Are Models becoming smarter than Modellers?

Presentation Notes

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<table>
<tr><td>Slide 1</td><td>Title</td></tr>
<tr><td>Slide 2</td><td>Presentation theme
Hi, everyone. I thank the ITEANZ committee for giving me the opportunity to make this presentation. You have read the Presentation theme. I won't read it now except that I've added the effect of artificial intelligence on our profession…
• Are Models becoming smarter than Modellers?
• Models in software applications are becoming increasingly more sophisticated.
• Artificial Intelligence becoming visible in all areas of our lives.
• Is this making modellers smarter or are they left behind?
• How is all this affecting the use of models, interpreting outputs, handling uncertainties in model results and translating model outputs into practical solutions?
and I'll add:
• How is all this affecting our profession? Is there a disruption / threat from technology?</td></tr>
<tr><td>Slide 3</td><td>Previous presentation at NZMUGS 2017
This is based on my keynote speech titled
Are smart models leading to dumb modellers?
presented at the New Zealand Modelling User Group 2017 Conference
held in Christchurch.
This theme was established by the organisers of that event. My presentation today is a significant update of the original speech.</td></tr>
<tr><td>Slide 4</td><td>Presentation plan
• The road traffic / transport system we are modelling
• Models
  o General Discussion
  o Experiment vs Theory
  o Complexity vs Simplicity
  o Uncertainty and Reliability
  o Calibration
  o Big Data
• Modeller
  o General Discussion
  o Understanding and improving model outputs
  o Lessons from Artificial Intelligence
I'll first talk about the characteristics of the road traffic / transport system we are modelling, then talk about models and modellers both generally and with specific reference to traffic modelling.</td></tr>
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	I'll skip some slides rather than talking on them at length as I have set them to be useful when the interested viewer downloads from our website when we make the presentation slides and notes available. I'll recommend various books and articles for reading. I have some quotes. I have included internet links where applicable. Now let's start …
Slide 5	**Artificial Intelligence in our daily lives** Meeting "Alexa" … I met *Alexa* a couple of years ago in the USA. It was fun to ask questions to Alexa, and it wasn't too long before I asked "Alexa, will you marry me?" Apparently over a million people asked Amazon's Alexa to marry them in 2017 and it turned them all down. https://amp.businessinsider.com/amazons-alexa-got-over-1-million-marriage-proposals-in-2017-2018-10 Digital voice assistants like Amazon's Alexa are applications of artificial intelligence (AI) that are increasingly part of our daily lives. They rely on natural language generation and processing and machine learning, forms of artificial intelligence, in order to effectively operate and perform better over time. https://bernardmarr.com/default.asp?contentID=1830 Artificial Intelligence is becoming visible in all areas of our lives.
Slide 6	**Self-driving vehicles** Another AI application which is much talked about, and is of great interest to traffic engineering / transport planning profession, is the self-driving vehicle. Discussion on this is included in a recent book which presents a general critical review of the current state of AI. I'll quote some aspects of this book later in this presentation due to their relevance to my discussion of models and modellers. MARCUS, G. and DAVIS, E. (2019). REBOOTING AI – Building Artificial Intelligence We Can Trust. Pantheon Books, New York. https://www.nytimes.com/2019/09/06/opinion/ai-explainability.html
Slide 7	**Examples of other AI applications affecting us** • GPS navigation • Automotive industry • War drones (autonomous weapons)
Slide 8	**Questing arising from Artificial Intelligence considerations** All this brings to my mind questions like : • How much intelligence is there in the models we are using in our profession? I believe they are not more than Expert Systems. • How would models with increasing intelligence affect modellers? • Do we have wish to have Expert Systems capabilities (decision-making abilities of a human expert) in our models? • Any threats / disruption to our profession? • Are there any lessons to learn from artificial intelligence methods? I'll discuss AI in the Modellers section of my presentation.

Slide 9	**The road traffic / transport system we are modelling** In discussing the models and modellers, we should first understand the characteristics of the road traffic / transport system we are modelling better …
Slide 10	**We are modelling a complex system (1)** Understanding the characteristics of the road traffic / transport system we are modelling: We are modelling a complex system. Answers to most questions will come from a good understanding of this. The system we are modelling is complex is complex because of the diversity of road users and diversity of areas of concern with multiple conflicting objectives to address. The best solution for one group of road users or one area of concern is not the best solution for another. Operational efficiency objectives for cars, buses, trucks and bicycles do not agree. The safest solution is not necessarily the most efficient.
Slide 11	**We are modelling a complex system (2)** The hourly, daily, weekly, yearly changes in travel demand and operating conditions make the analysis complex– even changes within an hour can have significant effect. Non-linearity is an important characteristic of the performance of traffic and transport systems. Sensitivity and uncertainty of operating conditions increase at a high rate when demand approaches and exceeds capacity of the system. The human element adds greatly to the variability of the system as drivers, riders and pedestrians adopt to varying conditions. For example, aggressive vs relaxed behaviour of drivers depends on traffic conditions. Diversity of traffic engineering practice around the world and the emergence of new practices over time add to the complexities. So what does it mean to model a complex system?
Slide 12	**Complex System** A complex system is any system with a large number of interacting components with resulting non-linearity and feedback loops. https://en.wikipedia.org/wiki/Complex_systems In fact, all aspects of life present complex systems. Our body is a complex system. Climate is a complex system. Social and economic systems are complex. We want our models to be as simple as possible. Is it possible to make simple models of complex systems?
Slide 13	**Models** • **General Discussion** • **Experiment vs Theory** • **Complexity vs Simplicity** • **Uncertainty and Reliability** • **Calibration** • **Big Data** Let's now discuss models generally…

Slide 14	**Models - General Discussion** My discussion will assume models implemented via computer software …
Slide 15	**Model Benefits** Models are useful for problem solving and decision making. They help with improved communication between modellers, facilitating them to speak the same language, and they impose an expert discipline. Perception and understanding of the "real system" and its relation to modelling is interesting. It is useful to discuss the difference between describing something against explaining something. However, we should ask some questions about models …
Slide 16	**Are models more sophisticated now?** Do the functionality improvements or increasing computing speeds mean smarter models? Is increased model complexity to do with the areas the modellers are required to address? Is the ability to do much more extensive analysis overwhelming the modellers? Is perception of "complexity" all relative? Does complexity mean "sophistication"?
Slide 17	**The model and the modeller** The following has been our motto in development: The modeller should understand that *no model is perfect* and has to understand *limitations* of the model in use. A black box solution is not desirable and model is only a professional tool. Will development of computer power coupled with artificial intelligence challenge this?
Slide 18	**"Reality" and "Modelling"** We should understand "Modelling" as a basic human brain process. We try to simplify the complex world around us, we try to describe ("how?") and explain ("why?"), and we try to predict the future. This quote from The Grand Design by Hawking and Mladinow states it clearly …
Slide 19	**What is a good model?** I discussed the basic nature of the traffic and transport system as a complex one. So what is a good model? Is it a representation of reality in a detailed way but as simple as possible? In this, we need to remember that making the model more complex does not necessarily make the accuracy of its estimates better. We also need to remember the importance of the clarity of model assumptions and the balanced use of experimental and theoretical elements.
Slide 20	**Models - Experiment and Theory**
Slide 21	**Experiment vs Theory** Discussion of the role of *experiment* and *theory* in models is an important one. Contrasting models as "empirical vs theoretical" represents a simplistic view since good models have basis in traffic behaviour theory and are empirical at the same time. As the famous quote goes "Experience without theory is blind, but theory without experience is mere intellectual play."

	Real-life observations, surveys can be done in many different ways. Theoretical basis provides a framework for observations. Otherwise, we could end up with a lot of data and don't know what to do with it. There's an excellent book titled "*Measuring the World*" I recommend to scientists and engineers. It is a novel about two German scientists, Alexander von Humboldt, a great experimentalist who went all around the world measuring everything, and Carl Gauss, a great mathematician who sat at his desk to develop theories of great importance.
Slide 22	**Explaining vs describing** Another book I recommend is "*To Explain the World – The Discovery of Modern Science*" as it is relevant to explain vs describing
Slide 23	**Models - Complexity vs Simplicity**
Slide 24	**Perception of "complexity" is relative** In discussing *complexity* vs *simplicity*, I'll give the example of the well-known delay model developed by Webster in 1950s. In his research paper, Webster stated that "*a theoretical calculation of delay is very complex*". He used simulation for this purpose ("*it was decided to use a method whereby the events on the road are reproduced in the laboratory by means of some machine which simulates behaviour of traffic …* "). This shows that perception of complexity is relative as there have been great theoretical developments of traffic delay models.
Slide 25	**Simple model for a complex system?** Einstein said " Everything should be made as simple as possible, but not simpler." A paper on *neural modelling* which I came across has a good statement of the case for a simple model for a complex system: "one of the most challenging aspects of model building is working out which details are important to include and which are acceptable to ignore." http://www.nature.com/nature/journal/v531/n7592_supp/full/531S16a.html?foxtrotcallback=true
Slide 26	**Have the models been getting smarter?** The models may be getting smarter but a lot of software models are still using those based on the assumptions of the days when we used the slide rule and punch cards. I list some examples here. Model simplifications such as the lack of iterative methods in the US Highway Capacity Manual were justified as we used tables and nomograms when we did not have computers. Today's computers allow us to implement sophisticated iterative algorithms.
Slide 27	**Model Complexity vs Model Error** This display provides some answer to the question of complexity versus simplicity. This shows that, by making the model more complex in an effort to replicate the details of the real-life system, we are also increasing the model error as each added element comes with some data error as well as model specification error. Thus, additional complexity does not necessarily produce more accurate model results.

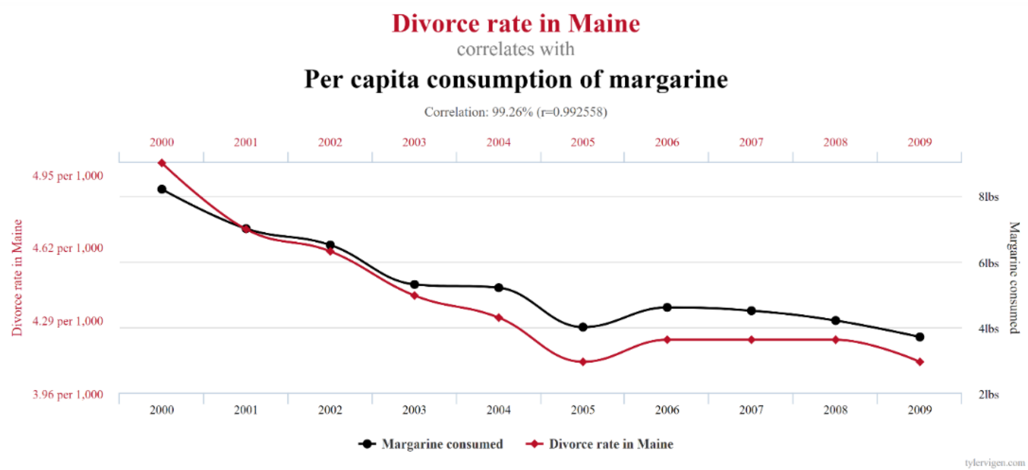
Slide 28	**Models - Uncertainty and Reliability**
Slide 29	**Uncertainty: Accuracy and Precision** This display by Williumsen is useful in discussing the issue of model uncertainty as it contrasts accuracy and precision. Our professional culture demands accurate and precise model results but uncertainty (accurate and imprecise) needs to be dealt with when it reflects a condition of the system modelled.
Slide 30	**Uncertainty and complexity** This paper from the area of *environmental science* presents techniques for dealing with uncertainty. It is interesting to read the statement "Often (it is) necessary to reduce the complexity of systems before analysing them." https://training.fws.gov/courses/alc/alc3194/resources/publications/scenario-planning/Zurek_Henrichs_2007.pdf
Slide 31	**Models - Calibration**
Slide 32	**Model calibration – a general principle** As a general principle for model calibration, the modeller needs to understand what the key parameters are. We recommended that, rather than specifying as constant input values, parameter values observed in the real-life system should be used to calibrate basic values of key parameters to allow model adjustment for changing conditions.
Slide 33	**Model calibration - difficulties** Diversity and variability of traffic conditions including driver behaviour, vehicle characteristics, road geometry and demand volumes are such that, while model calibration is an essential necessity, it is a difficult task partly because of the *difficulty of identifying relevant parameters in a model of a complex system*. Deep understanding and reasoning based on causality, abstraction and theory are needed rather than deep statistical analysis. This will be revisited in discussing the relevance of good artificial intelligence principles to modelling and modellers.
Slide 34	**Models - Big Data**
Slide 35	**Big data – usefulness?** Discussing "Big Data", let's remember the old adage "Data is not information, information is not knowledge, knowledge is not wisdom." The key word here is wisdom with a telling dictionary definition: "ability to make sensible decisions and give good advice because of experience and knowledge".
Slide 36	**Better use of Big Data** Can we extract information from *Big Data* that can that can be more useful in traffic / transport modelling? While *statistical* information that can be extracted from big data can have a great positive impact on modelling techniques, we should also be aware of a potential danger by way of losing the perspective of the *theoretical (conceptual) basis of modelling techniques* used. Statistical analysis of big data may be useful for some purposes but it should be possible to extract information from big data that can help with *improved model concepts and*

	algorithms. For example, could it help with determining travel demand data for small and large road networks, or facilitate modelling of all-day traffic rather than morning and evening peak periods.
Slide 37	**Modeller** • **General Discussion** • **Understanding and improving model outputs** • **Lessons from Artificial Intelligence**
Slide 38	**Modeller - General Discussion**
Slide 39	**Smart Modeller** What's a good, smart, wise modeller? Signs of a smart modeller include knowledge and experience, understanding of model concepts, model assumptions and input data limitations, understanding the model as a tool, and useful feedback to researchers and software developers towards model improvements.
Slide 40	**Dependence on technology** The relationship between model and the modeller is an interesting one. In a paper on modelling, Bargiela stated "*It is paradoxical however that the development of more natural interfaces leads to unnatural adaptations or changes in the user. In the progressively tighter coupling of user to interface, the user evolves as a cyborg*". https://en.wikipedia.org/wiki/Cyborg
Slide 41	**Modeller - Understanding and improving model outputs**
Slide 42	**Understanding the model to question model results** Understanding the model for providing appropriate inputs and interpreting model outputs towards wise decision making are essential characteristics of a good modeller. Understanding the fundamentals of the model helps with questioning the model. Understanding the parameter definitions and measurement methods is important in comparing output from different models (software), calibrating a given model using real-life data, and consistency in assessing alternative treatments.
Slide 43	**Queue Length – An example for importance of DEFINITIONS** There are many useful definitions of queue length as shown here. Average queue and percentile queue apply to each of these.
Slide 44	**First principles and rules of thumb** Thinking in terms of the "first principles", and simple rules of thumb help towards understanding the model to question model results. It should be appreciated that many different mathematical constructs are possible to model the same phenomenon, and many different approaches (techniques) are possible to model the same reality.
Slide 45	**A useful rule of thumb: an example** A good example of simple rule of thumb that works is related to gap acceptance parameters representing driver behaviour (follow up headway is 60 percent of the critical gap). This is confirmed by an inspection of the Austroads – SIDRA Standard model data for two-way sign control and the Australian roundabout data (as well as the US Highway Capacity Manual data not shown here).

Slide 46	**Modeller - Lessons from Artificial Intelligence**
Slide 47	**Fully automated design?** Would you like a fully automated design of an intersection or network by software (model)? This idea was strongly objected to by many practitioners in 1980s around the time when the first desktop PC emerged. But progress in the area of AI raises the question: Could an AI-based software modelling tool (involving all steps from data collection to automated output) make the choices and decisions expected of "wise" modellers? Or should a model remain simply as a tool for human decision making?
Slide 48	**Artificial Intelligence (AI)** This leads us to *artificial intelligence* (AI). All the themes I have been talking about, computer power, larger amounts of data, theoretical understanding, etc., come into artificial intelligence discussions. Autonomous car is an important example of AI application. This very general Wikipedia article on artificial intelligence is a useful one.
Slide 49	**Will computers take over the world?** When we asked this question in the near past, we would say no. • Hardware was bulky. • Computing was slow. • Memory was insufficient. • Communications were poor. Now we have mobile phones, internet, Google, Apple, Twitter, Facebook, LinkedIn, Research Gate. Consider the current status of work, social interactions, media, war … Haven't computers taken over the world?
Slide 50	**Future of professions (1)** In Chapter 2 ("Work") in his book titled "21 lessons for the 21st century " in his series of three books after "Sapiens" and "Homo Deus", Harari states: "It is generally agreed that *machine learning and robotics* will change almost every line of work. … However, there are conflicting views about the *nature of change* and *its imminence*. " HARARI, Y.N. (2018). 21 Lessons for the 21st Century. Jonathan Cape, London.
Slide 51	**Future of professions (2)** In the "The Future of Professions" written by father and son discussing "How technology will transform the work of human experts", Richard Susskind and Daniel Susskind suggest: "In the medium term, during 2020s, this will not mean unemployment but retraining and redeployment. In the long run, however, … there will be a steady decline in the need for flesh and blood professionals. " SUSSKIND, R. and SUSSKIND, D. (2015). The Future of Professions - How Technology Will Transform the Work of Human Experts. Oxford Press, Oxford.

Slide 52	**"Artificial Intelligence We Can Trust" (1)** This invites a brief discussion of Artificial Intelligence so that we can guess how our profession could develop in the near future and long-term future. The following recent book presents an excellent critical review of the current state of AI, pointing out its shortcomings, and gives suggestions toward better AI. MARCUS, G. and DAVIS, E. (2019). REBOOTING AI – Building Artificial Intelligence We Can Trust. Pantheon Books, New York An article by the authors of the book (New York Times, 6 Sep 2019): https://www.nytimes.com/2019/09/06/opinion/ai-explainability.html
Slide 53	**"Artificial Intelligence We Can Trust" (2)** Marcus and Davis discuss media overreporting abilities of AI, emphasise the need for deep understanding, adoptability to new and unusual circumstances, abstraction and generalisations, reasoning. "We need to stop building computer systems that merely get better and better at detecting statistical patterns in data sets (deep learning) and start building computer systems that … innately grasp three basic concepts: time, space and causality." "We can stick with today's approach to A.I. and greatly restrict what the machines are allowed to do (lest we end up with autonomous-vehicle crashes and machines that perpetuate bias rather than reduce it). Or we can shift our approach to A.I. in the hope of developing machines that have a rich enough conceptual understanding of the world that we need not fear their operation."
Slide 54	**Insights from the Human Mind (1)** In Chapter 6 of their book, Marcus and Davis discuss 11 aspects of about how "Human Mind" works. I'll summarise some of these in this and the following four slides. The discussions indicate the principles that modellers (practitioners), model (software) developers and researchers should pay good attention to. • **Abstraction and generalisation** play an essential role in cognition. Much of what we know is fairly abstract. A rich collection of abstract relations are used to strip very complex situations down to their essentials, giving enormous power in reasoning broadly about the world. • **Concepts that are embedded in theories are vital to effective learning.** General intelligence needs to embed the facts that it acquires into richer overarching theories that help organize those facts.
Slide 55	**Insights from the Human Mind (2)** • **Causal relations are a fundamental aspect of understanding the world.** We use approximations; we know things are causally related eve if we don't know exactly why. However, the route to causal knowledge is fraught with trouble as almost every cause leads to correlations but a lot of correlations are not causal.

From: Spurious Correlations by Tyler Vigen



Slide 56

Insights from the Human Mind (3)

- **Human brain** has 150 distinctly identifiable areas and a vast and intricate web of connections between them. Truly intelligent and flexible systems are likely to be full of complexity much like brains.
- **Cognitive systems are highly structured.** Neuroscience indicates a complex picture, in which hundreds of different areas of brain each with a distinct function coalesce in different patterns to perform any one computation.
- **Cognition** makes extensive use of internal representations like beliefs, desires and goals. Without a rich cognitive model, there can be no robustness.

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Insights from the Human Mind (4)

- **Complex cognitive structures are not blank slates.** How much of the structure of mind is **built in** and how much of it is **learned**? The evidence from biology, psychology and neuroscience is overwhelming: **nature and nurture work together**, not in opposition. Humans are likely born understanding that the world consists of enduring objects that travel on connected paths in **space and time**, with a sense of **geometry and quantity**, and the underpinnings of an **intuitive psychology**. It is also very likely that **some aspects of language are also prewired innately**.
- **We keep track of individual people and things.** Our world of experience is made up of individual things that persist and change over time, and a lot of what we know is organised around particular entities, their properties, individual histories and idiosyncrasies.

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Insights from the Human Mind (5)

Marcus and David concluded:

> "Once AI can take advantage of these lessons from **cognitive science**, moving the paradigm revolving around big data to paradigm revolving around **both big data and abstract causal knowledge**, we will be in a positions to tackle one of the hardest challenges of all: the trick of **endowing machines with common sense."**

Slide 59	**Are Models becoming smarter than Modellers?** In conclusion, in addressing the question "**Are Models becoming smarter than Modellers?"**, I wanted to extend the discussion from the **present** to the **future** and to **raise questions more than give answers** so that **you can try to answer** this difficult question. We would probably agree that **models are becoming smarter and that they are not smarter than modellers (yet)** but I wanted you to think **whether models will be smarter than modellers**, and possibly so much smarter that **models will be modellers**.
Slide 60	**Presenter** Dr Rahmi Akçelik is a leading scientist and software developer with 50 years of practical, research and training experience in the area of road traffic operations, traffic engineering, management and control. He is Director of Akcelik and Associates Pty Ltd (trading as SIDRA SOLUTIONS). He has about 350 technical publications in his area of expertise. He is the author of the SIDRA INTERSECTION and SIDRA TRIP software packages. Awards received by Dr Akçelik include the 2014 Roads Australia Award for Technical Excellence and 1999 Clunies Ross National Science and Technology Award for outstanding contribution to the application of science and technology.
Slide 61	End of presentation.

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