'game changer' for digitising the global construction sector.[65]

The need for transformation in the New Zealand construction sector has been widely reported.[66] The major areas of action highlighted closely mirror international trends and, notably, technology adoption and procurement and supply-side management.

BIM penetration in construction

Governments are mandating the use of BIM because of the solid body of data that shows adoption of BIM provides quantifiable business benefits by helping improve sector-wide collaboration, reduce costs and generally improve overall performance in the building and construction sector globally.[67]

In 2014, the European Commission published a survey regarding global BIM implementation, use and expertise, which included New Zealand.

Figure 16[68] outlines the results where, overall, the use of BIM in construction projects is reported to have accelerated in global construction markets. North America has the most active users, and European construction companies rank fifth.

[63] buildingSMART is a worldwide not-for-profit neutral industry body driving the digital transformation of the built asset industry. www.buildngsmart.org

[64] https://www.buildingsmart.org/buildingsmart-and-gs1-signed-a-memorandum-of-understanding-to-advance-global-standards-in-the-construction-sector/

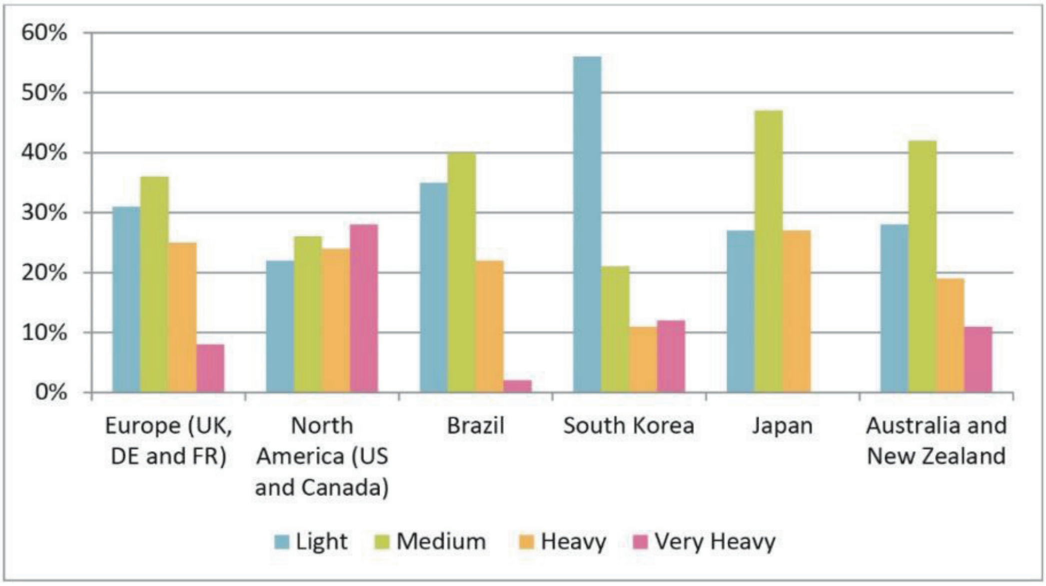
[65] Fredenlund, L. (2020, 9 January). *The digital supply chain in the built environment and your role in it* [Webinar presentation]. Available at https://vimeo.com/383801903

[66] Duncan, A., Kingi, V. & Brunsdon, N. (2018). *Adopting new ways in the building and construction industry*. BRANZ Study Report SR406. Judgeford, New Zealand: BRANZ Ltd.

[67] Geospatial Media and Communications. (2015). *Enhancing productivity, efficiency, compliances and mechanisation for construction industry*. New Delhi, India: Geospatial Media and Communications.

[68] European Commission. (2019). *Supporting digitalisation of the construction sector and SMEs including building information modelling*. Brussels, Belgium: European Commission.

Figure 16 Level of BIM implementation in 10 leading construction markets



While BIM processes have been mandated in some countries, in New Zealand this is not the case. However, in supporting the New Zealand BIM Acceleration Committee and assisting government clients to adopt BIM, the New Zealand Government is behind the development and uptake of BIM.[69] In New Zealand, the number of projects using BIM plateaued in 2019 (59%) after only a small increase in 2018.

Some industry commenters[70,71] go as far to position BIM front and centre as the 'backbone' of the new way of working, triggered and targeted by a digital strategy, given that different elements (such as software and infrastructure) should ideally be connected to it.

Benefits and opportunities of BIM

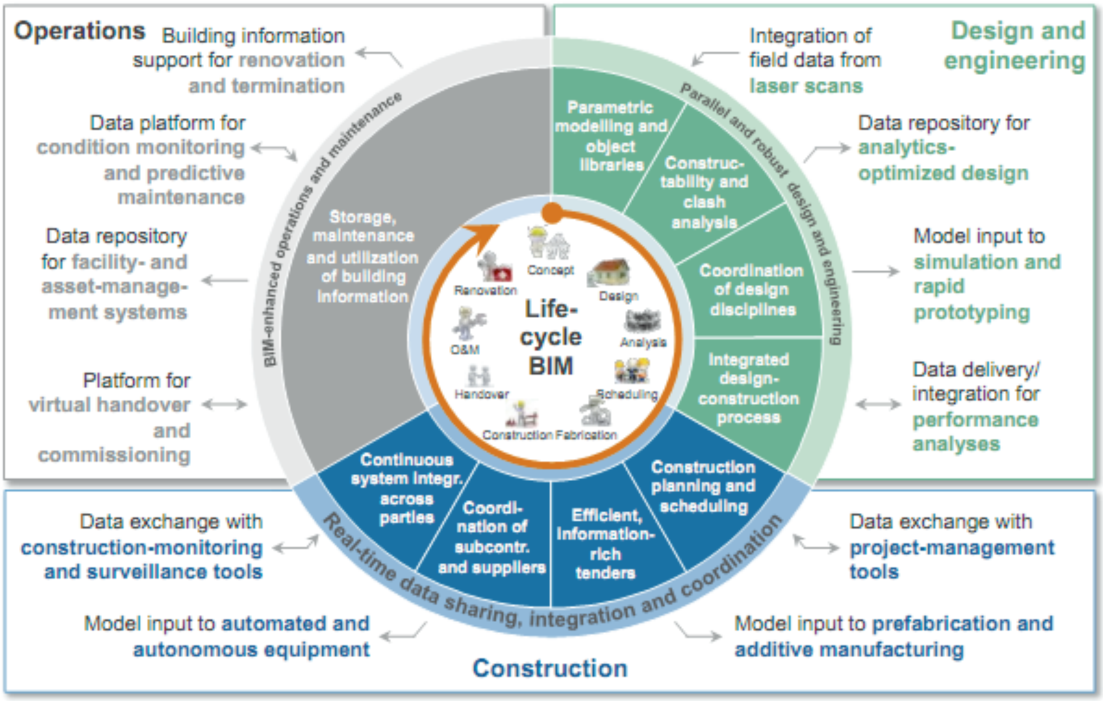
BIM is gaining currency as a platform for central integrated design, modelling, planning and collaboration. BIM provides all stakeholders with a digital representation of a building's characteristics – not just in the design phase but throughout its life cycle. It presents several important opportunities, as shown in Figure 17.

[69] BIM Acceleration Committee. (2019). *BIM in New Zealand: An industry -wide view. Retrieved from https://www.eboss.co.nz/bim-in-nz/overview*

[70] Oliver Wyman. (2018). *Digitalization of the construction industry: The revolution is underway.* New York, NY: Oliver Wyman.

[71] See footnote 51.

Figure 17 Applications of BIM along the engineering and construction value chain[72]



Of note is BIM's ability for stakeholder collaboration and integration opportunities throughout a project life cycle allowing all actors to contribute information to and extract information from the central model. By providing a lifelong view of construction projects, great benefits can be realised in the commissioning and operations phase. Core elements of the BIM model are structured master data and interoperable data platforms.

BIM also enables new business models, particularly in asset and data management. BIM will eventually produce a continuous build-up of know-how by enabling a seamless flow of information across different construction phases and stakeholders.

Industry commentators also appear to be aligned that real reform depends on data and systems integration offered to users – with those involved in concept design connecting to those responsible for managing construction who in turn connect to those responsible for making building and construction products and executing the work - and all the above connecting to the ultimate user. It is in the operation and use of this connectedness that real value lies.[73]

In January 2018, the UK BIM Alliance held a meeting of key protagonists in the field of product data with a view to getting an overview of the issues, particularly from a client and manufacturer perspective. The Alliance felt that, as an umbrella body for the whole industry (construction and infrastructure, client and supply chain) all with an interest in digitising the UK building and construction sector, it could serve as the source of focus and leadership that this fragmented topic required. Consequently, a UK Product Data Working Group was established.

The UK BIM Alliance Product Data Working Group outlined seven key areas of focus for the UK construction sector with regards to structured data and data standards:[74]

[72] See footnote 8.
[73] See footnote 67.
[74] See footnote 14.

- **Structured data definitions** to gain universal sector-wide agreement on a definition of structured data to enable interconnected dictionaries, structured data creation and approvals.
- **Product data standards** because there are no commonly agreed standards for digital product data in the UK or in Europe and given the landscape is both fluid and complex, common data standards need to be developed and agreed to by all stakeholders.
- **Product data journey** – there is no 'golden thread' of product information for most projects. "Because the data journey involves information provided at different times by different stakeholders, any system to manage that information may need to be connected to/merged with each other at different points in the journey. The way in which information moves through the construction supply chain needs to be significantly improved if we are to truly benefit from efficient and effective digital workflows".
- **Product data naming and product identification** – implementing a unified methodology to produce data templates in the UK is considered long overdue, unlike Europe, so the UK needs to align with European and international standards in a collaborative manner throughout the data journey.
- **Product data hosting** – in the absence of published standards on data structure and process, the recommendation is producing a standardised way in which product information is hosted and structured.
- **Product data security** – asset information security is relatively new, and the landscape is wholly inadequate to deal with issues arising. The whole area requires considerable thought and investment.
- **Product data steering committee** – it is recognised that, in the UK, there is no national body and education process or independent source of information, coordination or leadership in the field of product information in the built environment. The Alliance recommends the formation of a funded, cross-industry product data steering committee to provide a coordination and guidance role in this area.

A newly published ISO standard[75] related to BIM outlines methodologies to enable data dictionary interoperability and highlights that, in the digital build environment, there will not be a single data dictionary comprising of all definitions required in all BIM domains but interoperability in tools and applications between data dictionaries that are agnostic to geographic location. The document also outlined data governance rules and principles.

Construction sector transformation in New Zealand

In January 2020, the New Zealand Government launched a Construction Sector Transformation Plan positioned as a vision for a high-performing construction sector for a better New Zealand.[76] The document outlines challenges being faced in the New Zealand sector, which emulate closely many of those highlighted in the literature as we have outlined – skills and labour shortages, slowness to innovate and adopt new technologies in construction practice, design and materials, poor procurement skills and a lack of collaboration and

[75] ISO 23386:2020 *Building information modelling and other digital processes used in construction – Methodology to describe, author and maintain properties in interconnected data dictionaries.*
[76] Construction Sector Accord. (2020). *Construction Sector Transformation Plan.* Wellington, New Zealand: Ministry of Business, Innovation and Employment.

knowledge sharing, among others. Collectively, the issues highlighted, add up to stagnant productivity, higher costs and business failures. Conspicuously missing in the transformation plan, however, is any commentary on how the use and implementation of digital technology and innovation will assist in shaping the future direction of the sector in New Zealand, which is a strategic focus area highlighted in all of the literature reviewed in this analysis. The plan focuses on six areas designed to lift sector-wide performance over a three-year period, as outlined in Figure 18.

Figure 18 Six workstreams that will lift performance

In March 2020, a Bill was introduced to the New Zealand Parliament seeking to amend the Building Act 2004 in response to an underproductive construction sector. Proposed changes are seen to provide for more effective ways of working, help support productivity improvements, lift the efficiency and quality of building work and improve trust and confidence in the building regulatory system.[77] The Bill forms part of a wider programme of work to lift performance of the regulatory system in the hope of driving better outcomes for New Zealand. Key changes seek to achieve the following:

- Introduce minimum information requirements about building products available in the New Zealand market. The information will be set by regulation and require manufacturers, suppliers, importers and distributers to provide verified information on:

[77] https://www.building.govt.nz/getting-started/building-law-reforms/changes-to-the-building-act-introduced-to-parliament

- Product description.
- Supplier details.
- The scope and limitations of use.
- Design and installation requirements and maintenance.
- A declaration of whether the product is subject to a warning or ban.

- Introduce a specialist framework for modern methods of construction (MMC) such as off-site manufacturing and prefabrication, aimed at speeding up the consenting process. A new voluntary manufacturer certification scheme for MMC will be introduced spanning an end-to-end process from design to on-site installation.
- Strengthen CodeMark (MBIE's voluntary building product certification scheme) to improve trust and confidence in the scheme by clarifying certification rules while strengthening regulatory oversight.

A way forward

The building and construction sector is a foundation stone of the world's economy. Despite this, it has been far slower than many other industries to adopt new technologies. To move the global industry forward, all stakeholders in the value chain need to act. The importance of different transformation areas in the global sector have been widely reported, as summarised in Figure 19. Of the 10 areas of importance in shaping and driving transformation, adoption of new technologies, materials and tools ranks as important, second behind organisation optimisation (people). Industry should enhance coordination and cooperation across the entire value chain and agree common goals and standards.

In the context of New Zealand, several technologies outlined in this review show promise to enhance workforce efficiency. The government is being called on to create a fertile environment for transformation – one of the major themes in New Zealand cited in BRANZ research.[78]

[78] See footnote 3.

Figure 19 Importance of transformation areas for the building and construction industry[79]

[79] See footnote 8.

Appendix B: References

Alexander, A. (2017). Cloud momentum: More firms are embracing the technology. *Accounting Today*, *31*(9), 44–52.

Anthony, S. D., Cobban, P., Nair, R., & Painchaud, N. (2019, November 1). Breaking Down the Barriers to Innovation. *Harvard Business Review*, *November–December 2019*. https://hbr.org/2019/11/breaking-down-the-barriers-to-innovation

Australian Treasury. (2018). *E-Invoicing*. https://treasury.gov.au/consultation/e-invoicing

Barbosa, F. et al. (2017). *Reinventing construction: A route to higher productivity*. Brussels. Belgium: McKinsey Global Institute.

Bealing, M. & Leroy de Morel, L. (2020). *The Economic Cost of Quality Defects*. External Study Report ER 49. https://d39d3mj7qio96p.cloudfront.net/media/documents/ER49_Economic_Cost_of_Quality_Defects_LR10320.pdf

Bealing, M., Siddharth, P. & Leroy de Morel, L. (2020). *Economic potential of cloud-based business tools*. A report for Xero. https://nzier.org.nz/publication/economic-potential-of-cloud-based-business-tools

BIM Acceleration Committee. BIM in New Zealand – and industry-wide view 2019. *Baseline information on the use of BIM across the New Zealand construction industry*. 2019 www.biminnz.co.nz

BRANZ, Traceability #1. Research Now. June 2017. Wellington. Available at: https://www.branz.co.nz/cms_show_download.php?id=82b7d74da2646073f69f6a12ac54770aa6065066

BRANZ, Adopting new ways in the building and construction industry. Study Report SR406 [2018]. Wellington 2018.

Brathen, K (2015). Collaboration with BIM – Learning from the front runners in the Norwegian industry. From 8th Nordic Conference on Construction Economics and Organization. ScienceDirect. Procedia Economics and Finance 21 (2015) 439-445. Available at www.sciencedirect.com.

buildingSMART is the worldwide, not-for-profit, neutral industry body driving the digital transformation of the built asset industry. www.buildngsmart.org

Cobuilder AS (2019), Standardising Construction Object Data for Digital Use. Cobuilder AS, Norway. www.cobuilder.no

Construction Sector Accord (2020), Construction Sector Transformation Plan. Ministry of Business Innovation and Employment. Wellington. 2020 pp:11.

Deloitte. (2018). *Connecting Small Businesses in the US 2018* (p. 36).

Deloitte Access Economics. (2019). *The economic value of cloud services in Australia*. https://www2.deloitte.com/content/dam/Deloitte/au/Documents/Economics/deloitte-au-economics-value-cloud-services-australia-230719.pdf

Dowdell, D. (2018). Tracking materials electronically. *Build*, *166*. https://www.buildmagazine.org.nz/index.php/articles/show/tracking-materials-electronically

Dowdell, D, Page I, Curtis M. Electronic traceability of New Zealand construction products: Feasibility and opportunities. Building Research Association of New Zealand (BRANZ). SR365 [2017]. Wellington. 2017.

DSCRiBE User Group. Digital Supply Chains. *Data Driven Collaboration.* 2019. https://www.gs1.org /sites/default/files/digitalsupplychainsdatadrivencollaboration.pdf

European Commission. Supporting digitisation of the construction sector and SMEs, including Building Information Modelling. 2019. www.europe.eu

European Commission: A Digital Single Market Strategy for Europe, COM 2015 (192) Available at: https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:52015DC0192&from=FR

FIEC, Joint Manifesto on Digitalisation from the Construction Industry. http://www.fiec.eu/en/library-619/joint-manifesto-on-digitalisation-from-the-construction-industry .aspx

Fredenlund, L, The Digital Supply Chain in the Built Environment and your Role in it. Webinar Presentation 9 January 2020. Available at: https://vimeo.com/383801903

Gal, P., Nicoletti, G., Renault, T., Sorbe, S., & Timiliotis, C. (2019). *Digitalisation and productivity: In search of the holy grail – Firm-level empirical evidence from EU countries.* https://doi.org/10.1787/5080f4b6-en

Gardiner, J, (2014), Latham's report: Did it change us? Available at: http://constructingexcellence.org.uk/wp-content/uploads/2014/10/Constructing-the-team-The-Latham-Report.pdf

Geospatial Media and Communications. Available at: https://geospatialmedia.net/
UKBIM Alliance, (2018), A Fresh Way Forward for Product Data. Available at: https://www.ukbimalliance.org/wp-content/uploads/2018/11/UKBIMA_A_Fresh_Way_Forward_For_Product_Date.pdf

Geospatial Media & Communications. Enhancing Productivity. *Efficiency, Compliances and Mechanisation for Construction Industry.* India. 2015. www.geospatialmedia.net

Gil-Garcida, J. R., Chengalur-Smith, I., & Duchessi, P. (2017). Collaborative e-Government: Impediments and benefits of information-sharing projects in the public sector. *European Journal of Information Systems*, *16*, 121–133.

Hart, J, Adams, K, Giesekam, J, Densley Tingley, D, Pomponi, F, (2019). *Barriers and drivers in a circular economy: the case of the built environment.* 26th CIRP Life Cycle Engineering (LCE) Conference. ScienceDirect. Available at: www.sciencedirect.com

Ibrahim, N. H. (2013). Reviewing the evidence: use of digital collaboration technologies in major building and infrastructure projects. *Journal of Information Technology in Construction,* 18, 40–63. https://itcon.org/paper/2013/3

ISO 23386:2020 (en) Building information modelling and other digital processes used in Construction – Methodology to describe, author and maintain properties in interconnected data dictionaries. www.iso.org

Krugman, P. R. (1994). *The Age of Diminished Expectations: U.S. Economic Policy in the 1990s.* MIT Press.

Lathan, M, Constructing the Team. Final Report of the Government/Industry review of procurement and contractual arrangements in the UK construction Industry. Department of the Environment. 1994 (HMSO). Available at http://constructingexcellence.org.uk/wp-content/uploads/2014/10/Constructing-the-team-The-Latham-Report.pdf

Levitt, T. (1965). Exploit the Product Life Cycle. *Harvard Business Review, November 1965.* https://hbr.org/1965/11/exploit-the-product-life-cycle

McKinsey Global Institute, Reinventing Construction: A Route to Higher Productivity. February 2017.

McKinsey & Company, Strength in Unity. *The promise of global standards in healthcare*. October, 2012. https://www.gs1.org/docs/healthcare/McKinsey_Healthcare_Report_Strength_in_Unity.pdf McKinsey, 2017.

Ministry of Business Innovation and Employment, (2016), Building Better Homes, Towns and Cities. Retrieved from http://www.mbie.govt.nz /infoservices/science-innovation/national-science-challenges/buildingbetter-homes

Ministry of Business Innovation and Employment. (2013). *The New Zealand sectors report 2013: Featured sector—Construction* (p. 148). https://www.mbie.govt.nz/assets/77439ddc45/Construction-report-2013.pdf

National BIM Report. pp: 44. 2018. Available at: https://www.thenbs.com/knowledge/product-identification-the-missing-link-of-bim

New Zealand Government. (n. d.). *What is data content standardisation?* https://www.data.govt.nz/manage-data/data-content-standardisation/what-is-data-content-standardisation/

NZIER (2014), Bespoke residential housing demand and construction innovation, Retrieved from https://nzier.org.nz/static/media/filer_public/75/d9/75d98949-d425-4dcb-b9a919404be4bce2 /11024_bespoke_residential_housing.pdf

NZIER, Digital data productivity. Report to GS1. September 2020.

OECD. (2019). *Cloud Computing: The Concept, Impacts and the Role of Government Policy* [OECD Digital Economy Papers No. 240 Cloud Computing]. OECD Publishing.

Oliver Wyman et al., Digitisation of the Construction Industry: The Revolution is Underway. 2018. www.oliverwyman.com

Orihuela, P., Orihuela, J., & Pacheco, S. (2016). Information and Communications Technology in Construction: A Proposal for Production Control. *Procedia Engineering*, 164, 150–157. https://doi.org/10.1016/j.proeng.2016.11.604

Page, I. (2016). *Study report SR355 Consent documentation quality for new housing* (p. 24).

Parker, C. & Allison, N. (2014). *Economic benefits from BIM enabling meta data standards*. NZIER report to Wellington City Council.

Peansupap, V., & Walker, D. (2006). Information communication technology (ICT) implementation constraints: A construction industry perspective - ProQuest. *Engineering, Construction and Architectural Management*, 13(4), 364–379.

Powell, S, Molleson, A, The NBS (2018). Product Identification – The missing link of BIM. The NBS

Roland Berger GMbH. Think Act. Beyond Mainstream. Digitization I the construction industry. *Building Europe's road to 'Construction 4.0'.* Civil Economics, Energy & Infrastructure Competence Center. Munich, Germany. www.rolandberger.com

Sategna, L,G, Meinero,D, Volonta, M, (2019) Digitising the Construction Sector. Unlocking the potential of data with a value chain approach. Committee for European Construction Equipment. January, 2019. Available at: https://issuu.com/cece_europe/docs/final_nobianche2-ied_consulting_-_f

Schwartz, T., & McCarthy, C. (2007, October 1). Manage Your Energy, Not Your Time. *Harvard Business Review, October 2007*. https://hbr.org/2007/10/manage-your-energy-not-your-time

Shy, Oz. (2011). A Short Survey of Network Economics. *Review of Industrial of Organization,* 38, 119–149.

Shy, Oz (2010): A short survey of network economics, Working Papers, No. 10-3, Federal Reserve Bank of Boston, Boston, MA

Solow, R. M. (1957). Technical Change and the Aggregate Production Function. *The Review of Economics and Statistics*, 39(3), 312. https://doi.org/10.2307/1926047

Sorbe, S., Gal, P., Nicoletti, G., & Timiliotis, C. (2019). *Digital Dividend: Policies to Harness the Productivity Potential of Digital Technologies* (OECD Economic Policy Papers No. 26). https://doi.org/10.1787/273176bc-en

Statistics New Zealand. (2020). *Industry Productivity Statistics ANZSIC06.*

Statistics New Zealand. (2019). *National Accounts, Gross Domestic Product—Production measure, detailed industry groups.*

Statistics NZ (2012), Research and Development survey. Available at: http://www.stats.govt.nz /browse_for_stats /businesses/research_and_development/ResearchandDevelopmentSurvey _HOTP2012.aspx

Tabinda Chowdhury, Johnson Adafin, Suzanne Wilkinson (2019). Review of digital technologies to improve productivity of New Zealand construction industry. Journal of Information Technology in Construction (ITcon), Special issue: 'Virtual, Augmented and Mixed: New Realities in Construction', Vol. 24, pg. 569-587, DOI: 10.36680/j.itcon.2019.032

Vitalis, V. (2009). Domestic Reform, Trade, Innovation and Growth in New Zealand's Agricultural Sector. *OECD Journal: General Papers*, *2008*(4), 189–218. https://doi.org/10.1787/gen_papers-v2008-art28-en

World Economic Forum. (2017). *Shaping the future of construction: Inspiring innovators redefine the industry.* http://www3.weforum.org/docs/WEF_Shaping_the_Future_of_Construction_Inspiring_Innovators_redefine_the_industry_2017.pdf

World Economic Forum. Shaping the Future of Construction. *A Breakthrough in Mindset and Technology*. Prepared in collaboration with the Boston Consulting Group. May 2016. www.weforum.org

World Economic Forum. 8 ways the construction industry can rebuild itself for the 21st century. May 2017. Available at https://www.weforum.org/agenda/2017/05/construction-industry-recruit-talent.

Appendix C: NZIER assessment

Digital data productivity

In the construction industry

NZIER report to GS1

September 2020

About NZIER

NZIER is a specialist consulting firm that uses applied economic research and analysis to provide a wide range of strategic advice.

We undertake and make freely available economic research aimed at promoting a better understanding of New Zealand's important economic challenges.

Our long-established Quarterly Survey of Business Opinion (QSBO) and Quarterly Predictions are available to members of NZIER.

We pride ourselves on our reputation for independence and delivering quality analysis in the right form and at the right time. We ensure quality through teamwork on individual projects, critical review at internal seminars, and by peer review.

NZIER was established in 1958.

Authorship

This paper was prepared at NZIER by Michael Bealing.

The assistance of Sarah Spring is gratefully acknowledged.

Registered office: Level 13, Willeston House, 22–28 Willeston St | PO Box 3479, Wellington 6140
Auckland office: Ground Floor, 70 Shortland St, Auckland
Tel 0800 220 090 or +64 4 472 1880 | econ@nzier.org.nz | www.nzier.org.nz

Key points

Historically, the output of the construction industry in New Zealand has been driven by labour productivity

The construction industry is diverse and multi-faceted. To compete in the construction industry demands a wide variety of skills, competencies and technologies. People and their human capital are inexorably linked to the success and performance of the industry in New Zealand. Construction is currently an industry where productivity is heavily reliant on the productivity of labour, which has been relatively slow growing.

Information technology and infostructure[1] could deliver multi-factor productivity gains

Multi-factor productivity emerges from the combination of improvements in technology and business process. Infostructure, data standardisation and interoperability could be used to lift overall productivity of the industry.

Multi-factor productivity growth in ICT has been three times higher than in the construction industry

Between 1994 and 2019, multi-factor productivity in the construction industry increased by an average of 0.9% per year. In comparison over the same period, multi-factor productivity in ICT increased by an average of 3.1%. Over the long term, such differences have big effects on relative industry output.

The indicative benefits of using standardised, interoperable product data in the construction industry show the multi-million-dollar potential

A detailed assessment of the benefits of using digital product data was out of scope. Examples from other fields and studies provide a clear sense of the scale of potential gains that may be realised. For example, a 20% increase in the use of cloud-based business tools in the construction industry could raise the multi-factor productivity of the industry by 2.5% to 4.5% p.a. Such effects would take several years to be fully realised due to the learning curve and behaviour change associated with new approaches. However, it's estimated that the level of multi-factor productivity improvement could increase the industry's contribution to gross domestic product by $120 million–$220 million annually. This indicates how a small increase in the use of infostructure could have material effects on the economic performance of the construction industry.

1 Infostructure defined "An organizational structure used for the collection and distribution of information; (now usually) the information technology infrastructure, comprised of hardware, networks, applications, etc." https://www.lexico.com/definition/infostructure

From a bottom-up perspective, the interoperability of construction product data could be used to create productivity improvements and cost savings.

For example:

- Better product compliance data could be worth $23 million to the industry
- More complete product information in inspection documentation may save $33 million per year
- Enabling the use of BIM (building information modelling) data for local government is likely to save councils millions annually, in time savings, interoperability benefits and data standardisation.

The table below provides a summary of some estimate of the indicative comparative scale the benefits of construction product infostructure. Using examples from related areas. The right-hand column provides an indication of the importance of infostructure in facilitating the realisation of those benefits.

Table 1 Summary of the benefits and importance of infostructure

Benefit	Indicative comparative value	Importance of digital product infostructure
20% uptake in cloud-based digital tools in the construction industry	$120m–$220m p.a.	Critical to deliver interoperability
Product compliance	$23m p.a.	Important to deliver interoperability, standardisation and readily updatable information
More complete product inspection documentation	$33m p.a.	Provides standardisation and mobile retrieval
Enable BIM for construction and assets management in local government	Millions annually in savings for local government	Critical for interoperability, standardisation and independence quality assurance

Source: NZIER

Contents

Figures

Tables

1 Introduction

1.1 Purpose

The purpose of this report is to provide an indicative assessment of the productivity benefits of using a digital product database in the construction industry.

1.2 Scope

This report contributes to a scoping exercise, where the aim was to consider the nature and magnitude of the potential benefits of digital product data. The assessment is indicative and broad rather than detailed and specific. The value of completing an indicative assessment in a scoping exercise is that it provides a sense of the scale of the benefits before investing in intensive detailed modelling. The contribution from an indicative assessment emerges through the following:

- Identifying the long-list of benefits, implicitly or explicitly.
- Understanding the breadth of the investigation, while avoiding investing in the understanding the depth until a better sense of whether investing in a deep-dive is worthwhile.
- Gaining a clear picture of what's at stake and for whom.
- An early indication of the barriers that prevent the benefits from being realised immediately.

A detailed original assessment of the economic benefits is out of scope.

1.3 Structure of the report

The report begins with an overview of the construction industry and its contribution to the economy. Then the composition of the construction industry is explained to highlight the multifaceted nature of one of New Zealand's largest industry.

The case for the digital product database is framed in the context of productivity growth in the construction industry and other industries. Finally, the benefits of improving multi-factor productivity in the construction industry is explored.

1.4 Report funding statement

This report was funded by GS1, as a part of a subcontracted research for a larger project funded by the BRANZ Building Research Levy.

2 Getting to grips with the construction industry

The construction industry is diverse and multi-faceted. To compete in the construction industry demands a wide variety of skills, competencies and technologies. People and their embodied human capital are inexorably linked to the performance and success of the industry in New Zealand.

2.1 The contribution of the construction industry

In 2018, the construction industry contributed over $18 billion to gross domestic product

The contribution of the construction industry to New Zealand's gross domestic product (GDP) was $18.54 billion in 2018, which represents 7.0% of total GDP for that year (Statistics New Zealand, 2019). The total output of the construction industry was$64.0 billion in that same year, or 11.5% of New Zealand's economic output.

A source of revenue for other industries

The difference between GDP and output is important. Output is a measure of total sales. GDP is the value of production from an industry after the cost of intermediate inputs (intermediate consumption) is deducted from the output. Intermediate consumption is a national accounts concept that measures the value of the goods and services consumed as inputs in the process of production. In the case of the construction industry, it is the industry's spending in other sectors such as earth works, metal works, electricity, and glazing.

In 2018, the construction industry spent $45.5 billion in other industries (Statistics New Zealand, 2019). This is an indication of three things:

- the cost of doing business in the construction industry
- the role of the construction industry as a material source of revenue for other industries
- interdependencies within the economy.

The productivity and performance of the construction industry has flow-on effects to other parts of the economy including for suppliers and consumers of construction outputs.

The long-term trend in construction is up

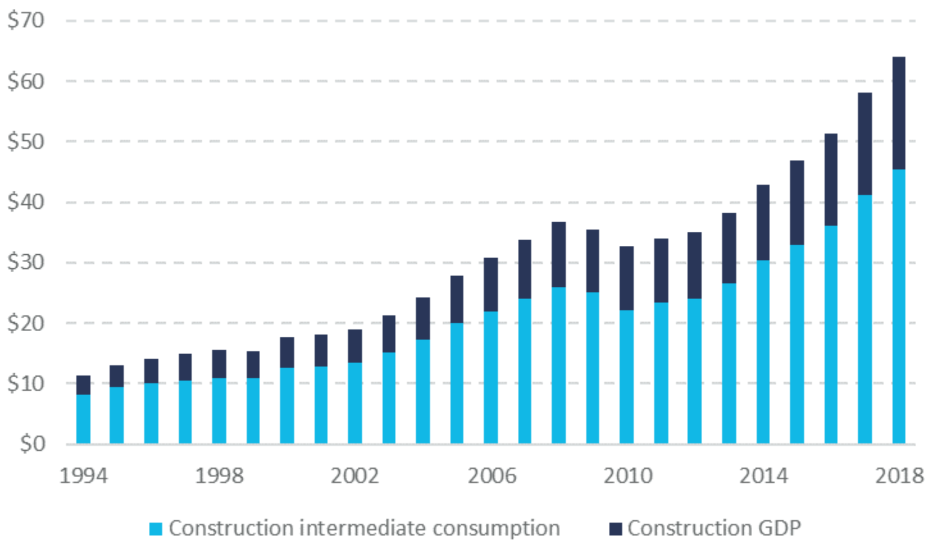
Figure 1 shows the total output of the construction industry in New Zealand from 1994 to 2018. Output is broken down into value-add, the contribution to GDP and the intermediate consumption of the construction industry in the process of doing business. The long trend is for the output of the construction industry to increase over time.

It took 5 years for the construction industry to get back to pre-global financial crisis levels

However, the effects of the global financial crisis (GFC) can be seen in the output following 2008. Clearly, the industry took a multi-billion dollar hit in the wake of the economic downturn and it was five years before the industry output recovered to the pre-crisis levels.

Figure 1 Long-term decomposition of the construction industry output

$ billions



Source: Statistics New Zealand (2019)

3 The composition of the construction industry

Globally the construction industry is one of many parts. The World Economic Forum cited that fragmentation and a lack of collaboration across the industry has constrained the industry's adoption of new technologies that could contribute to productivity improvements (World Economic Forum, 2017).

New Zealand's construction is also a diverse collection of related industries. Statistics New Zealand groups the construction industry into three sub-industries:

- **Building construction**: the combination of residential construction and commercial, vertical build construction.
- **Heavy and civil construction**: the construction for infrastructure such as roads, railways, ports, bridges and other major construction projects such as hydro-electricity generation power stations.
- **Construction services**: a large and diverse sub-industry including many occupations that are sub-contracted to small and large building projects. These include electricians, plumbers, concreters, carpet layers, plasterers, joiners and many more (Ministry of Business Innovation and Employment, 2013). Construction services provide support and services to all the other parts of the construction industry.

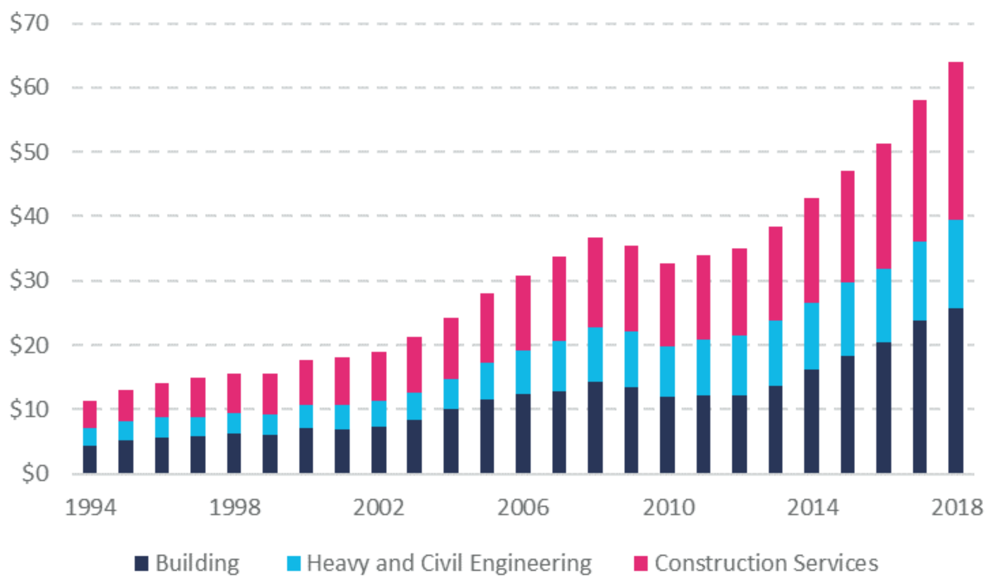
Figure 2 shows the contribution to total construction industry output by each of the three sub-industries. The infostructure[2] explored in this scoping report is relevant to all sub-

[2] Infostructure defined "An organizational structure used for the collection and distribution of information; (now usually) the information technology infrastructure, comprised of hardware, networks, applications, etc., used by a society, business, or other group; also as a mass noun". https://www.lexico.com/definition/infostructure

industries in the construction industry. Such neutrality and wide-ranging applicability are very beneficial for contributing to pan-industry productivity improvement.

Figure 2 Construction sub-industry output

$ billions

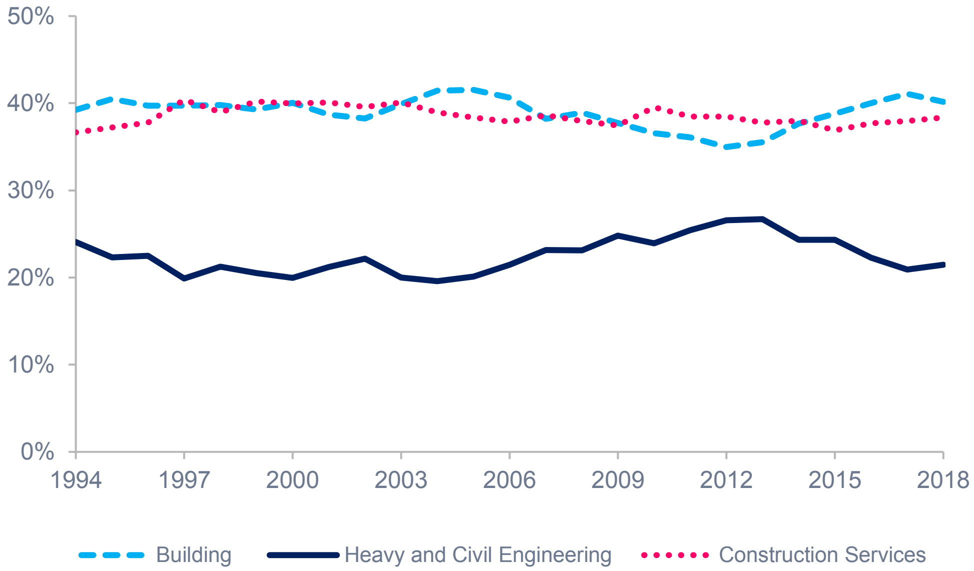


Source: Statistics New Zealand (2019)

The relative output across the three sub-industries has been relatively stable over time (Figure 3). This suggests that the sub-industries are influenced by common mega trends such as macroeconomic conditions, technology development and adoption, and labour market effects. In 2018, building contributed 40% of total construction industry output. Closely followed by construction services at 38%. Heavy and civil engineering contributed 21%.

Figure 3 Construction sub-industry relativity

Proportion of the overall construction industry output



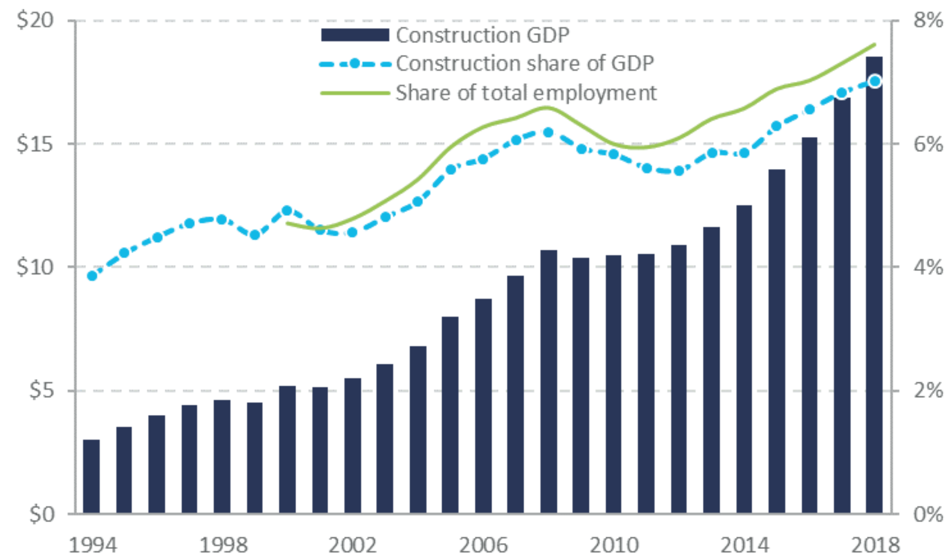
Source: Statistics New Zealand (2019)

Figure 4 shows three long-term macroeconomic trends associated with the role of the construction industry in the economy. The left-vertical axis shows the construction industry's contribution to GDP in billions of dollars, which has grown over time. The right-vertical axis shows the construction industry's share of employment and GDP. This illustrates that over the long-term the construction industry has increased its relative contribution of GDP, compared to other industries and it has also become a larger source of employment.

Figure 4 Construction industry GDP and employment

Industry GDP, $ billions

Share of GDP and employment



Source: NZIER based on data from Statistics New Zealand

The relationship between the construction industry's growth in employment and GDP indicates the primacy of labour and labour productivity in the construction industry. This remains an industry where the ability to deliver more output is tied to labour supply. An increased adoption and application of ICT and infostructure presents an opportunity to realise productivity gains from non-labour orientated sources of productivity improvement.

In the context of product life cycles which march through the following stages: market development, growth, maturity and innovation (or decline without innovation), the construction industry should look to infostructure as a source of productivity enhancing innovation to avoid stagnation and decline (Levitt, 1965).

4 Understanding productivity

Productivity is the most important determinant of a long-term outcomes. That is true for individuals, businesses and industries. The Nobel winning economist Paul Krugman said *"productivity isn't everything, but in the long run it is almost everything. A country's ability to improve its standard of living over time depends almost entirely on its ability to raise its output per worker"* (Krugman, 1994).

Five major productivity benefits of using digital tools and infostructure are recognized in the literature (OECD, 2019):

- increased multi-factor productivity
- improved accuracy of information
- enhanced flexibility and mobility
- more time to focus on business development
- network benefits.

The standardisation and interoperability offered by the infostructure scoped in this project are critical to realising these productivity benefits. A lack of standardisation across industry has been a leading factor in slow technology adoption rates in general (OECD, 2019). The construction industry in New Zealand has a valuable opportunity and potential productivity gains from adopting a common approach and avoiding the pitfalls of fragmented standardisation.

4.1 Increased multi-factor productivity

Multi-factor productivity measures the contribution of technology, advances in knowledge, improvements in management practices, organisational change, general knowledge, network effects, spill overs from production factors, adjustment costs, economies of scale, or change in production techniques. These factors include technological change, advancement in knowledge, organisational changes, etc. (Solow, 1957). It is a more comprehensive measure of productivity than single-factor productivity measures such as labour productivity and capital productivity.

Multi-factor productivity increases have second-round effects. Where the benefits of an initial productivity increase can ripple through an industry, transforming the way it operates, and can flow on to influence positively other industries in the economy. For example, the benefits of a multi-factor productivity increase will influence intermediate consumption of supplier outputs.

The increased use of modern ICT tools, such as cloud-based business tools can deliver significant multi-factor productivity improvements. A study of the digitalisation and productivity in European countries found that increasing cloud computing uptake by 10 percentage points increases multi-factor productivity by 0.9% instantaneously, by 2.3% after three years, and by 3.5% after five years (Gal et al., 2019; Sorbe et al., 2019).

4.2 Improved accuracy of information

Information accuracy delivered by E-invoicing is an example of the nature of the savings that can be realised from using digital data standards. The benefits of improved information accuracy include reducing the costs of business administration and accounting.

E-Invoicing creates cost savings by decreasing or eliminating manual input, manual errors and increasing payment time. An inter-governmental discussion paper suggests e-Invoicing could result in benefits to the Australian and New Zealand economies potentially in excess of $30 billion **over ten years** (Australian Treasury, 2018).

Similar types of benefits could be realised in the construction industry from reducing duplicate systems, eliminating manual input, manual errors and accelerating processing time. Dowdell (2018) found that the adoption of electronic tracking of construction materials could reduce the incidence and cost of non-compliance, saving the construction industry $23 million annually.

The digitisation of product specification and regulatory information reduces transaction and search costs (which include a professional's time). It also improves the confidence and certainty associated with the choice and application of construction projects, relative to regulatory requirements such as the Building Code. The productivity gains for the digitisation of construction production information has productivity benefits throughout the construction project life cycle and the supply chain.

Consenting is a small part of the construction process, but delays, mistakes and impediments to consenting can have significant implications for the commitments, scheduling, financial costs and liquidity of construction businesses. MBIE (2013) estimated the average product information gap costs ~$3,000 per consent. Page (2016) found that 30% of consents reviewed had information gaps. Based on these inputs, the cost of information barriers to consenting could be worth more than $30 million per year in the residential construction industry.

Figure 5 Cost of information gaps in consent documentation

$ millions

Source: NZIER based on new dwelling consents year ending in April

4.3 Enhanced flexibility and mobility for small and big business alike

Digitisation of construction industry product information is critical to facilitating tools that allow organisations and practitioners to access accurate information anytime and anywhere. This can support small and large construction industries to be more innovative, responsive, competitive and collaborative.

On an individual level, mobility can allow small business operators to have a better work/life balance, by saving time on transactional tasks (Alexander, 2017).

4.4 More time to focus on business development

Digitisation is ultimately about improving the speed of access, accessibility, quality and interoperability of construction industry information to improve performance and save time. Digitisation has the potential to free up construction business operators to invest a greater share of their time and energy on strategic business and product development. The core problem with working longer hours is that time is a finite resource. Energy is a different story (Schwartz & McCarthy, 2007). Having the capacity, energy and space to be creative and innovative is critical to realise the level of performance desired by operators and owners in the construction industry (Anthony et al., 2019).

Digital tools can also be used to store experience. Using analytical tools to assess opportunities for improved business performance can generate evidence-based insights for innovation (Orihuela et al., 2016).

5 What potential gains are at stake for the construction industry?

As part of the scoping exercise, the indicative benefits of greater use of digital product data have been explored. The approach to the assessment of the benefits is indicative, because the brief was to understand whether there was a case to invest in detailed modelling of the potential benefits for the construction industry before investing in intensive modelling and running the risk of going down a rabbit hole.

The approach to the indicative assessment of the benefits

The traditional approach to an indicative assessment of the potential benefits of the adoption of a new approach is to consider the following:

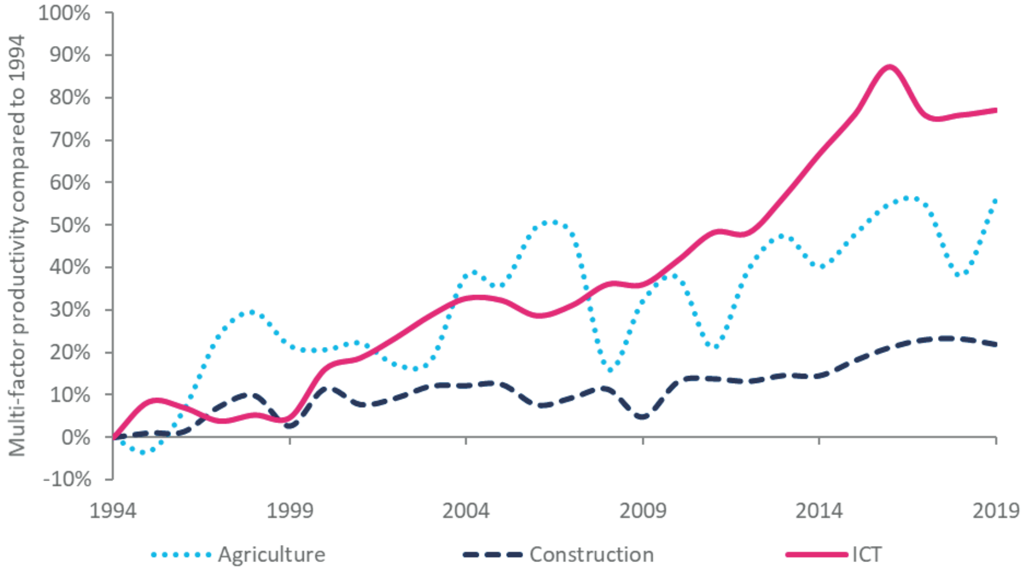
- look to the experience of other industries and other countries, where appropriate
- the benefit transfer approach – adapting and repurposing an estimate to a related topic
- draw on local and international literature.

A combination of these three have been used to provide an evidence-based sense of the magnitude of the benefits of better digital tools in the construction industry.

Figure 6 shows the change in multi-factor productivity in the construction, agriculture and ICT industries since 1994. Comparing with 1994 is a useful device because it represents a period in New Zealand's history when:

- The agricultural industry had begun to recover from the shock of the market-driven reforms and realise greater efficiency gains.
- The personal computer was common at work and home, beyond technology workers.
- The user experience and accessibility of computer technology significantly improved.
- The internet was emerging as a digital business tool.

Figure 6 Long-term multi-factor productivity growth in selected industries

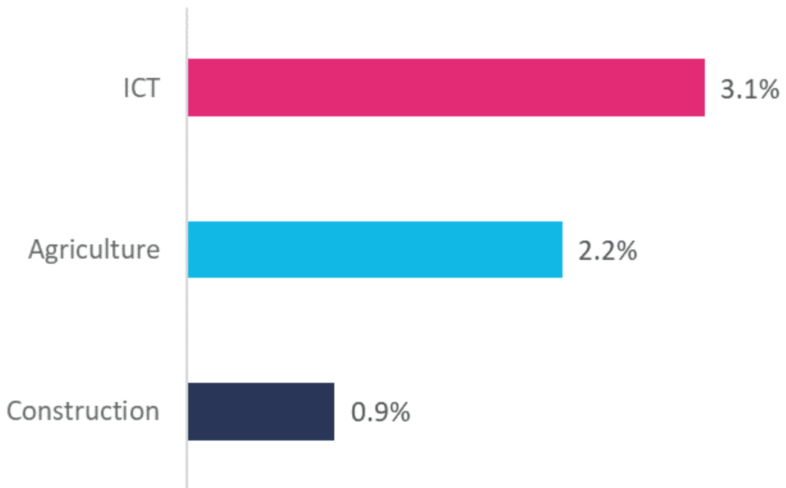


Source: NZIER based on Statistics New Zealand (2020)

Between 1994 and 2019, multi-factor productivity in the construction industry increased by 22%. This represents an annual average increase of 0.9% per year. In comparison over the same period, multi-factor productivity in agriculture by 56% (an average 2.2% p.a.) and ICT increased by 77% (an average of 3.1%). Annual growth in multi-factor productivity in the ICT industry was over three times higher than that of the construction industry. Agriculture's annual multi-factor productivity growth was more than twice that of the construction industry (Figure 7).

Figure 7 Annual growth in multi-factor productivity growth

Average growth per year 1994–2019



Source: NZIER based on Statistics New Zealand (2020)

One reason for the difference in the rate of multi-factor productivity growth could be the apparent position of the industries in the product life cycle. The construction industry appears to be an industry at maturity, which could mean that the new major innovations could spur new industrywide transformation and growth. The ICT industry is constantly evolving. The development, deployment and mass adoption of new technologies is a way of life in the ICT industry. Agriculture is an interesting case study, because the removal of almost all government support for agriculture forced the industry to compete globally based on efficiency gains (Vitalis, 2009). Competition, on an international scale encourages the consistent adoption on new technology in agriculture.

What do we know about the potential gain from productivity improvements in the construction industry and small business in New Zealand?

A decade ago, BERL (2010) estimated the standards used in the construction industry increased total factor productivity by 0.1% per year and 1% over 10 years. Using a CGE model of the economy they estimated that standards would increase GDP in 2021 by 1% over ten years or $2.4 billion in 2010 dollars. This is equivalent to $3.1 billion over 10 years in 2020 terms as a percentage of GDP. However, construction standards are much broader than the thin-layer of infostructure we are interested in. BERL's findings are consistent with the effect of a productivity improvement due to increased standardisation.

A recent published study by Bealing and Leroy de Morel (2020) found that eliminating quality defects in residential construction would be equivalent to a 5.4% and 2.4% productivity improvement for residential construction and construction services, respectively. As a result, residential construction output would increase by $112 million annually, and capital investment across the economy would increase by 1% annually. The results show that the economy-wide effects of an increase in productivity would see New Zealand's GDP rise by $2.5 billion, as the industry's overall costs of production decrease and the benefit flow-on to the rest of the economy.

Similarly, in another study published for Xero, Bealing et. al (2020) considered the economic benefits from a 20% increase in the uptake of cloud computing by businesses. Their modelling results indicated GDP would increase by between $3.5 billion and $6.2 billion (1.2–2.1%) at maturity. This was based on a 3.5% increase in multi-factor productivity after 3 years. The benefits of digital tools take time to be fully realised due to the learning curve, utilisation rates, embedding a new way of working etc. A 20% increase in the use of a cloud-based business tool in the construction industry could raise the multi-factor productivity of industry by 2.5% to 4.5% p.a. It is estimated that the level of multi-factor productivity improvement could increase the industry's contribution to GDP by $120m–$220m annually. Over ten years, the increase in the construction industry contribution to GDP would be between $1.4 billion to $2.5 billion.[3] This indicates how a small increase in the use of infostructure could have material effects on the economic performance of the construction industry.

Estimating the specific benefits of the multi-factor productivity gains from digital product data would require the kind of bespoke and sophisticated economic modelling undertaken the two reports cited above. However, they do provide useful comparators, broadly speaking. These results indicate that productivity improvements in the construction

[3] Using the ten-year average GDP growth rate from 2010 to 2020.

industry specifically, and small business generally, will yield significant improvements in GDP and wellbeing for the New Zealand economy and New Zealanders.

6 Barriers to uptake matter

Adoption or uptake of digital tools is critical for the construction industry to realise the benefits of greater use of ICT in the industry. It would be naïve to assume they are no barriers to the uptake of digital tools.

The barriers fall into two categories. Institutional network barriers and private barriers. Institutional network barriers affect the extent of collaboration between agents and the realisation of network benefits. Private barriers are costs or changes required at the individual or organisation face in relation to adopting the tools and accessing the infostructure network.

6.1 Institutional network barriers

Institutional network barriers happen in the relationship between people and organisations. Institutional barriers include the following:

- Agreement of the rules for shaping the standardisation
- The practice of standardisation
- Trust in the information and information security
- Agreement of the accountability for maintaining and updating the infostructure and information
- The terms of engagement and access to the infostructure
- Agreeing who sets fees for access and funding maintenance.

Collaboration and agreement in the nature, management and cost of infostructure are critical to overcoming the institutional barriers to infostructure. The question is whether there is enough common agreement to create and sustain the infostructure. This could be a single collaboration or potentially there is scope for multiple competition collaborations to emerge.

Industry leadership, information risks and understanding the value of interoperable information were identified by (Ibrahim, 2013) as key challenges in the use of digital collaboration technologies in construction.

A key to overcoming the barriers to collaboration around construction industry infostructure will be the identification of the appropriate leadership body or organisation to create a neutral space to agree on the terms of collaboration. This could involve the development of a neutral forum formed by government, industry associations and/or BRANZ to facilitate.

6.2 Private barriers

The lessons of other studies into the adoption of digital tools, such as cloud-based business tools are relevant to construction industry. Table 2 ranks the barriers to the adoption of cloud-based digital business tools in Australia and the US. Common themes include skill acquisition, skill shortages, privacy and security concerns, experience and costs.

Table 2 Key barriers to the adoption of digital business tools

Percentages refer to the proportion of respondents who identified the specified barrier

Australia	US
Challenges in staff education (37%)	Not relevant for their business (40%)
Issues in changing from legacy systems (37%)	Not effective for their business (38%)
Costs of adoption (35%)	Privacy and security concerns (34%)
Security issues (31%)	Inadequate experience with digital tools (30%)
Difficulty in switching data to new systems (30%)	Shortage of time to learn new systems (29%)
Change management issues (22%)	Costs of adoption (28%)
Skill shortages (22%)	Skill shortages (17%)
Cultural issues (9%)	No experience with digital tools (15%)
	Issues in changing from legacy systems (12%)
	Poor internet access (8%)

Source: Deloitte (2018); Deloitte Access Economics (2019)

In relation to the construction industry, Peansupap & Walker (2006) found the following constraints for ICT use included:

- limited budget for ICT investment
- commitment from other project participants
- issues of ICT standardisation
- security concerns.
- basic levels of computer experience
- time available to learn
- the trouble identifying the specific benefits of using ICT.

In Singapore, the adoption of digital business tools is actively encouraged by the government to support uptake and is highly subsidised for small business. However, the Singaporean experience is that subsidises may help with cost barriers, but cost may not be the only critical barrier. Small businesses struggle with competing demands on their time, so finding the time to implement a new digital tool is one challenge, but some businesses will struggle to find time to decide whether a tool is worth exploring at all.

7 References

Alexander, A. (2017). Cloud momentum: More firms are embracing the technology. *Accounting Today*, *31*(9), 44–52.

Anthony, S. D., Cobban, P., Nair, R., & Painchaud, N. (2019). Breaking Down the Barriers to Innovation. *Harvard Business Review*, *November–December 2019*. https://hbr.org/2019/11/breaking-down-the-barriers-to-innovation

Australian Treasury. (2018). *E-Invoicing*. https://treasury.gov.au/consultation/e-invoicing

Bealing, M. & Leroy de Morel, L. (2020). *The Economic Cost of Quality Defects*. External Study Report ER 49. https://d39d3mj7qio96p.cloudfront.net/media/documents/ER49_Economic_Cost_of_Quality_Defects_LR10320.pdf

Bealing, M., Siddharth, P. & Leroy de Morel, L. (2020). *Economic potential of cloud-based business tools.* A report for Xero. https://nzier.org.nz/publication/economic-potential-of-cloud-based-business-tools

BERL (2011) *the economic benefits of standards to New Zealand.* https://www.standards.govt.nz/assets/News/Economic-benefits-of-Standardisation-to-New-Zealand/BERLreportontheeconomicbenefitsofSNZAug2011.pdf

Deloitte. (2018). *Connecting Small Businesses in the US 2018* (p. 36).

Deloitte Access Economics. (2019). *The economic value of cloud services in Australia*. https://www2.deloitte.com/content/dam/Deloitte/au/Documents/Economics/deloitte-au-economics-value-cloud-services-australia-230719.pdf

Dowdell, David. (2018). Tracking materials electronically. *Build*, *166*. https://www.buildmagazine.org.nz/index.php/articles/show/tracking-materials-electronically

Gal, P., Nicoletti, G., Renault, T., Sorbe, S., & Timiliotis, C. (2019). *Digitalisation and productivity: In search of the holy grail – Firm-level empirical evidence from EU countries*. https://doi.org/10.1787/5080f4b6-en

Gil-Garcida, J. R., Chengalur-Smith, I., & Duchessi, P. (2017). Collaborative e-Government: Impediments and benefits of information-sharing projects in the public sector. *European Journal of Information Systems*, *16*, 121–133.

Ibrahim, N. H. (2013). Reviewing the evidence: use of digital collaboration technologies in major building and infrastructure projects. *Journal of Information Technology in Construction,* 18, 40–63. https://itcon.org/paper/2013/3

Krugman, P. R. (1994). *The Age of Diminished Expectations: U.S. Economic Policy in the 1990s*. MIT Press.

Levitt, T. (1965). Exploit the Product Life Cycle. *Harvard Business Review*, *November 1965*. https://hbr.org/1965/11/exploit-the-product-life-cycle

Ministry of Business Innovation and Employment. (2013). *The New Zealand sectors report 2013: Featured sector—Construction* (p. 148). https://www.mbie.govt.nz/assets/77439ddc45/Construction-report-2013.pdf

New Zealand Government. (n. d.). *What is data content standardisation?* https://www.data.govt.nz/manage-data/data-content-standardisation/what-is-data-content-standardisation/

OECD. (2019). *Cloud Computing: The Concept, Impacts and the Role of Government Policy* [OECD Digital Economy Papers No . 240 Cloud Computing]. OECD Publishing.

Orihuela, P., Orihuela, J., & Pacheco, S. (2016). Information and Communications Technology in Construction: A Proposal for Production Control. *Procedia Engineering*, 164, 150–157. https://doi.org/10.1016/j.proeng.2016.11.604

Page, I. (2016). *Study report SR355 Consent documentation quality for new housing* (p. 24).

Parker, C. & Allison, N. (2014). *Economic benefits from BIM enabling meta data standards*. NZIER report to Wellington City Council.

Peansupap, V., & Walker, D. (2006). Information communication technology (ICT) implementation constraints: A construction industry perspective - ProQuest. *Engineering, Construction and Architectural Management*, 13(4), 364–379.

Schwartz, T., & McCarthy, C. (2007, October 1). Manage Your Energy, Not Your Time. *Harvard Business Review*, *October 2007*. https://hbr.org/2007/10/manage-your-energy-not-your-time

Shy, O. (2011). A Short Survey of Network Economics. *Review of Industrial of Organization,* 38, 119–149.

Solow, R. M. (1957). Technical Change and the Aggregate Production Function. *The Review of Economics and Statistics*, 39(3), 312. https://doi.org/10.2307/1926047

Sorbe, S., Gal, P., Nicoletti, G., & Timiliotis, C. (2019). *Digital Dividend: Policies to Harness the Productivity Potential of Digital Technologies* (OECD Economic Policy Papers No. 26). https://doi.org/10.1787/273176bc-en

Statistics New Zealand. (2020). *Industry Productivity Statistics ANZSIC06.*

Statistics New Zealand. (2019). *National Accounts, Gross Domestic Product—Production measure, detailed industry groups*.

Vitalis, V. (2009). Domestic Reform, Trade, Innovation and Growth in New Zealand's Agricultural Sector. *OECD Journal: General Papers*, *2008*(4), 189–218. https://doi.org/10.1787/gen_papers-v2008-art28-en

World Economic Forum. (2017). *Shaping the future of construction: Inspiring innovators redefine the industry*. http://www3.weforum.org/docs/WEF_Shaping_the_Future_of_Construction_Inspiring_Innovators_redefine_the_industry_2017.pdf

BRANZ
1222 Moonshine Road
RD1, Porirua 5381
Private Bag 50 908
Porirua 5240
New Zealand
branz.nz

BRANZ Funded from the Building Research Levy

GS1 New Zealand

ISSN : 2423-0839