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Emerging technologies and innovation – who will deal with them?

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ABSTRACT: *As practicing engineers or managers, we need to keep abreast of contemporary and emerging developments in our field, primarily to provide competent and cost-effective solutions for the communities we live in, and at the very least to remain relevant and employable.*

Some emerging technologies and innovations in the road pavement discipline discussed in this paper are: pavement responses to a hotter and wetter climate associated with climate change; connected and autonomous vehicles; bitumen alternatives; nanomaterial modified bitumen; and substitution for or the sustainability of raw materials.

We need staff well prepared to deal with the introduction of new technologies in an informed manner, to manage risks and to maximise community benefits. It would seem that relevant continuing professional development is now becoming a survival skill rather than just a nice-to-have.

Austroads commissioned a BIS/Oxford Economics report (2018) Australia and New Zealand Road Capability Analysis 2017-2027*, which indicated that: road agencies are already experiencing skills shortages; the existing roads workforce will be under threat from rising activity in other sectors; the demand for new or expanded skills will accelerate; much needs to be done to place our workforce capability on a sustainable path.*

There is often a barrier between innovation and implementation, and this barrier can only be bypassed using knowledgeable people. The paper closes with a discussion of our preparedness, and what are our choices.

KEYWORDS: innovation, skills, education, training, sustainability.

1 Introduction

To expect the unexpected shows a thoroughly modern intellect – Oscar Wilde.

Prophesy is a good line of business, but it is full of risks – Mark Twain in *Following the Equator*.

My interest is in the future because I am going to spend the rest of my life there – C.F. Kettering.

Further to the above scene-setting, as practicing professionals we do need to keep abreast of contemporary and emerging developments in our field, and be able to manage their implementation into common practice.

This paper is intended as a thought-provoker / discussion starter. It commences with a grab-bag of emerging trends and new ideas, and then explores the question of who has the skills to get these into actual practice.

2 Environmental changes

The Australian Senate released an Environment and Communications References Committee report in August 2018, entitled *Current and future impacts of climate change on housing, buildings and infrastructure* [1]. In this report it was noted that:

"Climate change could mean that the lifespan of many infrastructure assets is shorter than planned or that maintenance costs increase significantly. For example, more frequent exposure to seawater as a result of sea level rise could reduce the lifespan of bridges and embankments. Storm surges are also resulting in local governments replacing or relocating coastal infrastructure, such as coastal trails, and it is expected that this activity will increase with sea level rise".

"Repairs and other maintenance may be needed more regularly. For example, flooding events from storm surges or high intensity rainfall could require more frequent road repairs. The National Climate Change Adaption Research Facility also observed that cooling infrastructure might require more frequent servicing".

"Similarly, materials used in transportation infrastructure could deteriorate more quickly, increasing maintenance costs and the frequency in which they need to be replaced. In addition to short term damage, droughts and floods can cause longer-term issues for ground-based transport infrastructure by altering ground conditions and destabilising their foundations."

"Higher temperatures are expected to increase heat stress on transport infrastructure, with sealed roads and rail lines particularly vulnerable" [1].

2.1 Specific climate effects on pavements

The topic of climate effects on pavements is talked about very rarely amongst pavement engineers, but in the view of the authors it should be. It could very well involve engineering risks that need to be managed and increased periodic maintenance expenditure.

2.1.1 Higher temperatures

There will be increased potential for rutting and shoving, requiring more rut resistant asphalt mixtures. This may require raising high-temperature asphalt binder grade and/or increasing the use of binder polymerisation and/or improved aggregate structure in asphalt mixes.

Increased use of rut resistant designs including thin, rut resistant surfaces, and the increased age hardening of asphalt binder using binders that age more slowly may be required.

Expanded use of asphalt pavement preservation techniques (e.g. rejuvenators) to address binder aging, could also help [2].

2.1.2 Higher precipitation

Reduction in pavement structural capacity due to increased levels of saturation will require activities such as

• Reducing moisture susceptibility of unbound base/subgrade materials through stabilization

• Ensure resistance to moisture susceptibility of asphalt mixes

• Improving surface and subsurface pavement drainage.

Higher precipitation will also likely negatively impact construction scheduling, resulting in a need to investigate construction processes that are less susceptible to weather-related delays [2].

2.1.3 Wetter Winters and Drier Summers

We will need to address increased potential for soil shrinking and swelling due to moisture changes, particularly in times of drought, and perhaps incorporate soil modification or stabilization into design.

We will require stiffer or improved pavement designs that are less susceptible to changes in subgrade properties incurred due to changes in moisture [2].

2.1.4 Pavement Design

Climatic data used in pavement design is based on history, and there is a need to consider updated climatic trends and the results of advanced climatic modelling.

Pavement performance models will require recalibration to reflect trends in performance resulting from climate change.

New long-term pavement designs will need to consider anticipated climate change over a 40-year design life [2].

2.1.5 Seal Design

When do we start using harder binder grades to manage bleeding? The New Zealand Transport Agency (NZTA) says it is developing an "improved specification for bitumen with climate change in mind" and trialling harder road surface binders that are more resistant to tracking. [3]. There may also need to be an increased use of polymer modified binders, with their associated higher softening points.

Our current sealing methods require dry, hot weather. Will our traditional sealing season with predictable start dates and end dates survive?

If we transition to emulsions, what do we know about emulsions and intense rainfall events?

3 Connected and Autonomous Vehicles

What should we expect/design for - more cars on the road, or less? Does this depend on the ownership models adopted – a mobility service provider or private ownership?

Of particular interest to pavement engineers is traffic wheelpath wander – will this be programmed in or programmed out?

If truck platooning became a reality and the headway between trucks decreases, what result would this have on the visco-elastic response of bitumen, and then rutting?

A report from the California Department of Transportation [4] predicts that

• private ownership of autonomous vehicles (AVs) will prevail after a transition period, as was the case in other technologies like computers, tractors, and cars.

• the cost of privately owning AVs will decline and they will be customized to meet individual tastes.

• will be an increase in vehicle miles travelled per capita, and there may be more vehicles on the road.

• an expansion of the transportation user-base to include those currently facing limited mobility.

4 Marginal materials

The best and most easily accessible materials have now been substantially used. Our current materials specifications are also based on these materials.

Austroads has published work on *the appropriate Use of marginal and non-standard materials in road construction and maintenance* [5] which will need implementation.

Otta Seals, quite common in South Africa, are now generating interest amongst local governments in Australia due to their ability to use existing material that would otherwise not meet a specification, and yet provide a durable, low maintenance, low-volume road treatment [6][7][8].

5 Alternative materials

Do we know for sure if any of the following actually improve the performance of a binder, asphalt mix or stabilised pavement?

• Waste photocopy and printing toner

• Waste paint

• Coffee grinds (Swinburne Uni have been researching this!)

• Glass

• Waste plastic

The reserve bank is able to do a bank interest rate 'stress test' to test our economic resilience. What about a 'stress test' for our key materials becoming unavailable?

5.1 Soybeans

Researchers at the University of Engineering and Technology Lahore, Pakistan, are investigating the improvement in the performance characteristics of asphalt binders mixed with soybean derived materials (SDM). Their results suggest that the SDM modified asphalt binders improved fatigue and rutting performance parameters by 67% and 45% [9].

Similarly, in the United States soybean oil is being investigated as a renewable polymer for use in asphalt pavements [10].

5.2 Electric arc furnace steel slag

Researchers in India are investigating the use of electric arc furnace steel slag as an alternative aggregate for open grade asphalt [11].

5.3 Waste plastic

On 18 July 2017 China announced to the World Trade Organisation that it will no longer accept certain kinds of solid wastes from 31 December 2017. This includes plastics waste, unsorted waste paper and waste textile materials [12].

Since then there has been a frantic increase in Australia in the use of waste plastics in asphalt pavements. This is not without its critics, who argue that unless it actually improves the engineering properties, and it can then also be re-recycled safely, then it is nothing more than linear landfill.

The New Zealand Product Stewardship Council (NZPSC) is concerned about moves to incorporate plastic packaging waste in roading asphalt, "The initiative is touted as a revolutionary means of 'recycling' our low-grade plastic packaging, but this isn't recycling, it's just another form of landfilling or dumping a material that is actually toxic" [13].

Some members of the NZPSC are concerned about the long-term environmental implications of using plastic waste in roads.

"Similar initiatives overseas have been slowed by roading engineers who cannot guarantee these plastic roads will not detrimentally affect the environment as the bitumen undergoes wear and tear from use or is damaged by possible natural disasters".

"Some have argued that adding plastic waste to roading is simply replacing one polymer with another. But that is not correct. Post-consumer plastics contain a wide range of toxic additives. When these eventually weather and break down into micro and nano sized pieces, they are more available as pollutants in soil, and they enter rivers and marine environments via stormwater systems. They also become airborne and pose risks to lung health when inhaled" [13].

5.4 Those yet to be developed by Artificial Intelligence.

Artificial Intelligence can slash the time needed to develop new materials [14]

Our ability to discover and master new materials has defined successive stages of economic development: wood and clay; bronze and steel; paper; glass; plastics; semiconductors. It is our mastery of silicone that allowed the digital revolution to unfold.

We can now harness the power of digital technologies to accelerate the discovery of new materials, by marrying A.I. and materials science. The Canadian Institute for Advanced Research reported earlier this year that leveraging A.I. could cut the average time needed to develop a new material from the current 10-20 years to one-two years [14].

6 Nanotechnology

A nanoparticle is generally defined as a particle with its least dimension being less than 100 nanometres (< 0.000000100 m).

A nanoparticle interacts with bitumen at the molecular level.

6.1 Carbon (Graphene) Nanotubes

Carbon nanotubes (CNTs) are one-atom-thin sheets of graphite shaped into a hollow cylinder. They are expensive to produce & separate, and dispersion into bitumen is a challenge. They could produce an improvement against fatigue and permanent deformation [15].

6.2 Graphene Nanoplatelet (GNP) Reinforcement

Graphene sheets of single layer of carbon atoms are made from exfoliated graphite. They have a significant effect on the complex modulus of the bitumen, give improved asphalt flexural strength at low temperatures, and allow faster asphalt compaction at lower temperatures [15].

6.3 Nano Modified Aluminium Oxide

Research in Saudi Arabia has shown that as the concentration of Nano Modified Aluminium Oxide increased, the resistance of asphalt binder to rutting and fatigue increased also. Increases in complex modulus values were consistently observed for all modified asphalt binders compared to the base asphalt binder [16].

6.4 Nano-Functionalized Clay

Synthetic polymers and bitumen are not naturally compatible. Conventional polymer modified binders can be unstable in storage, reverting from single phase to two phase systems. Organo-functionalised clay and bitumen is compatible. It is possible that the functionalised molecules on the clay simulates the saturates in bitumen thus enabling the two to become a single system. This removes issues of stability and phase separation, whilst improving temperature sensitivity performance [17].

6.5 Nanosilica

Research at the University of Tehran, Iran, investigates the modification and enhancement effect of two morphologically different nanosilica materials: (i) a synthesised fibrous with porous structure and (ii) a commercial spherical with nonporous structure, on asphalt binder [18].

7 Bitumen alternatives

7.1 Sawmill residue

Sawmill residue, which includes sawdust, remnant woodchips, shavings and offcuts, is currently used for lower value uses such as landscaping and boiler fuel.

On behalf of the Australian Government, the Australian Renewable Energy Agency has announced up to AU$500,000 in funding to investigate the feasibility of building a 'second-generation' biofuels refinery using the waste sawmill residues from the timber hardwood sawmill at Herons Creek near Port Macquarie.

If the study is successful, the proposed biorefinery could convert up to 50,000 tonnes of waste sawmill residue produced each year into transport-grade renewable diesel and bitumen [19].

7.2 Epoxy

Bitumen is used as a waterproof glue, to keep water out of the crushed rock pavement and to glue the skid resistant surfacing in place. Could epoxy do this too?

Epoxy modification of bitumen is being practiced in New Zealand in open grade asphalt [20]. If this were then to find its way into sprayed sealing [21] our historic seal design methods may no longer apply.

8 Skills in the workforce

Who in the workforce will ensure that the research discussed above is translated into reality – who can make it all happen?

It is reported that skills shortages remain a critical issue, with mid management professionals in engineering, technical and IT fields the most difficult to recruit. Employers have reported that technical skills have the highest impact on the effectiveness of their organisation [22].

What is a skills shortage? A good working definition is "*There are few people who have the essential technical skills who are not already using them and there is a long training time to develop the skills*" [23].

The general advice some recruitment specialists give to employees is to futureproof skills against automation. It is inevitable that robots will take over routine, repetitive tasks. Employers are looking for people who are proactive, embrace change and can add to strategic value. This creates a need for more highly skilled employees to perform higher value job responsibilities [22][24].

An Australian Local Government Association report found that Australian Councils are also struggling to fill engineering roles [25]. Local governments were asked to list their top five skills shortages. In all three categories of council – rural and rural remote; urban and urban fringe; and urban regional – engineers were listed as the occupation representing the greatest skill shortage.

The reasons given for the skills shortage were: inability to compete with the private sector on remuneration; lack of suitably qualified and experienced applicants; high demand across the labour market for specific occupations; shortage of skilled locals – limited talent pool; remoteness – hard to recruit skilled and experienced staff; lack of opportunity for career progression particularly in small councils; regional/remote location – lack of facilities/housing.

There were also some unpleasant findings around training. Of the local governments that participated in the survey, 60% have unmet training needs resulting from the high cost of training and lack of training available locally.

Austroads members are also experiencing skills shortages with transport analysts, planners and a range of designer cluster skills (engineers, surveyors, spatial scientists, cartographers and procurement managers) rated as being very difficult to source now. [26].

For Australia, the key 'roads related' occupations which are already deemed to be in shortage at the national level include [26]:

- Construction Trades Workers
- Architects in the eastern states
- Surveyors
- Civil Engineering Professionals
- Construction Estimators.

9 Will Robots take over our jobs?

With more tasks being done by machines, the kinds of skills employers need their workers to possess are changing. And the skills employers increasingly need are in short supply. Demand is shifting from manual skills to cognitive skills – from the hands to the head – and from routine to non-routine [27].

The news is not all bad.

For every problem there is a job, and we are not running out of problems [28].

New technologies will have the capacity to automate many tasks, but also create as many jobs as they kill, and employment is growing in roles that are hardest to automate [28].

10 Skills needed in Pavement Engineering

In 2019, the demand for pavement engineers in Victoria is greater than supply, and this may well impact on the delivery of the government funded Infrastructure

We know that road pavements have been around since the Roman army needed to shift their chariots – but pavements haven't stopped there. The road freight task keeps growing, the best quality natural materials are now harder to find, connected and autonomous vehicles will change behaviours – and there is a push to bury more plastic bags in our pavements.

In addition to the traditional skills, pavement engineers now need to have additional skills including utilising new materials and understanding expected pavement life.

10.1 Utilising new materials

Re-purposing waste material is currently a key focus. The community expects that waste materials can be used but do not want a lowering of the resultant level of service, or any increase in cost.

10.2 Predicting pavement performance

It can be expected that empirical modelling (based on past experience) will become less accurate as the quality and composition of pavement materials change into unknown territory, in which case mechanistic modelling will become more important; and stochastic (based on probabilities) is better than deterministic (a single mathematically exact solution) for managing risks. It is the view of some in the pavements industry is that predicting pavement behaviour is now one of the major challenges in pavement management.

11 Upskilling

We can best summarise upskilling with a selection of quotes.

The illiterate of the 21st century will not be those who cannot read and write, but those who can learn, unlearn, and relearn – a paraphrase of Alvin Toffler [29]. This was written 50 years ago and is hauntingly prescient!

It's not about what the future will look like – because we don't know ourselves – but to think more about flexible scenarios about what could happen and what we would do in each one. To think through the possibilities and keep managing it as you go. You have to be agile. No one can predict it. That skill, not to be stuck in one way of thinking, is very important. – An Australian university [26].

Keeping abreast of developments in technology, understanding what scenario is emerging and having the flexibility to adapt as required will be important skills in their own right [26].

12 CPEE Approach

Traditional universities were not serving specialist needs, and in particular the pavement sector. To fill this gap the Centre for Pavement Engineering Education was formed 25 years ago as a not-for-profit association, to promote, encourage, foster, and develop integrated quality education in the theory and practice of specialised pavement engineering and road technology, including asset management and related fields.

The academic functions of CPEE are managed by an academic board who are concerned with the integrity of teaching and scholarship.

CPEE has earned federal government accreditation as a higher education provider, and offers a Master's of Pavement Technology. Students are able to undertake study anywhere in the world via a dedicated online learning management system, allowing working practitioners to complement their current employment needs.

13 Benefits of online learning

Policymakers and commentators may worry that online education is a second-best option, but it is best not to confuse the quality of instruction the mode of delivery. Across the world, high-quality education providers can point to equivalent learning outcomes from blended and fully online learning.

Good teaching is good teaching — whether it's on-campus or online. It is all about course design and the quality of the learning and teaching. And there are great advantages to online education. Where students could easily get lost in an impersonal lecture theatre, when done properly, online students are enrolled into small classes of about 20 to 25 students, not lecture theatres of 1000.

Today's online students work with leading academics, tutors, peers, learning advisers and fellow learners across the globe, all brought together through vibrant and highly relational learning communities. This is what we call online education. Sometimes it's fully online. For campus-based students, it is a blend of both online and face-to-face. The constant is the technology-enabled continuous collaboration and interaction. This is the opposite of distance education. [30].

14 Conclusions

The engineering field needs staff well prepared to deal with the introduction of new technologies in an informed manner, to manage risks and to maximise community benefits. It would seem relevant continuing professional development is now becoming a survival skill rather than just a nice-to-have.

Continuing professional development for people working in regional areas should also not be neglected.

Online education has advantages, and can give continuous collaboration and interaction to anyone with an internet connection. This is the opposite of the older 'distance learning'.

Face to face training and the interaction it provides also has a valid place, and this can be the economical solution in a short-course context.

Finally, there is often a barrier between innovation and implementation, and this barrier can only be bypassed using knowledgeable people. The authors believe that our industry needs to be better prepared than what we are and strive hard to ensure that viable options are available to facilitate continuous learning – and re-learning.

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