SMARTER HEAVY VEHICLE REGULATION: THE OPPORTUNITIES AND BARRIERS FOR PROGRESSING INNOVATION WITH DIGITAL AND SMART REGULATION. IMPLICATIONS FOR ROAD AGENCIES AND THE TRUCKING INDUSTRY.

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Abstract

This paper examines the increasing role of digital and smart technologies in the regulation of the heavy vehicle industry. The research explores the opportunities and barriers that road agencies and the trucking industry face when seeking to progress the implementation of innovations in the form of digital and smart regulation. Digitised surveillance systems are highly effective and efficient in data collection and analysis and can be used to introduce sophisticated, customised, and discerning regulatory programs, can be linked to localised infrastructure management systems and provide more tailoring to the specific operational and business needs of individual operators across the trucking industry. Vehicle monitoring programs, such as applications of Intelligent Access in Australia, are illustrative of this new and high-tech approach to regulation. The findings of this research highlight traditional as well as new and unanticipated concerns that impact on the implementation of smarter digital business and compliance systems, and are relevant to road agencies and truck operators across the world.

Key words: Smart Regulation, digital regulation, heavy vehicle regulation, heavy vehicle safety and compliance.

1. Introduction

Since the early 2000s there has been a progressive and cumulative application of digital technologies and ICT systems in road network management, monitoring and the surveillance of vehicle compliance. Advances in technology and the implications this poses for road transport and freight have been the subject of analysis and review by various government agencies (Jont Standing Committee on Road Safety (Staysafe) 2018, National Transport Commission 2021, National Heavy Vehicle Regulator 2023, National Transport Commission 2024, Transport for New South Wales 2024). Digital systems, be they compliance orientated, network management focussed or specifically targeting smart asset monitoring and management, are now an essential component of freight strategies. And while the collection and analysis of data is central to the operation of efficient and safe road transport systems (infrastructure and fleet) critical questions around how data is generated, in what format data is collected (identified or deidentified) and who provides, stores and shares data remain a concern for all stakeholders in the road transport sector.

This paper provides an in-depth analysis of what regulators and industry perceive as the opportunities and barriers for the use of digital technology and the collection and analysis of data in the regulation of the trucking sector. We examine the trends and likely developments that key organisations identify as future possibilities in the space of digital regulation. Discussion also explores how the digital and technical capability of government and industry might impact on the progressive advancement of digitised systems in road transport regulation and beyond. Our findings point to both improvements in operational performance (efficiency and effectiveness of regulation and business practices) as well as emerging unanticipated complexities that appear to be impacting on the development and introduction of digital regulatory applications within the sector. Following this introduction discussion considers some of the contemporary issues, challenges and reforms being progressed in the space of digital regulation of the road transport industry. We then outline our research method and subsequently move to a presentation of the results, an analysis of the key findings and conclude with comment on future implications for both government agencies and industry.

2. The contemporary context: Issues, challenges and reform.

Central to industry's concerns remain increased access to the road network and vehicle productivity. The manner in which the regulatory framework provides seamless and efficient access and operates in a harmonised manner across levels of government (access to local, state and national roads) is seen to influence the efficiency, safety and environmental performance of the industry. Regulatory simplicity, transparency and consistency are seen as central to an efficient and productive road transport industry and increasingly the use of data and technology are seen as the means for achieving these desired outcomes. Therefore, key issues and current reform efforts now include numerous digital and data focused reforms. Some of these include; requests for increased automation of decision making (automated access assessments) and new ways to receive digital submissions; recognition and adoption of digital record keeping; an openness to new technologies and tools to manage and report on compliance requirements such as fatigue management and driving hours; consideration for how in-vehicle data is accessed for compliance purposes, recognising differing forms of in-vehicle technology and other industry monitoring systems for compliance purposes; and more

explicit rules on data sharing between industry and regulators. Reduced administrative and regulatory burden is seen to come with the automation of approval regimes, such as network access for high productivity vehicles, and the establishment of a digital interface with established compliance systems. Connecting such approvals with existing telematic monitoring systems helps smooth and align administrative requirements with compliance systems.

Data generated through telematics monitoring systems has a diversity of uses, ranging from vehicle compliance to more aggregated insights into network utilisation and asset management. In the current context of road transport management and compliance, telematic data presents significant opportunities for improving the evidence base for decision making on network performance and options for productivity improvements (Transport for New South Wales 2024). The adoption of telematic monitoring and reporting systems is now regularly linked to freight mass and access concession schemes and has encouraged industry take up of digital technologies. In Australia there are examples of in-vehicle telematic systems being linked to infrastructure monitoring systems that then permit higher mass access, thus lifting the productivity of industry and the network.

The increasing use of industry and operator profiling by regulators means that approaches to the monitoring of compliance and enforcement actions can vary depending on the associated risk. For known compliant operators self-management and less direct intervention from the regulator characterises the approach to regulation. Systems that are more reliant on the self-management of compliance are also more dependent on a stronger collaborative approach that encourages the sharing of data between industry and the regulator (Naitonal Heavy Vehicle Regulator 2022). Accreditation programs and other systems based approaches that rely on documentation and recording of business practices to assure compliance to specified standards, limits, or known best practices, generally include provision for some form of regulator access to company data. This represents a highly collaborative and open approach to regulation and compliance and is a distinctly different approach to the more traditional compliance and enforcement practices that emphasise external forms of monitoring, responding to incidences and the use of random and unexpected interventions to detect breaches and impose penalties.

Relying on regulatory systems that develop risk profiles and a stratification of industry compliance requires extensive network monitoring, data capture and analysis. The ongoing development of data-based compliance and monitoring systems highlights the emerging importance across the sector for the establishment of a technology and data sharing framework to help govern data access and use by industry, network managers and regulators. The contemporary context of freight management and vehicle compliance highlights the growing role and importance of data and technology systems that generate, analyse and connect multiple data sources.

2.1 Methodology

This is a qualitative study that examined the experience and insights of key stakeholders in the road transport sector across Australia and New Zealand. The work was supplemented with a review of relevant academic and grey literature on digitisation and industry regulation. This included a review of recent government reports that examined the impact of digitisation and

technology on transport, future innovations, and the challenges that are likely to be progressed through enhanced digitisation and the application of AI systems (see for example NTC (2022) *The Regulatory Framework for Automated Vehicles in Australia*, and Productivity Commission ((2020)) *Regulatory Technology: information Paper*).

We conducted semi structured interviews with senior staff in government and industry organisations who had a thorough knowledge and understanding of the heavy vehicle transport industry and how the industry is regulated and monitored for compliance. These discussions focused on seven broad themes. This included;

- the role of digitisation in regulation,
- the underlying forces influencing the adoption of digital approaches to regulation,
- the extent to which the digital capabilities of regulators and regulatees (trucking industry) influenced how far digital regulatory systems can progress,
- a broader system wide view on whether digital systems are coordinated and integrated across the road transport sector,
- future opportunities for the application of digital regulation,
- barriers to the development and implementation of digital regulation, and
- discussion concluded with a general overview of cyber security and the management of data and how concerns in these areas might have implications for the future development of digital regulation and other road network and road transport monitoring and surveillance systems.

We interviewed 12 individuals, representing nine public sector regulatory, road transport and infrastructure agencies, two trucking industry associations and one telematic provider. A total of nine interviewees were from Australian organisations and two from New Zealand and one from the UK. We grouped interviewees into four categories:

- Infrastructure managers (I)
- Regulators (R)
- Heavy vehicle operator representatives (industry representatives) (O)
- Data managers/telematics providers (D).

Each interview averaged 45 minutes and for analytical purposes these discussions were transcribed, representing a total of 336 pages. A detailed thematic analysis was then undertaken of each interview transcript, identifying alignment across common themes, as well as unique themes raised by one or two interviewees. The key issues and insights derived from the thematic analysis are discussed in more detail in section three, Results and Analysis. Where relevant, discussion of themes emerging from the interviews is referenced to similar ideas and issues raised in the literature. As might be expected, there is alignment with some of the key issues raised in government reports that explore future direction and implications for digitisation in road transport. However, this work aims to go further and draw out more explicit implications for digital regulation, its emerging role and impact on the institutional landscape, and how this connects with the broader interests of transport agencies, regulators and industry.

3. Results and Analysis

The interviews conducted for this study revealed several key themes that point to changes in relationships, roles, and how digital regulation and digital systems are reshaping

understandings of the role of data and its uses. The themes and insights are expanded upon below and are discussed under the following headings:

- Digital regulation means different things to different people
- Digital regulation challenges old laws and customary practices
- Digital regulation can reshape the relationship between industry and regulators
- Digital regulation shifts traditional boundaries between actors and highlights the importance of data
- Digital regulation introduces new actors and demands for data management frameworks
- Digital regulation advances infrastructure management and requires new ways of working across institutions

3.1.1 Digital regulation means different things to different people

The interviews revealed that digital regulation (in the road transport sector) means different things, depending on the role performed by individuals in the context of these four categories. Notwithstanding these differences, all agreed that digital regulation was critical to advance productivity, safety and efficiency outcomes in road transport. One regulator claimed "Well clearly,...it's fundamental" (R3) and another argued "... you can't regulate without digital technology. From an on-road enforcement perspective, there's no way we'd ever have enough 'boots-on-the-ground' to cover our geography… Technology and data is the obvious answer." (R1).

Similarly, one data manager said that "I think the importance of digital is profound ... there are what I'd say, monster challenges. And so, we need to be able to activate new ways of addressing these sorts of challenges in nontraditional ways" (D1). Consistent with these perspectives, one infrastructure manager declared that "I see digital regulation as absolutely crucial. It's going to underpin what we're doing in infrastructure in the future." (I1). Another infrastructure manager noted that technology and data provides ways to be more "finely grained in terms of how far you can go in sweating that asset" (I3). These final comments highlight how network data, regardless of its original purpose for collection, has relevance for other decision making practices that relate to transport and network management. All our interviewees agreed that data can be put to good use, and that "more people are understanding both from a regulator perspective and an industry perspective that data is not your enemy, it's your friend" (R1). These early discussions of regulatory data and digitised systems pointed to a growing understanding within the road transport sector that a more nuanced analysis of road system data can be used to advance safety, productivity, compliance, asset management and road access decision making practices.

3.1.2 Digital regulation challenges old laws and customary practices

There was a consensus amongst interviewees that digital technologies and the availability of data challenges old laws and customary practices. For regulators, it challenges conventional approaches to compliance and enforcement activities. "If you think of traditional law enforcement, it's about managing what's in front of you. I think that we can say that we've wrung as many safety benefits out of that enforcement model as we potentially can. So the whole thing then is to conceptually raise it a level. As we get smarter with the data, we're going to get smarter with the compliance targeting" (R3). There was also an awareness that

while digital regulation presented new opportunities, care had to be taken to ensure the adoption of technology did not just reconfirm existing practices through new methods. One industry stakeholder observed that "it's no good doing the same practice that you have on paper or by the roadside and digitalise it. You're then just doing the same thing with a different method. What I see is they are automating what they currently do rather than completely rethinking the model… its time for a step change" (O2).

Interestingly, one regulator observed that digitisation will drive change since traditional practices are not readily adapted to new technological approaches; "we have inherited operating models that don't necessarily fit the high tech processes that we're developing" (R3). The evidence here demonstrates that all stakeholder groups across the sector see great potential for change and reform through the use of digital systems, though also noting the risk of existing practices being further entrenched through digitisation.

Workforce capability and skills was identified as one important barrier to the progress of innovative thinking and new approaches to compliance. As one regulator noted, "A significant proportion of our workforce are men who generally prefer to be out on the roadside pulling trucks over rather than accessing and analysing data to derive insights" (R3). Nevertheless, it was evident from discussion with regulators that the need for skills development, the recruitment of staff with a range of data competent skills along with some structural reconfiguration of agency functions and units (building data analysis capabilities that feed into compliance strategy) were important organisational change plans. This was seen to extend the role of digital systems, as well as modernise and strengthen an agency's regulation and compliance functions. One regulator emphasised, "it's incumbent on us to be using the best technology that we can that supports us to make the best decisions that we can" (R1).

Digital regulation also challenges legacy laws and legal structures. Here we observe significant operational complexity shaped by the interaction of laws which extend beyond the field of heavy vehicle regulation into areas of privacy, workplace surveillance and cyber security. One interviewee very succinctly described this growing area of legal complexity. "Compared with the operational aspects of heavy vehicle regulation, the laws in place today did not contemplate the extent to which technology and data would have such primacy. The biggest obstruction we have now is navigating other laws which interact with heavy vehicle regulation. And making sure that the actions you take to manage heavy vehicle regulation do not fail other parts of the legislative fabric. While we might simply consider them as data points for heavy vehicle regulation, for everyone else it's private information" (R3). This observation points to critical issues concerning the collection, access, use, analysis and retention of data. There is an expectation that transparent arrangements are established between all parties articulating how data can be used as well as defining the limits of its use.

Aggregated and deidentified vehicle monitoring of road use is now widespread across Australia, supported by industry stakeholders who recognise the value of its use for network planning, asset management and road access decision-making. One infrastructure manager said that "If we don't have that transparency, then potentially we can't give the level of access that we're intending to provide without that assurance that underpins your asset management." (I4). The same data used for asset management can also be used for strategic compliance management activities, through the identification of patterns, trends and general

levels of heavy vehicle compliance. The use of data for multiple purposes (by infrastructure managers, regulators, industry and data managers) reveals a need for careful design and calibration of the instruments which operate within a legal framework to help derive the full value of technology and data generated through the various digitised systems. This includes the use of conventional, infrastructure-based network monitoring (such as camera-based systems and Weigh-In-Motion (WIM) systems), as well as vehicle generated data, captured by telematics systems and services.

3.1.3 Digital regulation can reshape the relationship between industry and regulators

There was a key difference observed between the perspectives of industry stakeholders about their ongoing relationship with regulators. One saw technology and data being used by *regulatees* to improve compliance (within their own business). Another saw technology and data being used by *regulators* to identify non-compliance. In other words, some indicated that digital regulation should be seen as 'internalised within the business activities of regulatees'. Conversely, others indicated that regulators should have primary responsibility for finding non-compliance by analysing network data that monitors vehicle movements and behaviour. The tracking of financial transactions across the banking sector to identify money laundering was used as an example to demonstrate how effective external monitoring of activity can help detect noncompliance. Interestingly, in a similar vein, one regulator noted that they're often seen as an "external onlooker" where they gather their own information about compliance. However, this was seen to limit the opportunity for more integrated thinking that connects compliance with broader network management and transport efficiency issues that also directly connect to the business and safety objectives of the industry. This perspective is influenced by the culture and ways of working within regulatory agencies and this is expanded further in section 3.1.6.

The two contrasting views raise an interesting question about where primary responsibility for digital regulation in a real-time digital environment is placed. By this we mean, does digital regulation remain a predominantly external surveillance system that monitors, detects and pursues non-compliant behaviour? Or does digital regulation allow for compliance systems to reach into a firm and operate as a shared program that connects with business records and practices and reports on data that has both regulatory and operational value? Under this latter model digital regulation moves compliance from externally imposed systems towards a more embedded and integrated model that connects relevant transport data as it is generated, with the compliance and network management objectives of the state. Here we see the role of regulators evolving as they build stronger connections with key actors across the transport ecosystem. This involves engaging with telematics providers to understand what data they can collect, analyse and share, engaging with trucking operators (and possibly truck and trailer manufacturers) to reach agreement on what, when and how to share relevant data, and finally working closely with infrastructure managers so that data relevant for infrastructure management and network planning is extracted from compliance data sets to strengthen the evidence base upon which decisions such as access and higher capacity vehicle tolerance are made. This collaborative approach that connects parties via their data requires a rethinking of relationships. As one infrastructure manager observed, "if people understood the collective goals and how we can work better together, fears of working together and sharing data might be alleviated" (I2).

3.1.4 Digital regulation shifts traditional boundaries between actors and highlights the importance of data.

As the above discussion suggests, interviewees observe that digital regulation creates opportunities for regulators, regulatees and technology providers to interact in different ways and this has the potential to shift conventional boundaries between actors. Central to this shift is the use and value of data. An industry stakeholder highlighted that "as the world is moving and data becomes more valuable, if you want to be in the game and have a voice to change regulation, you've got to be able to have the currency to justify the position you're advocating – and the modern currency is data" (O1). A recurring theme throughout our interviews was that data holds multiple values for different stakeholders.

Not only can digital regulation shift traditional boundaries, it can draw different stakeholders together through a convergence of interests. As discussed earlier (section 3.1.2) this convergence of interest centres on the use of aggregated and deidentified data that provides value to regulators, regulatees, infrastructure managers and data managers alike. This same data can be blended with other data sources providing further utility for an even broader range of actors. One data manager argued that while the utility of data exchange shows promise, legal safeguards are required to help facilitate such practices. "If you want information to be flowing both ways (to enable digital regulation and to improve other outcomes), there will need to be legal underpinnings, processes and digital businesses to manage safeguards and enable trust to be maintained" (D1). These comments align with earlier observations (section 3.1.2) that the legal framework needs revision to help ensure transparent arrangements (coupled with protections and safeguards) are put in place to enable data to be shared and used for multiple purposes.

Notably, industry representatives were amongst the most positive about the potential for data generated from vehicles to be put to other uses that are in the broader public interest. As one industry stakeholder noted, "I don't see a problem with the vehicle being tracked…. I don't see a problem personally with the use of anonymised data and knowing exactly where an AB Double is going all over the country. Privacy can be protected " (O2). These forms of vehicle and network tracking were seen as helpful in sustaining a level playing field and minimizing unfair competition in the sector. As another regulator noted, "So, in my view, regulated parties and the regulator almost always want the same thing. And, so the regulated parties want a fair playing field …. And I think digital regulation can aid that. We want the bad actors out and large amounts of data allow us to focus and use our resources better, and so leave the compliant operators alone and focus on where we actually need to focus, non compliance. And this seems like an easy sell to both parties" (R2). These reflections highlight how digital regulation and access to data (and the analysis of data) is seen as an effective way to shape and justify intervention (regulation and enforcement) to sustain competitive fairness amongst heavy vehicle operators.

While data collection and analysis may be designed to guide strategic enforcement action, one infrastructure manager noted the potential ethical and moral implications that may arise from having greater access to data, "Those insights might tell you things you know aren't good news. And even though you may not have been looking for it, you have to act on it." (I3). These instances highlight that while greater access to data brings higher visibility and insight into road network and road user performance, this also has implications for the decision making, priority setting and resource allocation of road agencies and regulators.

Building trust and assurance amongst stakeholders that data-driven approaches are contributing to improved infrastructure management and regulatory outcomes, is expected to be an area of increasing accountability for all agencies in the road transport sector. This points to the need for more formal governance frameworks that guide the sharing and flow of data amongst state and industry actors and this issue is discussed in more detail in the following section.

3.1.5 Digital regulation introduces new actors and demands for data management frameworks

Digital regulation introduces a new set of actors who complement the roles of regulatees, regulators and infrastructure managers, and this is the role of technology/telematics provider. As one data manager noted, "There's actually a lot more players... Historically, it would have just been the regulator and the transport operator. And now there's a number of intermediaries contributing … in a way that maybe is a little bit more connected… information is gathered in different ways and shared in different ways" (D2). This comment highlights how regulation now involves more actors, and their interaction tends to be shaped by different forms of motivations. As noted above, arrangements for the sharing and flow of data amongst key actors is now central to transport compliance, efficiency and effective network management. Notably, it was an infrastructure manager who emphasised that all actors were driven by self interest, "what's in it for me?'' (I4). One regulator suggested that one way of dealing with this question was to treat regulatees as customers. "If you take a customer service mindset to these types of interactions, what is it that you can offer them, to help them help us? For instance, what incentives are there to encourage them to share data with us?" (R2).

However, this approach towards benefit realisation was seen to create barriers for data sharing as awareness of the value and currency of data increased amongst transport stakeholders. One industry stakeholder put it succinctly; "It's our data. We want it. It's valuable to us. It has a monetary value associated with it. Even if we haven't figured out the business case yet, people know and think that there's money attached to it and they want to do something with it" (O1). The issue of data ownership is relevant in the context of other players participating in the digital regulation arena. For example, vehicle manufacturers (OEMs) increasingly want to retain and restrict access to the data their vehicles collect and this position has an impact on the dynamics of data sharing across the sector. One data manager noted, "So the OEMs are now saying, we want that data. We see value in that data. … the OEMs are now becoming the data custodians and that's going to change the field" (D2). Hill and Koniditsiotis (2023) anticipated the likely constraint on data access by OEMs and other telematic providers in their paper to HVTT17. They noted that just because data is generated does not necessarily mean it will be made accessible for infrastructure management and regulatory purposes.

The evidence here highlights not only the growing importance of data in regulation and transport system management, but also the realisation across a diversity of actors that they have a role in data generation and management. This has increased the complexity of regulatory governance in the transport sector and shifted the policy focus to broad issues of data management frameworks, particularly as more players have a role and voice in how data is generated, managed and accessed. As digital regulation advances operating models and

management frameworks that govern the collection, use and sharing of data are of increasing importance.

3.1.6 Digital regulation advances infrastructure management and requires new ways of working across institutions

While infrastructure managers are not new actors in the road transport regulatory space, what has become evident during this project is that as digital regulation increasingly engages a variety of tools and data sources, it has become more integrated and connected with the work of infrastructure managers. Here we see regulation move from the more traditional binary model of regulator and regulatee, to a more nuanced model of multi-actor engagement that now directly connects with the work of other interested parties such as road infrastructure managers. Our interviewees observed a shift in institutional arrangements and the development of digital relationships that connect concerns for road utilisation and asset management, planning, maintenance and capital investment, with the evidence of vehicle compliance and industry interest in higher productivity. In simple terms, greater use of technology, data collection and analysis enables infrastructure managers to 'sweat the asset' by developing a more finely tuned appreciation of vehicle utilisation (this includes data that identifies the types and weights of vehicles using the asset). As one infrastructure manager noted, "Digital technology can be used to manage the relationship between the road user, road assets and the investments you're putting into the asset" (D1). Another made reference to the suitability of the network for heavy vehicles and explained how technology and data can narrow the gap between the limitations of particular infrastructure and the demands of higher productivity vehicles: "How fit for purpose is the network for that task and how can we ensure that that gap continues to narrow…. Whether it's maintenance, whether it's investment, whether it's any kind of decision that we go out and touch a network for any reason. And the right information will continue to evolve as we make gains into that space" (I5). Another infrastructure manager emphasised how road access decisions for heavy vehicles are made by engineers "who make decisions on allowing heavy vehicle access to the network under certain assumptions. One of those assumptions is that heavy vehicle drivers and operators are complying with their conditions of that access. Digital technology and data gives our engineering colleagues insights into the actual use of their assets, and to validate their engineering assumptions based on actual operator behaviour." (I4).

In this context the example of Smart On-Board Mass (Smart OBM) was highlighted as a way of removing constraints for heavy vehicle access to the road network and advancing to a more sophisticated approach that integrates data relevant to heavy vehicles, bridge infrastructure, and regulatory limits (see Gordon and Hill (2023) presented at HVTT17). Access to data on vehicle mass is critical for granting access to certain infrastructure, thus lifting industry productivity and this form of data is in turn directly relevant to live systems that validate compliance. One infrastructure manager noted that data collection systems such as Smart OBM have "…effectively changed the parameters and the constraints you were previously working around, particularly around heavy vehicle access to bridges. So it's no longer a constraint and you can suddenly open up opportunities for the operator" (I1). Here we see vehicle compliance data playing a much more active role in the ongoing management of assets and infrastructure and the interaction between higher productivity vehicles and road networks, and this supports industry interest in lifting vehicle productivity. This infrastructure manager explained; "every single one of our business cases that requires any sort of strengthening or upgrade to a structure or pavement is now using telematics and compliance

data. This wasn't the case five years ago. And that's where this data is now being integrated into our department as a whole" (I1).

The evidence from this study points to an incremental expansion in the awareness and use of compliance and regulation data, predominantly stimulated by digital systems, into various areas of infrastructure maintenance and development. We say incremental since as one infrastructure manager cautioned, "We need to have a more coordinated approach and a greater understanding across all participants, including road managers, regulators and the transport industry, to communicate what we're trying to do. I think we're missing opportunities by not thinking big enough." (I2).

The access and use of compliance data in the planning and decision making of infrastructure managers is not, however, straightforward. In the Australian context there has been a progressive shift to institutionally separate infrastructure managers and the regulator. The National Heavy Vehicle Regulator now has carriage of compliance activities in Tasmania, Victoria, New South Wales and Queensland. This means the relationships and interfaces between infrastructure managers and regulators needs both systems and an effective governance framework to ensure shared access and a seamless flow of compliance and network data to help deliver more evidence based and informed decision making. During interviews a number of stakeholders indicated that the data feedback loop between regulators, regulatees and infrastructure managers was essential to deliver improvements in productivity, safety and compliance across the heavy vehicle sector. Most stakeholders felt there was an inherent tension between heavy vehicle access, asset management and compliance assurance, and without effective relationships and a focus on shared interests, the institutional arrangements could lead to sub-optimal outcomes for the sector. As one infrastructure manager lamented, "… everyone's not aiming at the same collective benefit. You know, sometimes I listen to conversations and think wow, we're just not on the same page. You've got people that have got different agendas, different ideas, different opinions. And we're all at cross purposes" (I2). Aligned with this observation was a general concern with the emergence of data silos across organisations and this again drew attention to the importance of establishing broad governance frameworks that give structure and definition to the sharing of data for those participants in the road transport sector who generate, store and analyse vehicle and network data.

4 Future issues and Conclusion

The intent of this paper was to examine the role of digital and smart technologies in heavy vehicle regulation, and to explore the opportunities and barriers that road agencies and the trucking industry face when seeking to progress the implementation of innovations in the form of digital and smart regulation. The analysis of documents and the critique of our interviews as presented above, revealed three overarching themes which provide insight into current practice and help identify future developments, issues and challenges. Firstly, the most evident observation is that all actors across the heavy vehicle sector are increasingly relying on data to perform their roles and functions. Second, the interest and use of data, particularly in obtaining data generated from multiple sources, is reshaping relationships between actors across the road transport sector and this needs careful management; and finally, the trend in digital relations is towards higher levels of collaborative regulation and

purposeful engagement since this is seen to more effectively achieve the shared objectives of sector efficiency, safety and maximises the performance capability of infrastructure.

The strategic question that emerges from this analysis is whether digital regulation and the supporting technology encourages a shift (or disruption) from the traditional command-and-control approach to higher forms of collaborative regulation? Greater collaboration is likely to result in regulatory innovation and the blending of policy objectives concerned with productivity, safety and efficient infrastructure management. As noted earlier in this paper digital systems do have the potential to entrench routine approaches to regulation (monitor, detect and penalise offenses) thus maintaining the traditional separation of regulators from regulatees. Our research identifies two possible future scenarios of stakeholder collaboration in the use and development of digital systems in regulation. This ranges from very limited collaboration with relatively independent investment and development of technology and data sharing capabilities, to a more highly integrated and collaborative scenario that involves high levels of data sharing and multiple uses of data across complex operating environments. Table 1 below presents a summary of the key elements that characterise each collaborative scenario.

Table 1: Defining characteristics of collaboration scenarios for digital technology and data in the heavy vehicle sector

Scenario 1 **Low levels of collaboration**	**Scenario 2** **High levels of collaboration**
Exclusive use of technologies and data	Shared use of technologies and data
Command-and-control posture	Co-regulation posture
Separation of stakeholder technologies	Connection of stakeholder technologies
Exclusive use of data	Multiple uses of data
Uni-directional data flows	Multi-directional data flows
Limited levels of innovation	Greater levels of innovation
Less complex operating arrangements	More complex operating arrangements

A critical question for the above scenarios concerns the extent to which road transport stakeholders (regulates, regulators and others) are willing to collaborate as they accelerate their use of digital technology and data to perform their respective roles. Although the wider use of technology and data can be transformational in nature, consideration needs to be given to what pre-conditions may be necessary to enable collaborative transformations to occur. Do current institutional and legal arrangements facilitate collaboration? What governance frameworks are required to support the appropriate sharing of data? And how ready are road transport agencies and regulators to grasp their expanding roles in data management and analysis? While our research suggests the future direction is towards higher levels of collaboration, it is likely that institutional and legal obligations will require the ongoing use of separate and independent digital regulation and data driven systems. There is, therefore, potential for the co-existence of two concurrent but distinctly different tracks of regulatory development. One distinctly external and independent of the trucking industry that monitors and penalises detected offences and another that combines data systems in a way that

facilitates compliance and greater industry productivity. The above questions and our concluding findings point to the need for further analysis and research, and drawing on the experience of other regulatory environments and industrial sectors similarly influenced by digital technologies may provide new and interesting insights.

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