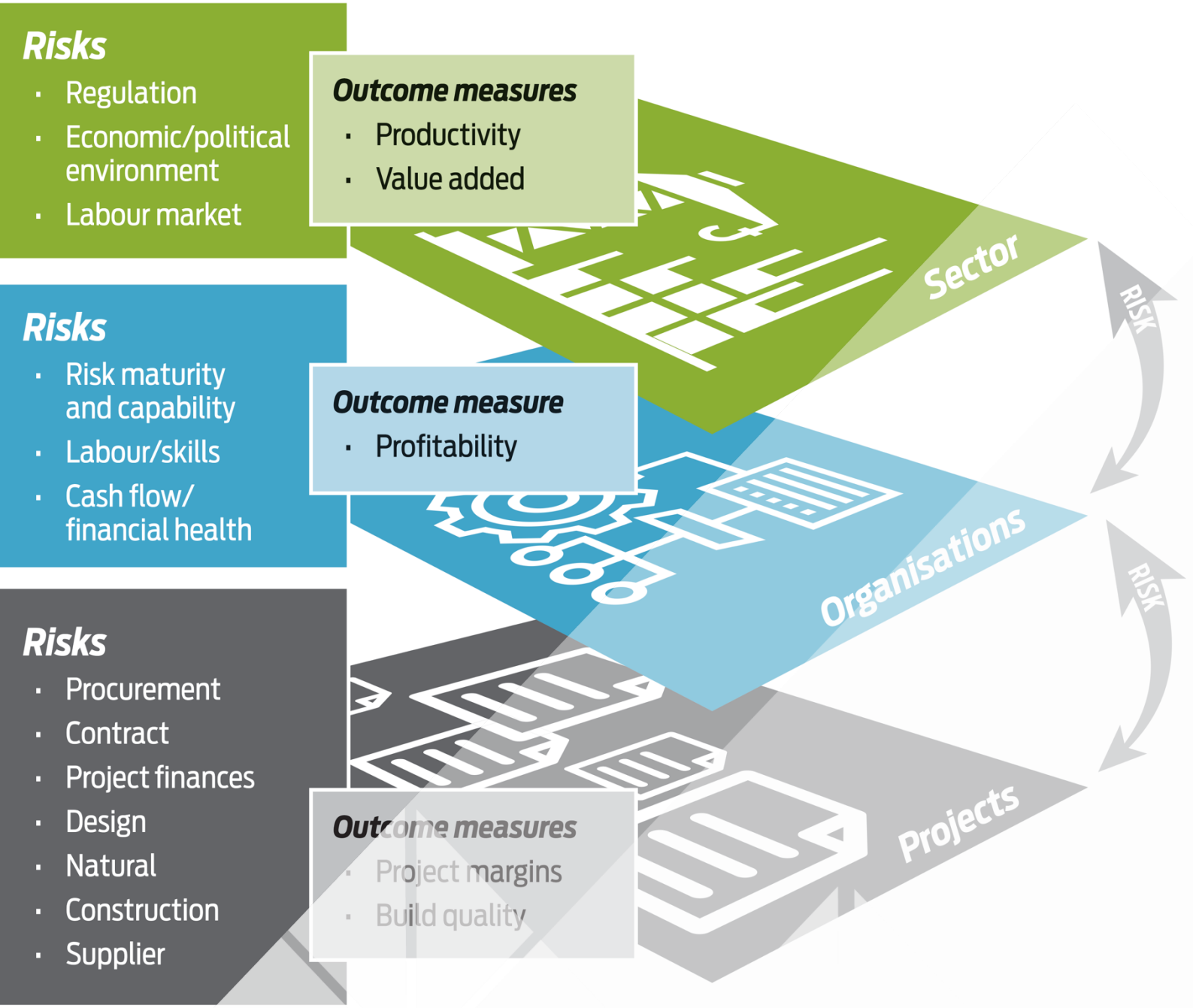
External Research Report ER59 [2021]

Building risk management strategies into the vertical construction sector

Charlotte Brown, Nicola McDonald, Alice Chang-Richards, Sophie Horsfall

Project LR10481

Resilient Organisations, Market Economics, University of Auckland



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

Funded from the Building Research Levy

ISSN : 2423-0839

Acknowledgements

The authors would like to thank BRANZ for sponsoring this project through the Building Research Levy.

We are grateful for the time and sharing offered by industry practitioners who participated in the interviews for this project. We also extend our appreciation to David Kelly (Chief Executive of the Registered Master Builders Association), Rick Herd (Chief Executive Officer of Naylor Love), Dr Grace Schaefer (Business Development Manager, McConnell Dowell Constructors Ltd), Greg Preston (Manager of Quake Centre, University of Canterbury) and Dr Ying Fei (Senior Lecturer, Auckland University of Technology) for their support and assistance.

We are grateful to all the contractors who took time to complete our survey. We are also grateful to BRANZ, Master Builders, NZIOB (New Zealand Institute of Building), and Civil Contractors New Zealand for sharing the survey with their networks.

Contents

Introduction

The construction sector has been a perennial underperformer in the New Zealand economy. The sector's low productivity reflects very challenging operating characteristics: order-based production, low-task repetition, and site-specific operations are all products of a market that largely deals in bespoke, complex projects requiring unique approaches. However, poor risk management can also play a part in low productivity through increased delays and errors, time-wasting, and ineffective problem-solving. Ongoing construction quality issues and high enterprise failure rates are signs that the sector is currently not managing risk as effectively as it could.

Nevertheless, some parts of the construction sector appear to be doing better than others. The recent success of horizontal infrastructure projects (e.g. pipes, roads, and cables) such as the Northern Toll Road Gateway, Waterview Project, and Christchurch Infrastructure Recovery are in contrast to ongoing challenges faced by the vertical construction sector (e.g. buildings).

The aim of this BRANZ funded project is to uncover core differences in how risk is managed in the horizontal and vertical construction sectors and identify opportunities for cross-sectoral learning. Our focus is on the role risk management plays in improving sector productivity.

Given the complexity of the construction sector, we have chosen to develop RISKFLOW, a system dynamics model, as a tool to help better understand the relationships between risks, risk management, and productivity in the construction sector, and how these relationships might differ between the vertical and horizontal sub-sectors.

This final project report describes the project method, the project key findings, the RISKFLOW prototype, and recommended next steps toward understanding risk and productivity in the construction sector.

Project method

The project was carried out in three main stages: interviews, surveys, and model development. The model was built in parallel with the interviews and surveys.

The project began with 15 semi-structured interviews with key practitioners in the sector, including both horizontal and vertical construction sector representatives.

The interview questions included topics such as:

- Differences between the horizontal and vertical construction sectors
- The greatest risks and where they exist in a project or in the sector
- Risk management practices
- Enablers/barriers to effective risk management
- Risk transfer and its effects
- Measures that can be taken to reduce the chance of company failure/collapse

The interview findings allowed for both a conceptual model of RISKFLOW and a causal network diagram of the key relationships in the sector to be developed.

Next, we surveyed 131[1] construction sector organisations to test the relationships in the causal networks and to begin to quantify those relationships. In particular, we used the survey to delve into organisational level risk management practices where there is less literature and data. The survey had 19 questions based around the following topics:

- organisation demographics (type (vertical/horizontal), role (head/sub), size),
- projects (the impact of risk factors on project delays, errors, pricing, productivity),
- current organisational performance (cashflow, staff satisfaction, staff turnover, forward workflow), and
- risk management and resilience.

All survey participants were offered a free personalised report based on their responses. The report included a comparison of their responses to the risk and resilience questions to other participants and some personalised advice on key risk and resilience capabilities to develop.

A working prototype of RISKFLOW was then built using the causal networks diagrams developed, data from the survey, and some expert elicitation to fill in data gaps where, due to survey length limitations, we were unable to gather data through the survey.

The full method and findings for each stage of the project are included in the appendices. Below is a summary of the main findings for the interview and survey stage and a description of RISKFLOW.

Key findings

Interviews

The interviews provided qualitative insight into the nature, challenges, and practices within both the horizontal and vertical construction sectors. Compared to the horizontal sector, most projects in the vertical sector, by nature, tend to be more complex, involving a larger number of activities, trades, specialists, and construction materials; and coordination of all these prove to be more challenging and difficult, creating opportunity for risk. Vertical construction is also largely dominated by private investment and is strongly affected by commercial clients' procurement methods. The current trend of 'lowest price bid' favoured by most clients in the vertical sector has aggravated the level of competition in the market, pushing the margin to a low point. This, combined with 'fixed price' contracts offered by some contractors to win projects, can have significant financial consequences for those whose balance sheet is not strong enough to absorb risks. As a result, staff turnover is higher in the vertical sector, further exacerbating skills shortage and capability problems.

The factors that influence how risks can be managed are multi-faceted and systemic. Structural issues in the construction sector, such as fragmentation of sub-sectors, trades, and contracts, and a lack of labour availability and capability, constrain the sector somewhat from effectively managing some risks and improving productivity and performance. Some contractual risk allocation practices are reflective of market behaviours of many commercial clients as well as norms of risk transfer within construction sector supply chains. There are also a number of factors that construction businesses have certain control over, either on their own or collaboratively, and provide opportunities for better risk management. Interviewees suggested attention should be given to better performance measures for incentivising professionalism and

[1] The majority of survey responses were from vertical contractors.

work ethic, better understanding of risk profile (including pricing risks and understanding contractual risks), risk culture and capability, and more prudent decision-making.

Procurement is a primary lever for influencing risk levels and practices within the sector. It affects the behaviour/conduct and competitiveness of construction businesses operating in the sector. Interviewees from the horizontal sector highlighted the benefits of using early contractor involvement (ECI), integrative design and build (DB) delivery approaches, target value design processes, and public target on Public Private Partnership (PPP) projects for better risk sharing and allocation among project stakeholders.

Overall interviewees suggested that for long-term improvement of productivity in the vertical sector, a better understanding of the implications of risk allocation and procurement practices for both clients and construction sector organisations is needed. Greater collaborations and partnerships (e.g. forming alliances or joint ventures) among construction businesses are also needed, especially for the small-scale players to build up their capability and skill base in addressing the risks and productivity losses caused by fragmentation in trades and contracts. In addressing the risk factors identified in this research, use of technology, better staff key performance indicators (KPIs), certainty of construction pipelines, and better alignment of training and demand were also suggested, which would have implications for productivity performance of individual companies and the sector as a whole.

Survey

The survey provided a rich tapestry of information which has fed into the RISKFLOW model. However, there were six key trends in the data that offer broad lessons for the sector around risk.

Respondents believe external factors have the greatest impact on productivity, rather than internal capabilities

The risk factors that reportedly caused the most delays, errors, and impacts on productivity tended to be external risks, such as the client changing their mind, council and other inspections, and design flaws and inadequacies. Some internal capabilities such as communication, project team experience, project management, and staff morale appeared to be important in reducing errors and increasing productivity, but they are less prominent. The authors note a caution that this finding could be influenced by Actor Observer bias that leads to a tendency to attribute actions to external causes. More research is needed to fully understand this finding.

Contractors adjust margins for risk but only when work is plentiful

The results demonstrate that contractors are willing to increase margins where there are significant risks related to the project (nature of work) or client. They also demonstrate that contractors are willing to reduce contract prices to bring work in the door. The willingness to reduce margins is a concern, as this lessens an organisations' capacity to cope with risks during a project.

High risk maturity improves productivity

The survey results show that there is a strong link between productivity and risk management. Higher risk maturity contributes to less project delays, lower error rates, both of which contribute to higher productivity. In addition, organisations with greater risk maturity scored better on organisation performance measures. This indicates that there is a value case for investing effort into good risk management.

Resilient organisations perform better

Similarly, resilient organisations (that is, those that not only manage risk but that have the capacity to adapt to unexpected change) perform better overall – including reduced delays, lower error rates, and high

productivity. Notably, compared with risk mature organisations, more resilient organisations are more aware of the importance of internal, less tangible risk management processes for improving productivity such as communication, staff morale, etc.

Horizontal contractors are potentially more nuanced in their consideration of risk than vertical contractors

The survey results were less clear when it came to the differences between vertical and horizontal contractors. The project hypothesis was that horizontal contractors were more productive and managed risk more effectively. The results only weakly support this. The results indicate that horizontal contractors are more nuanced in their consideration of risk, in particular how different risk factors impact errors and how they price risk into projects. Horizontal contractors appear to be aware of both internal and external risk factors. That said, it also appears that vertical contractors have to manage significant project complexity which impacts their productivity and timeliness.

Subcontractors and smaller organisations are less likely to actively manage risk

Overall, the data reflects the underlying understanding in the sector that risk is passed down the supply chain and subcontractors bear notable risk. In our results, risk manifests in delays and errors caused by (amongst other things) poor project management. Despite this vulnerability to delays and errors caused by others, subcontractors are much less likely to adjust their margins to account for risk (which according to our data are similar to head contractors' margins).

Our data indicates that small organisations are less nuanced in how they perceive and manage risk. Given 97% of construction sector organisations are small companies, this is an area worth further investigation.

Model

RISKFLOW has been developed progressively through the project. Following the interviews, a conceptual version of RISKFLOW was developed, Figure 1. The unique value of RISKFLOW is its ability to span across project, organisational, and sector levels. The majority of research and models to date focus on just one level of the construction sector (usually project level), however, the interviews and survey clearly demonstrated the strong links between project budget, programme and quality outcomes and an organisations' financial health, risk maturity, and forward workflow/labour availability. To understand the sector's productivity, we need to go beyond project level.

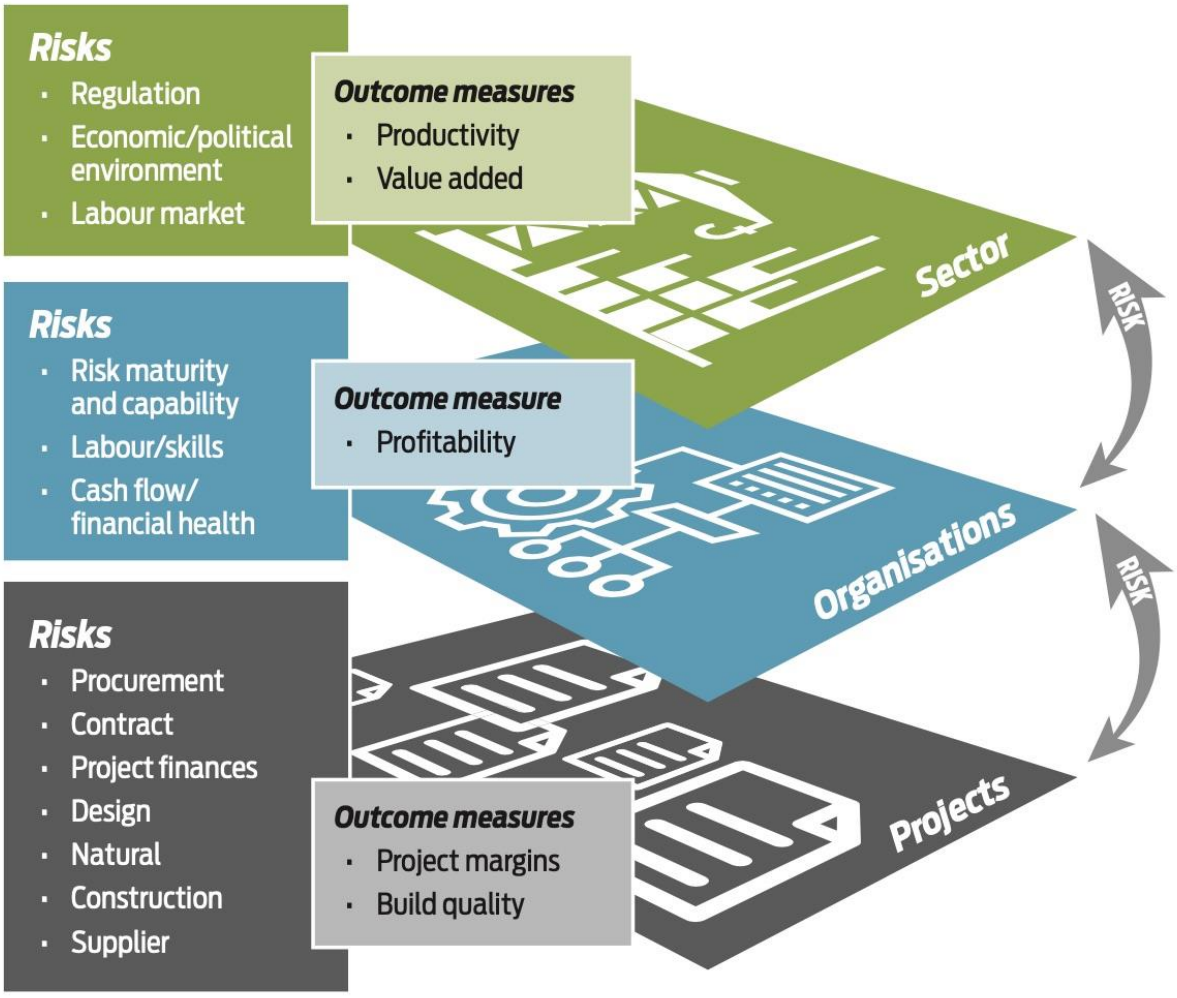


Figure 1 Conceptualisation of RISKFLOW

RISKFLOW has been built in Stella Architect, a system dynamics modelling software that allows complex systems, such as the construction sector, to be mapped and simulated over time. This helps users to explore and better understand how components of the system link together and overall generate system behaviours. A system dynamics model is based on causal network diagrams that show the relationships between different components of a system, see Figure 2 as an example.

Some of the key underlying premises that underpin the model's structure are as follows:

- The horizontal and vertical construction sectors are similar in terms of structure. Thus, while the specific parameters used to describe each sector may vary, the same types and forms of equations and relationships can be used to describe both sectors.

- Both the horizontal and vertical sectors can be described as operating at different process levels or scales. These are:
  - Project Procurement (who is commissioning work, how they choose contractors and procurement/contractual arrangements),
  - Project Progress/Workflow (including delays, errors, rework),

  - Organisation Scale (Head Contractors) (including organisational financial health, risk maturity, labour availability and capability), and – Whole-of-Sector Scale
  - In the development of the RISKFLOW model, we have looked closely at the relationships operating at each of these scales/levels, as well as key relationships operating between them. In addition, both sectors are closely connected with their relevant subcontracting sector.
- As well as identifying that there will likely be differences in construction operations depending on the sector under consideration, it was also identified, particularly out of the initial expert surveys, that the type of contracting model and client is important. Where relevant, the model is also constructed to allow for different parameters depending on the client type (Government, Developer-to-Sell, Developer-to-Keep, One-off) and contracting model (Build Only, Design-Build, Integrated).

- While head contractors are included 'individually' in the model, subcontractors are treated as a homogeneous group. Any attempt to model the population of subcontractors in a similar manner to main contracting organisations would add significant complexity to the model. Unnecessary complexity would overshadow the principal purpose of the project which is to investigate the differences between the horizontal and vertical sectors. Therefore, we have concentrated only on considering the impact of placing increasing pressure on subcontractors, in terms of the quantity of errors produced, within the RISKFLOW prototype. In turn, pressure arises by pushing the responsibility of fixing errors onto sub-contractors. Future development of RISKFLOW could include more detailed subcontractor modelling.

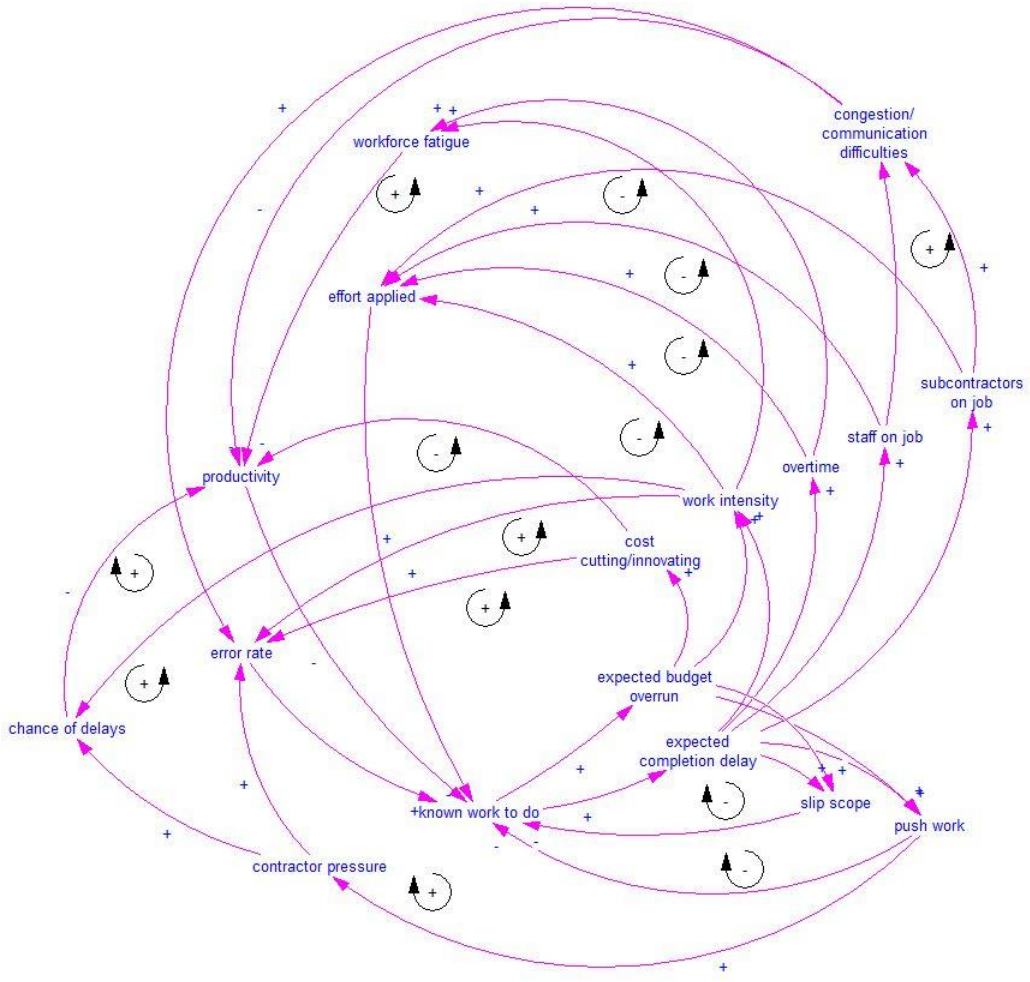
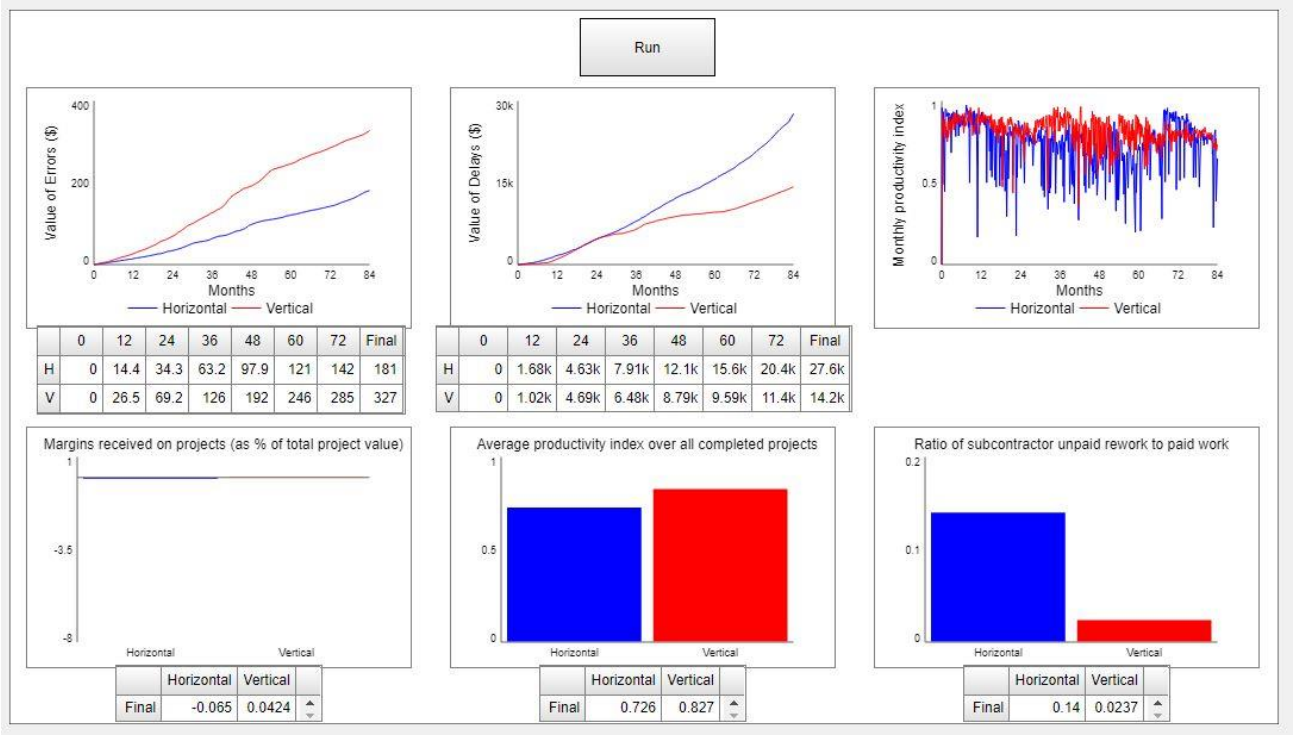


Figure 2 Example causal loop diagram

Model users can run simulations of the horizontal and vertical sectors, with each simulation tracking dynamics across the procurement, project, organisation and sector scales. Importantly, since many of the functions within the model are stochastic (e.g. the function defining whether a project will be subject to a weather delay at a particular point in time), outcomes from the model will vary for each simulation. Users can however run a series or ensemble of simulations to investigate the range of outcomes generated by the model.

A variety of measures and indicators can potentially be developed from the model's outputs, depending on how users wish to utilise the model. Thus far, a simple user interface has been developed that draws together some key summaries of sector and productivity information. A screenshot of this interface is provided in Figure 3. The results allow you to measure the differences between sectors. Users could change variables within the model to run simulations and look at the impact of policy intervention – for example altering the length of delays from council inspections – and see how this affects the project, organisational and sector outcomes.



	0	12	24	36	48	60	72	Final
H	0	14.4	34.3	63.2	97.9	121	142	181
V	0	26.5	69.2	126	192	246	285	327

	0	12	24	36	48	60	72	Final
H	0	1.68k	4.63k	7.91k	12.1k	15.6k	20.4k	27.6k
V	0	1.02k	4.69k	6.48k	8.79k	9.59k	11.4k	14.2k

	Horizontal	Vertical
Final	-0.065	0.0424

	Horizontal	Vertical
Final	0.726	0.827

	Horizontal	Vertical
Final	0.14	0.0237

Figure 3 Example results output

Summary

The original project hypothesis posed by BRANZ related to the anecdotal differences in productivity between the horizontal and vertical construction sectors. In addition, our project team hypothesised that the productivity difference is largely a result of risk management practices between the two sectors. The theory being that if an entity can manage risk better, the amount of rework will decrease, and this will have a positive effect on productivity.

The interviews and surveys have provided mixed results. Both the interviews and survey supported the idea that there is a link between risk and productivity. Generally, the interviews supported the notion that

the horizontal sector was more productive and better at managing risk – actively engaging in risk sharing procurement practices and risk management practices such as Early Contractor Involvement. However, the survey only weakly supported this. The survey suggested that the horizontal sector may be more nuanced in their understanding of how a broad range of risks can impact their project (including internal organisational risks and external project risks) and how they may need to adjust margins to adjust for these risks. Vertical contractors were mostly focused on the external risks they face in their projects.

The role of clients in risk management and productivity in the sector came up in both the interviews and survey. The type of client, and associated procurement approaches, influenced how contractors priced projects and the likelihood of delays, design flaws, and other risks eventuating. The split of client types and contractor types differed between the two sectors – with horizontal having a higher proportion of integrated projects and public clients. Early testing of RISKFLOW indicates that changing the proportion of projects that tend towards risk-sharing contract types will have benefits for sector productivity. But this needs to be assessed against the results for the client in terms of budget, time, and quality.

The fragmentation of both sectors is clearly a source of risk, and consequently productivity losses. In particular, the fragmentation of the vertical sector is a challenge. The survey results showed that smaller organisations have much poorer processes around risk management; they do not generally adjust their margins for risk and carry a lot of project risk. To improve productivity the sector needs to rethink its fragmented supply chain, and as suggested in the interviews, think about how to collaborate, and share risk more fairly.

Beyond the insights from the interviews and surveys, we have also developed RISKFLOW to help the sector better understand how risk is managed and how it can be better managed to improve the productivity of the sector. Prior to this project, the majority of system dynamics models relating to construction were at project level. But the reality is that the construction sector is complex, and projects are inextricably linked to the wider sector: the decisions and behaviours of individuals, construction companies, clients, and the regulatory environment. This project is an attempt to link all these complex and interconnected elements together. In particular, our focus was on how risk is managed in this complex environment by both vertical and horizontal construction sectors and how this flows to sector productivity. We have also attempted to integrate behavioural elements of risk management, which is rarely included in other research.

While RISKFLOW is still a prototype, and further validation of model relationships needs to be undertaken, the project demonstrates the potential for informing debate on policy interventions and provides a tool to develop a value case for investment in risk management initiatives in the construction sector. To our knowledge, our unique trans-disciplinary, mixed methods approach that focuses specifically on risk management and organisational resilience has not been attempted before.

The RISKFLOW model seeks to verify and validate the role of risk management and organisational resilience practices in construction sector productivity, focusing particularly on identifying where differences exist between the horizontal and vertical sub-sectors and where improvements can be made. We believe a tool like RISKFLOW, has the potential to create a case for driving risk management improvements in the whole sector and will likely contribute to overall productivity gains and improved socio-economic well-being in New Zealand.

The next section focuses on how to build on the RISKFLOW prototype and opportunities to embed it in industry, policy, and practice.

Next steps

Presently RISKFLOW is best viewed as a prototype model, useful for demonstrating the application of system dynamics thinking and techniques to the analysis of construction sector dynamics. Although significant effort has been undertaken, through literature reviews, surveys, and expert interviews, to develop an appropriate structure for the model, it is still the case that many of the function shapes and appropriate parameters are uncertain. The model development process would benefit from having a wider group of experts available to draw on to populate the model functions and parameters, and to help remove any distortion created by the perceptions of single individuals. With further time and resources for expert elicitation, testing, and calibration, it will be possible to iron out inconsistencies and develop a more robust parametrisation of the model, so that model outputs can be used with confidence.

Nevertheless, the RISKFLOW prototype demonstrates the potential power of this type of modelling to inform policy debate within the sector, create a value case for improving risk management (for both construction companies and clients), and its potential for use as a learning tool to better understand the sector and identify and design interventions to improve outcomes of the sector.

RISKFLOW could be used to analyse and interrogate a number whole of construction sector challenges, including:

- Procurement and contracting analysis – how do different procurement and contracting models affect the performance of the sector?
- Impact of improved risk management practices such as early contractor involvement, risk sharing, etc.
- Impact of different margins/project pricing strategies
- Value case for improving risk management capabilities within organisations
- Labour force management evaluation
- Impact of more robust workflow pipelines

Below, we suggest some potential future applications or adaptations for the model, along with some potential end-users for each use type.

Learning tool

System dynamics tools, like RISKFLOW, are ideally suited for use as learning tools. The tracking of cause-effect relationships enables users to build system intuition. The dynamic relationships allow for users to experiment by changing variables and experiencing the impacts of these changes. This can a) help sector members better understand the implications of their actions and b) enable researchers and regulators to better understand how the system works as a whole and where interventions might be best made for maximum benefit.

For use as a learning tool, potential improvements to the model include: further validation of the model, improved user interface, user manual.

> Potential end-user / collaborator: MBIE endeavour project, CanConstructNZ, “will model and report the dynamic inter-relationships of New Zealand’s infrastructure work pipeline (the proposed building, construction, and infrastructure projects) against the construction sector's

capacity and capability to deliver (including procurement & processes, supply chain & organisations, people, and technology & tools)." RISKFLOW has already started to explore and map out many of these complex issues and could be enhanced to contribute to the project.

Other potential end-users include MBIE and Construction Sector Accord, BRANZ, QuakeCentre, InfraCom, Engineering and construction management schools in New Zealand.

Policy analysis and evaluation

Policy analysis and evaluation is challenging in a complex sector like the construction sector. The link between cause and effect is often unclear. System dynamics models like RISKFLOW can provide some structure and rigour around identifying and evaluating the best policy interventions.

RISKFLOW, once validated, could be used to a) identify leverage points in the construction system where policy interventions might have the biggest benefit and b) help create a value case for proposed policy interventions.

Potential end-users: MBIE and Construction Sector Accord work on their Transformation Plan; QuakeCentre and their work on valuing the benefits of BIM; Infracom on infrastructure planning.

Organisational analysis tool

Aspects of RISKFLOW could be further developed to help individual organisations better understand their business and make better risk management decisions. The scope of this tool could be quite varied but could cover financial management, project pricing, site/team management approaches, project risk management approaches, and staff management. The tool could help highlight, amongst other things, the cost (financial and wellbeing) related to rework and quality issues, and poor project management.

Potential end-user: MBIE and Construction Sector Accord capability development programme

Client education tool

Throughout the project, the role of clients in project and organisational risk has been highlighted. There is a perception in the sector that some clients do not understand construction risk, and the way that projects are procured and managed unreasonably increases the burden of risk on the construction company and can impact the quality of the built environment.

Some of the thinking and modelling in RISKFLOW could be evolved to create a client tool which helps clients explore the pros and cons of a) different contract and procurement models, b) contractor selection criteria, c) design and scope changes, etc for different projects (type, size, complexity, location, etc).

Potential end-user: MBIE Construction Sector Accord construction sector capability development

Appendix 1: Interview report

Chang-Richards, A., Brown, C., Smith, N. (2019). Building risk management strategies into the vertical construction sector: A preliminary report. https://www.resorgs.org.nz/publications/building-risk-management-strategies-into-the-vertical-construction-sector/

(report also available from BRANZ on request)

Appendix 2: Survey report

Brown, C., Horsfall, S., Chang-Richards, A., McDonald, N. (2020). Building risk management strategies into the vertical construction sector: Survey report. https://www.resorgs.org.nz/wp-content/uploads/2020/08/BRANZ-Project-LR104810-Report.pdf

(report also available from BRANZ on request)

Appendix 3: Model report

McDonald, N., Brown, C., Chang-Richards, A. (2020). RISKFLOW Model. Technical Report. https://www.resorgs.org.nz/wp-content/uploads/2020/12/RISKFLOW_Technical_Report.pdf

(report also available from BRANZ on request)