

Studies in Applied Philosophy,  
Epistemology and Rational Ethics

**SAPERERE**

Fabio Fossa  
Federico Cheli *Editors*

# Connected and Automated Vehicles: Integrating Engineering and Ethics

 Springer

# Studies in Applied Philosophy, Epistemology and Rational Ethics

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Our scientific and technological era has offered “new” topics to all areas of philosophy and ethics – for instance concerning scientific rationality, creativity, human and artificial intelligence, social and folk epistemology, ordinary reasoning, cognitive niches and cultural evolution, ecological crisis, ecologically situated rationality, consciousness, freedom and responsibility, human identity and uniqueness, cooperation, altruism, intersubjectivity and empathy, spirituality, violence. The impact of such topics has been mainly undermined by contemporary cultural settings, whereas they should increase the demand of interdisciplinary applied knowledge and fresh and original understanding. In turn, traditional philosophical and ethical themes have been profoundly affected and transformed as well: they should be further examined as embedded and applied within their scientific and technological environments so to update their received and often old-fashioned disciplinary treatment and appeal. Applying philosophy individuates therefore a new research commitment for the 21st century, focused on the main problems of recent methodological, logical, epistemological, and cognitive aspects of modeling activities employed both in intellectual and scientific discovery, and in technological innovation, including the computational tools intertwined with such practices, to understand them in a wide and integrated perspective. **Studies in Applied Philosophy, Epistemology and Rational Ethics** means to demonstrate the contemporary practical relevance of this novel philosophical approach and thus to provide a home for monographs, lecture notes, selected contributions from specialized conferences and workshops as well as selected Ph.D. theses. The series welcomes contributions from philosophers as well as from scientists, engineers, and intellectuals interested in showing how applying philosophy can increase knowledge about our current world. Indexed by SCOPUS, zbMATH, SCImago, DBLP. All books published in the series are submitted for consideration in Web of Science.

Fabio Fossa · Federico Cheli  
Editors

# Connected and Automated Vehicles: Integrating Engineering and Ethics

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# Foreword

Transportation has always been deeply entangled with social and ethical values. Safety as the protection and promotion of road users' physical integrity has long been acknowledged as a pivotal objective in transport engineering. As a result, and even if much remains to be achieved, efforts have been taken to embed it into both technologies and engineering practices. But the social and ethical relevance of transportation extends well beyond safety. Social justice, equality, and fairness are also deeply influenced by accessibility to transportation options, with tangible effects on well-being and quality of life. The worrisome environmental effects of transportation in terms of emissions, pollution, consumption of non-renewable resources, land use, and so on also raise thorny ethical, social, and regulatory challenges. Addressing transport in isolation from these and similar problems is no longer acceptable. New approaches aimed at integrating ethical and technical expertise are needed to face the complex challenges of future mobility.

Technological innovation is a critical factor in the endeavour of transitioning towards a transportation system that better satisfies relevant social needs and promotes social well-being. Innovation offers unprecedented opportunities to tackle this challenge, while at the same time raising new risks that require to be carefully identified and handled. Driving automation fits this framework perfectly. On the one hand, much of the public and financial attention that the sector has attracted in the past years has also been justified by insisting on the ethical promises of the technology in terms of safety, environmental sustainability, accessibility, and traffic efficiency—so that a reference to ethical values and social well-being, in a sense, has always been part of the discourse. On the other hand, great expectations have been thus fuelled, and meeting them will require much more than solving the technical puzzles of driving automation. Moreover, new risks must be carefully determined and measured, so as to responsibly foresee their impacts and minimise their harmful effects.

Here as elsewhere, engineers are called to face issues that they are only partially used—or trained—to deal with. Even though social and ethical values are inextricably entangled with transport technologies and infrastructure, engineering curricula do not normally dedicate much space and resources to build the skills necessary to

identify socio-ethical issues and manage them responsibly. This is not just an apparent problem. It is also a missed opportunity. Acknowledging the relevance of socio-ethical challenges to the design of resilient technologies and providing engineers with the interdisciplinary support necessary to become aware of and manage them could contribute greatly to the socially beneficial development, deployment, and use of transportation technologies. Much there is to gain from the integration of engineering and ethics.

Sure enough, significant efforts are necessary to make the integration of engineering and ethics work on both individual and institutional levels. Many barriers need to be overcome—just think of the profound diversity in languages, methodologies, styles of thinking, skills, expertise, research contexts, and cultures that differentiate engineers from philosophers and social scientists. Even when the obstacles are successfully tamed, the problems to be addressed are extremely complex and multi-layered. Building a shared framework through which to rigorously and effectively deal with such thorny issues is certainly difficult. It is definitely a matter that requires plenty of energy, time, and resources. It is, however, also a matter of responsibility. Responsibility for building *better* technologies, and for building technologies *better*. Politecnico di Milano believes that this responsibility must not be waived. On the contrary, we have an obligation to acknowledge and practice it.

This book showcases the commitment of Politecnico di Milano to fostering a culture of scientific innovation that puts individual, social, and environmental values at the forefront of its mission. As part of a wider project intended to pursue this goal, and with the support of Fondazione Silvio Tronchetti Provera, a research position in ethics of driving automation has been funded at our Department of Mechanical Engineering. Thanks to this, engineering researchers working on different aspects of driving automation were given the opportunity to interact with philosophers and social scientists with the aim of bringing technological and socio-ethical requirements closer to each other and explore the many challenges of designing driving automation technologies in alignment with relevant ethical values. Several chapters of this volume testify to both the importance and complexity of interdisciplinary collaboration in the field of driving automation. Moreover, contributions by renowned international experts enlarge and enrich the debate, showing the relevance of the issues here brought into focus and setting the stage for a cutting-edge dialogue on such timely concerns.

The opportunities opened by these studies are as clear as the challenges that the future of transportation poses. Bringing engineering and human sciences closer to each other is fundamental to living up to the responsibilities associated with technological innovation. The new, hybrid culture we need to navigate through the agitated water of the technological age cannot but rest on interdisciplinary cooperation. Let us build it together.

May 2023

Ferruccio Resta  
Politecnico di Milano  
Milan, Italy

# Introduction

Connected and Automated Vehicles (CAVs) are often presented as an important step towards safer and more sustainable mobility. Thanks to this innovative technology, for instance, the number of road injuries and casualties is expected to be substantially reduced. In fact, road accidents are caused for the most part by inadequate human behaviours—such as negligence, carelessness, drunk driving, overtiredness, and so on—and driving automation could provide a solid solution to avoid human error. Also, driving automation is expected to allow for better traffic management, which might lead to both social and environmental benefits. Finally, CAVs revolutionise infrastructure needs, opening new possibilities to minimise the impact of transportation on nature and animal life. In sum, it seems there are strong ethical reasons in support of developing such technologies.

This does not mean, however, that CAVs come without any ethical risk. It would be even less appropriate to belittle or hide these risks not to undermine the good reputation of driving automation. To reap all its foreseen ethical benefits, it is instead crucial to carefully identify and clarify the risks raised by CAVs while thoroughly differentiating between ethically promising and worrisome deployment and adoption scenarios. Indeed, such a critical analysis is essential to anticipate and manage ethical concerns, elaborate on effective regulative frameworks, and establish best practices to minimise risks or, at least, mitigate their effects. Addressing ethical worries with commitment and care is fundamental to creating the conditions for the technology to be firmly, fairly, and optimally embedded in transportation systems.

Even though similar considerations might sound as overly cautious, they are going to play a central role in the future of driving automation. Integrating engineering and ethics—as our subheading reads—is a powerful means to secure an essential ingredient for sustainable innovation, i.e., justified user trust in technology. Earning justified social trust in the set of human actors involved in the design, development, production, validation, regulation (and so on) of CAVs will be crucial to foster their widespread adoption and, thus, reap the expected benefits while responsibly managing the related risks. A necessary step to get there is to think critically about the implications of the technology and to incorporate relevant ethical values in the scientific, technological, and social practices underlying the domain of driving automation.



Philosophy and applied ethics can provide valuable support in this respect. Joined efforts between engineers and philosophers is thus particularly recommended to pursue the goal of developing CAVs worthy of justified social trust.

This book aims at exploring theoretical and ethical issues concerning driving automation from different perspectives, so as to provide a rich overview of such a timely subject matter. In doing so, it takes part in a lively debate that since the mid-2010s has been massively contributing to the identification, study, and discussion of the many ethical challenges raised by the automation of driving and the deployment of CAVs. As proof of its vitality, in the last few months only, two volumes of collected essays—*Autonomous Vehicle Ethics. The Trolley Problem and Beyond* edited by R. Jenkins, D. Cerny, and T. Hribek for Oxford University Press; and *Test-Driving the Future. Autonomous Vehicles and the Ethics of Technological Change* edited by D. Michelfelder for Rowman and Littlefield—and a monograph—*Ethics of Driving Automation. Artificial Agency and Human Values* by F. Fossa for Springer—have been published, adding new voices and arguments to the dispute.

The distinguishing character of the present volume resides in the fact that it gathers several contributions authored by both philosophers and engineers. Its main objective is to foster a multidisciplinary approach according to which philosophy, ethics, and engineering are productively integrated, rather than just juxtaposed. Its scope reflects the belief that applied ethics issues such as those here under scrutiny can be appropriately discussed only in an interdisciplinary fashion committed to bridging gaps between theory and practice. The need for philosophers and engineers to work together in such a context is tangible. While engineers add the necessary technical knowledge to the table, philosophers can help clarify relevant concepts and shed light on thorny ethical problems. Both ingredients are required to merge theory and practice together and turn ethical discourses into actual efforts.

The contributions collected in this volume exhibit a two-fold, although deeply interwoven, nature. On the one hand, they present philosophical inquiries into the conceptual, scientific, social, and regulative relevance of driving automation, thus setting the stage for a wide critical appraisal of its socio-technical system. On the other hand, and against this background, they discuss more applied ethical issues concerning the design of CAVs, showcasing the results of interdisciplinary research teamwork aimed at tackling problems lying at the intersection of engineering and ethics.

More in particular, the book addresses many of the challenges posed by the concrete application of the recent European guidelines advanced in the 2020 report *Ethics of Connected and Automated Vehicles: Recommendations on Road Safety, Privacy, Fairness, Explainability and Responsibility*.<sup>1</sup> Indeed, principles are rather abstract notions, and guidelines only go so far in translating them into more concrete measures. As a result, it is not always easy to grasp how to apply them in the everyday practical contexts of technological research and development, social deployment, and use. The risk, then, is for them to remain dead letters, words incapable of sorting any

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<sup>1</sup> <https://op.europa.eu/en/publication-detail/-/publication/5014975b-fcb8-11ea-b44f-01aa75ed71a1/>.

appreciable practical effect. What is even worse, one might feel morally satisfied just by drafting a list of ethical principles and asking stakeholders to comply with them. Practitioners, on the other hand, might react to the difficulty of translating ethical values and guidelines into best practices and technical requirements by dismissing the framework as altogether inapplicable or settling for ultimately inconsistent measures. The risk run here is to render the ethical effort ineffective, relegating it to superficial actions. The objective, on the contrary, is to substantially modify the social practices linked to the design, development, deployment, and use of CAVs. To do so, a clear understanding of the magnitude and quality of the challenges that lie ahead is the most necessary step.

In line with the general objectives of the volume, and following the framework proposed in the European report, the book opens with in-depth discussions of the many difficulties that complicate the adoption of the ethical values relevant to driving automation in the practical contexts of the design, deployment, use, and regulation of CAVs. In the first chapter “[Minding the Gap\(s\): Different Kinds of Responsibility Gaps Related to Autonomous Vehicles and How to Fill Them](#)”, Sven Nyholm addresses the critical value of responsibility, analysing its multifaceted profile and tackling the worrisome problem of responsibility gaps. The second chapter “[Designing Driving Automation for Human Autonomy: Self-determination, the Good Life, and Social Deliberation](#)”, by Fabio Fossa and Filippo Santoni de Sio, focuses on the value of personal autonomy, identifying and discussing hurdles in its concretisation throughout various levels of driving automation and by reference to other noteworthy ethical values. The thorny task of implementing explainability into CAV perception systems is tackled in the third chapter “[Contextual Challenges to Explainable Driving Automation: The Case of Machine Perception](#)”, which presents the results of an interdisciplinary study by Matteo Matteucci, Simone Mentasti, Viola Schiaffonati, and Fabio Fossa. Subsequent chapters also report the outcomes of similar interdisciplinary research experiences. In the fourth chapter “[Design for Inclusivity in Driving Automation: Theoretical and Practical Challenges to Human-Machine Interactions and Interface Design](#)”, Selene Arfini, Pierstefano Bellani, Andrea Picardi, Ming Yan, Fabio Fossa, and Giandomenico Caruso consider the value of inclusivity and the many challenges that need to be proactively faced for its meaningful integration into driving automation technologies. The fifth chapter “[From Prototypes to Products: The Need for Early Interdisciplinary Design](#)”, by Stefano Arrigoni, Fabio Fossa, and Federico Cheli, discusses privacy and cybersecurity shortcomings that might emerge in the transition from prototyping to production of CAV communication systems, thus stressing the importance of engaging in ethically informed interdisciplinary practices since the very outset of the design process. In the sixth chapter “[Gaming the Driving System: On Interaction Attacks Against Connected and Automated Vehicles](#)”, Luca Paparusso, Fabio Fossa, and Francesco Braghin examine the cybersecurity risk of interaction attacks—i.e., potential situations where CAVs are intentionally designed to maliciously influence the driving behaviour of other CAVs, thus exerting indirect control over their operations—and consider possible countermeasures. The seventh chapter “[Automated Driving Without Ethics: Meaning, Design and Real-World Implementation](#)”, authored by

Katherine Evans, Nelson de Moura, Stéphane Chauvier, and Raja Chatila, tackles the much-discussed problem of unavoidable collisions by proposing a machine ethics algorithm based on the Ethical Valence Theory—a theoretical perspective that seeks to fully acknowledge the relevance of contextual factors and frames the issue in terms of claim mitigation.

Applied research is fundamental to moving from theory to practice and fostering the integration of ethical values into driving technologies, but it represents only one side of the whole endeavour. More general, high-level inquiries into driving automation are all-too necessary to inform practical work and regulatory angles. The last three chapters offer valuable insights in this regard, thus enriching the perspective on the ethics of CAVs developed in the volume. In the eighth chapter “[Thinking of Autonomous Vehicles Ideally](#)”, Simona Chiodo criticises the empirical framing of the unavoidable collision problem and proposes an analysis of the issue by drawing on the philosophical tools of abstraction and idealisation. The ninth chapter “[Thinking About Innovation: The Case of Autonomous Vehicles](#)”, by Daniele Chiffi and Luca Zanetti, discusses CAVs by reference to the literature on innovation and tries to determine to which category of innovative technology they belong. Finally, in the tenth chapter “[Autonomous Vehicles, Artificial Intelligence, Risk and Colliding Narratives](#)”, Martin Cunneen takes a closer look at the ethical narratives in which CAVs have been embedded, clarifying the economic interests behind such characterisations and calling for a thorough criticism of their main components.

Taken together, we believe that the contributions collected in this volume point to two main claims. First, much work is still needed to set the right path to the integration of engineering and ethics in the domain of driving automation. Narratives that salute CAVs as game-changing technologies destined to drive us into a more ethical transportation future grossly underestimate the amount of engineering, social, and regulatory efforts needed to convert promises into reality. Driving automation might very well offer valuable opportunities to steer the transportation domain towards less harmful directions and bring about the conditions for fairer, more inclusive mobility. However, catching these opportunities requires much more than putting CAVs on the streets. Any ethical benefit of driving automation can only be achieved proactively by raising social awareness, promoting widespread involvement, and supporting stakeholders in its intentional pursuit.

Second, the challenges to be faced in this process of theoretical awareness and practical endorsement are both massive and extremely intricate. Interdisciplinarity is key in this sense. Forming diverse research and design teams is a necessary condition to deal with these challenges at an adequate level of granularity. And yet, most chapters evidently submit more questions than answers, and applicability remains a puzzle to crack. Nevertheless, suggestions and insights on which to ground further inquiries are not missing either. Methodologies and research tools aimed at tackling its manifold aspects are proposed and preliminarily scrutinised, which opens promising avenues for future research and practice. Moreover, a disenchanting and thorough measurement of the complexity of the matter is also to be regarded as valuable information with reference to the wider socio-political goal of establishing

a more ethical transportation system—to which the contributions of CAV technologies are yet to be precisely determined. That being said, and however formidable the challenge of integrating engineering and ethics in the domain of driving automation might appear, a shared commitment to the task runs through the following pages and represents their most noticeable *fil rouge*.

The interdisciplinary nature of the book corresponds to the interdisciplinarity of its intended audience, which comprises philosophers of technology, ethicists, engineers, developers, manufacturers, producers, mobility experts, regulators, politicians, and so on. Its approach is meant to increase the opportunity to exchange ideas, anticipate potential risks, bring ethical issues into focus, study their potential social impacts, and think of possible solutions already at the design stage. It is not to be forgotten that making driving automation a factor in the ethical improvement of the transport system is primarily a social and political mission—one to which engineers can contribute greatly. By introducing ethical reflection directly into the social venues where technological innovation unfolds, we might have one more promising chance to appropriately manage ethical issues in driving automation, thus earning justified social trust and securing the benefits that the adoption of CAVs is often supposed to yield. We hope that this book might serve as a useful tool to bridge ethics and engineering in this field, thus concurring with the great challenge of designing, developing, deploying, and using CAVs in sustainable ways.

The preparation of this volume would have been much more difficult without the help of many colleagues and friends. First, we would like to thank the authors who accepted our invitation to participate in the book project for their cooperation and thoughtfulness. We are grateful to Paolo Bory, Simona Chiodo, Francesco Corea, Shreias Kousik, Giulio Mecacci, Francesca Foffano, Guglielmo Papagni, Luca Possati, Steven Umbrello, and Mario Verdicchio for offering insightful comments on previous versions of the chapters. Many thanks also to the members of the Polimi META Research group—Simona Chiodo and Daniele Chiffi in particular—for encouraging the project since the very outset and keeping an attentive eye on its development. We would also like to extend our gratitude to the former Rector of Politecnico di Milano Ferruccio Resta for agreeing to contribute a foreword to this volume as a much-appreciated token of support to the mission of integrating engineering and ethics in our institution. Finally, we are deeply grateful to Lorenzo Magnani for accepting our book proposal with enthusiasm, and to Leontina De Cecco and Shakila Sundarraman for the editorial and administrative assistance throughout the publication process.

Milan, Italy

Fabio Fossa  
Federico Cheli

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