Investigating the Potential for Artificial Intelligence and Blockchain Technology to Enhance the Transport Sector

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EXECUTIVE SUMMARY

As with previous waves of innovation the transport sector stands to gain a number of benefits from the application of advanced technologies, in particular Artificial Intelligence and Blockchain Technology. For instance The International Data Corporation believe that spending on artificial intelligence technologies will increase by more than 50 percent year over year, reaching $57.6 billion in investments by 2021 (Shirer 2017[1]). While the World Economic Forum predicts that by 2027 some 10 percent of global GDP will be Blockchain-based, in the order of US$8 trillion (WEF, 2015[2]).

Along with significant implications across a range of sectors these technologies will provide a number of new and unique opportunities in the transport. This report provides an overview of the functionality and application of a range of emerging applications of Artificial Intelligence and Blockchain technology to the transport sector. The purpose of the report is to provide the project partners with an overview of viable areas of investigation and, based on stakeholder workshops and interviews, present a short list of applications to be considered as part of the second stage of the project. The short list includes tangible applications in specific areas where further investigation stands to provide valuable guidance to transport agencies and transport-related companies.

The results of the shortlisting have identified a short list of 5 applications of Artificial intelligence for further investigation, as shown in Table A, namely:

1. Identification of Network Characteristics (vehicle data, engineering data, hazards,)
2. Traffic Management (Interruptions to flow, predictive congestion management),
3. Traffic Signal Optimisation (Based on real time conditions), and
4. Vehicle Prioritisation (Emergency and Mass Transit).

The results of the shortlisting have identified a short list of 3 applications of Blockchain Technology for further investigation, as shown in Table Bb, namely:

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

The next stage of the research project will investigate for each topic the associated risks and rewards and develop recommendations for implementation, including specific policies and mechanisms to underpin the applications. It is anticipated that this will inform the development of implementation focused projects as part of a follow on project.

[1] Shirer, M 2017, 'IDC Spending Guide Forecasts Worldwide Spending on Cognitive and Artificial Intelligence Systems to Reach $57.6 Billion in 2021', International Data Corporation, Press Release 25 September 2017.

[2] WEF 2015, 'Deep Shift: Technology Tipping Points and Societal Impact', *World Economic Forum*, September 2015.

Table A: Summary of findings from Stakeholder Review of Artificial Intelligence Applications

Applications of Artificial Intelligence	**Level of Perceived Value (V)** **Level of Current Application (A)**				
	V. High	*High*	*Med*	*Low*	*V. Low*
Identification of Network Characteristics *(vehicle data, engineering data, hazards)*	4V	2V A	V 2A	- A	- A
Self-Driving Vehicles *(Simulation of self-driving behaviours)*	3V	1V A	- A	3V A	- 3A
Traffic Management *(Interruptions to flow, predictive congestion management)*	5V A	2V 2A	V -	- 2A	- A
Vehicle Behaviour *(Baseline of expected behaviour, irregular behaviour)*	2V -	3V 2A	2V 1A	- 1A	V 2A
Identification of Breaches *(clearway, weight limits, vehicle type, right toll, etc..)*	V -	2V A	2V 1A	2V 2A	- 2A
Traffic Signal Optimisation *(Based on real time conditions)*	3V -	3V A	V A	- A	- A
Vehicle Prioritisation *(Emergency and Mass Transit)*	3V -	3V A	1V 2A	V A	- 2A
Route Optimisation *(Commercial and Freight vehicles, Emergency Response)*	2V -	3V A	V -	V A	- 3A
Traffic Risk Management *(Comparing real time conditions to vehicle risk profiles)*	V -	V -	3V 2A	- A	3V -
Optimisation of Ride-Sharing Services *(Mobily-as-a-Service)*	2V A	2V -	2VA	2V 3A	- 2A
Detecting Fare Evasion *(Detecting Turnstyle Shadowing)*	- -	2V -	3V -	V A	3V 3A
Routing and Management of Drones *(Controls on private drones, routing of service drones)*	V -	- -	2V A	2V A	V 3A
Asset Management Data *(Collecting data on assets and conditions to trigger alerts)*	3V -	2V A	- 2A	V -	- 3A
Monitoring Vehicle Locations *(freight/container locations, PT compared to schedule)*	3V -	V -	3V 2A	- 2A	- 2A
Compare Modal Trip Times *(monitor quickest options to communicate to travellers)*	3V A	2V A	V A	2V -	- 3A

Table B: Summary of findings from Stakeholder Review of Blockchain Technology Applications

Applications of Blockchain	**Level of Perceived Value (V)** **Level of Current Application (A)**				
	V. High	*High*	*Med*	*Low*	*V. Low*
Vehicle Ownership Documentation (*Reduced transactions, ownership and servicing validity*)	V A	V -	3V	2V A	- 3A
Real Time Road User Pricing (*Charging for time of day and road type usage*)	V -	3V A	3V -	- -	- 4A
Congestion Zone Charging (*Creating virtual zones for congestion management*)	V -	3V A	3V -	- -	- 4A
Collection of Tolls and Charges (*Virtual Toll Gantries*)	- -	4V A	3V -	V -	V 4A
Automatic Car Parking Payments (*Charging vehicle for time of use and location of parking*)	V A	V -	3V -	V -	- 4A
Establishing Identification (Digital drivers licences and vehicle ownership)	3V A	V A	3V -	- -	- 3A
Intermediary Free Ride Sharing (*Fares agreed between driver and passenger*)	2V -	V -	2V A	V -	V 4A
Vehicle Generated Collision Information (*Details of collisions securely store and validated*)	2V -	- -	3V A	V -	- 4A
Enhanced Freight Tracking and Authenticity (*Real time location and confirmation of delivery*)	5V -	V A	3V -	- -	- 4A

INTRODUCTION

The purpose of this report is 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. This report identifies specific potential applications and suggests where such technology can provide tangible benefits for the transport sector. The report covers various partner-preferred examples of application of such technologies such as congestion management, real-time operations, network optimisation, road user pricing, asset management, mobility-as-a-service (MaaS), and freight logistics. This report was used to identify a short list of potential applications for further investigation. The investigation was undertaken in two parts. Part 1 focused on identifying a list of potential applications of Artificial Intelligence and Blockchain Technologies to the transport sector. Part 2 then involved the research partners assessing this list to identify a short list of application for further investigation.

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 across the Australian transport sector?*". The objectives of the project are as follows, with this report presenting findings from Parts 1 and 2:

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.

The core industry challenge that this project seeks to address is how to quickly identify valuable applications of new technologies to harness increasing volumes of data and to build strategic approaches to their application in the transport sector across Australia. Advances in Artificial Intelligence and the emergence of Blockchain technology, stands to revolutionise the way value is created and transferred around the world and has a number of tangible applications to transport across all modes. According to the National Transport Commission in 2016, Blockchain stands to provide '*conditions of stable, trusted, interoperable and secure data communications within transport, and between transport and other service providers*'. A key element of harnessing this new technology platform will be to ensure that industry, government and researchers work together to identify early stage applications that provide reliable, fast, affordable and sustainable mobility in the Australian transport sector.

PART 1: NEW APPLICATIONS OF ARTIFICIAL INTELLIGENCE TO THE TRANSPORT SECTOR

What is Artificial Intelligence?

Artificial Intelligence can be a powerful tool for learning how to manage and predict flows of objects, making it particularly useful for the transport sector. For instance in 2016 data collected on crowd movement at the largest gathering of people in the world, the Kumbh Mela religious congregation in India was used to predict crowd movements and timings (Jain, 2018[3]). An application of Artificial Intelligence that is of particular value to the transport sector is called 'Machine Learning', which allows greater use of current data in decision making by machines. It is important to make a distinction between a rule-based learning and machine learning:

1. *Rule-Based Learning*: This is where a computer programmer writes a lengthy set of computer code and provides organised and labelled input data to allow for every eventuality that the program could face and provides options for each; in essence the programmer 'teaches' the computer. This is commonly referred to as 'Rule Based Learning' and can be thought of as '*Programmed Learning*'. For example, the code may call for the program to answer a question such as '*Are the doors on the train all closed?*' and then provide two command options. If after checking the data from the door sensor the answer to the question is 'Yes' then the program can move to the next question needed to answer before the driverless train departs the station, and if the answer is 'No' then the program may ask other pre-departure questions and then come back to this one with all requiring a 'Yes' in order to depart. This approach is intensive and limited as it calls for each eventuation to be foreseen and a set of options designed into the code. This approach is valuable, however, and is best used with a clear set of potential options and outcomes involving relatively small data sets.
2. *Machine Learning:* This is where the lengthy computer code involving questions and commands is replaced by programming, which typically uses artificial neural networks, to investigate the relationships between data to either predict an associated outcome, cluster like inputs, or identify when a new input varies from the typical inputs. This is commonly referred to as '*Self-Learning*' as the programming creates relationships between input data based on the data rather than being programmed. For instance a self-learning computer makes decisions based on comparing examples from the past and associated outcomes, with the current situation, to estimate a likely outcome, such as the anticipated average vehicle speed on a particular part of a roadway, updating itself as it goes much like the human brain does. Unlike the case of rule-based learning, self-learning, requires large data sets to enable the system to learn in order to be able to interpret a set of incoming data streams and make a decision as well as, or better than, a human.

[3] Jain, M 2018, 'NITI Aayog paper seeks AI boost, praises its use in 'Kumbh Mela Experiment'', *Business Standard*, 06 June 2018.

Machine Learning algorisms can be classified based on how they learn, namely:

a. *Supervised Learning*: In supervised learning, the algorithms are calibrated using pre-labelled sets of data to identify various elements (for instance a car has these characteristics, a pedestrian has these characteristics). The input variables/features and associated outputs based on historic data are provided to the algorithm to learn so it can recognise the input pattern to identify the output in real time.

b. *Unsupervised Learning*: In unsupervised learning, the machine identifies clusters, patterns and anomalies using input data alone, with no labelled outcomes to train from or with no human to provide guidance along the way. Identifying road usage patterns. For instance clustering all things that look similar on the road, such as a car, that can then be labelled 'a car' by a user, or detecting if a truck is using a car only road as it is an anomaly to the usual shape.

Much effort has been made to apply Artificial Intelligence to transport in order to enable vehicles to be driven by computers, freeing up the human driver and improving safety and efficiency outcomes. This is most commonly referred to as making the vehicle 'Autonomous', meaning that it does not need the human occupant to do anything. This term is misleading, however, as although the vehicle can drive itself, it will not be able to do so in all conditions and at this stage still needs assistance to refuel, recharge, pay for registration, go through the car-wash, etc; hence it is more accurate to call it a 'Self-driving' vehicle. It is likely that once self-driving is achieved, the focus will shift to the interaction with the traveller allowing a passenger to talk freely to the car (much like Google Home and Amazon Alexa), discuss routes, set functions in the vehicle like temperature and music, and access information to display on internal screens. Rather than being 'autonomous' and not needing any input from an occupant, these vehicles will be interactive with travellers.

How can AI be applied to the Transport Sector?

Although Artificial Intelligence is not a new technology there is a number of underutilised applications for the transport sector, including enabling self-driving vehicles, analysis of traffic patterns, and prediction of traffic volumes (Katte, 2018[4]). The following list includes some of these applications that harness AI to enhance transport systems:

Artificial Intelligence and Self-Driving Vehicles

Developed by Cornell University, 'DeepTraffic' is a computer program developed using neural network technology to simulate driving '*a vehicle (or multiple vehicles) as fast as possible through dense highway traffic*'. The focus of the software is to learn efficient movement patterns in traffic which prevents a vehicle from colliding by either preventing an action which would lead to a collision or altering the speed of the vehicle (Friedman *et al*, 2018[5]).

[4] Katte, A 2018, 'How Allahabad Police Uses AI for Crowd Management and Service Delivery', *Analytics India*, 19 March 2018.
[5] Fridman, L., Jenik, B., Terwilliger, J. 2018, 'DeepTraffic: Driving Fast through Dense Traffic with Deep Reinforcement Learning', Cornell University, 2018.

Artificial Intelligence and Traffic Management

The 'Malaysia City Brain' created by Alibaba uses Artificial Intelligence to process data from 300 traffic lights, 500 CCTV cameras, public transport data systems and other data streams to reduce traffic congestion (Bhunia, 2018[6]). The system uses the data to predict traffic conditions and can make recommendations for emergency services routing (MDEC, 2018[7]). The 'City Brain' AI technology was deployed in Hangzhou China in September 2018 and has resulted in '*an average traffic speed increase of 15 percent, and reporting traffic violations with 92 percent accuracy*' (E&T, 2018[8]).

Artificial Intelligence and Vehicle Behaviour

Data around how vehicles interact with other vehicles, the frequency and location of stops at petrol stations, time spent at various traffic signals etc. can be used by an AI system to build a baseline of expected behaviour on the traffic network. This baseline can then be used to identify abnormalities such as instances of irregular driving or avoided collisions that can be recorded for traffic infringements (Zoldi, 2018[9]). The data collected could also inform a vehicle of the level of risk of driving behind a particular vehicle and even be at the ready to provide an enhanced driver assist if the vehicle in front is exhibiting precursors for unsafe behaviour (Licata, 2017[10]).

Artificial Intelligence and Traffic Signal Optimisation

Despite progress to optimise traffic signalling delivering a system that can allow for variations in real time comes with challenges. In response to this 'Deep Q-Networks' (DQN) are being explored and early trials have demonstrated '*intelligent behaviour, such as the emergence of greenwave patterns, reflecting their ability to learn favourable traffic light actuations*' (Liu 2018[11]).

Artificial Intelligence and Vehicle Prioritisation

The Public Transport Information and Priority System (PTIPS) linked to the SCATS traffic system in Sydney can detect if a bus is more than 2 minutes behind schedule and provides priority signalling. A 2001 trial with the Sydney Airport Express Bus service showed the system 'reduced mean travel times of buses by 21 percent and variability of travel time by up to 49 percent' (BITRE, 2017[12]).

Artificial Intelligence and Route Optimisation

Logistics company UPS has created an AI system called ORION (On-road Integrated Optimization and Navigation) that identifies the most efficient routes for its fleet based on customer, driver and vehicle data.

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[6] Bhunia, P 2018, Malaysia City Brain initiative to use real-time, anonymised traffic data from Grab, *Open Gov Asia*, 20 April 2018.
[7] MDEC 2018, 'City Brain FAQ', Malaysia Digital Economy Corporation, 2017.
[8] E&T 2018, 'Alibaba's AI traffic management system to be rolled out in Malaysia', *Engineering and Technology*, 30 January 2018.
[9] Zoldi, S 2018, 'Blockchain and Artificial Intelligence Transform the Driving Experience', *Information Age*, 22 May 2018.
[10] Licata, J 2017, 'How Blockchain will transcend how AI is used in mobile transportation', *Hackernoon*, 09 June 2017.
[11] Liu, X., Ding, Z., Borst, S., Walid, A. 2018, 'Deep Reinforcement Learning for Intelligent Transportation Systems', 2018.
[12] BITRE 2017, Costs and benefits of emerging road transport technologies, Report 146, Bureau of Infrastructure, Transport and Regional Economics, BITRE, Canberra ACT.

The routes are updated in real time depending on road conditions and other factors, optimising the flow of up to 60 million packages a day in the US (Morgan, 2018[13]).

Artificial Intelligence and Traffic Risk Management

A system designed by UK company Predina uses AI and geospatial analytics to predict road transport risks. The system generates risk mitigation intervention suggestions based on historical incidents and near-misses, weather data, real-time traffic information and driver risk profiles (Carey, Macaulay & Williams, 2018[14]).

Artificial Intelligence and Ride-Sharing

Door2door is a company founded in 2012, which is developing an on-demand ride-sharing service. Specifically, the platform simulates demand and responds to it in real time, manages dispatches, bookings, route planning and drivers. The Ai algorithm optimises pooling configurations and routes (Nanalyse, 2018[15]).

Artificial Intelligence and Fare Evasion

A Spanish startup, AWAAIT, is pioneering an Ai-powered system to reduce fare evasion by sneaking through entry gates behind paying customers on the Barcelona Metro. The system is called "Detector" and it works by analysing camera images of travellers entering the metro entry barriers for suspicious behaviour. If the analysis triggers the alarm, the cameras take pictures of the suspect and the inspector can check the ticket of that person, resulting in a 70% decrease in fare evasion in initial tests. (Cullmann, 2018[16]).

Artificial Intelligence and Drones

Australian company Alphabet is testing the use of drones to deliver food and medicine to rural areas (Mogg, 2017[17]). The AI behind the system learns customer preferences but also the most efficient and safe way to access properties and deliver parcels. Such technology could be used to provide first responder relief in the case of natural disasters affecting road networks such as bushfires and flooding where traditional vehicle access is restricted.

[13] Morgan, B 2018, '5 Examples of How AI Can Be Used Across The Supply Chain', *Forbes*, 17 September 2017.
[14] Carey, S, Macaulay, T, & Williams, H 2018, 'AI Startups to Watch: The hottest machine learning startups in UK', TechWorld, 21 January 2019.
[15] Nanalyse, 2018, Top-10 Artificial Intelligence Start-ups in Germany, Nanalyse, 29 May 2018.
[16] Cullmann, V 2018, 'Spanish AI Startup AWAAIT makes sure you pay fare in Barcelona', *Novobrief*, 2018
[17] Mogg, T 2017, 'Drones are delivering burritos directly to the homes of rural Australians', *Digitial Trends,* 18 October 2017.

PART 2: APPLICATION OF BLOCKCHAIN TECNOLOGY TO THE TRANSPORT SECTOR

What is Blockchain Technology?

In response to the 2008 global financial crisis, an anonymous programmer released the blueprints for what they called a 'Bitcoin' which brought together various forms of cryptography and computer science to create a functioning digital currency that does not require a central authority. The underlying programming is now referred to as a 'Blockchain' and it overcomes the double spend issue of previous attempts to create a digital currency, by creating an online distributed database that contains encrypted time-stamped information that cannot be tampered with without detection.

In simple terms, this is done by replicating the database over many computers and rewarding those that hold it for validating transactions and ensuring an unamended version to allow comparison with others also holding the database to quickly identify hacking attempts; in doing so this has created a truly world-changing technology which has a range of applications to the transport sector among many others.

For the first time in human history, this new digital architecture allows for financial transactions to be done directly between two strangers without the risk of default or double spending; eliminating the need for an intermediary like a credit card company or a bank. Despite obvious resistance by financial intermediaries, in April 2017 Japan eliminated consumption taxes on such 'crypto-currency' transactions and deemed them a legal tender. Chief Executive of the Australian Stock Exchange, Elmer Funke Kupper, reflects that, '*Every now and then, something comes along that might just change everything. And this is one of those moments'* (Eyres, 2016[18]). Given the implications for the financial sector, it has been one of the first to adopt the technology.

According to a United Nations report, by 2016 over 60 percent of the global financial system had started to explore the application of Blockchain technology to increase operational efficiency and reduce transaction costs (UNEP, 2016[19]). For instance, HSBC, the Bank of America, Merrill Lynch, and the Infocomm Development Authority of Singapore are trialling a Blockchain-based 'Letter of Credit' system. A Letter of Credit is essentially a statement from a bank guaranteeing the payment for some form of goods or services in the future, mainly used when the buyer and seller are in different countries.

By using a Blockchain-based system, transactions can be broken down into multiple smart contracts, which can be monitored in real time by all parties. Benefits of this system include a reduction in paperwork needed, reduction in errors, and an increase in convenience and security for all parties (DHL, 2018[20]).

[18] Eyres, J 2016, 'Blockchain and how it will change everything', *The Sydney Morning Herald*, 6 February 2016.
[19] UNEP 2016, 'Fintech and Sustainable Development: Assessing the Implications', *United Nations Environment Programme*.
[20] DHL 2018, 'Blockchain in Logistics: Perspectives on the upcoming impact of blockchain technology and use cases for the logistics industry', *DHL Trend Research*.

The ability to operate a digital currency is just the beginning of the promise of Blockchain technology that can also store information, agreements, and contracts that cannot be amended and can have digitally self-executing functionality. Such records are also accessible by any computer in the world as an immutable record; which is a game changer for the global economy. Government agencies around the world are applying Blockchain technology for a range of applications, such as: tax and business registration (Singapore), health records (Estonia), real-time auditing land registry (Georgia), voting (Sierra Leone, Russia, Columbia), anti-fraud for imports and exports (Singapore), welfare payment and budgeting support (United Kingdom), government operations (Dubai), identity management (Switzerland), supply chain traceability (Texas), and storage of passports and birth certificates (Australia) (US DoT, 2018[21]).

Early movers in the transport sector include Toyota having launched a collaboration with the MIT Media Lab and a selection of Blockchain-based companies in 2017 to explore the value of the technology to the automotive industry. The focus of the initiative is to explore four main areas, namely: how it can assist uptake of automated vehicles, capture and share trip data from driverless vehicles, offer applications to enable greater ride sharing, and offer pay-as-you-drive options.[22] The Blockchain in Transport Association (BiTA) brings together over 300 companies from across transport, logistics and relevant technology sectors, including large players like FedEx, UPS and Schneider, to ensure consistent standards for the use of Blockchains in freight and logistics. According to BiTA, '*Members know that Blockchain is the way of the future … and understand that Blockchain isn't just an industry disruptor, it's technology that will revolutionize the way people do business*' (Baker, 2018[23]).

Blockchain technology can be further enhanced by combination with artificial intelligence options such as machine learning and deep learning algorithms. According to a survey by Forbes Insights involving over 400 senior transportation-focused executives, some '*65% believe the logistics, supply chain and transportation sector is experiencing nothing short of a tectonic shift*' (Forbes Insights, 2018). Further, the respondents highlighted a number of potential drivers for this shift, in particular '*technologies like artificial intelligence (AI), machine learning (ML) and increasingly, Blockchain*'.[24] In basic terms, 'Artificial Intelligence' is the capacity of computers to not only make decisions that were previously made by humans, but also to be able to make decisions that humans are not capable of making given the complexity and volume of data.

The academic field of Artificial Intelligence was created in the mid 1950's and more recently it has seen a revival of interest due to the proliferation of computers and growing amounts of data becoming available from all across society (used in Google searching, electronic home assistants, Spotify, etc.). Artificial Intelligence is more than just about making decisions; it is also concerned with developing computers that think and act like humans, and hence involves

[21] US DoT 2018, What Blockchains could mean for government and transportation operations, United States Department of Transportation, Volpe Centre, DOT-VNTSC-18-03.
[22] Shieber, J 2017, 'Toyota pushes into Blockchain Technology to enable the Next Generation of Cars', *Tech Crunch*, May 22, 2017.
[23] Baker, M 2018, 'Blockchain on the Rise and the Search for Solutions', *Freight Waves*, June 27, 2018.
[24] Forbes Insights 2018, 'How Blockchain May Impact Logistics, Supply Chain and Transportation: A Conversation with The Blockchain In Transport Alliance', *Forbes Insights*, September 4, 2018.

a range of disciplines such as computer science, psychology, ethics, cognitive studies and neuroscience.

How can Blockchain Technology be applied to the Transport Sector?

According to Rich Strader, Vice President of Mobility Product Solutions for Ford Motor Corporation, '*Blockchain will transform the way people and businesses interact, creating new opportunities in mobility*' (Peters, 2018)[25]. Craig Fuller, Managing Director of BiTA believes that Blockchain is ideally suited to the transport sector and its impact will be transformational (Forbes Insights, 2018 [26]). Fuller reflects on the potential of Blockchains by saying, '*Transportation is a massive segment of the global economy - as much as 12% of cash flows - and there are so many parties involved: shippers, carriers, customs and the companies that provide fuel for trucks, planes, trains, etc. There are so many transactions associated with any shipment. Now think about having to wait 60 to 90 days for payment across each and every segment from each and every participant involved. What if, instead, we use blockchain and smart contracts to speed up payments? That introduces trust and automation, speeding verification and eliminating an enormous drag; there's so much payment float in the global economy'*. German logistics company, JDA, is researching Blockchain solutions for managing supply chains and believe that it could be a game changer for Germany's food industry, which is currently monitored manually (Hanrahan, 2018[27]).

A report by the Queensland Investment Commission (QIC) found that Blockchain is initially being used in the automotive industry to help facilitate payments, pointing out that US company AT&T had filed for a patent to enable the use of crypto-currencies for payments direct from vehicles (QIC, 2017[28]). The QIC then suggests that the '*benefits of widespread adoption could be immense*' and considering the future prospects predicts that, '*Blockchain technology will enable vehicles to be reimagined as information-rich devices capable of mobile payments, and will be at the centre of initiatives to improve economic efficiency, quality of life and better commercial outcomes. It could enable greater optimisation of car parking assets and arterial road networks*'. For instance, a Blockchain could be used to collect real-time location information from vehicles and provide the ability to make and receive payments using a cryptocurrency wallet. As will be expanded further in this report, this has the potential for a number of applications, including road user charges, parking, congestion charging, toll collection and the increased utilisation of the transport network.

An early example of harnessing Blockchain in the transport sector is the 'Mobility Open Blockchain Initiative' (MOBI). MOBI is a global non-profit consortium exploring how Blockchain technology can make transportation safer, more affordable and more widely accessible. According to MOBI Chairman and CEO, and former CFO for Toyota Financial Services, Chris Ballinger, '*Blockchain and related trust enhancing technologies are poised to redefine the automotive industry and how consumers purchase, insure and use vehicles*.'

[25] Peters, B 2018, 'Ford, GM, IBM Want Transportation To Run On Blockchain', Investors Business Daily, 02 May 2018.
[26] Forbes Insights 2018, 'How Blockchain May Impact Logistics, Supply Chain and Transportation: A Conversation with The Blockchain In Transport Alliance', *Forbes Insights*, September 4, 2018.
[27] Hanrahan, B 2018, 'Industry gets on the Blockchain', *Handelsblatt Today*, April 27, 2018.
[28] QIC 2017, Blockchain is knocking at infrastructure's door, Queensland Investment Corporation, Brisbane, Queensland.

(Marinoff, 2018)[29]. MOBI is currently developing Blockchain applications for vehicle identity and history, supply chain tracking, autonomous payments, and pay as you travel charging and insurance. Together with the Trusted Internet of Things Alliance (TIoTA), MOBI has created the MOBI Grand Challenge (MGC), which offers $350,000 of prizes for organisations that can show potential uses of Blockchain to control traffic and improve urban transport.

Despite Blockchain technology being relatively new, there is a growing number of applications focused on the transport sector. The following list includes some of these applications that harness Blockchain-based platforms:

Blockchain for Traffic Management

Blockchain technology can provide the ability for vehicles to make and receive payments using a cryptocurrency wallet based on real-time vehicle location. This will allow for encouraging or discouraging the use of particular routes using a financial mechanism.

Blockchain for Logistics Documentation

Blockchain technology stands to enhance the transport and logistics industry by enabling secure and tamper-proof records in real time, bringing new levels of transparency and efficiency (Newman, 2018[30]). For instance, Europe's largest port, the Port of Rotterdam, has set up a 'BlockLab' and is using a Blockchain solution to replace the paper-based 'bill of lading' system used in ports with a digital system. This allows tamper-proof records that are available in real time to all necessary parties in the supply chain, significantly reducing transaction costs and time.

Blockchain for Global Freight Tracking

In August of 2018, IBM and Danish shipping container company Maersk released a joint electronic ledger for global freight tracking, with 94 groups initially involved. Information shared on the Blockchain includes customs releases, commercial invoices and cargo lists, which are shared with all parties right after they are produced. So far, over 160 million shipping events have been stored by the system, with roughly one million events happening per day (Mearian, 2018[31]).

Blockchain for Supply Chain Transactions

The company ShipChain has a similar Blockchain-based tracking system that tracks a product from the moment it leaves the manufacturer, to when it arriving with the customer. This tracking system allows for the automatic confirmation of delivery, which means that all the parties involved across the supply chain can automatically be paid when they have completed their part (ShipChain, 2018[32]).

Blockchain for Identification (Drivers Licences)

A Blockchain-based platform is helping ensure the security of the New South Wales

[29] Marinoff, 2018, 'New Blockchain Initiative for the Automotive Industry Announced in Dubai', Bitcoin Magazine, 02 May 2018.
[30] Newman, N 2018, 'Could blockchain transform transport?', *Engineering and Technology*, June 21 2018.
[31] Mearian, L 2018, 'IBM, Maersk launch blockchain-based shipping platform with 94 early adopters', *ComputerWorld*, August 20, 2018.
[32] ShipChain 2018, 'Using Blockchain to Better Understand the Total Cost of Transportation', *ShipChain*, November 15, 2018.

Government's rollout of digital driver's licenses. Secure Logic Group announced the launch of its 'TrustGrid' platform that has been used as the digital platform for a digital driver's license pilot in Dubbo, NSW, with 1,400 participants in November 2017. The platform is now being used as part of the first metro trial of the digital driver's license in Sydney's eastern suburbs. The second pilot will see more than 140,000 drivers entitled to opt-in for a digital driver's license that can be used for police checks and to gain entry to pubs and clubs in the trial area (Pearce, 2018[33]).

Blockchain for Establishing Provenance

Enhanced product-tracking through Blockchain technology can also have major positive effects in the food industry. Walmart is currently testing Blockchain technology to track the movement of food, from producer to the store. This allows Walmart to immediately know precisely which producer is responsible in the event of poor quality or spoiled food, including temperature sensor data from shipping spaces. In 2018, the Commonwealth Bank of Australia supported an experiment which used Blockchain technology to track an international shipment of almonds (CBA, 2018[34]). The use of an Ethereum-based Blockchain was successful in reducing administrative burden and enabling transparent tracking of both location and quality of the shipment. Devices were used to allow viewing of relevant conditions within the container such as temperature and humidity.

Blockchain for Establishing Authenticity

Authenticity can be a major problem in the transport sector, with counterfeit pharmaceuticals and luxury goods requiring extensive documentation to establish proof of legitimacy. Interpol estimates that around 1 million people die each year due to counterfeit drugs and up to 30 percent of pharmaceuticals sold worldwide are counterfeit (Southwick, 2013[35]). Blockchain technology can give all involved parties access to a list of the supply chain, which gives the consumer more knowledge about the product they are buying, including the authenticity, transportation conditions and the place of origin. In the UK, the company Everledger is developing a Blockchain system that provides access to secured proof of origin and sourcing evidence for a range of high-value goods including diamonds, wine and fine art (DHL, 2018[36]). De Beers mines, trades and markets more than 30 percent of the world's diamonds and plans to use Blockchain technology to allow permitted agents – such as those involved in mining, cutting, wholesale and retail – to enter or edit data to ensure validation of non-conflict and child labour diamonds. (Marr, 2018[37])

[33] Pearce, R 2018, 'NSW digital licence rollout driven by blockchain', *ComputerWorld*, September 10, 2018.
[34] CBA 2018, Commonwealth Bank Completes new Blockchain-Enabled Global Trade Experiment, Commonwealth Bank Media Release, 30 July 2018.
[35] Southwick, N 2013, 'Counterfeit Drugs Kill 1 Mn People Annually: Interpol', *InSight Crime*, October 24, 2013.
[36] DHL 2018, Blockchain in Logistics: Perspectives on the Upcoming Impact of Blockchain Technology and use cases for the Logistics Industry, *DHL Trend Research*.
[37] Marr, B 2018, 'How Blockchain Could End the Trade in Blood Diamonds - An Incredible Use Case Everyone Should Read', Bernard Marr & Co.

PART 3: HOW CAN ARTIFICIAL INTELLIGENCE AND BLOCKCHAIN BE COUPLED AND APPLIED TO THE TRANSPORT SECTOR?

Overview

As we have seen Blockchain technology can create arrange of solutions that can impact many areas of the transport sector, in particular enhancing ride-sharing and self-driving vehicles and streamlining logistics while providing new levels of traceability and transparency. Also Artificial intelligence can be used to process incoming data to optimize routes and maximize network efficiency. The combination of the two can unlock never before seen opportunities in the transport sector, such as the following examples.

Examples of application

Road User Charging

Blockchain: Combined with vehicle location technology a Blockchain solution could provide the option to charge vehicles a real-time fee for road use. This is of particular interest given the shift to electrification of vehicles which will see revenues decrease from the excise tax on the sale of petrol that contributes to road construction and maintenance. The alternative is to implement an odometer based 'pay by the kilometre' model. Such an approach however forgoes a number of other network management benefits. For instance an odometer-based approach will not provide information about what parts of the network the vehicle has used, when and how often the use it and for how long.

Artificial Intelligence: Given that the above approach will require data around exactly where vehicles are in the network an Ai system could undertake calculations in real time to calculate appropriate time of use vehicle charging on specific elements of the transport network to discourage vehicles entering peak congestion areas and use other preferred routes.

Congestion Charging

Blockchain: The above functionality could also be used to create virtual zones for congestion management by geo-fencing specific parts of the road network, either a zone of the city or a specific corridor. Unlike current methods that require physical infrastructure, vehicles would communicate with the system to allow them to be recognised entering different areas of the city. This then enables either a real time charge to discourage entry or the provision of an incentive to encourage entry, transacting directly to the vehicle using a cryptocurrency. For non-technology-enabled vehicles this will require installation of on-board equipment and the creation of a bitcoin wallet connected to the licence plate number.

Artificial Intelligence: The above interaction with vehicles will generate data around where vehicles are entering prescribed areas and how much of an impact a pricing mechanism has on this level of entry that machine learning could be used to optimise charging to achieve better network management outcomes.

Increased Utilisation of Transport Network

Blockchain: Extending the road user charging and congestion charging approach, a Blockchain can be used to identify every element of the transport network and apply a differential fee or incentive based on the preferred utilisation. For instance, an automated vehicle could calculate the route of travel based on both congestion levels and road charges and provide the occupant with either the fastest option or the cheapest option, or a combination of both.

Artificial Intelligence: Te above approach would allow machine learning to learn from the system and enact real-time interventions to increase travel costs and encourage vehicles to re-route away from areas of high congestion, ad hoc events such as sporting matches, construction works, areas of high pedestrian traffic, or just into underutilised sections of the network, etc; all while collecting road charges in real time.

Collection Tolls and Charges

Blockchain: According to the Queensland Investment Commission (QIC), smart vehicles linked to a Blockchain would allow for the use of 'virtual gantries' on motorways that could be placed in specific locations to collect variable tolls directly from vehicles (QIC, 2017[38]).

Artificial Intelligence: Machine Learning can make use of real-time data to make decisions around potential changes to the cost of charges depending on the time of day, type of customer, or levels of congestion on the road (this may even include incentives to use the motorway when it is underutilised or the provision of refunds if the motorway is interrupted by roadworks or a collision).

Car Parking

Blockchain: This functionality would allow for automatic car parking payments when vehicles leave a parking structure or a street car park. The functionality also allows for easy time-of-use charging that could, for instance, notify the vehicle of cheaper parking rates in specific locations during periods of low utilisation. The technology would also allow for automated parking infringements to be issued to and paid for by the vehicle when it exceeds parking restrictions or is parked illegally.

Artificial Intelligence: Machine Learning can use the data produced to allow for greater utilisation of parking assets along with identifying areas with parking shortages and recommending alternatives. Machine Learning may also provide insight into the implications for parking as the fleet transitions to driverless vehicles that may require less parking services.

Ride Sharing

Blockchain: The ability for a Blockchain to allow secure payments between two parties without the use of an intermediary allows for a new generation of ride-sharing. Rather than being offered by an intermediary like Uber, that can apply mandatory surge pricing, the rides would be agreed, booked and transacted directly between the rider and the driver (or driverless vehicle) as in the case of the ride-share app La'Zooz (Cassano, 2015[39]). This platform

[38] QIC 2017, 'Blockchain is knocking at infrastructure's door', Queensland Investment Corporation, Brisbane, Queensland.
[39] Cassano, J 2015, 'Could La'Zooz be the Ride-Sharing App We've Been Waiting For?', *Fast Company*. January 27,

would then offer the potential for lower ride costs as the driver or vehicle will receive the majority of the fare with a small proportion being absorbed by the transaction fee on the Blockchain. This also opens the potential for ride-share businesses to operate locally in cities rather than be monopolised by global corporations.

Artificial Intelligence: Along with standard traffic related data satellite imagery can be effectively used as data inputs to further enhance ride sharing applications. DigitalGlobe has developed an AI platform that uses high-resolution satellite pictures to 'increase the precision of pick up, navigation, and drop off between its drivers and riders'. The software can detect new road-surface markings, lane information, and street-scale changes to traffic patterns and add this data to the vector map. (NBC, 2018[40]).

Freight Management

Blockchain: According to the US Department of Transportation, '*the freight logistics sector could benefit greatly from Blockchains*'. In particular, using the ability of a Blockchain to store information that cannot be altered or edited after its inclusion, a range of information can be extracted in real time from freight vehicles to enhance logistics management. The US Department of Transport suggests that information such as '*accident records, GPS and accelerometer tracking, weather information, crew information, inspection and certificate data, and mileage could all be stored on a Blockchain*' (US DoT, 2018[41]). According to Mauricio Paredes, Vice President of technology for PS Logistics, '*Through Blockchain technology every transaction in the trucking ecosystem can be interconnected, providing the potential to dramatically change workflows and the way people do business for the better*' (Santori, 2016[42]). For instance, load boards are systems which allow transport brokers to post loads they need transported, which transportation companies apply for, allowing shippers and carriers to meet. Currently, load boards can be out of date, or the data may be entered multiple times in multiple different load boards. By using a single Blockchain system, all parties involved will be working off the same list, resulting in the correct information being available at the same time for everyone (TMW, 2017[43]).

Artificial Intelligence: Such a database would provide a rich pool of information for machine learning to optimise freight routes, staging and storage of freight, and inform the potential for sharing of facilities and avoiding running empty. For instance, Australian company 'Beefledger' uses a Blockchain solution to track the live beef supply chain that is enhanced through the real-time, rapid decision making using Artificial Intelligence. As part of the system each vehicle has an inbuilt processing unit capable of independent Ai decision making with access to data stored on the Blockchain. This allows validation of the authenticity of the cargo and the optimisation of travel routes (NTI, 2018[44]).

2015.

[40] NBC (2018), 'DigitalGlobe enables satellites to recognize details of objects up to 30cm in size', NBC News, 26 February 2015

[41] US DoT 2018, What Blockchains could mean for government and transportation operations, United States Department of Transportation, Volpe Centre, DOT-VNTSC-18-03.

[42] Santori. M 2016, 'The Delaware Blockchain Initiative', *Global Delaware*, June 10, 2016.

[43] TMW Systems 2017, 'Blockchain for Transportation: Where the Future Starts', *TMW Systems*.

[44] NTI 2018, 'NTI backs blockchain trial to support Australian agriculture and tighten export security', NTI, 10 December 2018.

Vehicle Ownership

Blockchain: A key concern with the purchase of used vehicles is the validity of the service information and previous history. Using the ability of a Blockchain to store timestamped information that cannot be altered, vehicle information could be stored to validate service history, previous ownership, mileage, etc., to inform buyers. This could then be taken a step further, to have the ownership of the vehicle entered into a Blockchain to facilitate an intermediary free change of ownership by having the current owner providing the new owner with the encryption to the ownership documentation and entering a record of the transfer of ownership (which may need to be validated by an intermediary).

Artificial Intelligence: Machine Learning may be used to asses such trusted data on vehicle maintenance and compare it to the vehicles road use, driving patterns, brand of oil and lubricants, etc., to provide valuable correlations for improving vehicle design and allowing for predictive maintenance. Predictive maintenance is where the vehicle monitors a range of sensors and alerts the driver/owner when it is likely to need maintenance rather than alerting after the damage has been done.

Accident Information

Blockchain: In the case where a vehicle has the ability to send data and transactions to a Blockchain it can store accident information to be accessed by incident investigators, insurance companies etc. According to the US Department of Transportation '*As autonomous vehicles become popular and humans are removed from the controls, investigators may rely on black boxes for reliable information after incidents happen. A black box could be made secure from hackers, but cybersecurity is irrelevant if the black box can be removed and destroyed. A Blockchain's inherent distributed database could provide information storage security*' (US DoT, 2018[45]).

Artificial Intelligence: Trusted accident data is a rich pool of information that can be mined by machine learning to inform network management, insurance premium levels, assist in identifying vehicle responsibility in collisions and infringements, etc.

Development of CarApps

Blockchain: According to Tapscott (2016[46]) in the seminal book 'Blockchain Revolution', '*think of the car itself, it would exist as part of a Blockchain-based network where everyone can share information, and various parts of the vehicle can do transactions and exchange money. Given such an open platform, thousands of programmers and niche businesses could customise applications for your car*'. Hence, once cars become suitably technology-enabled they will be able to do things like play music from Spotify, rather than Bluetooth to a mobile phone, and stream videos from Netflix. Then once they are able to access Blockchain based value exchange platforms they can access apps to book and pay for parking, pay for fuel, book in a vehicle service and provide real-time information to the garage, pay for registration and

[45] US DoT 2018, What Blockchain could mean for Government and Transportation Operations, United States Department of Transportation, Volpe Centre, DOT-VNTSC-18-03.

[46] Tapscott, D and Tapscott, A 2016, 'Blockchain Revolution: How the technology behind Bitcoin is changing money, business and the world', Penguin Random House, USA.

insurance as the car drives, and pay speeding fines and other infringements without the need for financial intermediaries like banks or credit cards that involve their own fees and delays.

Artificial Intelligence: Given this direction in technology-enabled vehicles, the level of data and the range of data sources will continue to increase providing, again, a rich pool of information that only machine learning, in particular self-learning machines, can interpret to generate new value for transport agencies, vehicle manufactures and travellers.

CONCLUSION

For the first time in human history, Artificial Intelligence allows for decision making far beyond the capacity of human beings and Blockchain Technology allows for trusted transactions to be done directly between two parties without the need for an intermediary. In the transport sector, this presents a range of opportunities worthy of detailed investigation, such as using the database functionality to track goods and allow for payments to be made along the supply chain in one single system, and allowing cars of the future to make payments for road user charges, parking, congestion charging, toll collection, etc., which can be used to influence time-of-use and route selection, improving utilisation of the transport network. It is the conclusion of this report that both Artificial Intelligence and Blockchain Technology both stand alone and coupled stand to revolutionise a number of functions across the transport sector and that this will soon lead to a significant increase of research and practice in this area.

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