Responsible innovation; responsible data. A case study in autonomous driving

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ABSTRACT

Autonomous Vehicles (AVs) collect a vast amount of data during their operation (MBs/sec). What data is recorded, who has access to it, and how it is analysed and used can have major technical, ethical, social, and legal implications. By embedding Responsible Innovation (RI) methods within the AV lifecycle, negative consequences resulting from inadequate data logging can be foreseen and prevented. An RI approach demands that questions of societal benefit, anticipatory governance, and stakeholder inclusion, are placed at the forefront of research considerations. Considered as foundational principles, these concepts create a contextual mindset for research that will by definition have an RI underpinning as well as application. Such an RI mindset both inspired and governed the genesis and operation of a research project on autonomous vehicles. The impact this had on research outlines and workplans, and the challenges encountered along the way are detailed, with conclusions and recommendations for RI in practice.

1. Background

A Responsible Innovation (RI) approach aims to ensure that research and innovation benefits society by placing processes of stakeholder engagement, anticipatory governance, and reflexivity at the core of both research questions and research methods (Ribeiro, Smith & Millar, 2017; von Schomberg, 2013). In practice this can be notoriously difficult to accomplish (Klaasen, Rijnen, Vermeulen, Kupper & Broerse, 2018), with challenges such as who to engage with, what to anticipate, and how to measure success (Yaghmaei & van de Poel, 2021). Other challenges than the simply procedural are rooted in broader questions around politics and power imbalances (van Oudheusden, 2014), values (Boenink & Kudina, 2020) and conceptual questions of what 'responsibility' means (Pellizzoni, 2004).

However, at the heart of RI is the need to consider societal impact of technologies, including anticipating possible negative effects (Nordmann, 2014), and responding accordingly to try and reduce these. Tools for these activities include envisioning techniques (Reeves, 2012) and moral imagination (Lehoux, Miller & Williams-Jones, 2020) to consider the possible impacts of technology and try to ameliorate downsides before they occur.

Such anticipatory approaches served as the founding principle of the RoAD (Responsible AV Data) project, funded in 2021 by the UKRI Trustworthy Autonomous Systems Hub.

1.1. Responsible data and RoAD

Autonomous vehicles have been discussed as a possibility for many years, but are approaching deployment in the UK, with the UK government's Centre for Connected and Autonomous Vehicles overseeing consultations and discussions about their use (eg Department for Transport, Connected, Vehicles & Rachel Maclean, 2021). The RoAD project'[1]s objective was to anticipate some of the potentially problematic impacts of autonomous vehicles (AVs) on society. In this context, we are focussing on AVs with SAE Level 3, 4 and 5—that is AVs with automated driving features (SAE J3016). In particular, the project sought to address the question of accidents and incidents involving AVs on public roads, reasoning that although such outcomes were undesired, they would inevitably occur[2] and consequently should be considered and the outcomes planned for. RoAD therefore focused on the need for societal trust in processes of accident investigation (Winfield & Jirotka, 2018). This focus was identified by examining parallels in other

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industries, for example in aviation, where rigorous safety protocols and post-accident procedures involving specialist investigators render an inherently dangerous activity societally acceptable, even banal, through supporting the societal need to understand 'what went wrong' and be reassured that the same thing will not happen again Winfield and Jirotka (2017). In a similar way to an aircraft's 'black box' data recorder, AVs record certain data while in operation. Although this data-collection has not been designed with a view to accident investigation, it could potentially be utilised for this.

This RI-grounded anticipatory work generated our main research question: *What is the social, legal and technical use of the data from AV data recorders, its value, utility, and availability?*

Our primary objectives were to establish

  i) *who has access* to the data in the event of an accident investigation?
  ii) *how valuable is the data* from the data-recorder (ie what information can be gathered from it)?
  iii) *how useful is the data* for legal or insurance purposes?

The RI mindset of the project, which informed the main accident-investigation avenue of enquiry and these primary objectives, also led to secondary questions.

 i) *What are civil society attitudes to a vehicle recording video as it operates?* Should AVs be deployed at scale there might eventually be hundreds of such vehicles recording the activity around them. Surveillance of civil populations is already heavy (some suggest that the average London resident may be caught on camera up to 300 times per day[3]) and AVs recording video could add significantly to this burden.
 ii) *What are the legal and ethical considerations around data – particularly video –collected from AVs?* Although superficially this might be seen as similar to recording in public spaces via CCTV, CCTV footage is covered by the GDPR and anyone who wishes to know what footage of them has been recorded can make a Data Subject Access Request[4]. The legal status of video recorded by an AV remains to be established, but would potentially be aligned with dashcam footage.

The identification of these secondary questions was driven by the need to anticipate and reflect on likely impacts, and to engage with stakeholders on these questions.

2. RI action plan

In its RI planning for the project the RoAD team drew on the AREA (Anticipation-Reflection-Engagement-Action/response) framework (Owen et al., 2013; Stilgoe, Owen & Macnaghten, 2013), while also being cognisant of other RI tools such as the Six Pillars seen in many EU projects (de Saille, 2015), which include equality and diversity, as well as open science. Literature was sought out on RI in autonomous vehicle development (Lukovics, Zuti, Fisher & Kézy, 2021; Stilgoe, 2018), but these works are primarily theoretical in nature – hence we suggest that our short case study on one of the aspects of AVs represents some of the earliest empirical work on the use of RI in AV development.

The RoAD project shaped its RI work using the AREA framework as a plan to:

1 **anticipate** impacts – both technical and socio-legal – from AV datasets
2 **engage** with a wide group of stakeholders: including insurers, professionals, scholars, engineering experts, and others to discuss legal and ethical implications of AV data (Fig. 1 and Appendix A); and a

public survey to evaluate public acceptance of AV data recorders/recording.
3 **reflect** on these engagements and iterate where necessary
4 **respond** by incorporating these reflections into RoAD's direction as it progressed, not least as informing the safety-critical scenarios from which test datasets were to be generated.

Finally, RoAD recorded its RI actions and deliberations, and plans to make these reflections and responses available as one of the project's outputs.

3. Impacts of an RI approach

As described above, the foundation of the project in an RI mindset shaped the initial and supplementary research questions. However, operationalising RI during RoAD's life also actively affected the project's development. This had not been anticipated, and the examples below provide an illustration of why an RI approach is necessarily iterative.

3.1. Additional stakeholder identification

Although the initial list of stakeholders to contact for interview had included diverse groups that the team believed would have an interest in or be affected by AVs (eg pedestrian and cycling groups, insurers, accident investigators), it had not included equestrians. After a public engagement activity, this omission was rectified. It was rapidly apparent that to have overlooked this group would have created a significant gap in the project data. Given the lack of research evidence around the possible interactions of equines with AVs, as well as the potential impacts of this, it is likely that this is a gap in many research projects involving autonomous systems.

After data-sessions during which we analysed and discussed our findings, and the implications of these, the team further concluded that it was important to obtain the police perspective on the topics we were exploring, and accordingly a vehicle specialist was interviewed. The Law Commission of England and Wales was also identified as a valuable participant, particularly as it was in the process of consulting on future governance of AVs. Later iterations also led to interviewing an AV manufacturer to discuss present and future plans for data-recording that
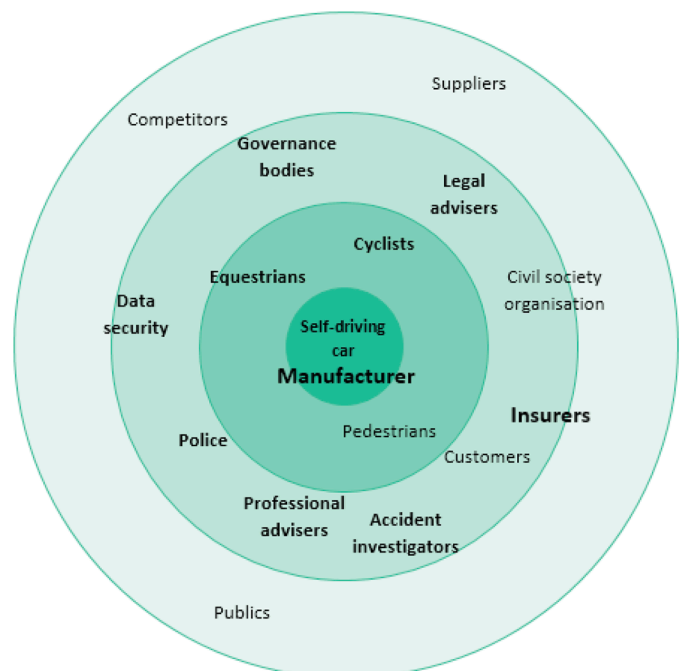

Fig. 1. Types of stakeholders impacted by AV data.

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could possibly be of value in accident-investigation.

The insights from these stakeholders were highly significant to the project's overall outcomes, underlining the importance of an RI-based process of engagement, reflection, and response.

3.2. Technical implications

Our RI approach also had implications for the technical side of the project, which was focused on the design of safety-critical scenarios that could be created and tested in a simulator. The project's initial design included the "Molly problem" (ITU 2022)[5] – the question of what should happen if an AV collides with a lone pedestrian in a situation where there are no other witnesses – but left other scenarios open to being defined through the responses to the stakeholder engagements. After analysing the stakeholder engagement data, it was apparent that an important omission from much policy and study design is the collection of 'near miss' data. Accordingly one of the scenarios created in the simulator incorporated a 'near collision' in order to enable analysis of such data. The inclusion of this scenario generated topics for further research including how such near collisions should be defined, recorded and analysed.

3.3. Wider responsible innovation approaches

During project interviews it became clear how much data could be generated by one single AV – particularly after interviewing a manufacturer that demonstrated how far the currently-recorded data is from being useful in an accident-investigation scenario and how much additional data would be required. The implications for security, chains of custody, and storage are significant. A responsible innovation approach is increasingly considered to include taking account of the sustainability of technology (Lubberink, Blok, Ophem & Omta, 2017) – therefore the vast quantities of data that would need to be recorded and retained to adequately support societal trust in AVs must be factored into questions around their deployment at scale.

These examples illustrate how the project's RI approach – incorporating a mindset that was open to adjustments in project design in response to early findings – helped to shape the progress of the work.

4. Conclusions and recommendations

RoAD endeavoured to ground the project's rationale and carry out its work as fully as possible using an RI mindset. Undeniably this affected the team's interpretation of data in terms of what was deemed significant or important, and using an RI lens drew attention to issues within the field of AVs such as the potential carbon impact of data storage. This had not initially been included in the list of possible concerns stemming from the data-recording carried out by AVs, but was revealed through the RI lens, demonstrating the creativity that an RI framework can engender (Batayeh, Artzberger & Williams, 2018). Had the team not been sensitised to RI issues then possibly other challenges would have drawn its focus. However, it is clear that the project's engagement with societal representatives, civil society organisations, professional, business, legal, and manufacturing perspectives, led to outcomes that were substantively different than if those engagements had not been made. This embedding within what RoAD saw as its necessary societal context led to both a process and an outcome that were demonstrably impacted by the RI mindset of the team.

The experience of operationalising RI in this context leads the team to make some concrete recommendations for further RI work within the field of AV research.

4.1. Recommendation 1: RI assessment

Projects that are mandated to incorporate RI should be assessed on their RI approach and operationalisation. RI was strongly foregrounded in the RoAD project plan, and was a necessary inclusion for all the researchers on the project rather than being represented as a separate strand – in this way the project took an embedded approach to RI concerns as described above. However, no metric of success was suggested through the call mechanism, required by the funding body, or chosen by the project. It therefore becomes difficult to critically assess how 'success' in RI terms might be represented. Further work is called for on agreeing indicators of success in RI terms (Heras & Ruiz-Mallén, 2017; Strand et al., 2015; Wickson & Carew, 2014), in order that projects can quantify their approach against a reliable set of measures.

4.2. Recommendation 2: sustainability considerations

The carbon impact of the recording, sharing, and storage of AV data should become a question for future research. Within the global context it is impossible to ignore the crisis around climate and carbon impacts. Consideration of the sustainability elements of computation-based research and innovation is and should be becoming more urgent (Lannelongue, Grealey, Bateman & Inouye, 2021), and leaders in RI have called for sustainability considerations to be viewed as part of responsible innovation[6]. The carbon impact of not just the manufacture and operation of AVs but specifically the Tb of data that they will generate (including eg duplication when it is shared or backed up), should be assessed and taken into consideration when weighing up the tradeoffs of this new technology.

4.3. Recommendation 3: engagement with policymakers

A responsible innovation approach should include engaging with policymakers. Through discussions with the Law Commission the team became aware of the Commission's ongoing work on the regulation of AVs and was thus able to contribute project findings to that work. This may form a significant element of the project's impact, and we would argue that a responsible innovation approach should consider, as an element of responsiveness, positively engaging with policymakers – whether through workshops, policy briefings, or input into technical standards and guidelines – to avoid research findings being limited to the research community.

This was a small and relatively brief project, but hopefully can serve as a useful case study for the ways in which an RI approach can positively influence a project's approach, and outcomes, through a recognition of the pre-eminence of societal need and the importance of connecting with societal stakeholders in the execution of research.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Acknowledgments

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[5] https://www.itu.int/en/ITU-T/focusgroups/ai4ad/Pages/MollyProblem.aspx

[6] Eg Jirotka 2021 https://www.informatics-europe.org/images/ECSS/ECSS2021/Slides/ECSS2021_Jirotka.pdf

Appendix A

List of stakeholders interviewed

Code	Type of stakeholder	Focus of stakeholder
S-30	Academia	Autonomous vehicles
S-15	Academia	Roboticist
S-14	Academia	Cyberlaw specialist
S-20	Academia	AHEAD - Aggregated Homologation-proposal for Event Recorder Data for Automated Driving
CS-36	Civil society	Police - crime investigation
CS-24	Civil Society	Cycling
CS-04	Civil Society	Equestrian road users
CS-07	Civil Society	Pedestrians and other non-vehicular road users
I-16	Industry	Data security company
I-34 & I-35	Industry	Insurer
I-09	Industry	Autonomous vehicle software
I-03	Industry	Insurer
I-12	Industry	Data management consultant
I-02	Industry	AV Manufacturer/design
PS-99	Policymaking/ governmental	Federal Ministry of Transport and Digital Infrastructure (Germany)
PS-04	Policymaking/ governmental	ITU focus group
P-29	Professional	Smart Cities and data
P-05	Professional	Law Commission
P-11	Professional	Aviation lawyer
P-13	Professional	Former air accident investigator

References

Batayeh, B. G., Artzberger, G. H., & Williams, L. D. A. (2018). Socially responsible innovation in health care: Cycles of actualization. *Technology in Society, 53*, 14–22. https://doi.org/10.1016/j.techsoc.2017.11.002

Boenink, M., & Kudina, O. (2020). Values in responsible research and innovation: From entities to practices. *Journal of Responsible Innovation, 7*(3), 450–470. https://doi.org/10.1080/23299460.2020.1806451

de Saille, S. (2015). Innovating innovation policy: The emergence of 'Responsible Research and Innovation. *Journal of Responsible Innovation, 2*(2), 152–168. https://doi.org/10.1080/23299460.2015.1045280

Department for Transport, Centre for Connected and Autonomous Vehicles, Rachel Maclean, M. P. (2021). Government paves the way for self-driving vehicles on UK roads. *GOV.UK.* https://www.gov.uk/government/news/government-paves-the-way-for-self-driving-vehicles-on-uk-roads.

Heras, M., & Ruiz-Mallén, I. (2017). Responsible research and innovation indicators for science education assessment: How to measure the impact? *International Journal of Science Education, 39*(18), 2482–2507. https://doi.org/10.1080/09500693.2017.1392643

Klaasen, P., Rijnen, M. C. J. A., Vermeulen, S., Kupper, F., & Broerse, J. E. W. (2018). Technocracy versus experimental learning in RRI. *Responsible Research and Innovation: From Concepts to Practices*, 77–98. Routledge.

Lannelongue, L., Grealey, J., Bateman, A., & Inouye, M. (2021). Ten simple rules to make your computing more environmentally sustainable. *PLoS Computational Biology, 17*(9), e1009324. https://doi.org/10.1371/journal.pcbi.1009324

Lehoux, P., Miller, F. A., & Williams-Jones, B. (2020). Anticipatory governance and moral imagination: Methodological insights from a scenario-based public deliberation study. *Technological Forecasting and Social Change, 151*, 1–13. https://doi.org/10.1016/j.techfore.2019.119800

van Lubberink, R., Blok, V., Ophem, J., & Omta, O. (2017). Lessons for responsible innovation in the business context: A systematic literature review of responsible, social and sustainable innovation practices. *Sustainability (Switzerland), 9*(5), 721. https://doi.org/10.3390/su9050721.

Lukovics, M., Zuti, B., Fisher, E., & Kézy, B. (2021). Autonomous cars and responsible innovation. *December*, 19–34. https://doi.org/10.14232/casep21c.2

Nordmann, A. (2014). Responsible innovation, the art and craft of anticipation. *Journal of Responsible Innovation, 1*(1), 87–98. https://doi.org/10.1080/23299460.2014.882064

Owen, R., Stilgoe, J., Macnaghten, P., Gorman, M., Fisher, E., & Guston, D. (2013). A framework for responsible innovation. In R. Owen, J. Bessant, & M. Heintz (Eds.),

Responsible innovation: Managing the responsible emergence of science and innovation in society (pp. 27–50). Wiley. https://doi.org/10.1002/9781118551424.ch2.

Pellizzoni, L. (2004). Responsibility and environmental governance. *Environmental Politics, 13*(3), 541–565. https://doi.org/10.1080/0964401042000229034

Reeves, S. (2012). Envisioning ubiquitous computing. In *Conference on Human Factors in Computing Systems - Proceedings* (pp. 1573–1582). https://doi.org/10.1145/2207676.2208278

Ribeiro, B. E., Smith, R. D. J., & Millar, K. (2017). A mobilising concept? Unpacking academic representations of responsible research and innovation. *Science and Engineering Ethics, 23*(1), 81–103. https://doi.org/10.1007/s11948-016-9761-6

Stilgoe, J. (2018). Machine learning, social learning and the governance of self-driving cars. *Social Studies of Science, 48*(1), 25–56. https://doi.org/10.1177/0306312717741687

Stilgoe, J., Owen, R., & Macnaghten, P. (2013). Developing a framework for responsible innovation. *Research Policy, 42*(9), 1568–1580. https://doi.org/10.1016/j.respol.2013.05.008

Strand, R., Spaapen, J., Bauer, M., Hogan, E., Revuelta, G., & Stagl, S. (2015). Indicators for promoting and monitoring Responsible Research and Innovation. https://doi.org/10.2777/9742.

van Oudheusden, M. (2014). Where are the politics in responsible innovation? European governance, technology assessments, and beyond. *Journal of Responsible Innovation, 1*(1), 67–86. https://doi.org/10.1080/23299460.2014.882097

von Schomberg, R. (2013). A vision of responsible research and innovation. In R. Owen, J. Bessant, & M. Heintz (Eds.), Responsible innovation (First edit, pp. 51–74). John Wiley & Sons, Ltd. https://onlinelibrary.wiley.com/doi/10.1002/9781118551424.ch3/summary.

Wickson, F., & Carew, A. L. (2014). Quality criteria and indicators for responsible research and innovation: Learning from transdisciplinarity. *Journal of Responsible Innovation, 1*(3), 254–273. https://doi.org/10.1080/23299460.2014.963004

Winfield, A.F.T., & Jirotka, M. (2017). The case for an ethical black box. In Y. Gao, S. Fallah, Y. Jin, & C. Lekakou (Eds.), Lecture notes in computer science (including subseries lecture notes in artificial intelligence and lecture notes in bioinformatics): Vol. 10454 LNAI (pp. 262–273). https://doi.org/10.1007/978-3-319-64107-2_21.

Winfield, A., & Jirotka, M. (2018). Ethical governance is essential to building trust in robotics and AI systems. *Philosophical Transactions A: Mathematical, Physical and Engineering Sciences, 376*(2133). https://doi.org/10.1098/rsta.2018.0085

Yaghmaei, E., & van de Poel, I. (2021). *Assessment of Responsible Innovation: Methods and Practices*. Routledge.