Mathematics-in-Industry NZ 2017

MINZ

26 - 30 June

Held at Massey University, Palmerston North

Organised by the Mathematics in Industry NZ, Massey University, and KiwiNet

Co-Directors:	Dr Luke Fullard Dr Richard Brown, Massey University
Deputy Directors:	Prof Graeme Wake, Massey University Lisa Hall, Fonterra
Administrators:	Seumas McCroskery, Kiwi Innovation Network
Plenary Speaker:	Dr Melanie Roberts, IBM Australia
Guest Speakers:	Prof Jan Thomas, Vice-Chancellor, Massey University
Organising Committee:	Dr Tammy Lynch Christine Burr Dr Cami Sawyer Dr David Simpson Dr Chris Tuffley Assoc Prof Bruce van-Brunt Prof Igor Boglaev Prof Robert McLachlan Dr Rose Davies

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Welcome

The MINZ (Mathematics-in-Industry for NZ) group is delighted to welcome you to the third Mathematics-in-Industry for NZ Study Group being held at Massey University, Palmerston North. This is a national event established to add value to our community and our industry as well as provide academic opportunities for many of us. We warmly acknowledge support from all our sponsors, but especially KiwiNet: a consortium established to foster industry links with experts such as those in the mathematics community. KiwiNet continues to provide the administrative structure to make this event happen.

We have six exciting challenges put forward to the mathematical group from six dynamic and important companies**: Fonterra, Transpower, Horizons Regional Council, Sanford, Zespri,** and **Fisher and Paykel Appliances,** it is a pleasing mix of those that have taken part in similar events and those new to the study group concept. Thank you all.

We are very pleased to welcome many participants from around New Zealand and further afield. One such guest is Dr Melanie Roberts, an applied mathematician working at IBM Research Australia, we are delighted to have her here and look forward to her plenary talk, and contributions both formal and informal throughout the week ahead.

It is a great honor to also welcome Professor Jan Thomas, the newly appointed Vice Chancellor of Massey University, who has graciously accepted our invitation to open MINZ 2017.

We trust that you will find the week ahead both stimulating and enjoyable, and wish you all the very best.

Co-Directors:

Dr Luke Fullard, and

Dr Richard Brown,

Massey University Palmerston North

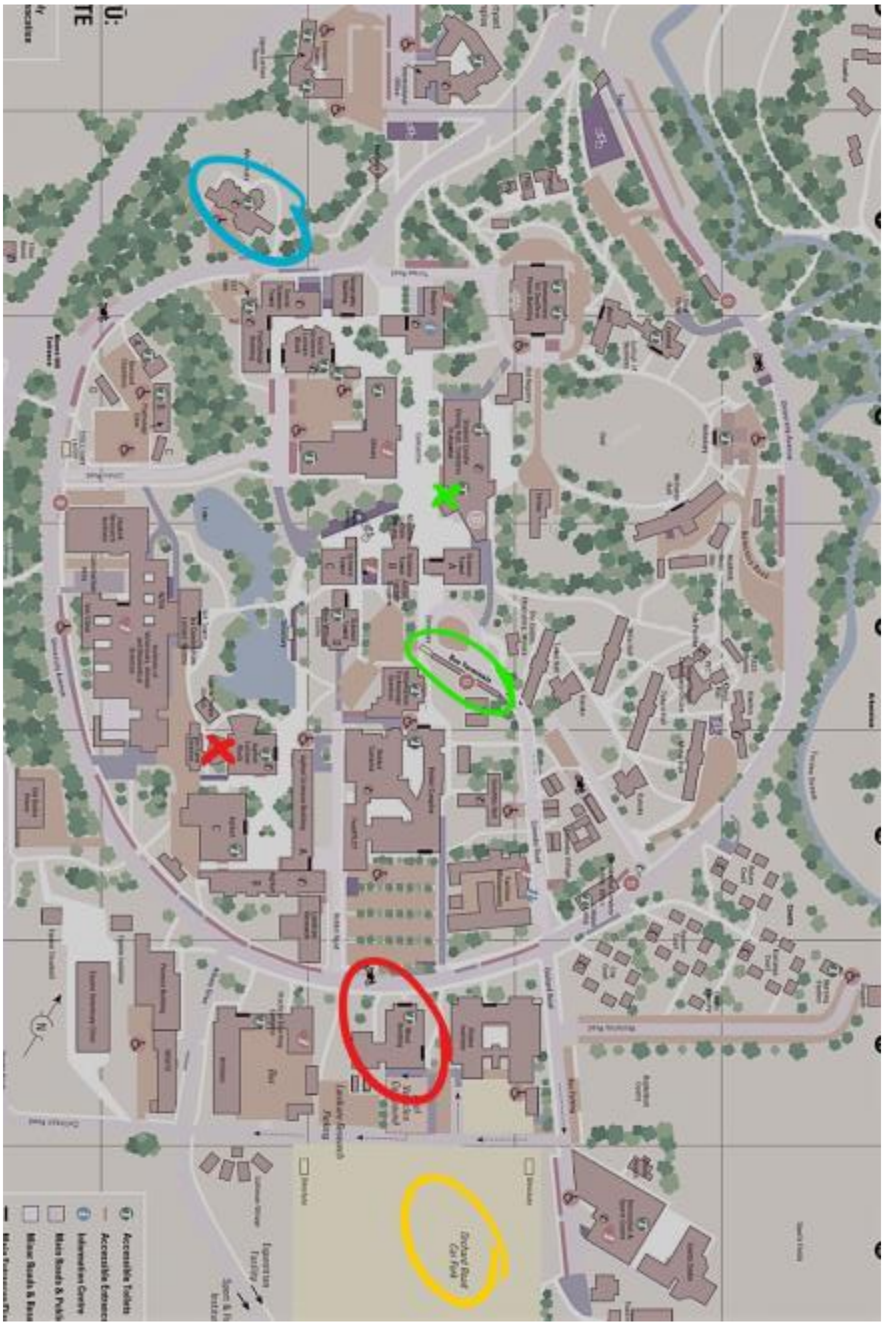
June 2017

Maps

The majority of the time we will be in the Wool building (circled in red on the map below) at Massey University, 26 – 30 June, 2017. There will be MINZ signage. Financial support for the hireage of this facility has been generously provided by the Institute of Fundamental Sciences, Massey University, Palmerston North.

There is paid parking in the Orchard road car park (circled in yellow), just behind the Wool building.

Other buildings used during the week include the MUSA lounge (marked with a green "X"), and the Ag Hort lecture block (marked with a red "X"). The main Massey bus terminal is circled in green, and the Wharerata Function Centre where the conference dinner is to be held is circled in blue.



Challenges

Challenge 1: Fonterra

Optimising the flavour profile and longevity of milk powders

Full Challenge Details

Challenge 2: Fisher & Paykel Appliances

Modelling the mechanical action of a front loading washing machine

Full Challenge Details

Challenge 3: Horizons Regional Council

How could we best optimise our Regions freshwater monitoring networks

Full Challenge Details

Challenge 4: Zespri

Predicting timing of kiwifruit harvest

Full Challenge Details

Challenge 5: Sanford Ltd

Comparing and contrasting shear forces and hydrodynamics of Industrial Larval Mussel tank design and operation

Full Challenge Details

Challenge 6: Transpower

Transmission Line Conductors - Big Data Cleansing, Probability of Failure Derivation and Asset Health Relationship

Full Challenge Details

MINZ- Study Group Agenda

Monday 26th June

Wool Building Room WB1

8:00 – 9:15am	Greeting/Registration
	Welcome
9.25 – 9.30am	MINZ Co-directors Dr Luke Fullard & Dr Richard Brown
	Opening Address
9.30 – 9.45am	Massey Vice Chancellor, Professor Jan Thomas

9:45 – 10:00am	What's coming up next
10:00 – 10:30am	**Morning Tea Rm WB1.24B**

Industry presentations

10:30 – 11:00am	Fonterra
11:00 – 11:30am	Fisher & Paykel Appliances
11:30 – 12:00pm	Horizons Regional Council
12:00 – 12:45 pm	**Lunch (not provided)**
12:45 – 1:15pm	Transpower
1:15 – 1:45pm	Zespri
1:45 – 2:15pm	Sanford Ltd
2.15 – 2.30pm	Group sorting
2:30 – 3:00pm	**Afternoon Tea**
3:00 – 5.00pm	Initial project Meetings (Led by moderators and Industry Reps).

Breakout Area 1	Fonterra Ltd
Breakout Area 2	Fisher & Paykel
Breakout Area 3	Horizons Regional Council
Breakout Area 4	Transpower
Breakout Area 5	Zespri
Breakout Area 6	Sanford Ltd

Note: Breakout rooms are: WB1, the rooms adjoining WB1.24B, and WB1.24B itself.

5.30 - 7:30pm	**Informal Reception MUSA Lounge**

Tuesday 27th June
Wool Building

Project working sessions as determined by the moderators and posted on noticeboards etc

8.30 – 5.00 pm

	Breakout Area 1	Fonterra Ltd
	Breakout Area 2	Fisher & Paykel
	Breakout Area 3	Horizons Regional Council
	Breakout Area 4	Transpower
	Breakout Area 5	Zespri
	Breakout Area 6	Sanford Ltd
10:30 – 10.50	Morning Tea	
12.30 – 1.30 pm	Lunch *(not provided)*	
2.30 – 2.50 pm	Afternoon tea	
5:15pm – 7pm	Student get-together @MUSA Lounge (*Pizza and drinks provided*) Informal talk by Dr Melanie Roberts	

Wednesday 28th June
Wool Building WB1

9:30 – 10.10am	**Plenary Speaker** – Dr Melanie Roberts, IBM	
10:30 – 10.50	Morning Tea	
12.30 – 1.30 pm	Lunch (*not provided)*	
2.30 – 2.50 pm	Afternoon tea	
	Breakout Area 1	Fonterra Ltd
	Breakout Area 2	Fisher & Paykel
	Breakout Area 3	Horizons Regional Council
	Breakout Area 4	Transpower
	Breakout Room 5	Zespri
	Breakout Area 6	Sanford Ltd
6:00 – 9.30 pm	Informal Dinner – @Wharerata	

Thursday 29th June

Wool Building

Project working sessions as determined by the moderators and posted on noticeboards etc

8.30 – 5.00 pm

	Breakout Area 1	Fonterra Ltd
	Breakout Area 2	Fisher & Paykel
	Breakout Area 3	Horizons Regional Council
	Breakout Area 4	Transpower
	Breakout Area 5	Zespri
	Breakout Area 6	Sanford Ltd
10:30 – 10.50	Morning Tea	
12.30 – 1.30 pm	Lunch (*not provided)*	
2.30 – 2.50 pm	Afternoon Tea	

Friday 30th June

Ag Hort building AH2

Project moderators reports on progress and recommendations followed by comments from Industrial representatives

8:50 – 9:00 am	Short address MINZ Co-directors Dr Luke Fullard & Dr Richard Brown
9:00 – 9:10 am	Short address by KiwiNet CEO, James Hutchinson
Challenge Summaries	
9:10 – 9:35 am	Fonterra Ltd (Moderator/Group + Industry rep)
9:35 – 10:00 am	Fisher & Paykel (Moderator/Group + Industry rep)
10:00 – 10:25 am	Transpower (Moderator/Group + Industry rep)
10:25 – 10:50 am	Morning Tea
10:50 – 11:15 am	Horizons Regional Council (Moderator/Group + Industry rep)
11:15 – 11:40 am	Zespri (Moderator/Group + Industry rep)
11:40 – 11:55 pm	Sanford Ltd (Moderator/Group + Industry rep)
11:55 – 12:00 pm	Closing remarks
12:00	Finish

Other Information

Reception

A welcome reception will be held in the MUSA lounge on Monday evening from 5:30pm (after the end of the day's workshops).

Student Pizza Evening

A casual student get-together will be held in the MUSA lounge on Tuesday evening from 5:15pm (free pizza!)

Conference Dinner

The informal MINZ dinner is being held at Wharerata Function Centre on campus from 6pm, Wednesday 28th June.

On-campus Internet Access

Look to the white board in break out rooms for internet access.

Bus Information and Timetable

Please see the following three pages.

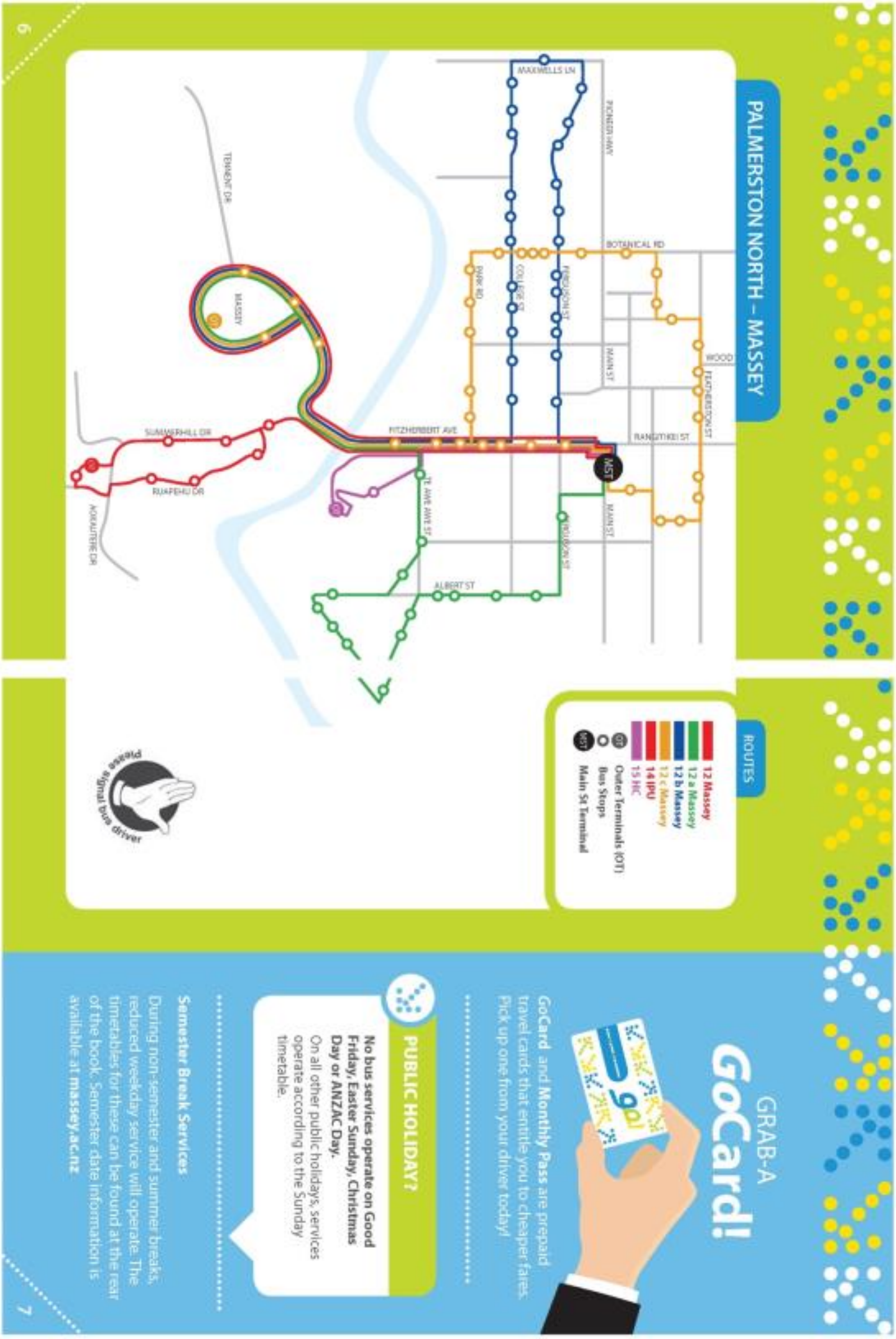
FARE PRICING

	Cash Fare	*GoCard* Fare
Child/Youth School-aged (If not in school uniform please provide ID) Under 5's travel FREE	$1.50	$1.20
Concessions* Student, Beneficiaries, Senior 65+	$1.80	$1.50
Adult	$2.50	$2.00
SuperGold Card Holders	FREE	FREE
Between 9am-3pm weekdays, all day on weekends and public holidays		
UCOL / Massey Students & Staff *	FREE	FREE
Adult Monthly Pass (initial purchase)	$62	
Adult Monthly Pass top-up	$55	
Child Monthly Pass (initial purchase)	$42	
Child Monthly Pass top-up	$35	

* On production of current ID or Community Services Card. Student fare available only with NZ tertiary education providers.

Fares subject to change. Please visit www.horizons.govt.nz for up-to-date fare information.

Horizons Regional Council plans and operates services according to the timetable, road conditions, traffic calming measures, special events and weather may cause delays.


PALMERSTON NORTH – MASSEY
FEATHERSTON ST
WOOD
BOTANICAL RD
RANGITIKEI ST
MAIN ST
PIONEER HWY
MST
FERGUSON ST
MAXWELLS LN
COLLEGE ST
PARK RD
FITZHERBERT AVE
TE AWE AWE ST
ALBERT ST
MASSEY
TENNENT DR
SUMMERHILL DR
RUAPEHU DR
AOKAUTERE DR
ROUTES
12 Massey
12 a Massey
12 b Massey
12 c Massey
14 IPU
15 HC
Outer Terminals (OT)
Bus Stops
Main St Terminal
Please signal bus driver
GRAB-A
GoCard!
GoCard and Monthly Pass are prepaid travel cards that entitle you to cheaper fares. Pick up one from your driver today!
PUBLIC HOLIDAY?
No bus services operate on Good Friday, Easter Sunday, Christmas Day or ANZAC Day.
On all other public holidays, services operate according to the Sunday timetable.
Semester Break Services
During non-semester and summer breaks, reduced weekday service will operate. The timetables for these can be found at the rear of the book. Semester date information is available at massey.ac.nz
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7

TO MASSEY (Non Semester)

Bus	MST	Hokowhitu	IPU	Massey	IPU
Monday-Friday					
12C	7.15			7.45 T	8.05
12	7.15			7.25	
12BA*	7.20			7.55 T	8.05
15	7.40	7.47		7.55	8.05
12	8.10			8.25	
12B	8.15			8.45	8.55
12C	8.15			8.45 T	8.55
15	8.20	8.27		8.35 T	8.55
12	8.20			8.35	
12A/14	8.20		8.40	8.50	
12	8.40			8.55	
15	9.00	9.07		9.15	
12C	9.20			9.50 T	10.00
12B	9.25			9.50 T	10.00
12A	9.25			9.50	10.00
12	9.40			9.55	
12	10.20			10.35	
12B	10.20		10.45	10.55	
12A	10.25			10.50	
12	10.40			10.55	
12	11.00			11.15	
12A	11.25			11.50	12.00
12B	11.25			11.50 T	12.00
15	11.40	11.47		11.55	
12	12.20			12.35	
12	12.40			12.55	
15	1.00	1.07		1.15	
12A	1.30			1.50	
12	1.40			1.55	
12	2.20			2.35	
14	2.35		2.45	2.55	
15	3.00	3.07		3.15	
14**	3.15		3.35	3.50	
14	3.40		3.55	4.05	
12	3.40		4.20	3.55	
14	4.10			4.30	
12	4.20			4.35	
12	4.40			4.55	
14	4.45		4.55	5.05	
15	5.00	5.07		5.15	
12	5.40			5.55	
14	5.50		6.00	6.10	
12	6.55			7.10	7.15

T Transfer bus for continuing to IPU, please ask driver for details
** Travels via Atawhai

FROM MASSEY (Non Semester)

Bus	Massey	IPU	Hokowhitu	MST
Monday-Friday				
14**	7.55	8.05		8.20
15	8.00		8.07	8.15
15	8.40		8.47	8.55
14	8.45	8.55		9.15
12	9.00			9.15
12	9.20			9.35
14	9.50	10.00		10.10
12	10.00			10.15
12	10.40			10.55
12	11.00			11.15
12A	11.05			11.30
12B	11.05			11.35
12	11.20			11.35
14	11.50	12.00		12.10
15	12.00		12.07	12.15
12	12.05			12.20
12	12.40			12.55
12A	1.05			1.30
12B	1.05			1.35
12	1.20		1.27	1.35
12	2.00			2.15
12B	2.05			2.35
12A	2.10			2.35
12	2.20			2.35
12C	2.35			3.05
15	2.40		2.47	2.55
12	3.00			3.15
12A	3.05			3.30
12B	3.10			3.40
15	3.20		3.27	3.35
12	4.00			4.15
12	4.00			4.15
12A	4.05			4.30
12B	4.30			5.00
12C	4.30			5.00
12A	4.35			5.00
15	4.40		4.47	4.55
12	5.00			5.15
12A	5.05			5.30
12C	5.15			5.45
15/14	5.20	5.25	5.32	5.45
12B	5.20			5.50
12	6.00			6.15
12AB	6.10			6.40
14	7.10	7.15		7.25

** Travels via Atawhai

Challenge Outlines

Challenge 1 – Fonterra

Moderators:	Steve Taylor, University of Auckland Tammy Lynch, Massey University
Student Moderator:	Valerie Chopovda, Massey University
Industry Representatives:	Lisa Hall Ralph Peters Roger Kissling Grant Abernethy

Title: Optimising the flavour profile and longevity of milk powders

Background

Fonterra is a global leader in the dairy industry, producing 1.5-1.6 million MT of milk powders annually. We are committed to providing high quality and nutritious dairy to countries all around the world. Maintaining the quality of our milk powder for the shelf life requested by the market has led to some challenges. Our aim is to optimise the flavour profile of our milk powders over their shelf life.

Accelerated storage trials are commonly used to assess shelf life and potential spoilage issues in many foods. Temperature is used as an accelerant in many of these trials. Accelerated storage trials for milk powders are complicated by the fact that temperature contributes to the chemical reactions causing oxidation and is a catalyst of the Maillard reaction which often overtakes more subtle flavours that appear as part of the aging process.

Fonterra has Selected Ion Flow Tube Mass Spectrometry (SIFT-MS) instruments that have the ability to measure very minute levels of a wide range of volatile compounds in the powder. It is now feasible to develop a chemical signature for milk powder to identify the presence of particular compounds. The data from determining this chemical signature at the time of manufacture and after two months of storage could then be used to inform mathematical models to predict the flavour profile over time. We also have some storage data which could be used in model validation.

A related challenge in the milk powder business involves the approval of new plant alignment for sensory sensitive customers. Can our SIFT-MS be used to characterize the sensory profile on the date of manufacture to capture the requirements of these customers? Can we use SIFT-MS data to model the differences in the sensory profile for powders manufactured in different plants and standardised with different ingredients?

Our problem

The problem for MINZ involves employing mathematics and statistics to assess the sensory shelf life of our milk powders, with an emphasis on whole milk powder (WMP). We are interested in the following:

- Modelling the key chemical reactions that produce chemical compounds that lead to unwanted sensory attributes in milk powder
- Estimating the reaction constants for these key chemical reactions for a range of storage temperatures
- Quantifying the ideal sensory profile of milk powder at time of manufacture to minimise the risk of undesirable chemical reactions occurring
- Using the chemical signature at two months to predict the flavour profile over the 24 month shelf life

We look forward to seeing you at MINZ 2017 as we work to optimise our milk powder business.

Challenge 2 – Fisher and Paykel Appliances

Moderators: Melanie Roberts, IBM, Australia
Celia Kueh, Massey University
Student Moderator: Emma Greenbank, Victoria University

Industry Representatives: Kirsty Davies
Jennifer Trittschuh

Title: Modelling the mechanical action of a front loading washing machine; Soil Removal and Gentleness of wash plus refinement

Background

The clothes washing process removes dirt particles and grease-like products by a synergistic combination of chemical action, thermal action and mechanical action. More action of one type can compensate, at least to some degree, for less action of another type (ex: if detergent is increased, wash time can be decreased.)
When describing mechanical action, the actual mechanisms for soil removal are garment-to-garment rubbing, within-garment rubbing and garment-to-washing machine drum-skin rubbing.

In the washing process customers are primarily concerned with 1. soil removal from their garments, but they are also concerned with the "wear and tear" that the garments are subjected to. This is referred to as gentleness of action, 2. Gentleness of action results from the rubbing actions described above.
Wash Performance (WP) is the sum of the Soil Removal and Gentleness. Many wash parameters can be changed to increase soil removal but will simultaneously decrease gentleness of action. Trade-offs need to be made and balances struck so that the overall wash performance will be acceptable to the user.

Wash performance testing of a particular washing machine is performed under controlled conditions: Water temperature, detergent concentration, load composition, load size, soil type and wash program. Swatches of special fabrics are attached to garments to provide estimates of soil removal and gentleness of action. Thus the chemical and thermal actions are fixed, leaving a number of mechanical and

wash program variables for F&P designers and developers to alter and improve Wash Performance.
There are many mechanical and wash program variables involved (see a basic list in table 1, below).

[1]Soil Removal

This is measured by the colour change of 20 or more “standardised dirt” cloth swatches after a wash cycle when compared to a “clean” standard swatch.
The Soil Removal is defined as two standard deviations less than the average colour change.

$$SR = C_{mean} - 2s$$

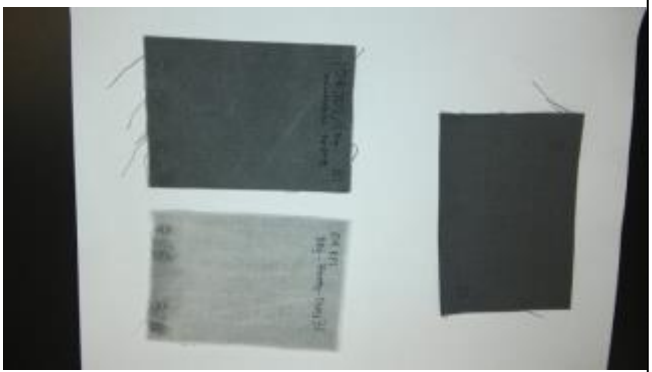


Figure 1: Soil removal swatches, before and after wash cycle (top was heavy cycle; bottom was delicate cycle)

[2]Gentleness of Action

This is measured by the amount of fray seen on 20 or so, 1dm squares of coarse-weave cloth after the wash cycle.

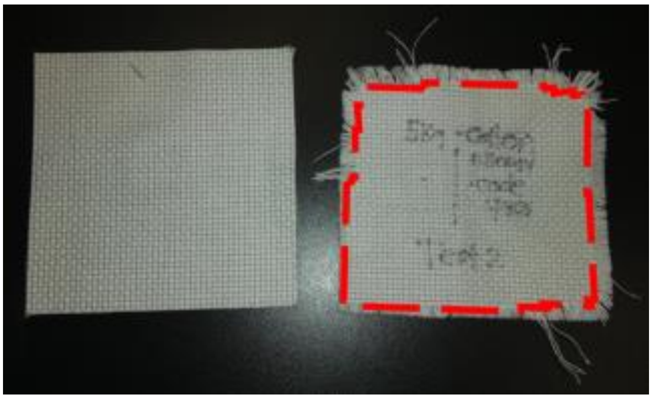
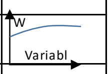
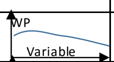
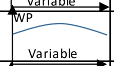
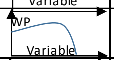
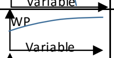
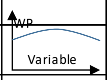
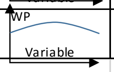
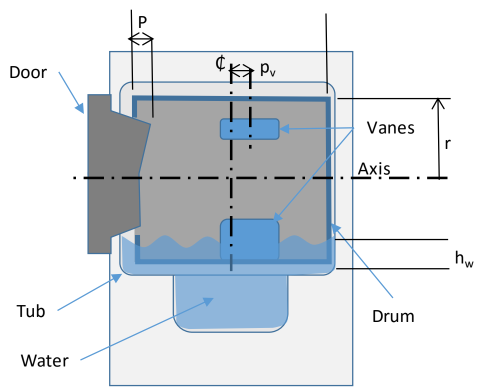


Figure 2: Gentleness of action (fray) swatches- before and after wash cycle

Table 1

Symbol	Unit	Name	Effect		Symbol	Unit	Name	Effect
r	mm	Drum radius			Ā	m^2	Mean area of clothes load	
d	mm	Drum depth			N	-	age of Load (0<N<80 washes)	
M	kg	Load size			p_v	mm	Position of Vane	
t	s	Total wash time				mm	Vane geometry	
s	rpm	tumble speed			CT	-	Cloth type factor	
V	Litre	Water volume			h_w	mm	Height of water puddle	
P	mm	Door protrusion (angle dependent)					tumble direction	



Desired Outcomes:

While physical testing will always be part of our development regime, we would like to improve our designs and reduce our development time by utilizing mathematical modelling. We would thus like to have a mathematical model plus an efficient experiment plan so that we can develop the relationship between the variables in Table 1 and wash performance. The model could be based on fundamental physics, empirical statistics, dimensional analysis or some other method.

Demonstration Equipment:

- Front loading washing machine
- Videos showing differences in movement of different drum diameters and tumble speeds
- appropriate clothes loads with colours that will show circulation
- Detergent
- Means for handling the water

Other Notes:

- There is variation in soil removal and gentleness of action and it is thought to be due to the variation in frictional rubbings (described above) across the load. Thus it would appear to be necessary to continually "mix[3]" the garments, so that the probability of each garment getting to each location in the drum is almost equal. This mixing seems to be a function of the circulation patterns shown.
- It has been shown that a protrusion at the top of the door has an effect on the circulation and thus on Wash Performance. This may be too complex to include in the model's first version but at a minimum, we would appreciate future proofing.
- One of our engineers thinks that Dimensional Analysis may be a way of developing the WP relationship. Table 2 shows his suggestions for some of the Dimensionless parameters. (This is provided as an option, not necessarily a preferred solution. We defer to your expertise to select the most appropriate model type.)

[3]**Mixing**
The sketch belows shows the directions of the slow movement of garments during the wash. If this circulation can be increased the variance can be reduced, and thus give better Wash Performance. It has been found that the door protrusion enhances circulation.

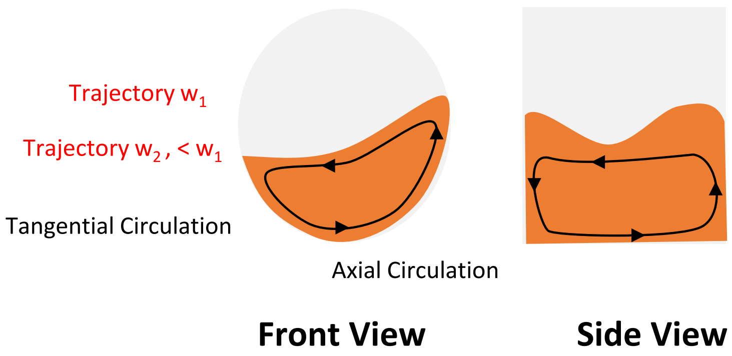


Table 2:

Dimensionless Number	Definition	Comment
π_1	d/r	Aspect Ratio usually between 1 & 2
π_2	hv/r	Vane height
π_3	dv/d	Vane depth
π_4	pv/d	Vane position from centre of drum
π_5	P/d	Door Protrusion
$\pi_{6,i}$	wi2r/g	Centripetal acceleration in units of [g] for the ith speed always<1
π_7	Δw/√(g/r)	Speed range as a fraction of speed that gives 1g acceleration
π_8	ύt/V	Recirculating flow
π_9	V/(πdr2)	Water volume ratio to volume of drum
π_{10}	M/(ρwtrπdr2)	Clothes mass ratio to mass of drum full of water

Glossary of Terms:

Load composition: what types of items and fibres make up the load. Ex: sheets; towels; clothing; synthetics; cottons; baby clothes; table cloths; active wear;

Load size: dry weight in kilos of load

Soil type: description of the dirt present that the washing process is expected to remove. Ex: body oil and skin; charcoal; protein; wine;

Gentleness of action: how much wear and tear a load is subjected to in a wash cycle. Quantified by the surface area of fabric swatches that has disturbed thread weaves at the end of a cycle.

Soil removal: how much dirt is taken away from a load during a wash cycle. Quantified by the colour change in commercially-prepared pre-soiled fabric swatches from a wash cycle.

Challenge 3 – Horizons Regional Council

Moderators: Jamas Enright, Statistics New Zealand
Stephen Marsland, Massey University
Student Moderator: Alex White, Massey University

Industry Representatives: Abby Matthews
Stacey Binsted

Title: 90% swimmable waterways in the Horizons Region by 2040: How could we best optimise our Regions freshwater monitoring networks to meet both national and regional objectives?

Background

Fresh, clean water is part of our national identity, it is essential for maintain healthy flourishing communities. In the Manawatu-Whanganui region we enjoy access to many beautiful rivers, lakes and streams. These waterways provide us with drinking water for animals and people, and support the water requirements of agriculture, energy and industry. Our waterways are a place to enjoy on those long summer days, and home to numerous fish and insects. Ensuring these waterways are safe for swimming, consumption, fishing and recreation is a big part of what we do at Horizons.

In February 2017, the NZ Government announced its target of 90% of rivers and lakes being swimmable by the year 2040. Currently 72% of our rivers and lakes meet the swimmable standard with approximately 10,000km of waterways needing to undergo improvement to achieve the nations 90% target. Horizons Regional Council is one step ahead with a number of freshwater initiatives underway, and is already in the process of developing a strategy to meet the swimmability targets in our Region.

Horizons is responsible for managing, monitoring and reporting on our region's natural resources, including our waterways. With changing requirements and emerging pressures on natural resources, it is important that Horizons continues to review and optimise our monitoring network to ensure it remains fit for purpose.

As a council we seek continuous improvement to ensure our environmental monitoring programmes are well aligned with both national reporting requirements and our science monitoring and research objectives. Our aim is to ensure that monitoring programmes are both efficient and effective in their delivery and that the key objectives (identified in the appendix below) are met. This includes both surface water and groundwater physico-chemical monitoring, aquatic biological monitoring and assessments of water availability.

Problem Details

Our proposed challenge is to establish what an optimal (spatially representative) water quality sampling network would look like for each of our major freshwater monitoring programmes. Our monitoring programmes have a number of regional and national objectives they must meet, so our challenge is focussed on answering the following three key questions:

1. What would an optimally designed and spatially representative regional monitoring network look like if it were designed from scratch to meet our objectives?
2. Given our established sampling locations, can you identify gaps in the spatial coverage of our existing network or areas that are over-represented when compared to an optimal network design?
3. What changes might be made to Horizon's monitoring network to better meet these objectives across the Region?

We can provide the following data for the Region

- Information on our current monitoring programmes and their objectives
- Hydrological information e.g. River network, catchments, rainfall, aquifer boundaries etc
- Geographical information e.g. topography, discharge locations, monitoring stations, geology, soils etc
- Consent information for water takes and discharges to water

Appendix: Policy information

The aim of our monitoring network is to ensure that:

- Each monitoring programme is fit for purpose, i.e. that monitoring samples are being taken from the right places, at the right time, following the correct protocols including those set out within the National Environmental Monitoring Standards (NEMS);

- Monitoring leads to key strategic outcomes such as water quality accounting, natural resources inventory and/or accounting for effects on environmental values; and
- Monitoring enables the measurement regional and national policy outcomes, such as alignment with requirements of the National Policy Statement for Freshwater Management (NPS-FM) and Horizons' Regional Policy and Plan (One Plan), along with objectives of the regional pest management strategies and other strategic resource management documents.

Currently we run a number of major monitoring programmes which exist to fulfil our regional and national objectives. These include: groundwater level and quality, lakes, estuarine and coastal, State of the Environment (surface water quality), discharge monitoring, sediment, swim spots / contact recreation, salt water intrusion, and biomonitoring (periphyton, cyanobacteria, fish, macroinvertebrates) programmes.

As a Regional Council we are continually striving to strike the right balance between making our natural resources available today while providing for the current and future needs of our environment. In reviewing our monitoring network we face similar challenges with regards to balancing competing needs with limited resources. Any changes to our monitoring network would need to be appropriately justified, cost effective and meet the various obligations we have to our community.

The key national and regional objectives in relation to monitoring which we aim to meet are as follows:

National Objectives

- *State of the Environment Monitoring* – This involves monitoring and reporting on how the physical, chemical and biological characteristics of the environment are changing over time. It is also used to identify emerging pressures.

- *National Policy Statement Freshwater Management (NPS-FM)* – the key actions of the NPS in relation to monitoring can be summarised as:

a) Develop a monitoring plan that:
   - i) establishes methods for monitoring progress towards - and the achievement of - a number of policies and objectives;
   - ii) identifies locations where monitoring will be undertaken that are representative of each delineated Freshwater Management Unit (FMU); and
   - iii) recognises the importance of long-term trends in monitoring results.

b) Establish, operate and maintain a freshwater quality and quantity accounting system.

- *Contribute to National Monitoring Programmes* – Including the National Pesticide Survey, National Age Tracer Survey, and National Groundwater Monitoring Programme.

Regional Objectives

- Inform and measure response of the environmental response to policy implementation;
- Inform non-regulatory programme development and implementation;
- Understand and report on state and trend on water quality sites depicting the cumulative catchment (zone) outputs;
- Identify areas of emerging pressure on our Region's water resource;
- Understand the effects of major point source discharges on water quality; and
- Meet Long Term Plan (LTP) performance measure to "track the health of the Region's water resource".

Challenge 4 – Zespri

Moderators: John Maindonald, Statistics Research Associates Limited
Graeme Wake, Massey University

Student Moderator: Rory Ellis, University of Canterbury

Industry Representatives: John White
Matt Atkins

Title: Predicting timing of kiwifruit harvest

Background

Zespri is the world's leading marketer of kiwifruit. Every year hundreds of thousands of tonnes of fruit are harvested, packed and coolstored before shipping to markets around the world. In order to deliver this fruit Zespri charters refrigerated ships that can transport about 5,000 tonnes of fruit at a time to markets in Asia and Europe. Alongside this hundereds of containers leave for over 60 markets around the world. It is the pride of Zespri and the New Zealand industry that fruit is only harvested when it has achieved the Zespri Taste Standard and is mature enough to be ripened on the early vessels for the markets.

Problem specification

Planning for the start of the season is a complex process with shipping needing to be ordered well in advance of the season start. Planning for packhouses such as ordering correct packaging, employing staff and readying coolstores all has to be timed for the beginning of the season.

In order to predict the likely start of the season Zespri runs a series of monitoring and modelling exercises to try and estimate the timing of the fruit maturity, volumes of fruit that will be ready and likely issues with the early part of the season.

The aim of this Challenge will be to investigate how Zespri can improve the current system and processes.

Prediction

- Two varieties
- Orchards harvested over a range of maturities that have different criteria
- Zespri has strict criteria for Clearance to pick which require thresholds of Dry Matter, Brix and Colour to be achieved. The specifications are based on a range of measures of a 90 fruit sample including means and fractiles.
- Monitoring leading up to harvest includes:
    - "Smart Monitoring" as set of orchards that are monitored every season and provide general regional trends
    - "Week 9 Monitoring" which takes a sample of a large number of orchards at a single point in time to try to build a full crop profile
- Other possible data sources:
    - Weather data
    - Previous season's monitoring
    - Previous season's actual harvest results

Possible outputs

- New analytics and tools for prediction the development of fruit over the first 3 weeks of harvest
- Improved designs for the sampling and monitoring systems

Challenge 5 – Sanford Ltd

Moderators:	Richard Clarke, University of Auckland Rose Davies, Massey University
Student Moderator:	Stephen Waite, University of Auckland
Industry Representative:	Andrew Stanley Mike Osborne

Title: Comparing and contrasting shear forces and hydrodynamics of Industrial Larval Mussel tank design and operation

Background

Aquaculture is one of the world's fastest growing primary industries and demand for aquaculture products is expected to continue growing as the world's population grows and wild-catch levels remain relatively static. Globally, aquaculture will soon produce more seafood than wild fisheries.

The New Zealand aquaculture industry, although relatively small on a global scale has positioned itself at the high-end of the market, exporting premium seafood products around the world. Sanford Limited is New Zealand's largest producer and exporter of aqua-cultured products, with Greenshell mussels representing the largest by volume and value.

Greenshell™ mussels (Perna canaliculus) are unique to New Zealand and are one of New Zealand's most iconic seafood offerings. Mussel aquaculture is one of the world's most efficient forms of food production and is considered a highly sustainable method of producing high protein foods.

The Government's Aquaculture strategy and five-year action plan supports sustainable growth of the aquaculture industry – balancing our economic, social, cultural and ecological values.

Historically, most green-lipped mussels in New Zealand are farmed in the same way. Spat (juvenile mussels) are collected from Ninety Mile Beach and elsewhere in New Zealand, where they wash up in their billions attached to clumps of seaweed. After arriving at a mussel farm, spat are transferred to nursery ropes and grown on the ropes in seawater until about 6 months of age. At this point, they are removed and reseeded onto longlines (stretches of rope up to several kilometres long) that are suspended between buoys.

Mussels are grown for a further 9–12 months before they are harvested. Mussel barges, which harvest the mussels, are mechanised and contain equipment for removing mussels from lines, then declumping, washing, sorting and packing.

Until now, New Zealand's mussel growers have relied on catching wild spat (baby mussels) around our coastline. Supply is unpredictable, yield levels are extremely low and the genetic profile of the mussels are uncontrolled. Through partnership with the New Zealand Government in the form of a primary growth partnership, we have developed a facility capable of selectively breeding Greenshell™ mussels and producing spat on a regular and controlled basis so our growers have the spat they need. SPATNZ (Shellfish Production and Technology New Zealand) operates this hatchery and research facility and its aim is to produce innovations to advance New Zealand's mussel aquaculture industry and deliver benefits for New Zealand's economy.

Preferred Project option 1 - Larval tank design and operation

One of the greatest challenges in the SPATnz project is to produce batches of larvae year-round. Mussels are naturally seasonal, and the technical challenges involved make it all the more difficult to consistency rear the highly sensitive larvae. We have observed differences in survival of larval rearing in various tank designs. At certain times of year we can get total loss of larvae in the commercial scale tank while the smaller scale (non-commercial) tanks continue to perform very well, so it has a big impact on our annual production. The reasons for the variation is unknown and one hypothesis is that the shear forces or hydrodynamics generated by aeration differ between these tanks, and interact with microbial communities and mussel larvae in ways that determine the success or failure of the batch. We are interested in comparing and contrasting the shear forces and hydrodynamic regime in these two tank designs. We are interested in hypotheses about why the difference in tank performance is seasonal.

Alterative Project option 2 - Invasive and unwanted species

Several invasive and unwanted species settle and grow on Greenshell mussel farms to the detriment of the NZ mussel farming industry, the most significant is the unwanted species Mytilus spp (blue mussels). The abundance of blue mussels has increased dramatically in the Marlborough Sounds and other growing areas in the last 10 years. There is a lot of historical data on blue mussel settlement and this has been analysed by Cawthron Institute and an app developed to predict blue mussel settlement. Given the impact of blue mussels on the GSM industry, we seek to understand the future trends and impacts of blue mussels and potentially other unwanted organisms. Will the prevalence increase, decrease or plateau and how will this affect the industry.

Alterative Project option 3 - Economic modelling of GSM selective breeding

A preliminary bio-economic model has been prepared to examine the economic importance of many factors influencing the profitability of mussel farming. The report is based on a spreadsheet model, and "user instructions" are available. We would be interested in a critique of this model and suggested further developments to enhance its utility of accuracy. The model does not currently incorporate changes to product condition over time, and is limited in its consideration of many external potential variables.

Links:

www.sanford.co.nz
www.aquaculture.org.nz/products/greenshell-mussels
www.wikipedia.org/wiki/Perna_canaliculus
www.spatnz.co.nz
www.cawthron.org.nz/coastal-freshwater/news/2016/app-helps-mussel-farmers/

Challenge 6 – Transpower

Moderators:	Napoleon Reyes, Massey University Mark McGuinness, Victoria University
Student Moderator	Sarah Pirikahu, Massey University
Industry Representatives:	Irvin Chew Conrad Edwards Simon Leitch

Title: Transmission line conductors - big data cleansing, probability of failure derivation and asset health relationship

Background

Transpower is central to the New Zealand electricity industry, connecting New Zealanders to their power system through safe, smart solutions for today and tomorrow. As the grid owner, we reliably and efficiently transport electricity from generators to distributors and large users.

To achieve this, a core component of our transmission network consists of transmission line conductors which enable the flow of electricity. Our asset management approach for conductors seeks to achieve a high level of reliability at least whole-of-life cost. This is further supported by the regulatory environment that we operate in, which ensures that our investment decisions are closely scrutinised and approved by the Commerce Commission up to 7 years in advance of the work being carried out.

There are approximately 12,000 route kilometres[1] of transmission line conductors along with numerous fittings such as conductor joints. Despite the large numbers of components in service, the reliability of conductors is high, and failures[2] are rare. The 10-year average rate of conductor drop incidents resulting from failures of conductors is approximately 2 events each year, based on records which go back to 1998. Most incidents are caused by mechanical failure of in-span joints, of which we have around 100,000 installed on the system. Therefore, the annual failure rate is closer to 2 x 10-5. Most joint failures are due to poor installation practices. Conductor failure may lead to loss of electricity supply and could cause serious physical harm to any people or objects underneath the conductor.

[1] Route length is the end-to-end distance traversed by the line; circuit length is the total length of the circuits carried on the line (for example, a double circuit line of 100 route km will be a 200 circuit-km line).

[2] Conductor failure is defined as the mechanical failure of the conductor and its components resulting in conductor drop.

Problem for MINZ

We are conscious that joint failure, whilst presently the leading cause of failures, is not the only reason that conductors drop. We are also conscious that we have an aging conductor asset base, which is degrading in condition and performance as time goes by. Indeed, we have a concern that there may be a so called "wall of wire" coming towards us, whereby the ever-aging conductor starts to be the primary cause of failure over coming years.

Degradation of conductor condition, hence life expectancy, depends primarily on the corrosiveness of the local atmosphere, but also on the construction (such as whether they have been greased to protect against corrosion) and the conductor material. Typical conductor types are Aluminium-Conductor Steel Reinforced (ACSR) and All Aluminium Alloy Conductors (AAAC).

To date, we have reduced conductor failures by means of monitoring and repairing, or replacing, where we judge that they are nearing their end of life (EoL). This is deemed to be the point whereby they have lost electrical performance capabilities or mechanical strength, with our designated nominal EoL factors being 15% loss of aluminium cross section, or 20% loss of strength. However, ground-based and structure-based visual assessments are of very limited use in predicting conductor end of life in a timely manner. This is because degradation (corrosion, fatigue, fretting) generally begins on the inside of the conductor, so is invisible until well advanced. Even detecting white corrosion product or small bulges is extremely difficult from the ground when looking up into the sky.

For long term expenditure forecasting, we currently have a very simplistic asset health model to predict conductor end of life, which considers the known factors in appointing a base life and additional life extension or reduction durations to identify an expected life. However, there is limited understanding of the different timeframes associated with each of the factors in different environments or for different conductor constructions, and therefore a wide tolerance on the accuracy of the asset health and EoL prediction.

We are currently embarking on an improvement journey where we are adopting a risk based asset health modelling approach, which considers factors such as age, corrosive environment, conductor construction to assign an asset health index (or score) against each section of conductor. This is nominally a proxy for the EoL calculations, but is to be used only for medium to long term (5-15yr) planning. Ultimately, we would like to be able to calculate each conductor's probability of failure based on their asset health index. This information can then be used to model the monetised network risk.

We are a long way from this goal, although in many ways, ahead of most of our peers internationally who are either not quite facing the same challenges as we are in NZ (which is prone to highly corrosive environments), or operate in a different (unregulated) market which allows them to make investment decisions under a different set of rules.

The end goal of this challenge is to develop a method for calculating conductor probability of failure at each asset health index score. We currently propose the following stages in approaching this problem:

Stage 1 – Big Data Cleansing

Data Available:

- Maintenance and project records of work undertaken on conductors. Database size: 109,386 x 30 matrix, 24.4MB.
- Asset information on conductor age, type, corrosive environment factor, condition scores, length and electrical loading.

Problem Specification

Our historical maintenance and project records (which can identify situations where we have avoided a conductor drop by repairing or replacing it), contain both textual and numerical information. Ideally we would convert this information to a structured format to identify trends/rates of defects or failures by type or region or condition or age, etc. This would be extremely difficult and time-consuming to do manually.

Desired Outcome

Create a mathematical model using a few example textual and numerical inputs for “learning” (e.g. machine learning or neural networks method) to output a structured data set from our maintenance and project records, which can then be used to derive number of defects or failures. The model would be customisable so that the inputs could change to assess different types of defects or failures. The identification of an estimated level of accuracy is also desirable.

Stage 2 – Probability of Failure Derivation

Data Available

- Converted maintenance and project records to a structured format identifying types of defects/failures – from Stage 1 or alternatively use “dummy” data if Stage 1 is unsuccessful
- Failure event records
- Asset information on conductor age, type, corrosive environment factor, condition scores, length and electrical loading. Database size: 52,890 x 41 matrix, 10MB.

Problem Specification

Historically, our conductors’ asset class has been very reliable, resulting in very few failures. As such, it is difficult to derive an age based probability of failure with high statistical confidence. However, this is mainly due to our diligence in addressing defects, as part of our project and maintenance work, prior to failure. Whilst we address defects based on their risk (e.g. anticipated likelihood to result in a failure and location or electrical loading), this is presently a subjective activity, reliant on several other variables such as accessibility and mechanical loading. It is currently unknown exactly how rapidly defects could lead to failures as they are proactively managed to avoid failure where possible.

Desired Outcome

Establish or determine, with a degree of statistical confidence, the relationships between types of defects (from Stage 1) and failures (Failure event records). Once that is established, an age based probability of failure (failure rate function or survivor curve) would be derived.

Stage 3 – Relationship to Asset Health

Data Available

- Probability of failure or defect curves – from Stage 2
- Asset information on conductor age, type, construction, corrosive environment factor, condition scores, length and electrical loading

Problem Specification

Our future state asset health models need to consider the latest condition assessments, environmental effects, asset type and many other factors and based on these factors it estimates or forecasts a probability of failure.

Desired Outcome

Assess the relationship between multiple factors and the probability of failure – considering some factors may be linear while others are non-linear to derive a mathematical model or equation that estimates the resulting probability of failure.

Asset Photos

The following photos show examples of transmission line conductors with defects.

Figure 3: Sample of conductor showing two bulges that are relatively large, but extremely difficult to see in span from ground.

Figure 4: Close-up of bulge 1 (the right-hand bulge of the previous photo)

Figure 5: Bulge 1 after removal of the outer layer of aluminium strands, showing the extent of internal damage of aluminium wires

Severe corrosion bulge at 'grease holiday'

Adjacent conductor with good grease

Multiple grease holiday bulges

Core exposed and no grease (white patches)

Figure 6: Grease holiday photos

Attendees

As at 9th June 2017

Catherine McKenzie	AgResearch
Hyuck Chung	AUT
Wenjun Zhang	AUT
Graeme Wake	Massey University
David Simpson	Massey University
Gonzalo Martinez	Massey University
Govindaraju Govindraju	Massey University
Napoleon Reyes	Massey University
Matt Wilkins	Massey University
Stephen Keen	Massey University
Cami Sawyer	Massey University
Stephen Marsland	Massey University
Edgar Santos-Fernandez	Massey University
Robert McKibbin	Massey University
Katharina Parry	Massey University
Luke Fullard	Massey University
Richard Brown	Massey University
Mo Li	Massey University
Celia Kueh	Massey University
Sunil Lal	Massey University
Robert McLachlan	Massey University
Xun Xiao	Massey University
Tammy Lynch	Massey University
Jonathan Marshall	Massey University
Rose Davies	Massey University, School of Aviation
Joon Heo	National Institute for Mathematical Sciences
Hyoungsuk So	National Institute for Mathematical Sciences
Kyungpyo Hong	National Institute for Mathematical Sciences
Steve Taylor	University of Auckland
John Cater	University of Auckland
Richard Clarke	Univerity of Auckland, Dept Engineering Science
Mathieu Sellier	University of Canterbury
Anton Good	University of Canterbury
Andrew Bassom	University of Tasmania
Krishna Raghuwaiya	University of the South Pacific
Mark McGuinness	Victoria University of Wellington
Shelley Fong	Auckland Bioengineering Institute, University of Auckland
Stephen Waite	Auckland Bioengineering Institute
Rotem Edwy	AUT
Tilahun Ferede Asena	Hawassa University
Fatoyinbo Hammed Olawale	Institute of Fundamental Sciences, Massey University
Ali Abdul Hussain	Massey University
Raziyeh Zarre	Massey University
Nadeem Caco	Massey University
Sunchai Tongsuksai	Massey University
Xin Zhou	Massey University

Valerie Chopovda	Massey University
Matthew Rushworth	Massey University
Nadeeka Premarathna	Massey University
Sarah Pirikahu	Massey University
Liam Bignell	Massey University
Alex White	Massey University
Ahmad Mahmoodjanlou	Massey University
Christian Offen	Massey University
Ellen Van Looy	Massey University
Daniel Corrigan	Massey University
Gareth Gordon	University of Auckland
Andy Lo	University of Auckland
Sibylle Van Hove	University of Auckland
Daniel Clarke	University of Canterbury
Roelant Hofmans	University of Canterbury
David Burton	University of Canterbury
Harriet Miller-Brown	University of Canterbury
Rory Ellis	University of Canterbury
Thomas Bourdin	University of Canterbury
Samuel Walker	University of Otago
Abdul Moiz	University Of Salerno, Italy
Emma Greenbank	Victoria University
Sam Fernando	Self-employed
Tony Gibb	Adelaide Advanced Engineering
James Williams	Isogonal Limited
Alan Williams	Isogonal Limited
Simon Woodward	DairyNZ
Seumas McCroskery	KiwiNet
Jamas Enright	Statistics New Zealand

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