Tuesday 3 December – OSHA Day on Health

09:00 – 10:00: Opening Plenary

- **Victoria J. Mabin** – Use of reframing in evidence-based modelling to support policy decisions

10:20 – 12:00: Logistics & Scheduling

- **Maaike Vollebergh** – Who will be covered and who will be left behind? Advising the Norwegian Air Ambulance Foundation on fairness
- **Caroline Jagtenberg** & **Andrew Mason** – Improving fairness in ambulance planning by time sharing
- **Snigdha Saha** – The optimisation of milk collection (Full paper)
- **Isaac Cleland** – Automatic nurse rostering for the Waikato District Health Board
- **Thomas Adams** – Comparison of objective functions for scheduling surgeries (Full paper)

12:40 – 14:20: Forecasting & Simulation

- **Michael O'Sullivan** – Simulation of Dargaville Medical Centre
- **Kian Wee Soh** – The utility of hybrid models in model selection or model averaging for predicting surgery durations
- **Ai June Lau** – Length of stay variability, and forecasting short-term unit occupancy, in an ICU
- **Toya Shaw** – Implementation of a pod system in a hospital emergency department
- **Andreas W. Kempa-Liehr** – Healthcare pathway discovery, conformance, and enrichment

14:45 – 16:45: Health Plenary & Analytics Forum on Wellbeing Analytics

- **Margaret Brandeau** What should we do about the opioid epidemic? Models to support good decisions

Wednesday 4 December

09:00 – 11:20: Energy & Emissions

- **James Tipping** – Key questions facing the NZ electricity sector – how can analytics help?
- **Andy Philpott** – Multistage capacity planning using JuDGE
- **Anthony Downward** – Management of hydro reservoirs with emissions charges and more renewables
- **Stephen Poletti** – Market power in the NZ wholesale market 2010–2016 (Full paper)
- **Grant Read** – Panel Discussion

11:40 – 13:00: Traffic & Logistics

- **James Tidswell** – Minimising emissions in traffic assignment with non-monotonic arc costs (Full paper)
- **Ali Akbar Sohrabi** – Finding an interval without negative cycles in shortest path sub-problems of a column generation approach for bi-objective multi-commodity flow (Full paper)
- **Parameshwaran Iyer** – Universal locker systems for urban metros (Full paper)
- **Michael Zhang** – Airline scheduling and crew scheduling rule modelling

14:00 – 15:40: Decision Support Tools & Analysis

- **Christopher Peace** – The goal tree: a research and practical tool
- **Warren Fitzgerald** – Preliminary system dynamics analysis of waste management practices in New Zealand
- **Hrishi Kodthuguli** – Developing a decision making tool for Housing New Zealand (Full paper)
- **Graham Scott** – The real problem with budgeting: A systems approach to the issues (Full paper)
- **Richard Logan** – The danger of oversimplifying complexity: Pike River - A mining disaster in New Zealand (Full paper)

16:00 – 17:00: Analysis of Complex Problems

- **Robert Y. Cavana** – Analysis of complex social issues: a multi-framing systems thinking case study of alcohol sales in New Zealand supermarkets
- **Maryam Mirzaei** – Application of evaporating cloud to project dilemmas
- **Sarah Marshall** – Mean value function of an alternating geometric process

Tuesday 09:00 – 10:00 ↑

Opening Plenary

Use of reframing in evidence-based modelling to support policy decisions

Victoria J. Mabin. *Victoria Business School, Victoria University of Wellington, New Zealand.*

Modelling to enable improved policy decisions requires the sound choice of models. However no one model can adequately capture most real problems: every model has merits and shortcomings, and modellers need to beware of each model's blindspots. Reframing using contrasting decision frames aims to overcome such shortcomings, by providing different perspectives, exposing flawed assumptions and providing new ideas for solutions. The use of reframing will be illustrated through multiple examples using various combinations of modelling approaches and problem structuring methods drawing on hard OR, soft OR and systems thinking methods including the theory of constraints. These examples will illustrate how the nature and success of problem-solving interventions can be frame dependent, and how using multiple frames helps cover more of the problem's facets. Benefits of reframing include building frame awareness, overcoming frame blindness, and the development of different perspectives using complementary models which can contribute to more robust and acceptable policy 'solutions' and implementations.

Keywords: reframing; theory of constraints ; robust policy implementations.

Logistics & Scheduling

Who will be covered and who will be left behind? Advising the Norwegian Air Ambulance Foundation on fairness

Maaike Vollebergh[†], *Caroline Jagtenberg*[‡] *& Jo Røislien*[♯]. [†]*Delft University of Technology, Netherlands;* [‡]*Engineering Science, University of Auckland, New Zealand;* [♯]*Norwegian Air Ambulance Foundation, Norway.*

Helicopter emergency medical services are considered essential in Norwegian health care, as Norway has large geographical variations in population density. In solving the ambulance location problem, often the focus is on maximizing the number of people served. As this approach benefits people living in cities over people living in remote areas, the aim of this study is to incorporate fairness in finding optimal air ambulance base locations. This study is done at the request of the Norwegian Air Ambulance Foundation.

We used municipality population data for Norway from 2015. Multiple facility location models are used to determine optimal helicopter base locations, using objective functions with different measures of aversion to inequality. Optimal locations for green field scenarios and conditioned on the existing base structure were determined, using key performance metrics defined by practitioners.

It appears that including fairness in determining optimal helicopter base locations has a lot of impact when the number of base locations is not enough to give full coverage of the country. Including fairness in the computation will avoid leaving whole areas uncovered and it will in particular increase service levels in the north of Norway.

Keywords: HEMS; air ambulance; fairness; facility location problem; MEXSLP; population density; coverage.

Improving fairness in ambulance planning by time sharing

Caroline Jagtenberg *&* ***Andrew Mason****. Engineering Science, University of Auckland, New Zealand.*

Most literature on the ambulance location problem aims to maximize coverage, i.e., the fraction of people that can be reached within a certain response time threshold. Such a problem often has one optimum, but several near-optimal solutions may exist. These may have a similar overall performance but provide different coverage for different regions. This raises the question: are we making 'arbitrary' choices in terms of who gets coverage and who does not? In this paper we propose to share time between several good ambulance configurations in the interest of fairness. We argue that the Bernoulli-Nash social welfare measure should be used to evaluate the fairness of the system. Therefore, we formulate a nonlinear optimization model that determines the fraction of time spent in each configuration to maximize the Bernoulli-Nash social welfare.

We solve this model in a case study for an ambulance provider in the Netherlands, using a combination of simulation and optimization. Furthermore, we analyze how the Bernoulli-Nash optimal solution compares to the maximum-coverage solution by formulating and solving a multi-objective optimization model.

Keywords: ambulance planning; fairness; social welfare.

The optimisation of milk collection

Snigdha Saha *&* *Olivier Graffeuille. Engineering Science, University of Auckland, New Zealand.*

The collection of milk is the first stage of the milk supply chain. The process of milk collection using a fleet of tankers can be modelled as a Vehicle Routing Problem (VRP), which produces a schedule when solved. The collection of milk has additional challenges including capacity constraints, multiple farm time windows and stochastic milk supply. Stochastic milk supply can result in an event called overflow, where tankers are not being able to collect all the milk from a farm. This incurs recourse costs.

We developed two optimisation models to generate tanker schedules. These were used to investigate methods of generating robust tanker schedules. The first optimisation model is a multi-stage set partitioning algorithm, which considers stochastic milk supply and the risk of overflow when pricing individual tours in order to develop robust schedules. The second optimisation model is developed using Google OR Tools, and achieves robust results by artificially inflating milk supply or artificially reducing tanker capacity.

All our investigated methods were successful generating robust schedules. We found that incorporating stochastic milk supply produced the most robust schedules, but that artificially changing parameters was computationally less expensive.

Keywords: vehicle routing problem; set partitioning; Google OR Tools; robust optimisation; stochastic supply.

Automatic nurse rostering for the Waikato District Health Board

Isaac Cleland*, Andrew Mason & Michael O'Sullivan. Engineering Science, University of Auckland, New Zealand.*

During 2019, the Waikato District Health Board put into practice, on three occasions, our automatic nurse rostering algorithm. Despite a large number of complex rules given by both the nurses' contract and various fairness metrics, our algorithm produced high-quality roster solutions.

Given that throughout NZ nurses follow the same Multi-Employer Collective Agreement with the same rostering rules, our research has demonstrated a future for automatic staff rostering for nurses in NZ. The benefits from our practical application of this research was a reduction in rostering development time, fewer skills shortages and greater fairness.

This talk will discuss the nurse rostering problem that was solved along with some of the modelling techniques used. It will also outline how we modified our column generation based algorithm with some novel heuristics to solve these problems significantly faster. Finally, it will discuss our experience when applying automatic nurse rostering in practice.

Keywords: column generation; nurse rostering; heuristics; matheuristics.

Comparison of objective functions for scheduling surgeries

Thomas Adams*, Michael O'Sullivan & Cameron Walker. Engineering Science, University of Auckland, New Zealand.*

The Ministry of Health has set a target to improve access to elective surgery by increasing the number of operations performed by 4,000 per year. More efficient scheduling of operations into surgical sessions can assist in meeting this target.

This paper presents a mixed integer programming model for scheduling, and rescheduling operations. Further, the effects on the surgical schedules of two types of objective function (a risk neutral and a risk averse objective), as well as other model parameters are compared.

By applying the model to a case study at a surgical centre, it is demonstrated that, with the appropriate values of the other model parameters, the risk neutral objective can achieve similar schedules to the risk averse objective, and results in problems that are easier to solve.

Keywords: healthcare; surgery scheduling; mixed integer programming.

Forecasting & Simulation

Simulation of Dargaville Medical Centre

Michael O'Sullivan. Engineering Science, University of Auckland, New Zealand.

The Dargaville Medical Centre (DMC) serves 14,000 patients of the Kaipara area. It provides three key services for patients: appointments, acute consultations, and triage over the phone. We will present the simulation modelling process for DMC, the simulation implementation in JaamSim (open source simulation software) and some preliminary findings from this research.

Keywords: simulation; health; modelling.

The utility of hybrid models in model selection or model averaging for predicting surgery durations

Kian Wee Soh, Cameron Walker & Michael O'Sullivan. Engineering Science, University of Auckland, New Zealand.

Variabilities of surgery durations depend on factors such as procedure complexity, surgeon's experience and patient's health condition. The task of finding, from a historical set of surgeries, a prediction approach or model that gives accurate predictions of surgery durations is challenging. The chosen prediction model generally predicts well for the majority of but not all surgeries. For surgeries without good predictions, they may benefit from the utility of another prediction model. This leads to a "hybrid model" with the distinctive feature that the dataset for prediction is partitioned by values of categorical explanatory variables. In essence, given a list of viable prediction models for predicting surgery durations, each subset of surgeries chooses one of the viable models trained on the historical dataset. This framework is based on a model selection procedure.

An alternative to model selection is model averaging which can be implemented within the framework that leads to a hybrid model. The implementation is considered an extension of the jackknife model averaging. In particular, the weighted average of predictions from all models included in the prediction approach is computed to predict a surgery duration. Each subset of surgeries takes a different weight corresponding to a model.

In this talk, the hybrid models (model selection and model averaging) are presented. Results using the hybrid models on simulated and actual datasets are promising.

Keywords: prediction; hybrid model; model selection; model averaging.

Length of stay variability, and forecasting short-term unit occupancy, in an ICU

Ai June Lau[†]*, Michael O'Sullivan*[†]*, Cameron Walker*[†] *& Ilze Ziedins*[‡]*. *[†]Engineering Science, University of Auckland, New Zealand; *[‡]Statistics, University of Auckland, New Zealand.*

The Cardiothoracic and Vascular Intensive Care Unit (CVICU) at Auckland City Hospital is typically staffed for 20 patients and has the capacity to accommodate an additional four patients. Patient mix and stochastic arrival rates that change throughout the day, combined with highly variable lengths of stay, resulting in occupancy of the CVICU fluctuating between 13 and 22 patients.

Approximately 80% of all patients stay for only one night before being discharged. The variability in a patient's length of stay from their second night onwards has a considerable impact, not only on occupancy but also on the consequent planning for elective surgeries 2 or 3 days in the future. Since elective surgeries make up 75% of all arrivals to the unit, occupancy can be balanced by adjusting upcoming elective schedules to improve utilisation of the CVICU (when there is low occupancy) and minimise the risk of cancellations (when there is high occupancy).

This talk shows the impact length of stay variability has on unit occupancy and presents a Markov model developed in conjunction with expert opinion to forecast unit utilisation and inform short-term adjustments to the elective surgery schedule.

Keywords: forecasting; utilisation; Markov model.

Implementation of a pod system in a hospital emergency department

Toya Shaw[†]*, Thomas Adams*[‡]*, Cameron Walker*[†]*, Michael O'Sullivan*[†]*, Anil Nair*[‡] *& Franco Schreve*[‡]*. *[†]Engineering Science, University of Auckland, New Zealand; *[‡]Auckland City Hospital, New Zealand.*

Emergency Departments (ED) are integral in maintaining healthy populations through the provision of acute, unscheduled access to healthcare 24 hours a day. However, EDs are facing a multitude of complex problems impacting the delivery of safe, timely and effective care, including: rising per capita presentations annually, older and multi-morbid patients who are sicker on arrival to hospital, high inpatient occupancy resulting in boarding and exit block for patients awaiting inpatient admission, budget and resource constraints, and crowding as a consequence of all of these issues. Additionally, the scope of emergency medicine continues to grow with advances in knowledge and technology, resulting in more care being delivered in the ED setting, in turn influencing emergency medicine providers and rates of inpatient admission. These factors are driving interdisciplinary research that aims to identify novel methods for improving flow of patients through the ED. One such method that has been proposed are dedicated zones, or 'pods', which deal with a pre-defined group of patients presenting to ED to improve efficiency.

This research aimed to identify if the introduction of dedicated geographic zones, or pods, within an ED improved Key Performance Indicators (KPI) associated with patient throughput in the department. In particular, this research aimed to explore the impact of a new fast-track zone, implemented using existing ED bed space but with dedicated healthcare providers, on KPIs.

A discrete-event simulation of the department with the proposed fast-track zone was built before changes were made in the clinical space, to determine if this was a feasible solution to address the identified issues. Five configurations were explored in a simulation model, with varying degrees of change to the zones and staff numbers. The best performing simulation was chosen to implement in practice. Following the introduction of the new fast-track zone, a before-after analysis of data routinely collected during ED attendances was undertaken, with data taken from the period immediately preceding the new model of care compared with data obtained at set time points following the implementation of the fast-track zone.

Results of the simulation model demonstrated that changing to pods with dedicated staff and increased physician numbers had a beneficial impact on KPIs, including time from triage to doctor and total length of stay. Implementation of this model in the ED improved both time to doctor and total length of stay in the department, even with sustained increases in presentations during the trial period, but had no significant on time to clinical decision. Conclusions: The implementation of an additional defined geographical zone within this ED was beneficial in improving KPIs related to patient throughput, particularly among the lowest triage categories. However, a simultaneous increase in the number of healthcare professionals with decision-making capabilities rostered to each shift likely played an important role in the improvements reported. Further research needs to be undertaken with healthcare professionals in this setting to understand how this change process was pursued, and the experiences of different professional groups in providing care in the models before and after the change.

Keywords: emergency department; performance; patient throughput; ED crowding; length of Stay; pods; zones.

Healthcare pathway discovery, conformance, and enrichment

Andreas W. Kempa-Liehr[†]*, Christina Lin*[†]*, Randall Britten*[‡]*, Delwyn Armstrong*[‡]*, Jonathan Wallace*[‡]*, Dylan Morda & Michael O'Sullivan*[†]*. *[†]Engineering Science, University of Auckland, New Zealand; *[‡]Auckland District Health Board, New Zealand; *[‡]Waitemata District Health Board, New Zealand; *[R]University of Adelaide and Flinders University, Australia.*

Healthcare pathways define the execution sequence of clinical activities as patients move through a treatment process, and they are critical for maintaining quality of care. The aim of this study is to investigate the utilization of business process modelling (BPM) to design an adaptive healthcare pathway mining methodology, with particular emphasis on producing pathway models that are easy to interpret for clinicians without a sufficient background in process mining.

Machine learning methodologies based on probabilistic programming are utilised to explore pathway features that influence patient recovery time.

Keywords: healthcare pathway; process mining; electronic health record; probabilistic programming.

Tuesday 15:00 – 16:00 ↑

Health Plenary

What should we do about the opioid epidemic? Models to support good decisions

Margaret L. Brandeau. Stanford University, California, USA.

The US is currently experiencing an epidemic of drug abuse caused by prescription opioids and illegal opioid use, including heroin. In addition to crime and social problems, rising levels of drug abuse have led to a sharp increase in overdose deaths in the US as well as significant outbreaks of infectious diseases such as HIV and hepatitis C. How should we deploy limited public health resources to help solve this complex public health problem? This talk describes models to support decision making regarding the control of drug abuse – and associated diseases such as HIV and hepatitis C – in the US. We conclude with discussion of key areas for further research.

Keywords: healthcare policy; epidemic; opioids.

Energy & Emissions

Key questions facing the NZ electricity sector – how can analytics help?

James Tipping. Electricity Authority, New Zealand.

Electricity systems around the world are changing rapidly, largely as a result of the combination of environmental policy objectives and technology evolution. Internationally, having a well-functioning, low-carbon electricity system has been recognised as a critical component of the transition to a low-emissions energy sector, and a low-emissions economy.

These changes are occurring in New Zealand too, albeit with some subtly different manifestations. The transition is raising some interesting questions and challenges for the New Zealand electricity sector, many of which can be addressed and informed analytically. This presentation introduces the New Zealand electricity sector at a high level and uses material from recent industry research to illustrate some of the forecast trends and changes that may occur over the coming decades. It concludes by posing (but not necessarily answering) some of the key questions facing the sector from a policy and market design perspective.

Keywords: electricity sector; emissions; analytics.

Multistage capacity planning using JuDGE

Andy Philpott[†], *Anthony Downward*[†] *& Regan Baucke*[‡]. [†]*Engineering Science, University of Auckland, New Zealand;* [‡]*CERMICS, ENPC, Paris, France.*

Julia Dynamic Generation Expansion (JuDGE) is a Julia package for solving stochastic capacity expansion problems formulated in a "coarse-grained" scenario tree that models long-term uncertainties. The user provides JuDGE with a coarse-grained tree and a JuMP formulation of a stage problem to be solved in each node of this tree. JuDGE then applies Dantzig-Wolfe decomposition to this framework based on the general model of Singh et al. (2009). The stage problems are themselves single-stage capacity expansion problems with integer capacity variables, but quite general constraints that can model, for example, operations in random environments, or even equilibrium constraints, as long as they can be solved exactly (e.g. via reformulation as mixed integer programs).

This presentation outlines the theoretical background for JuDGE, and shows the results of applying it to several problem instances:

i. a knapsack problem with expanding capacity;
ii. optimal capacity expansion in an electricity distribution network subject to reliability constraints;
iii. national capacity expansion to meet renewable energy targets;
iv. optimal transmission expansion for an electricity wholesale market with imperfectly competitive agents.

Keywords: capacity expansion; uncertainty; Dantzig-Wolfe decomposition; Julia.

Reconsidering the management of hydro reservoirs as we head towards 100% renewables

***Anthony Downward** & Andy Philpott. Engineering Science, University of Auckland, New Zealand.*

Hydroelectric generators provide approximately 60% of New Zealand's electricity annually, with another 20% delivered from renewable sources, such as wind and geothermal. In order to meet government emissions targets fossil fuel plants are expected to close or reduce their output substantially over the next 30 years.

This study uses stochastic dual dynamic programming to analyse how changes in available thermal capacity, along with carbon pricing, may affect the management of hydro generators and examines how average spot prices may change in response.

Keywords: infinite horizon; hydro management; electricity market; renewables.

Market power in the NZ wholesale market 2010–2016

***Stephen Poletti**. Economics, University of Auckland, New Zealand.*

Using a computer agent based model we compute markets power rents in the New Zealand electricity market over the period 2010-2016 and find that these are substantial. They are similar or even higher, as a fraction of revenue, to those found by Wolak (2009). Over the 7-year period of the study total simulated market revenue was $14.9 billion. Total market rents are $5.4 billion, which is 36% of revenue. If we calculate market rents using actual prices (rather than simulated) and our competitive benchmark we find that over the 7-year period total market rents are 6.0 billion, or 39% of revenue – about 10% higher than the results using simulated prices, reflecting slightly higher actual prices. The distribution of rents is also different, with lower rents in the earlier years and higher rents in the later years compared to the simulated results.

Keywords: New Zealand electricity market; lake level dynamics; market power.

Panel Discussion

***Grant Read**. Electric Power Engineering Centre, University of Canterbury, New Zealand.*

Discussion about the challenges facing the electricity sector, and how operations research and analytics can help to shape government policy.

Traffic & Logistics

Minimising emissions in traffic assignment with non-monotonic arc costs

James Tidswell[†], *Anthony Downward*[†], *Clemens Thielen*[‡] *& Andrea Raith*[†]. [†]*Engineering Science, University of Auckland, New Zealand;* [‡]*Technical University of Munich, Germany.*

The modelling of vehicle emissions within traffic assignment (TA) has been studied in literature, where emissions such as carbon monoxide and carbon dioxide are detrimental to the populaces health as well as to the environment. TA is employed as a means to identify the potential to reduce vehicle emissions by the manipulation of traffic patterns. Studies that make use of emission arc cost functions in TA generally assume a positive, increasing function, or do not discuss the computational complexities that arise when the cost functions are non-monotonic, such as the emission function.

In this paper we investigate the issues that exist within TA methodology when the arc costs are non-monotonic, and present adjustments to algorithms to allow an equilibrium to be found. We suggest several heuristics to employ in order to find good solutions to the TA problem with non-monotonic arc costs, where the TA problem is non-convex. We compare the heuristic methods by applying them to several test networks for a range of emission types.

Keywords: traffic assignment; emissions; non-monotonic; optimisation; heuristics.

Finding an interval without negative cycles in shortest path sub-problems of a column generation approach for bi-objective multi-commodity flow

Ali Akbar Sohrabi *& Andrea Raith. Engineering Science, University of Auckland, New Zealand.*

Multi-commodity network flow is an important network optimization problem, which has also been studied in the bi-objective case. Moradi et al. (2015) proposed column generation approach to solve a bi-objective multi-commodity network flow problem. Danzig-Wolfe decomposition was integrated with bi-objective simplex to solve this problem. Because the arising column generation sub-problems are fractional, they proposed a new bi-objective optimization problem to find its optimal solution. This sub-problem is a bi-objective shortest path problem with reduced costs as arc costs, which can be negative. The weighted-sum method is employed to convert the bi-objective problem to a single objective one, and the Belmond-Ford algorithm is used to solve it. However, there exist some instances with negative cycles, hence the Belmond-Ford algorithm cannot solve the optimization problem for all weight choices. In this paper, a new algorithm is presented to find an interval of weights without any negative cycles.

Keywords: column generation; bi-objective multicommodity flow; shortest path problem.

Universal locker systems for urban metros

Parameshwaran Iyer[†], *Ronald Veldman*[‡] *& Yao Zhang*[♯]. [†]*Information Systems and Operations Management, University of Acukland, New Zealand;* [‡]*PostNL, Netherlands;* [♯]*Castlery, Singapore.*

E-commerce has led to a surge of parcel deliveries owing to the mix of lower price and higher convenience for consumers. This has significantly increased parcel shipments, resulting in congestion within the urban metros, leading to worsening traffic and pollution levels. Parcel locker system is a way to optimize the deliveries. However, individual companies taking up this initiative have not been effective, as customers tend to switch to the most convenient option.

We explore the possibility of a universal locker system facilitated by New York City government in the Manhattan area. We propose using the city's public facilities as potential locker locations. We assess demand distribution using sample shipment data. Set-covering method determines the minimum number of lockers needed for different levels of service. Subsequently, p-median method recommends the actual locker locations to optimize the weighted average distance to customers.

A solution with 360 lockers would ensure 93% (or 100%) of the population have access to at least one locker within 250m (or 750m). Full roll-out of the system decreases the distribution cost by 75% in comparison to a home delivery model. We recommend an incremental coverage of deliveries over a 3-year time-frame. The financial analysis shows a payback period of 3 years (IRR of 44%), making the project worthwhile. This study can be extended to any large metro with support from city government.

Keywords: universal locker system; last mile delivery; augmented route cost estimation; set covering problem; p-median method.

Airline scheduling and crew scheduling rule modelling

Michael Zhang*, Andrea Raith & Andrew Mason. Engineering Science, University of Auckland, New Zealand.*

The world of airline scheduling involves a large variety of decisions, ranging from scheduling possible flights to fly, several months in advance; assigning various aircraft to flights; scheduling specific routes of the aircraft and flight crew; creating personalised line of work for their employees; to the recovery of day-to-day operations. Difficulties in decision making can arise from the need to satisfy the numerous industry regulations as well as rules imposed by the airlines themselves.

At the heart of these decisions are mathematical models. Crew scheduling can be modelled as a set partitioning problem. Due to the large formulations that arise, the crew scheduling problem can be solved with column generation, which is commonly solved as resource constrained shortest path problems (RCSPP). The set of rules that guide the decision rules are modelled as resource constraints in the RCSPP, for example, the total flight time or the number of days off.

This presentation will give an introduction to airline scheduling and the decisions involved. It will also outline the RCSPP and the complications involved in finding a potential solution. Furthermore, it will present some initial experiments and thoughts into how the modelling of the rules can improve runtime and solution quality of the models.

Keywords: airline scheduling; crew scheduling; resource-constrained shortest paths.

Decision Support Tools & Analysis

The goal tree: a research and practical tool

Christopher Peace[†], *Victoria J. Mabin*[†] *& Carolyn Cordery*[‡]
[†]*Victoria Business School, Victoria University of Wellington, New Zealand;* [‡]*Aston University, United Kingdom.*

The goal tree (GT), from the Theory of Constraints, uses a hierarchical tree structure to show the critical success factors (CSF) and necessary conditions (NC) needed for a system to succeed in meeting its Goal. Whereas a checklist shows what has or has not been done, a GT portrays, using necessity logic, how incomplete actions at a lower level prevent the achievement of other NC or CSF, and thus the Goal. The GT itself may form part of a cascade of trees.

As part of a PhD research project, a tentative GT was developed to show the CSF and NC for an effective risk assessment. This single GT was used to analyse data from a published case, five new case studies and an online survey. The NC and CSF were colour-coded to rate the magnitude of success of each and linked by qualitatively weighted lines to indicate the strength of the effects. The GT was found to provide a pragmatic tool to show which NC had to succeed for the goal to be achieved.

This research confirmed the use of the GT in practice to evaluate past risk assessments and provide a guide for future risk assessments.

Keywords: theory of constraints; goal tree; risk assessment.

Preliminary system dynamics analysis of waste management practices in New Zealand

Warren Fitzgerald, Robert Y. Cavana & Vipul Jain. Victoria Business School, Victoria University of Wellington, New Zealand.

The New Zealand Waste Strategy lays the foundations for two high-level goals aimed at reducing the harmful effects of waste and improving the efficiency of resource use. Solid waste is just one form of waste, and in New Zealand, this is usually dealt with by sending it to landfills. Understanding the behaviour of landfills over time can also help people assess the potential harm/risks to the environment and the wider communities. Neglecting these risks in the face of greater uncertainties and climatic issues has already shown to have widespread environmental and economic effects (e.g. Fox Glacier Landfill).

A system dynamics methodology has been used to model the decomposition of 12 different solid waste streams when buried in a landfill over a 100 year time frame. The behaviour of different materials are examined and different future scenarios are investigated. A poster presentation places this work in context with the wider waste management system and the basic model outputs are discussed. This work is the basis for future research into where and how future policies can improve the sustainability of our waste management system, and how these may vary with location.

Keywords: system dynamics; waste management; environmental modelling.

Developing a decision making tool for Housing New Zealand

Hrishi Kodthuguli, Michael O'Sullivan & Cameron Walker. Engineering Science, University of Auckland, New Zealand.

Housing New Zealand is the largest residential landlord in New Zealand. As Housing New Zealand continues to grow through its partnership with the New Zealand Government, it is looking to improve its existing decision-making framework. This report describes the development of visualisation and decision-making tools that Housing New Zealand can use to bolster its existing decision-making processes.

The decision-making tool is a multi-objective model that seeks the best trade-off between financial metrics and wellbeing measures. Furthermore, the visualisation tool, consisting of an interactive map, can help Housing New Zealand observe the impacts of their decisions on regions across the country.

The tool is currently suitable for Housing New Zealand and can be incorporated into their decision-making processes. The decision-making tool is flexible as objectives and constraints can be easily added and removed, as per the priorities of Housing New Zealand. Thus, given adequate data, the tool can optimise any financial metric or wellbeing measure.

Keywords: decision making; geospatial visualisation; Housing New Zealand.

The real problem with budgeting: A systems approach to the issues

Graham Scott[†] *& Victoria J. Mabin*[‡]*.* [†]*GW Scott & Associates Ltd., New Zealand;* [‡]*Victoria Business School, Victoria University of Wellington, New Zealand.*

Traditional Budgeting is widely used in organisations, despite being criticised for over 50 years as not being strategically focused, disempowering staff, causing siloing in organisations, wasting time and wasting money. Various researchers have estimated that 25-40% of spending is wasted and that solving the problems could increase productivity by 50-100%.

The aim of this research was to explore the reasons behind these issues in order to identify the direction of a solution.

A literature review uncovered numerous problems with traditional budgeting. TOC's causal mapping process was used to connect the identified factors into a tentative Current Reality Tree.

Managers in two NZ public sector organisations were then interviewed to ascertain whether they experienced the same factors and effects as those reported in the literature. TOC mapping tools were also used to provide explanations for these issues and their likely causes.

The findings revealed that NZ managers faced similar issues as those reported in the international literature. Most importantly, the waste caused by traditional budgeting is significant and worth addressing. To capitalise on this waste, any alternative to Traditional Budgeting must address either the unpredictability of costs or the negative consequences for being wrong. Any other approach will just be addressing symptoms.

Keywords: budgeting; theory of constraints; budgetary slack.

The danger of oversimplifying complexity: Pike River – A mining disaster in New Zealand

Richard Logan, Robert Y. Cavana, Ian Yeoman & Bronwyn Howell. Victoria Business School, Victoria University of Wellington, New Zealand.

This article investigates why it is dangerous to oversimplify complexity. The starting point is Simon's concept of bounded rationality / satisficing when decision-making under uncertainty / complexity, where complexity is simplified. These simplifications are usually essential, beneficial and normal, for sense-making, but occasionally the inherent underestimation of the risks involved, cause a surprise negative event of extreme impact, called a black swan event. Building on the individual's natural inclination to simplify complexity, is Ashby's Law of Requisite Complexity as advocated by Boisot & McKelvey (2011), that applies to organisations. This requires the organisation's internal ability to deal with complexity to at least match the external complexity, otherwise the organisation is prone to failure. Explore/ exploit strategies can be used to increase/ decrease the organisational complexity. (Bar-Yam, 2004, Snowden, 2005).

The Pike River Coal mine disaster of 2010 was used as a case study. The study found that the key decision makers of the Pike River coal mine had a simplified view of reality due to their bounded rationality simplifications and the company had failed to meet Ashby's Law of Requisite Complexity with tragic results, being 29 deaths and the loss of all funds invested (over $300m).

Keywords: complexity; bounded rationality; black swans; Ashby's Law of Requisite Complexity; Pike River mine disaster.

Analysis of Complex Problems

Analysis of complex social issues: a multi-framing systems thinking case study of alcohol sales in New Zealand supermarkets

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Societal problems pose challenges for policy makers due in part to the multiplicity of stakeholders and uncertainty surrounding the likely effects of any proposed changes. Systems thinking tools can help by representing multiple viewpoints, and mapping cause and effect relationships in such situations.

In this presentation, we illustrate how a combination of systems thinking tools, from qualitative system dynamics and the theory of constraints, was used to explore the question of whether alcohol sales in supermarkets should be banned, prompted by news stories on New Zealand's drinking problem. The NZ Medical Association argued that sales in the supermarket alongside bread and milk send the wrong signals that alcohol is an ordinary consumable product. Such implicit normalisation of alcohol contrasts with their view that alcohol is a psychoactive drug that is toxic to human tissue, being a carcinogenic and aggressigenic drug. Supermarkets use heavy discounting of alcoholic products. Easy access and cheaper pricing 'encourage' more young people in NZ to get drunk, engage in 'binge drinking', with consequential negative medical and social outcomes. Clearly substantial conflicts exist regarding the commercial and human-wellbeing effects of alcohol sales in NZ society. A number of 'solutions' are examined, and benefits of multi-framing are discussed.

Keywords: systems thinking; causal loop modelling; theory of constraints; alcohol sales; social issues.

Application of evaporating cloud to project dilemmas

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Successful management of a project depends upon a series of appropriate decisions throughout the project life cycle. Such decisions are not necessarily straightforward and project managers who make those project-level decisions often face dilemmas.

This paper presents findings from a research project that uncovered some of those dilemmas in the context of multi-case study in the software industry. We used a Theory of Constraints thinking process tool called the Evaporating Cloud to analyse dilemmas by examining their underpinning reasoning and assumptions. Four dilemmas were identified and investigated which were related to customer satisfaction, ensuring security and flexibility, defining specifications, and responding to new opportunities. Analysing these dilemmas led to useful insights into the challenges of choosing best practices in project management. It was found that the root cause of those challenges was the process of interpreting and transferring prescriptive project management concepts and methods to an actual project. The Evaporating Cloud was found to be a powerful tool to explain the problem at hand and expose faulty assumptions.

Keywords: dilemma; evaporating cloud; project management; project manager.

Mean value function of an alternating geometric process

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An alternating geometric process can be used to model consecutive operational and repair times of a system. In this study we are interested in a system that is ageing, and thus we use a decreasing geometric process to model the consecutive operational times and an increasing geometric process to model the consecutive repair times of the system. In this type of system, the expected number of failures and the expected number of repairs by a given time, is often of interest. In this talk we will introduce the alternating geometric process (AGP) and present new results for the computation of the mean value function of two counting processes related to the AGP, namely the number of failures and the number of repairs up to a given time. We illustrate our results for a variety of parameter values and discuss their relevance to warranty cost analysis.

Keywords: alternating geometric processes; warranty analysis; stochastic processes.