Investigating the Viability of Artificial Intelligence and Blockchain Technology to Enhance the Transport Sector

Research Report No. 2 – Final Report

Authors: Dr Karlson 'Charlie' Hargroves, Professor Bela Stantic, and Dr Darcy Allan

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Project Steering Group

Project Leader: Dr Karlson 'Charlie' Hargroves, Curtin University Sustainability Policy Institute, Curtin University.

Researchers: Professor Bela Stantic, Griffith University; Dr Darcy Allan, RMIT.

Core Members: Ken Michael AO (Chairperson), Keith Hampson, CEO SBEnrc; Steve Atkinson and Ash Radhakrishnan, MRWA; Claire Thompson, WA DoT; David Scott and Jamie Noda, NSW RMS; Charlie Hargroves and Daniel Conley, Curtin University; Bela Stantic, Griffith University; Jason Potts, Nicola Narayan, Darcy Allan and Alastair Berg, RMIT; Slaven Marusic, Aurecon.

Project Partners: Matthew Yong, John Calomiris, and Callum Beutel, Qld TMR; Sue Hellyer, and Dominique Thatcher, Fremantle Port Authority.

Affiliates: Charles Karl, ARRB; Rob Hanson, Data61 (CSIRO); Kasey Kaplan, Blockchain in Transport Alliance (BiTA); David Hollands, HP; Erik Lecis and Paul Philips, NVIDIA; and Alex Stott, Roads Australia.

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1 EXECUTIVE SUMMARY

In response to growing interest in the availability of new digital technologies to assist the transport sector the SBEnrc was tasked by its partners to investigate specific use cases of both Artificial Intelligence and Blockchain Technology to identify real world applications. The research project identified 15 use cases for Artificial Intelligence and 9 use cases for Blockchain (as shown in Table A) and undertook an investigation into each to inform the selection of a short list for further investigation based on the level of interest to project partners. As part of the process the research team facilitated a series of partner workshops to present an entry-level overview of the main functionality of both types of technology, namely Artificial Intelligence and Blockchain Technology, with an emphasis on what is new or unique, and focusing on functionality rather than the technical nature. The sessions then considered the potential value to partners of each use case and the current level of implementation and received input into the selection of the short list. As a result a short list of three use cases were selected for each type of technology, informed by the level of value and the level of current application across the partners.

The next stage involved a process to refine the short list to identify a lead use case for each technology type. Working closely with partners, a set of criteria was created to investigate the use cases and prioritise the importance to partners of each, this was then used as the basis to select the lead use cases (See Table B). The following use cases were identified:

1. The use of Artificial Intelligence to enhance traffic optimisation with a focus on traffic management and signalling, and

2. The use of Blockchain Technology to enhance freight tracking and authenticity, including real-time location and confirmation of origin and delivery.

This report presents research findings for each of the two areas in response to the following questions:

- How is the technology currently being used and what new functionality is being promised?

- Which of the applications are most suited and what are the associated risks and rewards?

- What are recommended strategic approaches to implementation that transport agencies should consider?

- What policies and mechanisms should be used to support these technology applications?

Given the rapid advancement of technology in both Artificial Intelligence and Blockchain Technology applications this report provides a valuable resource to clarify not only how to identify and interrogate such technologies for their suitability for implementation, but also clarify the current state of play on two lead use cases of most interest to partners.

2 PURPOSE OF REPORT

Building on the research undertaken in SBEnrc Project 1.45 Big Data, Technology and Transportation, the aim of the project is to investigate "*How can Artificial Intelligence and Blockchain Technologies provide value to the transport sector, and what planning and policy recommendations would underpin their implementation?*". The purpose of this project was to explore a range of digitally-driven opportunities and challenges in seeking to get cities moving and functioning better; with a focus on the application of Artificial Intelligence and Blockchain Technologies.

The objectives of the project are to:

1. Develop a clear working understanding of the functionality of Artificial Intelligence and Blockchain Technology (relevant to project scope),

2. Investigate the potential for Artificial Intelligence and Blockchain Technology to be used to deliver value in the transport sector (and create a short list of preferred options),

3. Identify the risks and rewards associated with the application of Artificial Intelligence and Blockchain Technologies in partner-preferred areas,

4. Develop recommendations around selected options for the implementation of Artificial Intelligence and Blockchain Technologies in the transport sector, and

5. Review and recommend specific policies and mechanisms to underpin the application of selected Artificial Intelligence and Blockchain Technology options in the transport sector.

This report presents the findings of extended findings of Item 2 to include a process of assessment of the short listed use cases using partner preferred criteria.

3 SUMMARY OF PROJECT FINDINGS TO DATE

In response to growing interest in the availability of new digital technologies to assist the transport sector the SBEnrc was asked by its partners to investigate specific use cases of both Artificial Intelligence and Blockchain Technology to identify real world applications that may be of interest to the partners, with a list of 24 use cases identified and shown in Table A.

Selected Applications of Artificial Intelligence	
Identification of Transport Network Characteristic	*Enhanced Traffic Risk Management*
Simulating Behaviours of Self-Driving Vehicle	*Optimisation of Ride-Sharing Services (MaaS)*
Enhanced Traffic Management	*Detecting Fare Evasion and Turnstile Shadowing*
Tracking Vehicle Behaviour	*Routing and Management of Drones*
Identification of Vehicle Breaches	*Enhanced Asset Management*
Enhanced Real Time Traffic Signal Optimisation	*Monitoring Vehicle Locations*
Vehicle Prioritisation (Emergency and Shared Transit)	*Comparing Modal Trip Times*
Route Optimisation (Emergency and Freight)	
Selected Applications of Blockchain	
Verified Vehicle Ownership Documentation	*Establishing Identification*
Real Time Road User Pricing	*Enabling Intermediary Free Ride Sharing*
Congestion Zone Charging (Virtual Zones)	*Vehicle Generated Collision Information*
Collection of Tolls and Charges (Virtual Gantries)	*Enhanced Freight Tracking and Authenticity*
Automated Car Parking and Payments	

Table A: Summary of use cases identified that stand to provide value to the transport sector

Once the initial list of use cases was identified the project undertook a series of stakeholder workshops in order to achieve three outcomes, namely:

1) Present an entry level overview of the main functionality of both types of technology, namely Artificial Intelligence and Blockchain Technology, with an emphasis on what is new or unique, and focusing on functionality rather than the technical nature.

2) Consider the potential value to partners of each use case and the current level of implementation, including identification of ways the technologies might be synergistic.

3) Receive input into the selection of a short list of use cases that are of greater interest to partners for inclusion in the next stage of the project, or subsequent projects.

As a result of the findings from the workshop series, with sessions in Perth, Melbourne, Sydney and Brisbane, a short list of use cases was selected, informed by the level of perceived value and the level of current application across the partners. In addition to the short list the workshop in Perth identified particular interest from both Main Roads Western Australia and Fremantle Ports to explore the potential for synergies between freight movements and the traffic management system. This may be achieved by interaction between a Ports Blockchain that is set up to streamline transactions in and out of the Port that can also allow encrypted permissioned access to particular freight operator data, to allow for mutually beneficial interaction with the traffic management system.

As a result of the preferences from partners the following 6 options were chosen for further investigation to identify the final use cases for detailed investigation.

Short-Listed Use Cases for Artificial Intelligence in Transport

- Identification of Network Characteristics and Asset Management.
- Traffic Optimisation (Management and Signalling)
- Vehicle Prioritisation (Emergency and Shared Transit)

Short-Listed Use Cases for Blockchain Technology in Transport

- Real Time Road User Pricing (Charging for time of day and road type usage).
- Establishing Identification (Digital drivers' licences and vehicle ownership).
- Enhanced Freight Tracking and Authenticity (Real time location and confirmation of delivery).

Following the identification of the short list a process of engagement with partners was undertaken to identify preferred criteria to inform the selection of the lead use cases for detailed investigation, with the findings presented in Table B.

Criteria for Consideration of Use Cases	**Level of Importance**		
	High	*Med*	*Low*
Level of maturity of technology (*has the technology been proven or is it still in development? Is there venture capital behind it? Is there a regulatory framework?*)	4	0	0
Potential for quick wins with minimal expenditure and time commitment to catalyse early efforts (*are there opportunities for 'low hanging fruit'?*).	4	0	0
Prerequisites for data availability, format and interval (*what expectations of data, requirements for data collection or cleaning, existing standards?*).	4	0	0
Capital and operational expenditure (*what costs are involved in both setting up the system and running it?*).	3	1	0
Level of difficulty (*can the solution be implemented and maintained internally without expert support? Is it modular and/or open architecture?*)	2	2	0
Current level of uptake (*is it implemented by at least 1-2 organisations in Australia or preferably around the world and are benefits being reported?*).	1	3	0
Potential for multiple benefits for various users and departments (*who benefits and can some applications benefit a wider group of stakeholders?*).	1	3	0
Level of integration required across departments (*does it require approvals and involvement from multiple departments?*).	0	2	2
Potential for early efforts to underpin future applications (*can early adoption provide enablers for additional functionality?*).	0	1	3

Table B: Findings of partner perceptions of the level of importance of criteria for consideration of use cases

The following presents the findings from the investigation of each use case against each of the key criteria. The next stage was to select two lead use cases for investigation of risk and rewards in order to inform strategic recommendations. Based on the findings of the desktop review the following lead topics were selected, and based on the questions listed below a final investigation was undertaken by the research team with the results provided in this report:

1. The use of Artificial Intelligence to enhance traffic optimisation with a focus on traffic management and signalling (led by Professor Bela Stantic, Griffith University).

    - How is artificial intelligence currently being used to enhance traffic management and what new functionality is being promised?
    - Which of the applications of AI are most suited to traffic optimisation in Australia and what are the associated risks and rewards?
    - What are recommended strategic approaches to implement the AI applications that transport agencies should consider?
    - What policies and mechanisms should be used to support the AI applications?

2. The use of Blockchain Technology to enhance freight tracking and authenticity, including real-time location and confirmation of origin and delivery (to be led by Dr Darcy Allan, RMIT).

    - How is Blockchain Technology currently being used to enhance freight tracking and authenticity and what new functionality is being promised?
    - Which of the applications of Blockchain Technology are most suited to freight tracking and authenticity in Australia and what are the associated risks and rewards?
    - What are recommended strategic approaches to implement these Blockchain Technologies that transport agencies should consider?
    - What policies and mechanisms should be used to support these Blockchain Technology applications?

4 FINDINGS OF CRITERIA ASSESSMENT OF USE CASES

The purpose of this section is to present a succinct summary of the findings of the performance on the selected criteria of each of the use cases to inform the selection of use cases to undertake a deep dive investigation

4.1 Use Case 1: Identification of Network Characteristics and Asset Management

4.1.1 Data Requirements

Few open source datasets are available on this topic however some data repositories such as Kaggle, MARTA Hackathon, catalog.data.gov, and statistica.com appear to have associated datasets. In addition, a large number of diverse data sources (ranging from health to climate related data) are available from various government and organisational sources to improve the IoT technologies under free usage or creative commons licences. For example, GPS trajectory dataset was created by Microsoft Research Asia Geolife project, Social IoT, free datasets from public and government sources are available for downloads on various organisational websites.

4.1.2 Level of Maturity

There are 11,400 articles published on the 'IoT-transport' topic in 2019 alone, this suggests that this technology can be considered as a 'Mature' and even a trendy field of innovation. There are numerous IoT applications in transport technology with the most common use cases being asset management,[1] fleet management, public transit management, smart inventory management, optimal asset utilisation, and geo-fencing.[2] IoT has already generated significant interest from both emerging and traditional capital investment communities including corporate VCs (i.e CISCO, Intel, Google), accelerators, and government. A significant portion of this capital is also directed towards industrial IoT start-ups.[3] The transportation industry has started to rely heavily on IoT and experts are forecasting the transportation industry will spend $40 billion annually on IoT by 2020.[4] In Australia, the 'IoT Alliance Australia' (IoTAA) works as a regulatory body and has developed a guideline on security and IoT called the 'Internet of Things Security Guideline'.[5] There are currently no federal cybersecurity frameworks in the USA that explicitly address security or management of IoT. Some non-governmental organisations like the 'Industrial Internet Consortium' have issued IoT security frameworks, but there is no clear consensus.[6] IoT regulation and policies are under development in many countries.

4.1.3 Potential for Quick Wins

Suggestions for small IoT projects or investments that stand to generate short term payback include:

- Connected operations (e.g. network of devices, sensors and meters),
- Remote operations (Monitor, control, and asset management),
- Predictive analytics (E.g. Identify, understand and immediately take best actions), and

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[1] IBM (2019) Understanding the impact and value of enterprise asset management, White Paper, IBM.
[2] Verma, S (2018) *Top 5 Use Cases or IoT in Transportation*, DZone, 06 August 2019.
[3] Blackman, J. (2019) *Venture capital flows for industrial IoT start-ups – 2018's biggest bets on Industry 4.0*, Enterprise IoT Insights, 03 January 2019.
[4] Cosgrove, C. (2018) *IoT Applications in Transportation*, IoT for All, 18 September 2018.
[5] IoTA (2017) Internet of Things Security Guideline, IoT Alliance Australia.
[6] Sherman, J. (2018) U.S. *Federal IoT Policy: What You Need to Know*, Tripwire, 18 September 2018.

- Predictive maintenance (increase uptime and productive hours).

Each of these applications can then be expanded into more strategic IoT implementation options.[7] It is clear from the literature that the consensus is that implementing the right IoT asset management solution pays back in increasing productivity, cost reduction, improved quality, and smart decision making.

4.1.4 Capital and Operational Expense

When considering IoT applications the expense is often considered as a hybrid of both CAPEX and OPEX without one dominating the other as can be the case in other technologies. The initial investment in an IoT project is sufficiently low compared to the cost and/or value and/or planned duration that it stands to provide tangible value cost effectively. The operational cost of running IoT is the cost of operating the IoT deployment, including software licensing, cloud access, or local infrastructure deployment. Traditional ROI - or even a Return on Marketing Investment (ROMI) - model would not work for IoT. The initial investment is the main differentiator of this index: as it's the only element in the function representing a point in time cost, whereas all other factors are recurring cost and/or revenue. With these factors in mind, a simple formula can be proposed: the overall return, in terms of all up value, of an IoT investment for Digital Transformation is informing an index that we will be calling ‘Return on IoT Adoption’ (ROIA).[8] It looks like this:

> *Return of IoT Adoption = (Incremental value generated by IoT - Operational cost of running IoT) / Initial investment*

4.1.5 Level of Difficulty

Implementation challenges in developing IoT projects are multi-dimensional as many technologies are involved. For example, data security, technology and communication infrastructure, immaturity of IoT standards, and procuring IoT, are the main issues. Implementing such projects often involves procuring devices, instrumentation, communication networks, storage, and data management consultants. The complexity of such projects requires domain expertise during implementation.

4.2 Use Case 2: Traffic Optimisation (Management and Signaling)

4.2.1 Data Requirements

A Google dataset search found more than 50 data sources on traffic optimisation, however few websites have made the data available under creative commons licences. Catalog.data.gov, datadiscoverystudio.org, data.wu.ac.at, data.nasa.gov, purr.purdue.edu figshare.com are some websites found having data on traffic management and optimisation. Highways England network journey time and traffic flow data could be a useful source for modelling traffic optimisation problem.[9]

4.2.2 Level of Maturity

Google scholar shows that 24,100 publications are available on this topic since 2015 whereas 16,400 research articles are published in the year 2019, which shows a steep increase of interest among research community. Australia’s VC firms suggest that logistics and transport industries are ripe for a major “shake up”, and are paying particular attention to this area.[10] A recent article on techcruch.com

[7] Kranz, M. (2017) *How to Get Started with IoT and Generate Quick Returns on Your Investment*, IoT for All, 28 April 2017
[8] Majonshi, M (2019) *Measuring the true impact of IoT*, Linked-In, 19 April 2019.
[9] See webtris.highwaysengland.co.uk.
[10] Powell, D. (2018) *Five things one of Australia’s VC firms says it’s looking for in startups*, StartCompany, 23 January 2018.

reported that more than $120 million fund from Autotech ventures is focused on ground transportation start-ups and technologies.[11] The NSW government has targeted Sydney's congestion issues with a transport management system upgrade and funded cubic corporation $123 million contract to help tackle Sydney's congestion. Upgrading Sydney's Transport Management Centre (TMC) is anticipated to help reduce the time it takes to respond to traffic incidents by automating manual processes.[12]

4.2.3 Potential for Quick Wins

Adaptive traffic signals are getting smarter through Vehicle-to-Infrastructure (V2I) technology.[13] The better the idea of traffic flow and how long a vehicle sits and idles at stop lights, the better a city or corridor can modify traffic signal timing to accommodate changes in traffic conditions throughout the day. Cities in the US are using data gathering from government fleet vehicles as part of smart city pilot programs to improve the timing of traffic signals. In addition, real-time traffic feedback and tracking pedestrian movements are two interesting fields which have potential under the V2V and V2I technology.

4.2.4 Capital and Operational Expense

There are 3 cost components involved in traffic management project: engineering (data collection), services (network modelling, signal timing optimization, preparing new timing directives) and administrative (implementing signal timing).[14]

4.2.5 Level of Difficulty

As the technology is mature there are many published articles and reports on successful case study projects available. Examples of implementation of different forms of associated algorithms are available on GitHub repository. Initiation stages of implementation may require consultation from domain experts.

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[11] Loizos, C. (2017) *A new transpiration-focused fund just landed $120 million from a wide range of transport companies*, Techcrunch, 13 July 2017.
[12] Pearce, R. (2018) Cubic scores $50 million contract to help tackle Sydney's congestion, Computerworld, 29 August 2018.
[13] Sotra, M. (2017) 7 Smart city solutions to reduce traffic congestion, Geotab, 16 November 2017.
[14] Chien, S. Kim, K., and Daniel, J. (2006) Cost and Benefit Analysis for Optimized Signal Timing—Case Study: New Jersey Route 23, ITE Journal, October 2006.

4.3 Use Case 3: Vehicle Prioritisation

4.3.1 Data Requirements

Some conventional data collection mechanisms have been developed by road transport agencies over many decades as the most cost-effective sources of data to manage operations and plan for future network needs. Like all data collection methods, there is generally a trade-off between collection cost, network coverage and data accuracy. Existing traffic data collection generally relies heavily on embedded vehicle detection equipment such as road traffic sensors (e.g. inductive loops, pneumatic strips and piezo-electric sensors), along with road-side observers, traffic cameras are dominant devices for data collection. Other data resources may include Tom-Tom API service congestions data and U.S. Department of Transportation.

4.3.2 Level of Maturity

Google scholar found more than 4000 research articles based on searching vehicle prioritisation as keywords and 'vehicle prioritisation traffic management' keyword found more than 6000 papers. This is a hot topic in research and industry and it's an important component in driverless vehicles research. According to a Reuters' article the traffic management system market is expected to be worth US$18 billion by 2023 and the key players in this field are Accenture PLC, Alstom Holding SA, CISCO System Inc., Cellint, Cubic Corporation, GE Transportation, IBM Corporation, Kapsch AG, Lg Cns and Siemens AG.[15] Many VC Firms are investing in the mobility of the future and some of them have dedicated funds for auto-mobility,[16] such as Autotech Ventures, a three-year-old bay Area-based venture fund that is focused on ground transportation start-ups.[17]

4.3.3 Potential for Quick Wins

Transportation prioritisation can be implemented in virtually any geographic area and by any level of government, although it tends to be most appropriate in areas where there is moderate to large demand for alternative modes (transit, ridesharing, cycling and walking).[18] This is one of the key challenges in multi-modal cities and has enormous scope for balancing loads on traffic networks.[19]

4.3.4 Capital and Operational Expense

Depending on the type of system implemented and the number of junctions on the transport network to be equipped with new technologies, costs can vary greatly. The cost categories that need to be considered are: the cost of upgrading existing infrastructure; cost of additional equipment for vehicles; and the cost of implementing a priority system at traffic lights.[20]

4.3.5 Level of Difficulty

A number of steps are involved for successful implementation, such as, collection of required data, approval from many stakeholders, technology development, information campaigns, etc.[21] Some existing technology and simulation might be available, however, expert consultation will be required.

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[15] Daniel, A. (2018) *Traffic Management System Market To Be Worth USD 18 Billion By 2023*, Reuters, 26 July 2018.
[16] Sandler, E. (2017) *10 VC Firms Investing in the Mobility of the Future*, AutoFinance news, 02 October 2017.
[17] Loizos, C. (2017) *A new transpiration-focused fund just landed $120 million from a wide range of transport companies*, Techcrunch, 13 July 2017.
[18] VTPI (2017) *Prioritizing Transportation: Prioritization in Transportation Planning, Funding and Management*, Victoria Transport Policy Institute, 02 January 2017.
[19] King, D. (2014) *3 Big Challenges for Planning Multi-Modal Cities*, CityLab, 09 October 2014.
[20] CIVITAS (2010) Policy Advice Notes: Prioritisation of Public Transport in Cities, CIVITIAS.
[21] CIVITAS (2010) Policy Advice Notes: Prioritisation of Public Transport in Cities, CIVITIAS.

4.4 Use Case 4: Real Time Road User Pricing

4.4.1 Data Requirements

Data is required on the real time location of the vehicle in order to assign a charge for use of the transport network. Data collection and requirements will differ with the specific application of pricing and may raise privacy concerns, including issues around the de-identification of data. Note that much of the focus of real time road user pricing has emphasised the future application of self-driving vehicles—rather than existing vehicles—and is closely tied with questions around falling fuel taxes.

4.4.2 Level of Maturity

The application of real-time road user pricing is immature due to lack of a suitable technology platform and early efforts have focused on the future of self-driving vehicles that have such technologies. There is no clear regulatory framework, but there are some consortia seeking to coordinate adoption, such as the Mobility Open Blockchain Initiative (MOBI).

4.4.3 Potential for Quick Wins

Unlikely for quick wins given this would likely require a significant infrastructure upgrade on vehicle and across the transport network long with the coordination of many parties. Unlike some other applications it is difficult to run a parallel road pricing system without replacing the existing one which is based on fuel taxation rather than actual road use, which made sense pre-electrification of vehicles.

4.4.4 Capital and Operational Expense

Potentially high capital and operational expenditure but no clear precedent to inform estimates.

4.4.5 Level of Difficulty

Reliant on external parties and many stakeholders. This would require external support including governments. The nature of architecture would depend on the specific application. It would be difficult to organise around standards.

4.5 Use Case 5: Establishing Identification and Ownership

4.5.1 Data Requirements

Licences: Likely to face significant privacy questions and this will determine the nature of data stored on-chain or off-chain. Further, apart from self-sovereign identity Blockchain projects, this is likely to require significant government involvement at the state level.

Vehicle Ownership: One major challenge with vehicle ownership on a Blockchain will be obtaining historical information about the vehicles (ownership history, service history). For clean data this application will likely only apply for new vehicles.

4.5.2 Level of Maturity

Licences: A digital drivers licence that utilises Blockchain has been trialled in NSW (1400 motorists) and will soon be expanded. Legislation was passed for the digital licence in May 2019 in NSW noting that physical or digital licences are recognised.

Vehicle Ownership: The technology to record a registry of vehicle ownership exists, but there are likely to be significant challenges around the on boarding of existing ownership history and ensuring robust data entry from vehicle servicing companies.

4.5.3 Potential for Quick Wins

Licences: Unlikely for quick wins given this would require wholesale government recognition and support of the system, however trials in NSW may advance this. One fast approach would be through running a parallel identification system. Or on an opt-in basis. Unclear what the specific benefit would be compared to an existing licence system, except when more broadly integrated into identification systems reducing onus on providing identification in some cases.

Vehicle Ownership: Few clear quick wins. New vehicles could be registered and tracked throughout their lifecycle and information around service history could be stored and validated to provide to prospective buyers or to support insurance claims.

4.5.4 Capital and Operational Expense

High, given interactions with other government applications.

4.5.5 Level of Difficulty

This would require external support including governments. In the NSW they worked with Secure Logic.

4.6 Use Case 6: Enhanced Freight Tracking and Authenticity

4.6.1 Data Requirements

What data is required is still an open question and will change depending on what is being tracked. For example, data could be generated through manual inputs (less reliable but smaller infrastructure upgrade) to implementing sensors (such as RFID tags and new IoT devices). There are no clear existing data standards but there are efforts at the international level to develop data standards (as well as smart contracting standards). Ensuring data integrity will be critical.

4.6.2 Level of Maturity

This is one of the major applications of Blockchain Technology and has received significant investment from major corporations including IBM, Maersk, Walmart. There is no regulatory framework that has been developed, but the International Standards Organisation (ISO) has a sub-committee focused on this application. Information about tracking will have to be integrated into existing domestic and international compliance requirements.

4.6.3 Potential for Quick Wins

Faster than others due to existing platform infrastructure and investments. Can begin with short trips and trials and run in parallel to other tacking systems. For instance, Commonwealth Bank has completed a trial tracking almonds and there are several other Australian companies working on these applications.

4.6.4 Capital and Operational Expense

The level of expenditure varies depending on the nature of tracking as well as the physical technology (installing IoT infrastructure) and on the type of institutional infrastructure (Blockchain platform). Any potentially high costs must be compared to the existing tracking system, which is costly.

4.6.5 Level of Difficulty

Applications would likely require external parties through Blockchain as a service. For freight tracking this would likely require a third party such as TradeLens or UCOT to provide the foundational Blockchain infrastructure and UX.

5 INVESTIGATION OF THE USE OF ARTIFICIAL INTELLIGENCE TO ENHANCE TRAFFIC OPTIMISATION WITH A FOCUS ON TRAFFIC MANAGEMENT AND SIGNALLING

5.1 How is artificial intelligence currently being used to enhance traffic management and what new functionality is being promised?

Traffic congestion has significant detrimental impacts on the economy, environment and quality of life of the community as evidenced by Review Sydney (2013):[22]

- Increase in transportation costs associated with road and freight tasks, which negatively affects national productivity and competitiveness.
- Increased CO_2 emissions from vehicles, due to increased idle time.
- The public discontent about the lack of effective traffic management as destination travel time is increased.

The increasing population of car and transport vehicles cannot be curbed; however, congestion on roads can certainly be managed through various infrastructural reforms and major usage of Artificial Intelligence. The following listed projects are only a few example cases related to traffic management.

5.1.1 Traffic light optimisation

Improving traffic flow and reducing congestion plays a critical role in Intelligent Transportation Systems (ITSs), which is a pervasive issue impacting urban areas around the globe. Rapidly advancing vehicular communication and edge cloud computation technologies provide key enablers for smart traffic management. However, operating viable real-time actuation mechanisms on a practically relevant scale involves formidable challenges. Policy iteration and conventional Reinforcement Learning (RL) techniques suffer from poor scalability due to state space issues. Motivated by these issues, the potential for Deep Q-Networks (DQN) is explored to optimise traffic light control policies. As an initial benchmark, the DQN algorithms yield the 'thresholding' policy in a single-intersection is established. Next, the scalability properties of DQN algorithms were examined and their performance in a linear network topology with several intersections along the main artery. DQN algorithms demonstrate that intelligent behaviour, such as the emergence of "green wave" patterns, reflecting their ability to learn favourable traffic light actuation.

5.1.2 Traffic fleet optimisation

The rise of the driverless and connected car, and the emergence of a ‘sharing economy’ of transportation seem poised to revolutionise the way personal mobility needs will be addressed in cities. The way current modes of transportation such as the private car, taxi, or bus operators will be challenged and increasingly replaced by personalised, on-demand mobility systems operated by vehicle fleets, similar to what companies like Uber and Lyft have started to offer. One fundamental unsolved problem is how to best size and operate a fleet of vehicles, given a certain demand for personal mobility. A scalable solution without requirements of changes in human attitudes towards mobility has been proposed by Vazifeh (2018)[23]. A network-based solution is proposed to the following ‘minimum fleet problem’: given

[22] IA (2013) A Review of Current Traffic Congestion Management in the City of Sydney, Infrastructure Australia (IA).
[23] Vazifeh, M., Santi, P., Resta, G., Strogatz, S. and Ratti, C. (2018) Addressing the minimum fleet problem in on-demand urban mobility. Nature, 557(7706): 534, 2018.

a collection of trips (specified by origin, destination, and start time), what is the minimum number of vehicles needed to serve all the trips without incurring any delay to the passengers. By introducing the notion of a 'vehicle-sharing network', an optimal computationally efficient solution to the problem, as well as a nearly optimal solution amenable to real-time implementation is provided. In an experimental dataset containing 150 million taxi trips taken in the city of New York over one year the real-time implementation of the method with near-optimal service levels allows a 30 percent reduction in fleet size compared to current taxi operation.

Public vehicle systems are envisioned to be a promising approach for efficient traffic-management platforms to solving traffic congestions and pollutions for future smart cities. Public vehicle systems provide online/dynamic peer-to-peer ride-sharing services intending to serve the sufficient number of customers with a minimum number of vehicles and lowest possible cost. A key component of the public vehicle system is the online ride-sharing scheduling strategy. Zhu *et. al.* proposed an efficient path planning strategy that focuses on a limited potential search area for each vehicle by filtering out the requests that violate passenger service quality level so that the global search is reduced to local search.[24] Performance of the proposed solution such as a reduction ratio of computational complexity is analysed.

5.1.3 Predictive logistics

Artificial Intelligence can help the logistics industry fundamentally shift its operating model from reactive actions and forecasting to proactive operations with predictive intelligence.[25] Most air freight lanes and networks are planned using historical data and expertise from professionals with decades of industry experience. DHL has developed a machine learning based tool to predict air freight transit time delays to enable proactive mitigation. By analysing fifty eight different parameters of internal data, the machine learning model can predict if the average daily transit time for a given lane is expected to rise or fall up to a week in advance. Furthermore, this solution can identify the key factors influencing shipment delays, including temporal factors like departure day or operational factors such as airline on-time performance. This can help air freight forwarders plan by removing subjective guesswork around when or with which airline their shipments should fly. Hidden deep within online browsing data, YouTube video views, and conversations on social media, AI in its current state can identify both the quantitative rise in interest in a topic, as well as the context of that interest from a semantic understanding of the unstructured text.

5.1.4 Traffic accident detection

Vision-based frameworks for object detection, multiple object tracking, and traffic near accident detection are important applications of an Intelligent Transportation System (ITS), particularly in video surveillance, etc. Real-time systems that monitor and analyse road users will become increasingly critical in smart cities. In recent years, deep neural networks have achieved success in many computer vision tasks. A uniformed framework for all three tasks is still challenging due to the demand for real-time performance, complex urban setting, highly dynamic traffic event, and considering many traffic movements. Huang *et. al*. (2019)[26] proposed a two-stream 'Convolutional Neural Network' architecture that performs real-time detection, tracking, and near accident detection of road users in traffic video data. The two-stream model consists of a spatial stream network for object detection and a temporal stream network to leverage motion features for multiple object tracking. The system detects near-accident scenarios by incorporating appearance features and motion features from two-stream

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[24] Zhu, M., Liu, X. and Wang, X (2018) An online ride-sharing path-planning strategy for public vehicle systems. IEEE Transactions on Intelligent Transportation Systems, 2018.
[25] Gesing, B., Peterson, S. and Michelsen, D. (2018) Artificial intelligence in logistics, IBM.
[26] Huang, X., He, P., Rangarajan, A. and Ranka, S.(2019) Intelligent Intersection: Two-Stream Convolutional Networks for Real-time Near Accident Detection in Traffic Video,2019.

networks. A Traffic Near Accident Dataset (TNAD) covering various types of traffic interactions that are suitable for vision-based traffic analysis tasks has also been developed using aerial videos.

5.1.5 Artificial intelligence in rail network

4Tel and the University of Newcastle are working together to develop specialist artificial intelligence and deep machine learning systems for use in the rail environment. Using driverless car technologies, the solution uses a hardware system called 'Horus' which is an Artificial Intelligent (AI) system to assist train drivers in detecting hazards in the rail corridor. Rail corridors rarely change making it ideal to explore and develop real-time visual detection software. By capturing the corridor master sequence and then using on-board visual processing, the corridor information is cross-checked with a detailed database enabling the system to detect if an object is in a potentially dangerous position to the train's path. While the system won't stop incidents from happening, it will minimise the impact through earlier detection.[27]

5.1.6 Case Studies

Machine learning, specifically deep learning technology, has been extensively used to process data to make real-time decisions and predictions on traffic and transport management.[28]

Intelligence Traffic Management System in Delhi, India

The Delhi Traffic Police have developed an intelligent traffic management system based on radar-based monitoring with the help of Artificial Intelligence.[29] One of the key tools in the system will be automated traffic signals. It will help the Delhi Traffic Police to analyse the traffic pattern, overall volume, and number of vehicles on a cloud which will be further used to manage the traffic. It will also contain features like high-resolution CCTV cameras to capture commuters and motorists breaking laws and automated number plate recognition cameras to directly send the fine. Approximately, 7,500 cameras with multidirectional infrared and colourless laser sensors will count the volume on arterial roads based on image pattern analysis. The aim is to all but eliminate the manual interface. Ideally, a traffic official on the road would leave the carriageway opened for equal minutes for a smoother flow of traffic. However, not all carriageways have a similar volume of traffic which means that the carriageways should be opened for a particular time duration depending on the volume of traffic it has. AI would use camera live feeds, sensors and even Google Maps to inform a predictive algorithm to instruct traffic signals to function accordingly. The management also plans to install 1,000 LED boards that will be synced with AI software and the cameras to display real-time information about traffic conditions during peak hours.

AI-based traffic management in Kuala Lampur

In Kuala Lumpur, Chinese e-commerce company Alibaba has launched a traffic management service called the 'City Brain'. The service use cloud computing and machine learning to minimise congestion on the city’s roads. City Brain sorts through a mass of incoming data from 300 traffic lights, 500 CCTV cameras, and public transport systems to minimise road congestion. It will use data mining, video processing, image recognition, and other processes to determine live traffic predictions and recommendations, for instance, calculating the fastest and least disruptive route for an ambulance through the city using the inflow of real-time data. City Brain was earlier deployed in China where average traffic speed increased by 15 percent and traffic violations were reported with 92 percent accuracy, according to Reuter’s reports.[30]

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[27] 4Tel (n.d.) *Artificial Intelligence*, 4Tel
[28] Baker, F. (2018) *The technology that could end traffic jams*, BBC, 13 December 2018.
[29] Kumar, V. (2018) *Artificial Intelligence: Application in traffic management system*, Medium, 12 October 2018.
[30] Kumar, V. (2018) *Artificial Intelligence: Application in traffic management system*, Medium, 12 October 2018.

Technologies that could end traffic jams

In Bengaluru, India, which regularly faces long traffic jams and the average speed on some roads at peak hours is just 4km/h (2.5mph), Siemens Mobility has built a prototype monitoring system that uses AI and traffic cameras. Traffic camera footage is used to automatically detect vehicles and this information is sent back to a central control centre where algorithms estimate the density of traffic on the road. The system then alters the traffic light patterns based on real-time road congestions. The data sources used by the AI system come from traffic monitoring systems, road infrastructure, cars and drivers themselves via their mobile phones.

Researchers at The Alan Turing Institute in London and the Toyota Mobility Foundation recently launched a new project to explore how traffic management systems can become more dynamic and responsive through the use of AI. They are currently using simulations that scale up in complexity and evolve, helping their algorithms to learn how to predict changes in the traffic. Although they are still testing the system, they hope to soon apply their systems in the real world. An adaptive traffic control system developed by researchers at the Robotics Institute, Carnegie Mellon University, has been rolled out around the city by a company called Rapid Flow Tech. Their Surtrac technology is being used at 50 intersections in Pittsburgh and since launching, it has reduced wait times at intersections by up to 40 percent, according to the company. It also claims that journey times in the city have fallen by 25 percent while vehicle emissions have dropped by up to 20 percent. The system uses video feeds to automatically detect the number of road users, including pedestrians, and types of vehicles that are at an intersection. The AI software then processes this information second by second to come up with the best way to move traffic through the intersection, changing traffic lights depending on the most optimal way of keeping traffic moving. Decisions can be made autonomously and shared with neighbouring intersections to help them understand what is coming their way.

Siemens Mobility is operating a fleet of 1,400 electric bikes in Lisbon, Portugal, using machine learning to analyse various data sources like the weather to predict the future demand at each of the 140 bike-sharing stations. This allows them to monitor the availability of bikes and spaces in charging docks for those returning bikes. The predictions are used along with recent traffic information to help bike collection teams restock docking stations and provide optimal routing for service technicians who maintain the bikes. Vivacity feeds the data into a machine learning model that learns typical daily patterns and combines this with how the traffic responds to transient changes in the road network. It evolves and adapts over time, improving its predictive power and minimising the amount of human intervention required. It provides historical and live data, and predicts traffic flows for the day. The system is already predicting traffic conditions 15 minutes in advance with 89 percent accuracy compared to what happens in reality.

Each of the above projects show how state of the art AI technology can be adopted to provide increased functionality, learning from real time data.

5.2 Which of the applications of AI are most suited to traffic optimisation in Australia and what are the associated risks and rewards?

A review of current traffic congestion management in the City of Sydney for Infrastructure Australia identified some applications which have potential to improve detrimental impacts of traffic congestion on the economy, environment, and quality of life of the community.[31] It is therefore recommended that recent AI development include highly advanced computational methods and the application of AI in the transport field has the potential to overcome the challenges the existing challenges to a great extent.

[31] IA (2013) A Review of Current Traffic Congestion Management in the City of Sydney, Infrastructure Australia (IA).

So, technologies such as ATCs, Green Wave; can be supported and enhanced by employing recent state of the art AI technologies.

5.2.1 *AI-based Adaptive Traffic Control Systems (ATCSs)*

ATCSs utilise real-time traffic data in an attempt to optimise the timing and length of the traffic light signals. As a result, effective ATCSs aim to minimise stop times and delays in a bid to reduce traffic congestion in major urban areas. A large number and variety of ATCSs have been developed and researched using different control methods and structure to reduce travel times and congestion. In addition to traditional and popular ATCSs such as the Sydney Coordinated Adaptive Traffic System (SCATS), several new developments, each with similar yet different underlying principles, are being implemented around the world, including OPAC, RHODES, ACS Lite and InSync.[32]

However, the rapid pace of developments in Artificial Intelligence (AI) is providing unprecedented opportunities to enhance the performance of different industries including the traffic and transport sectors. The innovations introduced by AI include highly advanced computational methods and the application of AI in the transport field is aimed at overcoming the challenges of increasing travel demand, CO_2 emissions, safety concerns, and environmental degradation. The availability of a huge amount of quantitative and qualitative data and AI in this digital age have made addressing these concerns more efficiently and effectively. Examples of AI methods that are finding their way to the transport field include Artificial Neural Networks (ANN), Genetic algorithms (GA), Simulated Annealing (SA), Artificial Immune system (AIS), Ant Colony Optimiser (ACO) and Bee Colony Optimisation (BCO) and Fuzzy Logic Model (FLM) The successful application of AI requires a good understanding of the relationships between AI and data on one hand, and transportation system characteristics and variables on the other hand. Moreover, it is promising for transport authorities to determine the way to use these technologies to create a rapid improvement in relieving congestion, making travel time more reliable to their customers and improve the economics and productivity of their vital assets.[33]

5.2.2 *Incident Detection*

Many attempts have been made to establish identity, time, location and severity of an incident to support traffic managers to mitigate congestion. These attempts range from manual reports, to automated algorithms, to Neural Networks. Manual reports written by humans can have a delay in detecting incidents. On the contrary, algorithms can measure the flow characteristics before and after the incident through data collected from sensors along the road. An algorithm for incident detection has been first implemented using statistical techniques such as California Algorithm. However, it is difficult to use an algorithm on arterial roads, because of the street parking and traffic signals. For this reason, algorithms have been developed to neural networks approaches. A classification neural network algorithm was evaluated to detect incident occurrence in a freeway. Moreover, incidents in real-time can be detected from social media such as Twitter as a cost-effective and efficient technique to acknowledge incident occurrence on both, freeway and arterial roads.[34]

5.2.3 *Green Wave*

Green wave is a traffic management control strategy which synchronises the green phase of traffic lights to allow the efficient flow of traffic. Once a vehicle has been detected by a sensor, it will progressively receive green signals at intersections without the vehicle stopping for the desired distance. The cars are

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[32] IA (2013) A Review of Current Traffic Congestion Management in the City of Sydney, Infrastructure Australia (IA).
[33] Abduljabbar, R., Dia, H., Liyanage, S. and Bagloee, S. (2019) Applications of Artificial Intelligence in Transport: An Overview. Sustainability, 2019, 11, 189.
[34] Abduljabbar, R., Dia, H., Liyanage, S. and Bagloee, S. (2019) Applications of Artificial Intelligence in Transport: An Overview. Sustainability, 2019, 11, 189.

grouped in platoons of varied sizes, determined by signal timings, which progress through the green wave at uniform speed. The spaces that are left between the platoons have an ideal time gap which can be exploited by platoons in the other direction in a grid road structure without interference. This can be implemented statically with the use of timers that control the green light signals for a pre-determined speed. However, the model has a high probability of green wave breakdowns which can occur when there is a disturbance in which vehicles cannot maintain the uniform speed. Usually, this arises when there is turn-in traffic from across the street which enters the green wave traffic. Leading to queue formation during the red phase and forces the decrease in vehicle speed, this speed disturbance propagates through the green wave. An adaptive control system can overcome this inefficiency using real-time sensor data on traffic lights, which can account for the delay time by measuring the inflow and outflow of vehicles through an intersection. The main advantage of the green wave traffic signal optimisation arises with the consistent flow of traffic, resulting in the reduction of congestion from stopping and starting in addition to wasteful energy and emissions. Results from a case study in Manchester showed that there was a 7.6 percent decrease in CO_2 emissions and more significantly, a 35.2 percent reduction in journey time compared to an unsynchronised network.[35]

5.2.4 Pre-Emptive Traffic Signals

There is scope for improvement to the green wave idea as it can be extended to the use for emergency vehicle pre-emption (EVP) by detecting when emergency vehicles are approaching an intersection and changing the signals to prioritise the movement of these vehicles. This similar logic can be used to solve congestion issues, especially from the build-up of traffic during peak hour, which is exacerbated by larger vehicles such as buses. Buses and emergency vehicles can be fitted with transponders for the use of GPS and infrared to communicate with detectors upstream, to prioritise the bus flow through traffic using the green-wave progression from coordinated signal controllers. Traffic-adaptive pre-emption technique has shown to improve travel-time of these vehicles by 39 percent. Bus priority has been implemented in Portland USA using encoded infrared communication technology to extend a green period downstream when a priority request is made. As flow theory suggests, larger vehicles contribute more to congestion; therefore, by fitting these sensors on buses there would be a significant improvement in the average speed of public transport. Thus, a reduction in traffic time would incentivise more road users to adopt public transport. The flow-on effect would reduce the number of private vehicles, hence further decreasing congestion.

5.2.5 Floating Car Data

The current traffic control system in Sydney relies on stationary monitoring units, such as induction loops built into roads, to gather traffic data. The data gathered by these detectors is incomplete and does not provide a clear picture of the nature of traffic. It is impossible to infer from the gathered data any useful information on travel times or the volume of congestion. The term 'floating car data' refers to data that is provided either from a mobile phone or GPS unit that is stationed inside the moving car. Mobile phones continuously transmit location data, along with a timestamp, to the service provider. The speed that the phone is moving at can be derived from this data, and hence used as an indicator of congestion. A report by Gühnemann *et. al.* (2003)[36] analysed a trial whereby a large number of taxis in different European cities were fitted with GPS to track their journey. Each taxi has an individual I.D and from the data collected, a database has been generated showing which roads of each city experience large amounts of congestion, and at what times of the day. It was reported that '*Depending on the intensity with which measures can be implemented (e.g. share of vehicles equipped with dynamic routing systems*

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[35] IA (2013) A Review of Current Traffic Congestion Management in the City of Sydney, Infrastructure Australia (IA).
[36] Gühnemann, A., Schäfer, R., Thiessenhusen, K. and Wagner, P. (2003) Monitoring Traffic and Emissions by Floating Car Data, Sydney: Institute of Transport Studies.

or the utilisation of adaptive traffic signal control systems) and the specific situation' an increase in network capacities by 3 percent to 10 percent for Germany was estimated.[37]

5.2.6 Parking Detection

Parking-related traffic contributes to at least 30 percent of congestion, as vehicles circle their destination to find an available place to park. A parking detection and guidance system could be used to acquire real-time data of available parking spaces for road users, decreasing congestion to some extent. Established parking management schemes employ the use of fixed sensors and roadside units. These sensors or units are wireless detectors that are installed in the car space to sense the presence of a vehicle. The data collected is then processed by the central control unit. The parking status can then be displayed on variable message signs for vehicles searching for parking spaces. The city of San Francisco has installed these sensors throughout car spaces across the city, under the SFPark project, which additionally uses mobile phone application technology to navigate vehicles to available on-street parking. However, the shortcoming of this scheme is that the estimated costs of installation and the parking management system are between $250-$800 per parking spot. Other initiatives are user-driven applications such as the Waze integrated with Google Maps that automatically crowdsources traffic information by tracking where and how users drive, to report changes in road conditions. The advantage of this technology is that it is free and can be used as a method of calculating the volume of cars in congested pinch-points; this data can then be used to optimise the current intelligent transport systems.

5.3 What are the risks and rewards associated with the use of AI

AI and driverless vehicles technologies will have a significant impact on social inequalities.[38] Driverless vehicle technologies have the potential to produce and perpetuate new and existing forms of social inequality. The design of driverless vehicles, for example, is not necessarily value-neutral. Jensen (2007) highlights how the development of new mobility systems can intensify social segregation, leading to multi-tier services based on differential speed and comfort. For driverless vehicles, the elite may have greater access to autonomous vehicle services, allowing them to travel further and faster than others, and these privileged services may also provide higher levels of flexibility and comfort. This effect may be transient; however, it will be important for industry and government to be aware of these potential inequalities and ensure equitable standards of design and implementation.

Australia is 'playing from behind' according to the State of AI in the Enterprise report by Deloitte, which investigated market readiness across seven countries to effectively leverage AI technologies, such as machine learning, deep learning, and natural language processing.[39] The report also lists some concerns which could be well applied to AI-based transport domain. These concerns included:

- AI stealing sensitive or proprietary data.
- Using AI to impersonate authorised users to defeat cybersecurity defences.
- Loss of human empathy in AI/cognitive decisions.
- Using AI to automate tasks involved in executing cyber attacks.

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[37] Gühnemann, A., Schäfer, R., Thiessenhusen, K. & Wagner, P., 2003. Monitoring Traffic and Emissions by Floating Car Data, Sydney: Institute of Transport Studies.
[38] Walsh, T., Levy, N., Bell, G., Elliott, A., Maclaurin, J., Mareels, I., and Wood, F. (2019) The effective and ethical development of artificial intelligence: An opportunity to improve our wellbeing. Report for the Australian Council of Learned Academies (ACOLA).
[39] Deloitte (2019) Australia unprepared for AI risks: Australian businesses are the most concerned but least prepared for AI risks, Deloitte, 07 May 2019.

- AI/cognitive code that has bugs which make it vulnerable to attack.

Besides, most organisations reported a significant AI skills gap, with 68 percent of global respondents indicating a ‘moderate-to-extreme' gap. Australia currently has no dedicated national AI strategy, and several prominent Australian business and industry leaders are urgently pushing for a national debate on the policies needed to address AI risks. AI will demand new skills and capabilities, and adaptability, in our workforce. Micro-credentialing (a form of education in which ‘mini-degrees’ are achieved in specific subject areas) is likely to become useful for certifying basic education and digital literacy in AI.[40]

The main advantage of the traffic signal optimisation arises with the consistent flow of traffic, resulting in the reduction of congestion from stopping and starting in addition to wasteful energy and emissions. Results from a case study in Manchester showed that there was a 7.6 percent decrease in CO_2 emissions and more significantly, a 35.2 percent reduction in journey time compared to an unsynchronised network. Besides, the use of IP cameras with the advanced control system would allow the visual monitoring of all intersections across urban environments, resulting in more rapid and efficient detection of traffic delays, accidents or poor weather conditions.[41]

5.4 What are the recommended strategic approaches to implement the AI applications that transport agencies should consider?

Artificial Intelligence holds vast promises across the transport industries and sectors. Andrew Ng, one of the world's foremost AI Evangelists, lists creating an AI Strategy as a key element in his AI Transformation Playbook. Sensible strategy in the transport industry is very important to harness the power of AI because AI is set to transform the industry. Do organisations need to understand what exactly constitutes an AI Strategy? The 'AI Transformation Playbook' by Landing.ai in 2018 draws on insights gleaned from leading the Google Brain team and the Baidu AI Group, which played leading roles in transforming both Google and Baidu into great AI companies.[42] Any enterprise can follow this Playbook and become a strong AI company, though these recommendations are tailored primarily for larger enterprises with a market cap/valuation from $500M to $500B. These steps are equally important strategic steps for transport agencies or smaller organisations to consider for AI-based transformation with some modifications.

These are the steps recommended for transforming an enterprise with AI and discussed in the playbook, with a summary of the key material from the Playbook provided:

- Execute pilot projects to gain momentum.
- Build an in-house AI team.
- Provide AI training.
- Develop an AI strategy.
- Develop internal and external communications.

When discussing the step to 'Execute pilot projects to gain momentum' the playbook states:

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[40] Elliott, A. (2019) *A $23 trillion opportunity: Why Australia must embrace the AI revolution*, Smart Company, 30 July 2019.
[41] IA (2013) A Review of Current Traffic Congestion Management in the City of Sydney, Infrastructure Australia (IA).
[42] Ng, A. (2018) AI Transformation Playbook: How to lead your company into the AI era, Landing AI, 13 December 2018.

"*It is more important for your first few AI applications to succeed rather than be the most valuable AI projects. They should be meaningful enough so that the initial successes will help a company to gain familiarity with AI and also convince others and projects should not be so small that others would consider it trivial. The important thing is to get the flywheel spinning so that your AI team can gain momentum. Suggested characteristics for the first few AI projects are the following:*

- *It should ideally be possible for a new or external AI team (which may not have deep domain knowledge about the transport business) to partner with your internal teams (which have deep domain knowledge) and build AI solutions that start showing traction within 6-12 months.*

- *The project should be technically feasible. Too many companies are still starting projects that are impossible using today's AI technology; having trusted AI engineers do due diligence on a project before kick-off will increase a conviction in its feasibility.*

- *Have a clearly defined and measurable objective that creates business value*."

When discussing the step to 'Build an in-house AI team' the playbook states:

"*While outsourced partners with deep technical AI expertise, can help an organisation gain that initial momentum faster, in the long term it will be more efficient to execute some projects with an in-house AI team. Further, you will want to keep some projects within the company to build a more unique competitive advantage.*

In the AI era, a key moment for many companies will again be the formation of a centralised AI team that can help the whole company. This AI team could sit under the CTO, CIO, or CDO (Chief Data Officer or Chief Digital Officer) function if they have the right skillset. It could also be led by a dedicated CAIO (Chief AI Officer). The key responsibilities of the AI unit are:

- *Build up an AI capability to support all the AI applications.*

- *Execute an initial sequence of cross-functional projects to support different divisions/business units with AI projects. After completing the initial projects, set up repeated processes to continuously deliver a sequence of valuable AI projects.*

- *Develop consistent standards for recruiting and retention.*

- *Develop company-wide platforms that are useful to multiple divisions/business units and are unlikely to be developed by an individual division. For example, consider working with the CTO/CIO/CDO to develop unified data warehousing standards*."

With a new AI unit, the CEO will be able to a draw on AI talent to support different divisions in order to drive cross-functional projects. An AI strategy will guide a company toward creating value while also building experience and resilience to associated challenges. Once teams start to see the success of the initial AI projects and form a deeper understanding of AI, the company will be able to identify the places where AI can create the most value and focus resources on those areas. AI is enabling companies to build unique competitive advantages in new ways. Design strategies aligned with the "Virtuous circle of AI" positive-feedback loop shown in Figure 5.1, stand to provide robust frameworks for successful projects. Data is a key asset for AI systems. Thus, many great AI companies also have a sophisticated data strategy.

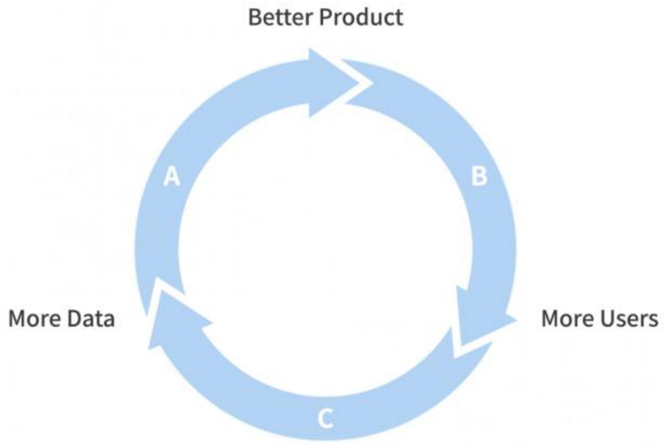

Figure 5.1: The Virtuous Cycle of AI
Source: Landing.ai

Useful AI systems can be built with anywhere from 100 data points ("small data") to 100,000,000 data points ("big data"). But having more data seldom hurts. AI teams are using very sophisticated, multi-year strategies to acquire data, and specific data acquisition strategies are industry and situation-specific. For example, Google and Baidu both have numerous free products that do not monetise but allow them to acquire data that can be monetised elsewhere. If a company has 50 different databases siloed under the control of 50 different VPs or divisions, it will be nearly impossible for an engineer or for AI software to get access to this data and “connect the dots.” Instead, consider centralising your data into one or at most a small number of data warehouses.

It is critical to recognise what data is valuable, and what is not. It is not true that having many terabytes of data automatically means an AI team will be able to create value from that data. Expecting an AI team to magically create value from a large dataset is a formula that comes with a high chance of failure, avoid acquiring wrong data by bringing an AI team in early during your process of data acquisition, and let the AI team help prioritise what types of data to acquire and save.

When discussing the step to 'Develop internal and external communications' the playbook suggests that AI will affect the business significantly. To the extent that it affects even key stakeholders, so running a communications program to ensure alignment is necessary.

- Government Relations: Transport is one of the many regulated industries (self-driving cars, healthcare) facing unique challenges to stay compliant. Developing a credible, compelling AI story that explains the value and benefits AI can bring to an industry or society is an important step in building trust and goodwill along with direct communication and ongoing dialogue with regulators.

- Talent/Recruitment: Because of the scarcity of AI talent in the present situation, strong employer branding will have a significant effect on an organisation's ability to attract and retain such talent. AI engineers want to work on exciting and meaningful projects. A modest effort to showcase an initial success can go a long way.

- Internal Communications: Because AI today is still poorly understood and Artificial General Intelligence specifically has been over-hyped, there is fear, uncertainty, and doubt. Many employees are also concerned about their jobs being automated by AI, though this varies widely by culture (for example, this fear appears much more in the US than in Japan). Clear internal communications both to explain AI and to address such employees' concerns will reduce any internal reluctance to adopt AI.

5.5 What should policies and mechanisms consider to support AI applications?

Organisations need to consider many factors when building or enhancing an artificial intelligence infrastructure to support AI applications and workloads. The ultimate success of AI projects will likely depend on how suitable its environment is for such powerful applications. While the cloud is emerging as a major resource for data-intensive AI workloads, many projects still rely on their on-premises IT environments for these projects. The following material is an edited version of crucial points from the findings from the following three sources, Violino 2018[43], Zawadzki 2019[44], Kerravala 2018[45].

5.5.1 AI data storage[46]

It is one of the most important factors in AI-based applications, specifically the ability to scale storage as the volume of data grows. As organisations prepare enterprise AI strategies and build the necessary infrastructure, storage must be a top priority. That includes ensuring the proper storage capacity and reliability to deal with the massive data amounts required for effective AI applications. For example, for advanced, high-value neural network ecosystems, traditional network-attached storage architectures might present scaling issues. Similarly, a services company that uses enterprise AI systems for real-time decisions may need fast all-flash storage technology. Many companies are already building big data and analytics environments that leverage Hadoop and other frameworks designed to support enormous data volumes, and these will likely be suitable for many types of AI applications.

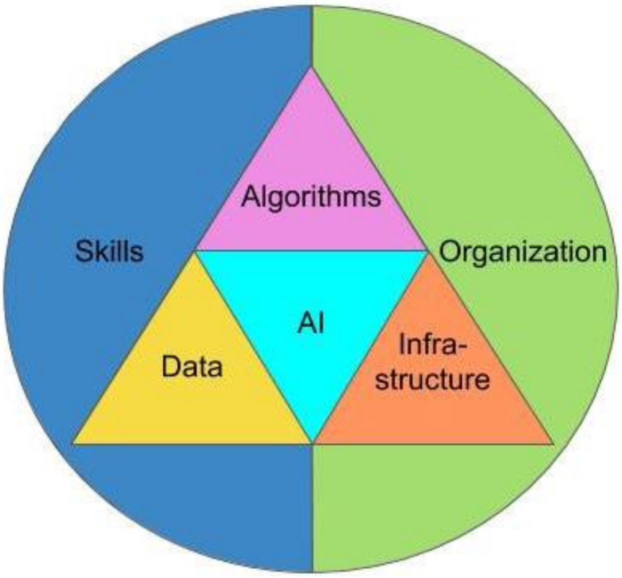

Figure 5.2: AI Strategic Core Concepts

Source: Zawadzki (2019)[47]

Another factor is the nature of the source data. AI applications depend on source data, so an organisation needs to know where the source data resides and how AI applications will use it. For instance, will applications be analysing sensor data in real-time or will they use post-processing? How much data AI applications will generate is also an important thing to consider. AI applications make

[43] Violino, B (2018) *Designing and building artificial intelligence infrastructure*, TechTarget, 05 April 2018.
[44] Zawadzki, J. (2019) *The Secrets to a Successful AI Strategy*, Medium, 09 July 2019.
[45] Kerracala, Z. (2018) *Want to use AI and machine learning?* NetworkWorld, 21 December 2018.
[46] Violino, B (2018) *Designing and building artificial intelligence infrastructure*, TechTarget, 05 April 2018.
[47] Zawadzki, J. (2019) *The Secrets to a Successful AI Strategy*, Medium, 09 July 2019.

better decisions as they're exposed to more data. Normally databases grow over time; companies need to monitor capacity and plan for expansion as needed.

5.5.2 AI networking infrastructure[48]

Networking is another key component of an AI infrastructure. To provide high efficiency at the scale required to support AI, most organisations will likely need to upgrade their networks. Deep learning algorithms are highly dependent on communications, and enterprise networks will need to keep stride with demand as AI efforts expand. That's why scalability must be a high priority, and that will require high-bandwidth, low-latency and creative architectures. So, organisations should consider automation whenever possible. For example, they should deploy automated infrastructure management tools in their data centres. Network infrastructure providers, meanwhile, are looking to do the same. Software-defined networks are being combined with machine learning to create intent-based networks that can anticipate network demands or security threats and react in real-time.

5.5.3 Processing AI data[49]

It is critical for an artificial intelligence infrastructure to have sufficient computation resources, including CPUs and GPUs. A CPU-based environment can handle basic AI workloads, but deep learning involves multiple large data sets and deploying scalable neural network algorithms; CPU-based computing might not be sufficient for such cases. To provide the necessary compute capabilities, organisations must turn to GPUs. Deploying GPUs enables organisations to optimise their data centre infrastructure and gain power efficiency. Currently, many projects rely mostly on repurposed GPUs for their AI efforts, but they also take advantage of cloud infrastructure resources, as well as the general declining cost of processors (Nvidia and Intel are both developing AI-focused GPUs).

5.5.4 Preparing AI data, management and governance[50]

Organisations have to choose where they will store data, how they will move it across networks and how they will process it, they also have to choose how they will prepare the data for use in AI applications. One of the important tasks for successful enterprise AI is data cleansing or data scrubbing, it's the process of updating or removing data from a database that is inaccurate, incomplete, improperly formatted or duplicated. Organisations should consider deploying automated data cleansing tools to assess data for errors using rules or algorithms as most AI projects are largely data-driven. Data quality is especially critical with AI. If the data feeding AI systems are inaccurate or out of date, the output and any related decisions will also be inaccurate.

Another important factor is data access. An organisation should have the proper mechanisms in place to deliver data securely and efficiently to the stakeholders. So, part of the data management strategy needs to ensure that users, machines and people have easy and fast access to data. It should be accessible from a variety of endpoints, including mobile devices via wireless networks. Access also raises several privacy and security issues, so data access controls are important. Companies need to look at technologies such as identity and access management and data encryption tools as part of their data management and governance strategies.

5.5.5 AI and IoT[51]

[48] Violino, B (2018) *Designing and building artificial intelligence infrastructure*, TechTarget, 05 April 2018.
[49] Violino, B (2018) *Designing and building artificial intelligence infrastructure*, TechTarget, 05 April 2018.
[50] Violino, B (2018) *Designing and building artificial intelligence infrastructure*, TechTarget, 05 April 2018.
[51] Violino, B (2018) *Designing and building artificial intelligence infrastructure*, TechTarget, 05 April 2018.

No discussion of artificial intelligence infrastructure would be complete without mentioning the growing impact of the internet of things (IoT). IoT involves gathering and analysing data from countless devices, products, sensors, assets, locations, vehicles, etc., that are connected via the internet. AI and IoT are closely tied because organisations need to apply intelligence to gain insights from all the information coming in from connected things. Gartner estimates that the number of connected things or devices will reach 20.4 billion by 2020, and the staggering amount of data generated by connected objects would be enormous, and it will be important to integrate, manage and secure all of this information. From an artificial intelligence infrastructure standpoint, organisations need to look at their networks, data storage, data analytics, and security platforms to make sure they can effectively handle the growth of their IoT ecosystems. That includes data generated by their own devices, as well as those of their partners.

5.5.6 AI training and skill requirement

Last, but certainly not least: Training and skills development is vital for any IT project, and especially AI initiatives. Organisations will need data analysts, data scientists, developers, cybersecurity experts, network engineers and IT professionals with a variety of skills to build and maintain their infrastructure to support AI and to use artificial intelligence technologies, such as machine learning, natural language processing and deep learning, on an ongoing basis.[52] The following question in AI Strategy is very important: An organisation should build an in-house team or outsource the tasks?[53] As mentioned previously, AI expert Andrew Ng recommends building an in-house AI team. AI feeds off domain knowledge, and that can be hard to outsource in certain industries. Outside consultants likely don't know your data, infrastructure, and problems as well as your employees. Hence, the feasible way is to bundle enthusiastic employees and educate them about AI.

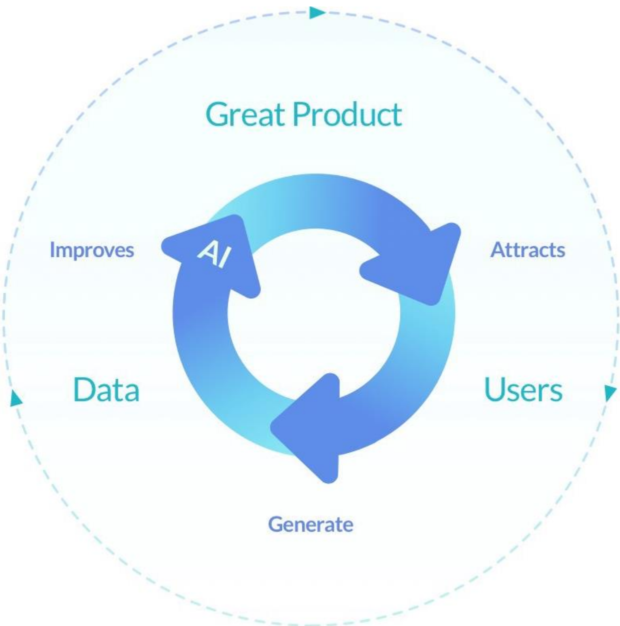

Figure 5.1: AI product improvement cycle
Source: Zawadzki (2019)[54]

Creating an AI Strategy is different for corporations and start-ups. Raphael Kohler explains that corporations have to consider legacy systems and are also challenged with change management of the

[52] Violino, B (2018) *Designing and building artificial intelligence infrastructure*, TechTarget, 05 April 2018.
[53] Zawadzki, J. (2019) *The Secrets to a Successful AI Strategy*, Medium, 09 July 2019.
[54] Zawadzki, J. (2019) *The Secrets to a Successful AI Strategy*, Medium, 09 July 2019.

existing organisation, while start-ups can focus on entering the virtuous cycle of AI. The core components might be of different importance in different applications, but they are always relevant. The core components of an AI Strategy are Data, Infrastructure, Algorithms, Skills, and Organisation.

Innovation and Science Australia (ISA) consulted with stakeholders across the Australian innovation, science and research system throughout 2017 and received recommendations. The consultation and recommendation helped inform and shape the AI policy and plan. The plan makes 30 recommendations that underpin five strategic policy imperatives:[55]

- Education: respond to the changing nature of work by equipping all Australians with skills relevant to 2030.
- Industry: ensure Australia's ongoing prosperity by stimulating high-growth firms and raising productivity.
- Government: become a catalyst for innovation and be recognised as a global leader in innovative service delivery.
- Research and development (R&D): improve R&D effectiveness by increasing translation and commercialisation of research.
- Culture and ambition: enhance the national culture of innovation by launching ambitious National Missions.

[55] Australian Government (2017) Australia 2030: Prosperity through Innovation: A plan for Australia to thrive in the global innovation race, Australian Government Department of Industry, Innovation and Science.

6 THE USE OF BLOCKCHAIN TECHNOLOGY TO ENHANCE FREIGHT TRACKING AND AUTHENTICITY, INCLUDING REAL-TIME LOCATION AND CONFIRMATION OF ORIGIN AND DELIVERY

6.1 How is Blockchain technology currently being used to enhance freight tracking and authenticity and what new functionality is being promised?

Freight transport and logistics services account for up to 10 per cent of GDP and contributes over $130 billion to the Australian economy.[56] As Australia's freight task is projected to double in the next 20 years, there is growing interest in how improvements can be made to the productivity, efficiency and capacity of Australian transport infrastructure.[57] One potential area of improvement is the recording, maintaining and coordination of information about freight as it moves. Through the process of globalisation, we have developed a complex and often inefficient mix of institutional infrastructure (e.g. databases). This infrastructure services the demand of logistics providers, governments and consumers for information. However, estimates demonstrate the high costs of this infrastructure, including as a portion of total trade costs. For instance, one study found that a simple shipment of refrigerated flowers from Kenya to the Netherlands required trade documentation and administrative processes to pass through around 30 actors and organisations with over 200 interactions.[58] In the 34 days it took from farm to retailers, 10 days were spent waiting for document processing. Such examples raise the question of how we can build better institutional infrastructure for supply chains and freight logistics.

Current systems of managing and recording information along supply chains are often paper-based and are spread across multiple organisations. The attention being paid to Blockchain and other distributed ledger technologies is because they act as a new decentralised alternative to supply chain information. Blockchain technology offers a potential technological solution to the problem of tracking freight, and therefore helping to ensure the authenticity of products. Rather than storing information within siloed centralised databases, supply chain participants could use Blockchain as a decentralised digital infrastructure for holding verified and authentic information about freight. This process includes creating digital representations for products, where records are updated to include information such as ownership, location, history, characteristics and finance and tax obligations. This information can be made selectively visible, including both consumers and governments. Ultimately this movement from hierarchical governance towards decentralised platform governance has significant implications for how supply chains are organised, and will shape how we trade goods and services in the future.[59]

While Blockchain technology is nascent—and will rely on other complementary technologies as sources of information—there is significant investment from major international companies, such as IBM and Maersk, to create new digital supply chain infrastructure. As with all frontier technologies, however, there are risks and rewards in adoption. Some of these challenges are strategic—for instance, it might simply be too early to invest in this infrastructure today. Other challenges relate to the background policy environment, or governance challenges of bringing together supply chain actors into a consortium. Our aim is to examine the potential for Blockchains for freight tracking and authenticity, and to do so we arrange our discussions across four areas.

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[56] Department of Transport (2018) Perth and Peel@3.5million: The Transport Network, Western Australian Government.
[57] Commonwealth of Australia (2018) Inquiry into the National Freight and Supply Chain Priorities, Commonwealth of Australia.
[58] IBM (2017) Maersk and IBM Unveil First Industry-Wide Cross-Border Supply Chain Solution on Blockchain, IBM.
[59] Allen, D., Berg, A. and Markey-Towler, B. (2019) 'Blockchain and Supply Chains: V-form Organisations, Value Redistributions, De-commoditisation and Quality Proxies', *The Journal of the British Blockchain Association*, vol. 2, no. 1, pp. 57-65.

1. *Current implementations of Blockchain for freight tracking and authenticity*: Blockchain applications are rapidly evolving and with several different focuses. Across these projects there are two main benefits being sought. First, the traceability of products, such as provenance and the characteristics of goods for both consumers and logistics provider. And second, how that deeper supply chain information can lower regulatory compliance costs by reducing (and automating) paperwork.

2. *Applications most suited to freight tracking and authenticity:* There are hundreds of different types of Blockchain applications with different bundles of features. Freight tracking and logistics providers should particularly consider two different aspects of Blockchain applications. The first is the type of Blockchain deployed—permissioned or permission-less. Most supply chain applications are permissioned networks so that participants can retain data authenticity and privacy. The second potential for consideration is the application of Blockchain smart contracts, where contracts are automatically executed on Blockchain networks using external data sources.

3. *Recommended strategic approaches to implement technologies:* Because Blockchains cannot authenticate information—they are more effective at ensuring information is not tampered with—a central strategic implementation is how information will be inputted. The Internet of Things (IoT) is being used to provide trusted and authentic information into Blockchain ledgers. These IoT applications might help overcome the 'garbage-in-garbage-out' problem, and logistics providers should focus on this problem. This data problem must be solved so that other technologies such as Artificial Intelligence (AI) can be leveraged to further optimise value chains.

4. *Policies and mechanisms to support Blockchain technology applications:* There are both ongoing and emergent policy questions for Blockchain applications in the logistics sector. We briefly examine three dimensions to this. First, the notion of "crypto-friendliness" as a framework to understand Blockchain policy developments. Second, the emergence of data rights and standards, including the potential for international coordination of policy. And third, the current freight and logistics inquiry that might shed further light on some of these issues. Blockchain technology might become the new digital infrastructure underpinning dynamic supply chains, storing synchronised real-time data across organisational boundaries.[60] There are two main implementations of Blockchain systems in supply chains: freight tracking (including authenticity) and regulatory compliance. The first looks to dramatically increase the tracking of goods along the supply chain. The second is to use this information and integrate it into existing regulatory processes, enabling a reduction in the costs of regulatory compliance. These two benefits are therefore tightly related, and many projects ultimately seek to achieve both. The small number of projects we outline are in various stages of development including proof of concept, pilot, and commercial scale deployment.

Traceability and tracking in supply chains matters for logistics providers, governments and consumers. Logistics providers need to know where products are to optimise their services. Governments need to know the history of products to determine their regulatory obligations. And consumer price decisions are increasingly a function of information about the identities of products, such as their organic or ethical concerns. These latter traceability and information about the identity of products could dramatically affect the pricing of premium products (some of Australia's major exports).

One of the most prominent applications of Blockchain supply chains is a network created through a collaboration by IBM and Maersk, TradeLens. TradeLens tracks shipments in real-time on a secure, permissioned Hyperledger Fabric Blockchain platform.[61] The TradeLens Ecosystem comprises of third-party logistics companies, inland and intermodal providers, ports and terminals, ocean carriers and some customs and other governmental authorities.[62] Over 1.5 million shipping events are recorded per day, including information on contractual shipping data, cargo movements, IoT sensor information, and

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[60] DHL (2018) *Blockchain in Logistics*, DHL Trend Research.
[61] Biazetti, A. (2019) *5 key points about TradeLens platform security*, TradeLens.
[62] TradeLens (2019) *New members set stage for next wave of TradeLens growth*, TradeLens.

identification details about shippers, carriers and other participants.[63] TradeLens enables permissioned sharing of data between authorised parties, and is working on developing new standardised structured document types for better document functionality and analysis (including integration into existing systems). The Blockchain technology underlying TradeLens also ensures the immutability and integrity of documentation by checking the consistency of documentation against their previous record.

In Australia there are several companies working in Blockchain-based freight tracking. Much of the effort in Blockchain supply chains is anticipated to occur in high-information markets where there are levels of fraud and error. AgriDigital is a cloud-based commodity management platform that utilises Blockchain to create digital trust. This solves two key issues for the agricultural industry: matching title transfer of assets to the payment, and supply chain provenance and traceability. The platform manages contracts, deliveries, inventory, orders, invoices and payments in real-time. The platform gives users "\'live information about the location and status of their product at any given time as it moves through the supply chain'.[64] AgriDigital is expanding from the Australian grain market into other agricultural commodities in the global supply chain.[65] Another Australian company is BeefLedger, who is tracking beef exports from Australia. BeefLedger is an "integrated provenance, Blockchain security and payments platform" that enables consumers to validate the beef products they are buying.[66] BeefLedger is based on tokens (BEEF tokens) on the Ethereum Blockchain that enable tracking along the supply chain journey. Other companies such as UCOT are developing Blockchain-based ecosystems that rely on IoT sensors to input information into a Blockchain-based distributed ledger. That is, with a greater focus on the physical hardware technologies that help to track products.

Traceability and information about products is also important to reduce the costs of regulatory compliance. Regulatory authorities mandate logistics companies to comply with manual data-entry and paper-based documentation processes.[67] Customs or other regulatory compliance issues can arise if entities cannot ascertain the authenticity of documents and the provenance of goods. International import and export approval processes can incorporate up to 30 paper-based, individual approvals.[68] Customs clearance delays can result from mismanagement of documents or paperwork, where information is missing, inaccurate or fraudulent. Delays can also be attributed to the inability to adapt to and comply with new regulations or laws of bordering jurisdictions.

Blockchain can be used to verify the authenticity and accuracy, as well as facilitate the creation, management, and dissemination of, import and export documents. The success of Blockchain-based supply chain traceability, however, will be limited by the extent to which ports accept Blockchain-based information as being compliant, and, as we will see below, there are problems of regulatory coordination between different jurisdictions.[69] We can see several examples of Blockchain-supported document management systems:

- TradeLens guarantees the immutability and traceability of shipping documents.[70] The digitisation and exchange of trade documents, as well as the automation of business processes

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[63] Targett, E. (2019) *Two New Mega Members Put "Half World's Shipping Data" on IBM's Blockchain*, TradeLens.
[64] Australian Government (n.d.) *AgriDigital - allows local Australian farmers to connect to the global supply chain*, Australian Trade and Investment Commission.
[65] AgriDigital, AgriDigital launches in United States as the North American grain harvest gets underway, 30 August 2019, https://blog.agridigital.io/agridigital-launches-in-united-states-as-the-north-american-grain-harvest-gets-underway-9c08f6a406f; Future Farming, Agridigital to create 'digital trust' in supply chains, https://www.futurefarming.com/Tools-data/Articles/2019/5/Agridigital-to-create-digital-trust-in-supply-chains-424208E/
[66] BeefLedger, The Platform, https://beefledger.io/#platform
[67] https://www.logistics.dhl/content/dam/dhl/global/core/documents/pdf/glo-core-Blockchain-trend-report.pdf
[68] CB Insights 2018 Major Links in the Global Trade Supply Chain
[69] Allen, Darcy WE, Chris Berg, Sinclair Davidson, Mikayla Novak, and Jason Potts. 'International policy coordination for Blockchain supply chains.' *Asia & the Pacific Policy Studies*, vol. 6, no. 3 (2019).
[70] TradeLens, 5 key points about TradeLens platform security, https://blog.tradelens.com/news/5-key-points-about-tradelens-platform-security/

such as import and export clearance, has created efficiencies of up to 40 per cent in transit time for US shipments.[71]

- Customs Speed is currently developing a customs clearance solution.[72] The Hyperledger Fabric-enabled platform will allow manufacturers or suppliers, transportation carriers and border control agents to store and verify documents.[73] The benefits arising from this customs clearance solution are data transparency; faster cross-border deliveries; improved process efficiency; and savings on warehouse or other overtime fees.

- AgriDigital Consignments is an AgriDigital platform feature that manages all "international contracting, document creation and distribution, container and logistics management, inventory tracking, asset delivery, plus invoicing and payments".[74] AgriDigital Consignments enable parties to access verify documents from each stakeholder, be it the manufacturer, financial institution or courier, and makes this information available to participants.

Over the longer term there are opportunities for automation of regulatory processes. Commercial freight and supply chain processes could be automated using smart contracting technology and IoT sensors. As IoT infrastructure on 'smart containers' record information in a Blockchain, port authorities could automatically determine regulatory compliance, and levy relevant tariffs using smart contracts to the owner of the goods. This will require not just an institutional or software upgrade of existing systems, but also a physical upgrade of ports. Greater transparency over freight networks might facilitate auditing and invoice management. Currently $140 billion per day is spent in disputes of payments in the transportation industry, with average invoices taking 42 days to be paid out.[75] Blockchain-based freight tracking enables smart contracts to be implemented that might remove the potential for these disputes, including through insurance pay-outs. Smart legal contracts might save on administrative overhead costs and assist clients in avoiding conflicts. However, we are yet to see an entire ecosystem of dispute resolution emerge, presenting a risk in adoption.[76] A Russian Based shipping company, Infotech Baltika, is developing a Blockchain-based system for port logistics called Edge.Port. They claim that it will reduce time spent in port operations from 4 hours to 25 minutes, and increase port capacity by 3-5 percent.[77] There are also other potential efficiency gains through Blockchain-based trade infrastructure, including optimisation of logistics flows using the data.

6.2 Which of the applications of Blockchain technology are most suited to freight tracking and authenticity in Australia and what are the associated risks and rewards?

Blockchain technology isn't just a single technology that can be deployed to solve problems of trust across supply chains. There are hundreds of different types of Blockchains that vary in terms of their decentralisation, scalability, cost, speed and privacy. Furthermore, we are seeing constant innovation

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[71] GTR, TradeLens Blockchain platform for global trade expands to Russia, https://www.gtreview.com/news/fintech/tradelens-Blockchain-platform-for-global-trade-expands-to-russia/
[72] CryptoChicks Hatchery, https://cryptochicks.ca/cryptochicks-hatchery/#PROJECTS. CryptoChicks, a non-profit organisation, was founded by Natalia Ameline, mother of Ethereum creator Vitalik Buterin.
[73] Jennifer Tran, Blockchain Applications for Freight Customs Documents, 2019, https://docs.google.com/presentation/d/1H42Zvl6rGJ25T4urXZI2nD5UjQg9R8i32ntzj1YLi0s/edit#slide=id.g60e789ee3a_0_45; Gayathiri Muragamoorthy, Jennifer Tran, HATCHERY Customs Speed, 2019, https://drive.google.com/file/d/1_xBXSbydE2paFV8Try5UzFVV3zfAZmii/view.
[74] AgriDigital, 'Consignments: the next frontier in international agri-supply chains', https://blog.agridigital.io/consignments-the-next-frontier-in-international-agri-supply-chains-e1e872befb01
[75] https://www.fleetowner.com/electronic-security/Blockchain-trucking-what-about-middlemen
See also https://www.winnesota.com/Blockchain
[76] See Allen, DWE, Lane, AM and Poblet, M (forthcoming), 'The Governance of Blockchain Dispute Resolution', *Harvard Negotiation Law Review*.
[77] See https://cointelegraph.com/news/russia-cargo-shipping-firm-to-use-Blockchain-in-port-logistics

within the Blockchain ecosystem to develop new types of Blockchains that enable more desirable trade-offs between these characteristics.

One of the central questions for Blockchain-based supply chains is the problem of data privacy. Indeed, for many supply chain and logistics companies, information about tracked goods is proprietary information. To discuss data privacy we can broadly distinguish between two different types of Blockchain distributed ledger technology.[78] The first type is referred to as public, or permission-less, systems that generally implies that anyone can join, use and leave the network without permission. Bitcoin, the first application of Blockchain technology, was a public Blockchain. The challenge with a public Blockchain is not just that the network of nodes must come to agreement and avoid malicious actors, but also that the network must be incentivised to continually maintain and update the Blockchain with new transactions. For the bitcoin Blockchain, the bitcoin cryptocurrency is necessary as an economic incentive for miners to maintain the public network. Public Blockchains are built to be robust and decentralised, but also tend to have much more open read and write access that might conflict with the underlying business models of participants.

In contrast, there are also permissioned distributed ledger systems.[79] Rather than anyone being able to join and access the network, read and write permissions are only given to approved (and known) participants. For instance, a consortium of parties within a supply chain will be given different rights to view and write to the Blockchain ledger. For instance, in the TradeLens example the read and write permissions are a selected number of shippers, logistics providers and other authorities. Each of these known parties maintain the network. A recent study that surveyed 105 supply chain projects found that around half were using permissioned Blockchains.[80] One of the reasons why private or permissioned Blockchains are preferred is because they enable control of read and write access for the data stored in the Blockchain. Certain data might only be viewable to certain supply chain or logistics participants (e.g. customs authorities) and not others (e.g. competitors or consumers). This is particularly important where the value of data is closely connected to the underlying business model of the logistics provider. While having a wide connected network of participants is important to gain the benefits of tracking and authenticity—that is, to get visibility over the entire ecosystem—it also generates questions around data privacy.

Governance of Blockchain-based supply chain networks will be critical for the industry going forward. Who decides who can read and write to the network? Is there a controlling party who could change the rules? One challenge is coordinating industry-level coordination between different parties. As a University College London report notes: "*The technological solutions are there and have been proven to work. The challenge is aligning a wide group of stakeholders around implementation – which is particularly challenging in the case of complex logistics and dynamic supply chains*."[81] It is difficult both in terms of standards—that there are different providers building Blockchain infrastructure in different ways—and through the need to form a consortia to work together on one platform. The TradeLens project is one example of the latter consortia-building problem, where they had early challenges of adoption in the consortia.

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[78] In addition to the public and private distinction outlined above, freight and supply chain projects can occur at different layers of the Blockchain ecosystem. The protocol layer is the fundamental layer of the Blockchain system and is comprised of code. Hyperledger, Ethereum Enterprise Alliance and Corda are examples of software platforms that work on protocol level solutions. The network layer comprises of peer-to-peer networks that interconnects participants to enable data sharing and verification. Examples of network layer solutions include TradeLens and Komgo. Products and services, such as supply chain tracking and notarisation, are provided at the application layer. See UCL Report page 45.

[79] The distinction between public and private Blockchains is a matter of degree rather than kind.

[80] University College London Centre for Blockchain Technologies, *Distributed Ledger Technology in the Supply Chain*, August 2019, http://Blockchain.cs.ucl.ac.uk/dlt-in-the-supply-chain-report/

[81] UCL Report, page 45

Logistics providers will also need to consider the potential for smart contracts. The notion of smart contracts that automatically execute on the internet dates back decades.[82] Smart contracts are agreements that are written into code that can be automatically executed when specific conditions are validated. The creation of the contract and all subsequent contract interactions are recorded by the Blockchain. Blockchain technology can act not just as a technology to enforce the contract over a network, but also as a source of trusted validated information to execute those exchanges. That is, information in a Blockchain—for instance about the condition of a product in a supply chain—can act as a trusted source of third-party information (i.e. an "oracle") that triggers a smart contract. For instance, if a container is recorded as going above a certain temperature, it might trigger a smart insurance contract that pays out to the owner of the product or fines the freight operator.

There are some examples of smart contracting platforms for supply chain and logistics emerging. For instance, US law firm, BakerHostetler, and smart legal contract software platform, Clause, are developing a Blockchain-based legal agreement for the freight market.[83] The smart contract will enable stakeholders across the supply chain to notarise the occurrence of events. But there are several risks that come with smart legal contracts both practically and theoretically.[84] Contracting parties, for instance, should consider jurisdictional boundaries and conflict of laws. What jurisdiction applies to a smart contract? Further, are there conflicts between the immutability of smart contracts and the application of contractual remedies? How does technical program language (i.e. code) interact with legal language? We are yet to see how these problems will be solved. Further, smart contracts are reliant on trusted external information sources to trigger them (see below for on the consideration of information inputs for Blockchains).

6.3 What are recommended strategic approaches to implement these Blockchain technologies that transport agencies should consider?

There are various stages of development in Blockchain supply chain solutions. The Cambridge Centre for Alternative Finance has found that successful projects adopt a long-term perspective and commitment.[85] Many of the benefits of Blockchain-based infrastructure are based on network effects and having entire ecosystems on the platform—this is likely to take some time. One of the central strategic questions for Blockchain in logistics is understanding complementarities with other technologies.[86] Our focus here is on how Blockchain can support and be supported by complementary technologies, and thus be integrated holistically into a technology stack.

Internet of Things (IoT) technologies can help with accurate input of data into a Blockchain. While distributed ledger technologies can validate whether data within the ledger has been altered after it has been entered, it cannot ensure the validity of that data. How can supply chain and logistics providers ensure that the data associated with a token (a digital representation of a physical product) aligns with the actual characteristics of the underlying product? Indeed "*whilst the Blockchain ledger can create an entirely secure set of data, the 'on ramp' from the physical product to the product information is a potential weak link which has the potential to undermine the trust in the entire Blockchain solution*."[87]

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[82] Szabo, N 1997, 'The idea of smart contracts', Nick Szabo's Papers and Concise Tutorials.
[83] https://www.bakerlaw.com/press/bakerhostetler-links-with-clause-brings-Blockchain-based-legal-agreements-to-market-in-the-freight-transportation-industry
[84] See Ryan, P 2019, *Trust and Distrust in Digital Economies*, Routledge.
[85] Michel Rauchs, Apolline Blandin, Keith Bear, and Stephen McKeon, 2nd Global Enterprise Blockchain Benchmarking Study, https://www.jbs.cam.ac.uk/fileadmin/user_upload/research/centres/alternative-finance/downloads/2019-ccaf-second-global-enterprise-Blockchain-report.pdf
[86] Stanford, J., & Grudnoff, M. (2018). The Future of Transportation Work: Technology, Work Organization, and the Quality of Jobs. Centre for Future Work at the Australia Institute, https://www.tai.org.au/sites/default/files/the-future-of-transportation-work.pdf
[87] See UCL Report, page 38.

IoT is a connected network of interrelated digital and mechanical devices, software and sensors and appliances. IoT devices transmit collected information over the network using built-in chips, and this information can be stored on Blockchain-based ledgers.[88] IoT enables connected navigation, real-time routing and shipment tracking, autonomous vehicles and flight navigation, transport sharing, asset and fleet management, freight monitoring, and transport and coastal surveillance drone management.[89] An IoT device, for instance, may be used to take temperature or humidity measurements during a freight shipment, and transmit the data according to its connectivity capabilities. An immutable, accurate and trusted information log—that is, storing IoT data onto a Blockchain-based ledger—helps assure a product's quality.

Blockchain and IoT are complementary technologies. Blockchain can both store and respond to data transmitted by IoT devices. Smart contracts allow the autonomous execution of pre-determined transactions and can be triggered to execute terms as a result of incoming IoT data. Blockchain can also be used to uphold the trust and transparency of the IoT technology stack, by storing and validating the cybersecurity certification of IoT devices.[90] One key strategic consideration for those seeking to adopt Blockchain across logistics and the supply chain will be how to leverage existing IoT technology. There are also likely to be questions around who in the network pays for the necessary hardware upgrades or sensors.

There are several current examples of IoT and Blockchain projects (in addition to UCOT mentioned earlier). For instance, AT&T is developing and consulting on IoT and Blockchain solutions for improving fleet and cargo management, goods tracking and regulating driver compliance.[91] IoTeX is building a privacy-centric Blockchain platform tailored towards interconnecting IoT networks.[92] Bosch has developed an open-source-based Bosch IoT Suite to connect over 10 million devices by various manufacturers. Bosch and German energy supplier EnBW announced a prototype e-car recharging process in May 2019, which offers customers transparent e-car recharging offers from nearby providers.[93] Reserving and paying for e-charging services is wholly conducted on a Blockchain. Bosch also partnered with Siemens to develop a Blockchain-based smart parking management system, whereby vehicles communicate with parking facilities and negotiate optimal parking terms for both parties. If successful, these use cases may be transferred to the supply chain sector, enabling automation of the refuelling and parking processes. In 2018 World Wildlife Fund and ConsenSys piloted a project with TraSeable and Sea Quest Fiji Ltd to trace tuna throughout the supply chain using radio-frequency identification and QR codes.[94]

There are many ongoing challenges with IoT technology. These should be considered in the strategic implementation of Blockchain technology because the process of inputting reliable, verified and trusted data will likely prove to be crucial in developing successful projects. IoT challenges include the adequate maintenance of information security of IoT and associated devices and properly managing data. Information security can be supported by limiting the transfer of information to selected parties and

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[88] IoTeX, The Blockchain & IoT Tech Stack, https://hackernoon.com/the-Blockchain-iot-tech-stack-163dd1d59d27
[89] Patents and the Fourth Industrial Revolution. The inventions behind digital transformation | December 2017, http://documents.epo.org/projects/babylon/eponet.nsf/0/17FDB5538E87B4B9C12581EF0045762F/$FILE/fourth_industrial_revolution_2017__en.pdf page 19.
[90] Ricardo Neisse, Jose L. Hernandez-Ramos, Sara N. Matheu, Gianmarco Baldini and Antonio Skarmeta, Toward a Blockchain-based Platform to Manage Cybersecurity Certification of IoT devices, https://arxiv.org/pdf/1909.07039.pdf
[91] AT&T, The new era of IoT in the supply chain, https://www.business.att.com/learn/top-voices/the-new-era-of-iot-in-the-supply-chain.html; AT&T, AT&T Fleet Complete, https://att.fleetcomplete.com/; AT&T, AT&T Announces Suite of Blockchain Solutions, https://about.att.com/story/2018/att_Blockchain.html
[92] IoTeX, The Future of IoTeX: 2019–2020 , https://medium.com/iotex/the-future-of-iotex-2019-2020-30d56dcd1633
[93] Bosch, 'DLT restores trust in the internet', https://www.bosch-presse.de/pressportal/de/en/dlt-restores-trust-in-the-internet-189824.html
[94] Yolanda Redrup, WWF develops Blockchain solution to improve transparency in tuna industry, https://www.afr.com/technology/wwf-develops-Blockchain-solution-to-improve-transparency-in-tuna-industry-20180107-h0ejtb

implementing an appropriate security routine.[95] Issues related to Blockchain architecture and governance are also relevant. Scalability, whereby Blockchain platforms can operate under large traffic volumes, may be an issue as the number of participants and volume of data increases. Some of these scalability challenges are overcome through more permissioned networks, or the development of new consensus mechanisms. Cooperation between IoT companies in sharing data and imposing an effective governance system will improve system cohesiveness and efficiency.

It is worth noting that a host of other technologies complement Blockchain-based supply chains. Other technologies are likely to emerge to use the data inputted, for instance, by IoT. AI, for instance (as outlined elsewhere in this report) might use the data in Blockchains to augment decision making. As we have seen, AI is able to detect patterns in data and act as prediction machines.[96] For logistics providers and retailers this could help to manage inventory, sourcing and supply of products on-demand, adjusting price data, predictive shipping of goods through anticipated demand, and choosing the fastest transport route.[97] Furthermore, air freight companies can accentuate their operations by using predictive-maintenance techniques, demand analytics and network modelling, and participating in enhanced data-exchange systems spread across stakeholders.[98] In a Blockchain-based supply chain world there are ongoing questions around the collection and property rights of data, and data markets might be a necessary part of enabling these other technological applications.

6.4 What policies and mechanisms should be used to support these Blockchain technology applications?

Blockchain technology was invented only one decade ago. As an institutional technology that competes with firms, markets and governments to solve coordination problems, Blockchains are expected to have fundamental impacts on the structure of modern economies. This raises questions around how Blockchain technology interacts with policy and regulatory frameworks. The relationship between Blockchain and the regulatory state is complex and evolving for many reasons. On one hand Blockchain might facilitate the process of regulatory enforcement and compliance (e.g. RegTech), while on the other it will disrupt some of the fundamental roles of government (e.g. replacing government-maintained asset registries). As Blockchain technology is applied in practice further regulatory challenges are inevitable. Our aim in this section is to explore some of the policy considerations relevant to Blockchain in freight and logistics, canvassing some of the current considerations.

As Michael Casey and Pindar Wong suggest, marrying the "old-world body of law, and the human-led institutions that manage it, with the digitally defined, dematerialised, automated and denationalised nature of Blockchains and smart contracts will be difficult."[99] The notion of crypto-friendliness is a way to think about government accommodation of Blockchain technology innovation. Crypto-friendly policy jurisdictions are those that are accommodating to the changes and new functionality that Blockchain will bring. In many ways crypto-friendliness faces an inherent trade-off between certainty and lock-in. While entrepreneurs and existing businesses seek certainty in how Blockchain technology will fit with existing laws, developing standards too hastily can lock-in technologies and business models. There is currently a process of jurisdictional competition between different countries and regions to provide

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[95] Nikos Fotiou and George C. Polyzos, Smart contracts for the Internet of Things: opportunities and challenges, https://arxiv.org/pdf/1901.10582.pdf
[96] Agrawal, A., Gans, J., & Goldfarb, A. (2018). *Prediction machines: The simple economics of artificial intelligence*. Harvard Business Press.
[97] https://www.australianindustrystandards.org.au/wp-content/uploads/2019/06/tli_sf2019_final_pages_low_res.pdf
[98] McKinsey & company, Air freight 2025: Agility, speed, and partnerships, Page 3
[99] Michael J Casey and Pinday Wong, Global Supply Chains Are About to Get Better, Thanks to Blockchain, *Harvard Business Review*, 13 March 2017.

crypto-friendly policies to attract investment.[100] Some of this competition will also emerge as governments come together and coordinate efforts to streamline and recognise Blockchain-based information as compliant with domestic regulations.[101]

One positive aspect for crypto-friendliness are current government efforts to develop a framework for freight and supply chain priorities. In 2017 the Australian Government launched the *Inquiry into National Freight and Supply Chain (Inquiry) Priorities* to elucidate the emerging freight and supply chain challenges which affect productivity and performance.[102] To respond to and navigate these challenges for the next 20 years, all Australian governments developed the *National Freight and Supply Chain Strategy (Strategy)* and *National Action Plan*. The Strategy identifies four key target areas for improvement: smarter and targeted infrastructure; improved supply chain efficiency; better planning, coordination and regulation; and better freight location and performance data.

A significant early action taken towards achieving the Strategy's outcomes is the establishment of the National Freight Data Hub (the Hub) by the Australian Department of Infrastructure, Transport, Cities and Regional Development.[103] The Hub aims to enhance collection of and access to freight data by establishing best practice models for data: collection, privacy, dissemination and hosting. It will also set up a freight data exchange pilot to enable real-time access to freight data.[104] Synchronised and up-to-date data can be accessed by permitted parties or can be made public. Permitted parties can have synchronised access to current data. Blockchain can secure data consistency across jurisdictions due to the technology's auditability and verification properties.

Because Blockchain-enabled systems store and distribute various types of data, there are several data retention and sharing questions from a legal perspective.[105] Legal issues associated with data generation, storage and control are of critical relevance to Blockchain platforms. These questions are difficult and evolving but should be considered in deploying Blockchain-based infrastructure. For instance, who owns the data stored in Blockchain platforms? What organisations (including governments) have the permission to access and use the raw and/or aggregated data? For what purpose do users have access or permission to use the data? How secure and private is the data? What will happen to the data when the contract ends, or either party winds up their business? Data rights should be clearly defined in agreements with contracting parties. Often, technology companies rely on standard-form, non-negotiable software contracts that can, by default, restrict a producer's control, ownership and use of the collected data. Issues with standard-form contracts have led the American Farm Bureau Federation, an agricultural industry body, to develop data principles to support the creation of clear, simple and transparent contracts.[106] Transparent contract terms may better prepare contracting parties to comply with data-management governance, policies and frameworks.

Some examples of data mismanagement have increased efforts for data privacy. The Australian Precision to Decision Agriculture Project found that 56 percent of producers have no or little trust in service or

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[100] Pochesneva, A., and M. Novak. (2019) "Toward a Crypto-Friendly Index for the APEC Region", *Journal of the British Blockchain Association*, vol. 2, no. 1, pp 39-45.
Novak, M. (forthcoming). "Crypto-friendliness: Understanding Blockchain Public Policy", *Journal of Entrepreneurship and Public Policy*.

[101] Allen, D.W.E., Berg, C, Davidson, S, Novak, M, & Potts, J (2019). International policy coordination for Blockchain supply chains. *Asia & the Pacific Policy Studies*, vol. 6, no. 2.

[102] Inquiry into National Freight and Supply Chain Priorities, https://www.infrastructure.gov.au/transport/freight/freight-supply-chain-priorities/index.aspx

[103] https://www.freightaustralia.gov.au/sites/default/files/documents/closer-look-actions-underway.pdf

[104] Better freight location and performance data, https://www.freightaustralia.gov.au/what-are-we-doing/better-freight-location-and-performance-data

[105] Australian Government - Department of Agriculture and Water Resources, Technical Report - Accelerating Precision Agriculture to Decision Agriculture, p 13.

[106] American Farm Bureau Federation, Privacy and Security Principles for Farm Data, www.fb.org/issues/technology/data-privacy/privacy-and-security-principles-for-farm-data

technology providers to maintain their data privacy.[107] In lieu of technical standards or regulations governing best practice in data management, use and control, technical service providers may choose to set a high and transparent standard.[108] Doing so may increase trust among software users. The challenges or data rights and standards may have also contributed to problems of consortia-building as described earlier. Where there are significant controlling players in permissioned Blockchain networks, those joining the networks express concerns over data rights. Through time we might develop an appropriate legal and technical framework that facilitates data privacy, safety and security will minimise risks associated with the misuse, or negligent transfer of sensitive business data. Digital asset creation, and how data is created and validated with respect to the digital asset, is not currently being standardised.[109]

A final policy consideration concerns financial transactions on Blockchains. Financial transactions could reduce reliance on trusted third parties to enact payments at requisite points along the supply chain. There are several examples of Blockchain-enabled financial transactions in supply chains are detailed below. AgriDigital deploys a system in which payments are simulated with 'Agricoin', a token that is minted by AgriDigital and is pegged 1:1 to the Australian dollar. First, AgriDigital generates a digital title for grower's physical commodity. A smart contract transfers the asset's digital title to the buyer when the buyer pays for the commodity in Agricoin. All Agricoins minted for the transaction are destroyed when the parallel, traditional banking method completes the fiat currency payment to the grower. Agricoin may not need to be regulated if the token performs a mere utility token function, and the final payment is made using traditional banking methods. Similarly to AgriDigital, GrainChain uses a smart contract to settle transactions.[110] When commodity shipments are verified, growers are paid in 'GrainPay', a dollar-backed stablecoin. GrainPay tokens are destroyed when they are converted to fiat currency. A key difference between AgriDigital and GrainChain is that the latter charges a commission for each platform transaction, which is automatically deducted using the smart contract. GrainPay may be a utility token with payment token characteristics.

These examples might also generate some legal issues.[111] Transactions utilising payment tokens, for instance, may be subject to financial services laws. Operational roadblocks may arise in jurisdictions that forbid certain financial transactions, or when regulatory inconsistencies between jurisdictions are insurmountable. Complying with regulation may also be excessively complex, which can push up company compliance and operational costs. Key regulatory questions arise for token payments facilitated by smart contracts. Do cryptocurrency tokens serve a mere utility function, or do they serve a payment function? If they serve a payment function, do they constitute one transfer of value, or two or more transfers of value?[112] If there are two or more transfers of value, specific regulatory treatment may apply to each token purchase and sale event. Companies such as AgriDigital have advocated for a government-issued digital currency to more easily integrate digital currencies into Blockchain platforms.[113]

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[107] Australian Government - Department of Agriculture and Water Resources, Summary Report - Accelerating Precision Agriculture to Decision Agriculture, https://www.crdc.com.au/sites/default/files/CRD18001-001%20CRDC%20P2D%20Report%20low%20res.pdf
[108] https://blog.agridigital.io/demystifiying-data-in-the-digital-age-7f3be3073fb8
[109] AgriDigital, Why Is Proof of Location Important For Digital Assets?, https://blog.agridigital.io/why-is-proof-of-location-important-for-digital-assets-19ff4fd4830c; AgriDigital, We Need to Talk about Data, https://blog.agridigital.io/demystifiying-data-in-the-digital-age-7f3be3073fb8
[110] GrainChain, https://www.grainchain.io/.
[111] UCL report p 49.
[112] UCL report p 49.
[113] Dominic Powell, Agriculture Blockchain start-up 'AgriDigital' closes $5.5 million raise with plans for integrated digital currency, https://www.smartcompany.com.au/startupsmart/news/agriculture-Blockchain-startup-agridigital-5-5-million-plans-agricoin-digital-currency/

7 CONCLUSION

In the last 5 years there has been significant progress in the advancement of technology in both Artificial Intelligence and Blockchain applications relevant to the transport sector. This rapid pace has made it difficult for both transport agencies and related companies to keep up with developments and inform decisions around deployment. This presents a significant challenge given technology deployment is considered for medium to long term application and decisions around the type of technology can therefore be locked in for some time to come despite new and emerging options providing greater value. Hence the conclusion of this investigation is that there is strong merit for the further investigation of the application of Artificial Intelligence and Blockchain in the transport sector and that this stands to present significant value to both the government agencies and companies involved - along with an improvement of service.

When considering Artificial Intelligence, the research found that there are a number of mature applications of artificial intelligence available for improving transport network management such as traffic light optimisation, fleet optimisation, predictive logistics, accident detection, rail system optimisation and general traffic management. The research also found that there are emerging applications that could provide great value including adaptive traffic control, vehicle prioritisation, parking detection, and greenwaves. The research suggests that efforts to support strategic approaches should focus on well informed pilot projects, the development of in-house AI capability, and clear communications strategies.

When considering Blockchain technology it is important to understand that the technology is less than a decade old and its potential has barely been glimpsed let alone harnessed. Given the fact that it’s functionality will compete with many existing systems (including the banking and finance system) there has been and will continue to be push back from incumbents using misinformation and other mechanisms to attempt to block uptake, however in the end the functionality will speak for itself and the market will choose, as has happened in every wave of innovation since the start of the industrial revolution. Governance considerations around this new technology are complicated, as it stands to both enhance current processes while also replacing others, calling for careful investigation around the benefits of being crypto-friendly. When seeking to create a Blockchain there are issues to consider such as such as privacy (how is data stored and linked to its source), security (how is the data protected from unauthorised users), access (how are authorised users allowed to access data), ownership (who owns the data in the Blockchain), transactions (are these subject to financial services laws), and what happens to data after the purpose of the Blockchain has been achieved.

In conclusion both Artificial Intelligence and Blockchain present significant to opportunities to enhance all sectors and the transport sector is no exception with calls for transport systems to be 'AI-Ready' and 'Crypto-Friendly'. This report presents valuable early stage learning and recommendations and should be fully considered to inform areas of further investigation.