Ethical consequences of implementing driverless haul trucks onto South African open pit mines.

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# **Introduction**

The South African mining industry is facing many challenges. At the beginning of 2016 the commodity prices were low (PWC, 2014; Hermanus, 2017). Where, for instance, the prices for energy minerals fell by 45% year on year from 2014 to 2015 (Group World Bank, 2016). There remain many regulatory risks (PWC, 2014, p. 15). These include policy uncertainties that affect the real effective exchange rate (Hlatshwayo and Saxegaard, 2016, p. 22) thus affecting the returns the mines get from selling their commodities. Labour relations also remain strained and is a major risk to mining operations (PWC, 2014, p. 15). Strikes like the 2014 platinum strike affects not only the industry but the South African economy as a whole (Bohlmann *et al.*, 2014). Additionally, the industry has struggled from a reduction in Research and Development spending since the 1990’s (Hermanus, 2017). Leading to a lack of innovation.

One way the South African mining industry is combatting these challenges is by following the global trend of deploying driverless haul trucks on open pit mines. Internationally both Caterpillar and BHP have deployed driverless haul trucks to Australian mines (Hyder, Siau and Nah, 2018). This is part of a general trend to automate the mining industry (Bodin *et al.*, 2015).

The introduction of driverless haul truck onto South African open pit mines are in its initial phases. The international telecommunications company Cisco completed a proof of concept on an unnamed South African mine in early 2018 (Moolman, 2018).

Deploying driverless haul trucks onto mines bring with it many advantages. Firstly, this form of automation has many potential economic benefits for the mine. Fewer drivers need to be employed. According to Bellamy and Pravica (2011) a haul truck driver can earn $A100000 per annum. Which would equate to significant saving for the mine.

AI-controlled haul trucks also require less fuel than manned haul trucks (Bellamy and Pravica, 2011, p. 152). Driverless haul trucks tend to have fewer waiting times because dispatch updates the AI-driver with information about how busy the road is and how long it would take to get there. Where human drivers generally drive to the next stop at maximum speed. The driverless haul truck generally paces to drive as economical as possible.

The design of open pit mines will also reap benefit from driverless haul trucks. The roads these driverless trucks require need not be as wide as those road that were designed for human operators (Bellamy and Pravica, 2011, p. 153). Narrower roads mean less road building i.e. “blasting and hauling”. In fact, the required width of the roads could potentially be reduced by a third.

Improvements in safety is another huge benefit for automating the driving process on open pit mines. There will be fewer human beings on the site, thus reducing the likelihood for injury. These machines also do not get tired. Unlike human beings that tend to be hampered by fatigue especially during night shifts (Bellamy and Pravica, 2011, p. 153).

In cases where a machine takes over the responsibility of executing a task, that a human being used do, ethical considerations need to be considered. The ethical consequences of such a new technology might not be understood by all involved parties.

Automating haul trucks can be considered to be an easier problem than automating vehicles for public road use (Hyder, Siau and Nah, 2018, p. 2).

Driverless or autonomous vehicles is currently a hotly debated topic in academic circles.

# **Defined research focus**

The focus of this study will be limited to driverless haul trucks on open pit mines. Examples of open pit mines in Limpopo province include Venetia Diamond Mine, Mogalakena[[1]](#footnote-1) and Grootegeluk Mine[[2]](#footnote-2). In the Northern Cape there is Sishen[[3]](#footnote-3) near the town of Kathu and Finsch Diamond Mine near Kimberley. These are just some of the mines that will be asked to participate.

We will not include driverless LHD’s (Load Haul Dumper) and ADT’s (Articulated Dump Truck) in any underground mines.

# **Problem statement**

The problem statement identified for this research is, which kind of ethical problems will the introduction of driverless haul trucks, onto South African open pit mines, bring?

The impact of driverless haul trucks has been studied in the Australian context (Bellamy and Pravica, 2011). The study maintains that with driverless haul trucks, workers with a greater skill level will be required. Thus, creating more highly skilled jobs. But the number of lower skilled jobs will be reduced. Safety on the mines will also be increased for instance due to driverless haul trucks not getting fatigued during night shifts like human operators.

A recent study (Gumede, 2018) was made to investigate the socio-economic effects of mechanizing hard rock mines in South Africa. This is the only study that we can find that describes the levels to which the people in the South African Mining industry understand some of the issues related to automation. Nevertheless, the author admitted several limitations to the study. Firstly, the study was unable to be representative of all labour unions. One labour union was unwilling to participate and another has capacity issues. For these reasons the labour unions will be excluded from this study. The focus would be only on those in the industry that will interact and be directly affected by driverless haul trucks. It is worth noting that even with a high level government program like Operation Mining Phakisa[[4]](#footnote-4), created by the Presidency, had difficulties in involving the trade union AMCU (Association of Mineworkers and Construction Union) (Hermanus, 2017, p. 815).

Cross-sectional vs longitudinal

Quantitative

communities

A study (Bellamy and Pravica, 2011) was performed on how the introduction of autonomous haul trucks impacted the Australian surface mining community.

Benefits:

* There is a great potential to save on wages. The average wage of a haul truck driver in Western Australia was $A 100000 per year in 2008 (Bellamy and Pravica, 2011, p. 152). **(maybe get an updated number)**
* The potential fuel savings are large (Bellamy and Pravica, 2011, p. 152).
* Truck availability
* Tyre life
* Pit design
* Safety

# **Research question**

The main research question this proposal would like to put forward for consideration is the following:

What are the ethical consequences of introducing driverless haul trucks onto South African open pit mines on South African open pit miners?

Whether or not automation will increase the profitability of the mine will not be considered. As this does not necessarily affect the miners since these profits might not make it into the hands of the general open pit miner.

# **Research sub questions**

The first research sub question will be:

How will the safety on mines be affected?

In various studies (Bellamy and Pravica, 2011, p. 153; Gumede, 2018, p. 2) it is stated that there will be safety improvements with mechanization. This must be shown to be true with driverless haul trucks on South African open pit mines.

The second research sub question will be:

How will the socio-economic situation of miners be affected?

# **Research objectives**

# **Literature Review**

## **Introduction**

The development of new technologies, that give rise to new ethical concerns, is not a new phenomenon unique to the 20th or 21st centuries. In 1890, Warren and Brandeis published their seminal paper “The Right to Privacy” (Warren and Brandeis, 1890). Regarding the new privacy concerns with regards to new development is photographic and printing technologies.

Cybernetics, developed by Norman Wiener in the 1950s, can be regarded as the foundational discipline for Computer Ethics. (Floridi, 2015, p. 91) His new discipline covered many of the same topics that we would today regard as central to Computer Ethics. These include access to computers for people with disabilities, computer security, professionalism in computing, unemployment due to computing, automation and many more. (Bynum, 2016)

The Computer ethics of today covers a broad range of topics including: security, privacy, copyright as in computer “piracy”, access to computing for the disabled, environmental impact and sustainability of computing system and research ethics etc. Of these, privacy, is currently the most discussed topic in the field (Stahl *et al.*, 2016, p. 3,28). The term “Computer Ethics”, has its origins with Walter Maner (Maner, 1980; Bynum, 2016).

A recent development is Responsible Research and Innovation (RRI). Researchers can now use the principles of (RRI) to manage the ethical considerations of how their research impact on society (Eden, Jirotka and Stahl, 2013, p. 1).

## **Definition of Ethical Computing**

According to the Cambridge Dictionary of Philosophy, ethics is “the philosophical study of morality” (Audi, 1999). Therefore, Ethical Computing relates to the study of morality as it relates to Computing. In simple terms, morality can be thought of as the study of what is right and what is wrong.

James H, Moor defines Computer ethics as “… the analysis of the nature and social impact of computer technology and the corresponding formulation and justification of policies for the ethical use of such technology” (Moor, 1985, p. 266).

There are a few competing ethical theories used in Computer Ethics.

Firstly, we can classify these ethical theories into a couple of categories namely Consequentialism, Deontology and Virtue ethics. All of which are Normative ethical theories and try to determine what ought to be done in ethically challenging situations and is thus a prescriptive in nature (Stahl *et al.*, 2016, p. 4).

In Consequentialism, whether an action is good or bad, i.e. ethical, depends on the consequences of the action in question. The most prominent consequentialist theory is utilitarianism. Which can be describes as doing the most amount of good to the largest amount of people (Stahl *et al.*, 2016, p. 4).

Deontology on the other hand hold that the intention of agent doing the action determines whether it is ethical or not (Stahl *et al.*, 2016, p. 4). The name comes from the Greek for “duty”. The most famous deontological theory is Kantianism. Named after its creator, the 18th century German philosopher Immanuel Kant (Stahl, 2012, p. 641).

Where in virtue ethics, morality depends on the individual character (Stahl, Eden and Jirotka, 2013). An example of this kind of work is Wiltshire (2015), where an attempt is made to develop an artificial agent with “heroic” attributes (Stahl *et al.*, 2016, p. 4).

A prominent theory is Luciano Floridi’s theory of Information ethics (Stahl *et al.*, 2014, p. 812). Floridi’s theory is an ontology of information. Everything can be fundamentally seen as information with an emphasis on the relationship between information agents (Ess, 2008, pp. 160–161). As Floridi puts it “moral actions are the result of complex interactions among distributed systems integrated on a scale larger than the single human being” (Floridi, 2008, p. 198). In a system with such “Distributed Morality”, the criterion for judging the morality is not the action of each component, but rather on the impact on the larger environment this system is in. This is because in such a system, individual agents can be morally neutral, e.g. a GPS System or AI Driver, and thus complicating the ability to judge morality on the agent level (Floridi, 2013, pp. 727–731).

The “trolley problem” is a common thought experiment uses in computer ethics literature to discuss some of the problems related to self-driving vehicles (Hevelke and Nida-Rümelin, 2015; Wilson and Scheutz, 2015; Frison, Wintersberger and Riener, 2016; Nyholm and Smids, 2016; Wiseman and Grinberg, 2018). This thought experiment was first introduced in Foot (1967). There have been many versions of the “trolley problem” since then. At its core the “trolley problem” describes a situation where there are a group of people on a track or road. A vehicle is hurtling towards the group at speed. If there is no intervention then the vehicle will hit the group of people, killing them. The vehicle has an alternative path it could take. Either a side road, sidewalk or side track. Also, there is a single human being on this alternative path. For the vehicle to take this alternative path there must be some action taken to put the vehicle on the alternate path. The ethical dilemma is that when no action is taken a lot of people will die and if action is taken, the person or agent taking the action will be directly responsible for someone’s death. (Bonnefon, Shariff and Rahwan, 2016)

According to utilitarian ethics, the action should always be performed, because it will benefit more people by minimizing the number of casualties. Bonnefon, Shariff and Rahwan (2016) conducted studies into what would be peoples preference. In general, people preferred a utilitarian ethic where few people would be sacrificed for the good of many. Except where they would be the person that would be sacrificed. Then the respondents preferred a solution where they would survive. Bonnefon, Shariff and Rahwan (2016) suggests that a potential solution is government regulation. As in, as people are forced by government regulation to immunize their children, the public can be forced to adopt vehicles that follow utilitarian algorithms and might decide to kill its occupants. This form of government regulation is supported by Gogol and Műller (2017, pp. 694–696).

SAE International, an international, professional and standards organization for the automotive and aerospace industries, have a standard to classify the level of automation of a vehicle. This system has already been adopted by the US National Highway Traffic Safety Administration (NHTSA, 2016, p. 9). It consists of SAE Level 0 to SAE Level 5, where a SAE Level 0 vehicle contains no automation and SAE Level 5 where the vehicle is fully automated under all conditions.

A haul truck is significantly larger than a car. Is there literature tat compares the size and the ethics?

## **Importance of Ethical Computing**

In our society we are constantly inundated with ethical dilemmas in the Information and Communication Technology sector. From issues about privacy and consent (Carter, Laurie and Dixon-Woods, 2015; de Bruin and Floridi, 2017) to copyright infringement (Chiou, Wan and Wan, 2012, p. 108). Most prominent are issues relating to privacy. Examples are the 2010 cyber-attack on Gmail and the NSA spying scandal of 2013 (de Bruin and Floridi, 2017, p. 22).

The reason why we need ethical theory is because people have an innate sense of right and wrong (Stahl, 2012, pp. 638–640). What is right or wrong can differ between nationalities, groups or peoples. These ideas need to be openly discussed and reasoned about. But there needs to be agreement on what is regarded right or wrong.

As previously mentioned, according to Moor it is policy vacuums that create computer ethics problems (Moor, 1985, p. 266). RRI can be used to develop policies for how researchers are to respond to the consequences of their ICT research and innovation (Eden, Jirotka and Stahl, 2013, p. 1). This approach has become prominent in Europe where it will underpin Horizon 2020, the European research framework (Stahl, 2013, p. 1).

Incorporating values in the design from the outset can have a bearing on the successfulness of the project. The Google Glass project was tested in 2014 and did not seem to consider the ethical problems associated with the technology and how society would react to it. Many people were concerned about how much this new technology would infringe upon their privacy. This led to the project being stopped in 2015 (Van Den Hoven, 2017, p. 71).

The design process of technological devices and technologies incorporates certain ethical assumptions into the device or technology. These assumptions can be unknowingly added by the developer. Value-sensitive design (VSD) as a field of study tries to make values a key part of technological design process. In a sense making any ethical views built into the system known. This field of study started at Stanford in the 1970s (Van Den Hoven, 2017, p. 69). Some believe that VSD can support RRI and that RRI can benefit from the knowledge gained in the VSD field (Simon, 2016, p. 220).

When an ICT system breaks or does something society sees as immoral, the developers of that system are usually blamed (Kraemer, van Overveld and Peterson, 2011, p. 251). This is justified when the developers have control over the actions of the ICT system (Matthias 2004). But this becomes a problem in systems based on learning, for example machine learning algorithms like neural networks. Here the developer does not understand everything about how the system reaches certain conclusions. Is the developer now responsible for an outcome they could not have foreseen or at least was very difficult to foresee? Answers to this ethical dilemma is required. The field of computer ethics have not found a consensus to this dilemma. But many agree that more research is needed.

## **Some guidelines on being ethical within the computing environment**

One study (Van Den Hoven, 2017, pp. 66–70) felt that researchers and developers in the Information and communications technology (ICT) industry needs to understand that moral assumptions are made during the development of new technology and products. The researcher or developer brings in their own “views and values” into the product. The product is thus not “morally neutral”. Ethical issues need to be brought up early in the development process. The earlier in the development lifecycle these considerations are addressed, the easier it is to make the necessary changes. Additionally, these ethical requirements should be put on par with the other non-ethics related requirements and not regarded as secondary or less important requirements.

Governance of RRI needs to be “reflective”. The persons in charge of overseeing the RRI process, should ensure that the process “reflect(s) upon its own assumptions, presuppositions and required consequences”. This needs to be applied to different views there currently is on privacy and to what extend privacy is wanted or needed (Stahl, 2013; Stahl, Eden and Jirotka, 2013).

The most discussed topic in computer ethics literature is privacy (Stahl *et al.*, 2016, p. 22). One form of privacy is Data Protection. This can enabled through an electronic privacy policy when paper based policies fail (Mizani and Baykal, 2007, p. 695).

While in the European Union, Data Protection is a “fundamental right” according to Article 8(1) of the Charter of Fundamental rights of the European Union (European Union, 2012). This right to Data Protection will be enforced through the new General Data Protection Regulation (GDPR) (European Union, 2016). According to Stahl (2013, p. 712) these regulations “show that there are ways of democratically regulating contested technology related issues”.

Even though standardizing ethical approaches through policy or legislation has benefits, this can lead to a reduction in researcher’s engagement with ethical decision making. This leads to a “tick-box” approach to ethics (Leonelli, 2018, p. 7) and becomes an uninteresting daily task that must be performed. What is needed is for researchers to ask more questions and critically evaluate each ethical problem that arises (Leonelli, 2018, p. 10).

## **Conclusion**

Ethics of computing is a large vibrant field with many competing theories trying to explain ethical approaches to issues in the ICT field. Ethics in computing remains relevant and influences our lives with topics reaching the mass media, like the Google Glass fiasco of 2014 or the Cambridge Analytica scandal of 2018.

The European Union is on the forefront of the implementation of RRI and all the fruits of their labour remains to be seen.

More research needs to be done to solve problems like privacy in social media or who is ethically responsible for computer agents developed with neural networks where responsibility can be difficult to assign.

Ethics of computing remains relevant and requires more attention.

# **Research strategy**

This study will use the epistemological stance of interpretivism. Expand on where interpretivism comes from. We will follow this stance because what is considered ethical can differ between different groups of people (Stahl, 2012, pp. 638–640). A deductive approach will be followed since a lot of theory already exist for this topic as outlined in the literature review. We will be gathering a lot of data on the mines and their employees. This will be simplified by using surveys. Sapsford, R. (2007) Survey research. 2nd ed. London: Sage. Quantitative methods will be used since the surveys will ask quantifiable questions that are not rooted in opinion or experience. This will also be a longitudinal study, because how driverless haul trucks effect miners will be a process that will take many years to complete.

This study will follow a utilitarian view of ethics i.e. implementing driverless haul trucks will be considered ethical if it does the most good to the most amount of people.

We require information on how well workers in the South African mining industry understand the ethical consequences of introducing driverless haul truck onto South African open pit mines. This implies that we want to gather information at one point in time and are not concerned with how the understanding of ethical concerns change over time. This study will need to involve a wide selection of people from various socio-economic and educational backgrounds. Also, getting various stakeholders to participate can be difficult in the mining industry (Hermanus, 2017, p. 815; Gumede, 2018, p. 8). For these reasons we will carry out a cross-sectional study rather than a longitudinal one.

# **Data collection**

There will be 2 efforts of data collection. The first will be gathering data from the mines on how they have been affected by the automation of haul trucks. Secondly several individuals from the mines will be queried on how they have been personally affected.

## **Data collection on mines**

A mine representative from each mine in the study will be asked questions in a survey including the following:

* How many haul trucks do they operate and how many of them are driverless? This includes how many are operational and in use and not just the total number in the mines inventory. Knowing how many haul trucks a mine operates, gives a baseline reading on the economic activity on the mine. The number of haul trucks could vary due to external factors. For instance, there could be an economic turndown and the number of haul trucks needed could be affected. This will help during the analysis stage to help interpret the data independent of such external factors.
* How many drivers are currently employed by the mine? This is to establish how many driver jobs were lost in the period surveyed.
* How many haul truck maintenance and operational personnel are employed by the mine? It is believed that new jobs will be created during the automation process (Gumede, 2018, p. 3). These metrics will monitor the actual job creation that took place.
* How much has automation increased the viability of the mine? This includes asking how the forecast lifetime of the mine changed in the year and what the new cost per ton is. Automated haul trucks can increase the viability of a mine by increasing its productivity (Bellamy and Pravica, 2011, p. 154). As the cost per ton drops, sections of a mine that was considered uneconomic to mine can become a viable mining resource.
* Questions on safety. How many haul truck related accidents occurred in the last year? Also, how has the severity of these accidents changed? These are pertinent since one of the main believed benefits of automation is an increase in safety (Bellamy and Pravica, 2011, p. 153).

## **Data collection on miners**

Miners will be given a standardized questionnaire relating to how they have been affected by driverless haul trucks. They will be given the same questionnaire annually for a period of 5 years. This questionnaire will be broken down into various sections.

The first section will comprise of the socio-economic situation of the respondent.

* Is the mine worker still employed on the mine?
* What is the mine workers current salary?

How much do you believe automation will save jobs in the long run? In Gumede (2018, p. 6) more educated respondents believed automation will save jobs in the long run. This question needs to be asked to a larger number of respondents.

Survey (Quantatative) vs interviews (Qualitative)

# **Data analysis**

This study will be able to determine how much more viable the surveyed mines have become due to automation. But it will not be able to gather information on mines, that were closed due to not being economically viable, that can be reopened when the cost per ton has dropped to the required levels. Because, these mines will not be part of the study and will not be known at the beginning of the study. The same holds for new mines.

Discuss any bias (measurement,selection,recall,interviewer)

# **Data verification**

# **Ethical consideration**

Sensitive information regarding miners financial and medical status will be gathered by this study. Efforts need to be made to ensure the security of this information. Before the data is given for data analysis, the data needs to be anonymized. Only then can the data be analyzed or published. Interviewers will facilitate the answering of the questionnaires and should hand over the questionnaires to the study leader as soon as possible. Access to the raw data i.e. questionnaires will be restricted. After processing the questionnaires will be stored in a safe location with only the study leader and supervisor having access.

# **Conclusion**

# **Completed references list**

Audi, R. (1999) ‘The Cambridge Dictionary of Philosophy, Second Edition’.

Bellamy, D. and Pravica, L. (2011) ‘Assessing the impact of driverless haul trucks in Australian surface mining’, *Resources Policy*, 36(2), pp. 149–158. doi: 10.1016/j.resourpol.2010.09.002.

Bodin, U. *et al.* (2015) ‘Remote controlled short-cycle loading of bulk material in mining applications’, in *IFAC-PapersOnLine*, pp. 54–59. doi: 10.1016/j.ifacol.2015.10.077.

Bohlmann, H. R. *et al.* (2014) *The Impact of the 2014 Platinum Mining Strike in South Africa: An Economy-Wide Analysis*. Available at: https://www.up.ac.za/media/shared/61/WP/wp\_2014\_72.zp39321.pdf (Accessed: 3 November 2018).

Bonnefon, J. F., Shariff, A. and Rahwan, I. (2016) ‘The social dilemma of autonomous vehicles’, *Science*, 352(6293), pp. 1573–1576. doi: 10.1126/science.aaf2654.

de Bruin, B. and Floridi, L. (2017) ‘The Ethics of Cloud Computing’, *Science and Engineering Ethics*, 23(1), pp. 21–39. doi: 10.1007/s11948-016-9759-0.

Bynum, T. (2016) *Computer and Information Ethics*. Winter 201. Edited by Edward N. Zalta. Metaphysics Research Lab, Stanford University. Available at: https://plato.stanford.edu/entries/ethics-computer/ (Accessed: 25 March 2018).

Carter, P., Laurie, G. T. and Dixon-Woods, M. (2015) ‘The social licence for research: why care.data ran into trouble’, *J Med Ethics*, 41, pp. 404–409. doi: 10.1136/medethics-2014-102374.

Chiou, W.-B., Wan, P.-H. and Wan, C.-S. (2012) ‘A new look at software piracy: Soft lifting primes an inauthentic sense of self, prompting further unethical behavior’, *Int. J. Human-Computer Studies*, 70, pp. 107–115. doi: 10.1016/j.ijhcs.2011.09.001.

Eden, G., Jirotka, M. and Stahl, B. (2013) ‘Responsible research and innovation: Critical reflection into the potential social consequences of ICT’, in *Proceedings - International Conference on Research Challenges in Information Science*. doi: 10.1109/RCIS.2013.6577706.

Ess, C. (2008) ‘Luciano Floridi’s philosophy of information and information ethics: Critical reflections and the state of the art’, *Ethics and Information Technology*, 10(2–3), pp. 89–96. doi: 10.1007/s10676-008-9172-8.

European Union (2012) ‘CHARTER OF FUNDAMENTAL RIGHTS OF THE EUROPEAN UNION’, *Official Journal of the European Union (OJ)*, 326(2), pp. 391–407. Available at: https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:C2012/326/02&from=EN (Accessed: 10 June 2018).

European Union (2016) ‘Regulation 2016/679 of the European parliament and the Council of the European Union’, *Official Journal of the European Union (OJ)*, 119(59), pp. 1–88. doi: http://eur-lex.europa.eu/pri/en/oj/dat/2003/l\_285/l\_28520031101en00330037.pdf.

Floridi, L. (2008) ‘Information ethics: A Reappraisal’, *Ethics and Information Technology*, 10(2–3), pp. 189–204. doi: 10.1007/s10676-008-9176-4.

Floridi, L. (2013) ‘Distributed Morality in an Information Society’, *Science and Engineering Ethics*, 19(3), pp. 727–743. doi: 10.1007/s11948-012-9413-4.

Floridi, L. (2015) *The onlife manifesto*. Springer. doi: 10.1007/978-3-319-04093-6.

Foot, P. (1967) ‘The Problem of Abortion and the Doctrine of the Double Effect’, *Oxford Review*, 5, pp. 5–15. Available at: https://philpapers.org/archive/footpo-2.pdf (Accessed: 15 November 2018).

Frison, A.-K., Wintersberger, P. and Riener, A. (2016) ‘First Person Trolley Problem: Evaluation of Drivers’ Ethical Decisions in a Driving Simulator’, in *Adjunct Proceedings of the 8th International Conference on Automotive User Interfaces and Interactive Vehicular Applications*, pp. 117–122. doi: 10.1145/3004323.3004336.

Gogoll, J. and Müller, J. F. (2017) ‘Autonomous Cars: In Favor of a Mandatory Ethics Setting’, *Science and Engineering Ethics*, 23(3), pp. 681–700. doi: 10.1007/s11948-016-9806-x.

Group World Bank (2016) *Commodity Markets Outlook, January 2016*. Washington, DC. Available at: https://openknowledge.worldbank.org/bitstream/handle/10986/23680/CMOJan2016FullReport.pdf?sequence=1&isAllowed=y (Accessed: 3 November 2018).

Gumede, H. (2018) ‘The socio-economic effects of mechanising and / or modernising hard rock mines in South Africa’, *South African Journal of Economic and Management Sciences*, 21(1), pp. 1–11. doi: 10.4102/sajems.v21i1.1848.

Hermanus, M. (2017) ‘Mining redesigned - innovation and technology needs for the future - a South African perspective’, *Journal of the Southern African Institute of Mining and Metallurgy*. scieloza, 117, pp. 811–818. doi: 10.17159/2411-9717/2017/v117n8a12.

Hevelke, A. and Nida-Rümelin, J. (2015) ‘Responsibility for crashes of autonomous vehicles: an ethical analysis’, *Science and engineering ethics*. Springer, 21(3), pp. 619–630.

Hlatshwayo, S. and Saxegaard, M. (2016) *The Consequences of Policy Uncertainty: Disconnects and Dilutions in the South African Real Effective Exchange Rate-Export Relationship*. Available at: https://s3.amazonaws.com/academia.edu.documents/46368682/wp16113.pdf?AWSAccessKeyId=AKIAIWOWYYGZ2Y53UL3A&Expires=1541235919&Signature=ypOrT1%2BBY%2BtM0pBptuTc8Ppaiuo%3D&response-content-disposition=inline%3B filename%3DThe\_Consequences\_of\_Policy\_Uncertain (Accessed: 3 November 2018).

Van Den Hoven, J. (2017) ‘Ethics for the Digital Age: Where Are the Moral Specs?’, in Werthner, H. and van Harmelen, F. (eds) *Informatics in the Future*, pp. 65–76. doi: 10.1007/978-3-319-55735-9\_6.

Hyder, Z., Siau, K. and Nah, F. F.-H. (2018) ‘Use of Artificial Intelligence , Machine Learning, and Autonomous Technologies in the Mining Industry’, in *Thirteenth Midwest Association for Information Systems Conference (MWAIS)*, pp. 1–5. doi: 10.17818/NM/2015/SI8.

Kraemer, F., van Overveld, K. and Peterson, M. (2011) ‘Is there an ethics of algorithms?’, *Ethics and Information Technology*, 13(3), pp. 251–260. doi: 10.1007/s10676-010-9233-7.

Leonelli, S. (2018) ‘Locating ethics in data science: responsibility and accountability in global and distributed knowledge production systems’. doi: 10.1098/rsta.2016.0122.

Maner, W. (1980) ‘Starter kit in computer ethics’, *Hyde Park, NY: Helvetia Press and the National Information and Resource Center for Teaching Philosophy*.

Matthias, A. (2004) ‘The responsibility gap: Ascribing responsibility for the actions of learning automata’, *Ethics and Information Technology*, 6(3), pp. 175–183. doi: 10.1007/s10676-004-3422-1.

Mizani, M. A. and Baykal, N. (2007) ‘A software platform to analyse the ethical issues of electronic patient privary policy: The S3P example’, *Journal of Medical Ethics*, 33(12), pp. 695–698. doi: 10.1136/jme.2006.018473.

Moolman, V. (2018) *Autonomous mining vehicle test at SA coal mine successfully completed*, *MINING WEEKLY*. Available at: http://m.miningweekly.com/article/autonomous-mining-vehicle-test-at-sa-coal-mine-successfully-completed-2018-05-11/rep\_id:3861 (Accessed: 28 October 2018).

Moor, J. H. (1985) ‘What is Computer Ethics?’, pp. 67–69. Available at: https://pdfs.semanticscholar.org/2b26/2968529c25ebc2647f58cbb50a46fffcce17.pdf (Accessed: 25 March 2018).

NHTSA (2016) ‘Federal Automated Vehicles Policy’, pp. 1–116. doi: 12507-091216-v9.

Nyholm, S. and Smids, J. (2016) ‘The Ethics of Accident-Algorithms for Self-Driving Cars: an Applied Trolley Problem?’, *Ethical Theory and Moral Practice*, 19, pp. 1275–1289. doi: 10.1007/s10677-016-9745-2.

PWC (2014) ‘Highlighting trends in the South African mining industry’, *SA Mine*, 6(November). Available at: www.pwc.co.za/mining (Accessed: 3 November 2018).

Simon, J. (2016) ‘Value-Sensitive Design and Responsible Research and Innovation’, *The Ethics of Technology: Methods and Approaches*, 1, pp. 219–236. Available at: https://s3.amazonaws.com/academia.edu.documents/52749810/Simon-VID-in\_Hansson.pdf?AWSAccessKeyId=AKIAIWOWYYGZ2Y53UL3A&Expires=1528215809&Signature=kQAXeLR7ym1SyJoMwFHPDaDA8z0%3D&response-content-disposition=inline%3B filename%3DValue-Sensitive\_Design\_and\_ (Accessed: 5 June 2018).

Stahl, B. C. (2012) ‘Morality, Ethics, and Reflection: A Categorization of Normative IS Research’, *Journal of the Association for Information Systems*, 13(8), pp. 636–656. Available at: http://search.proquest.com.ezproxylocal.library.nova.edu/docview/1039704452?accountid=6579.

Stahl, B. C. (2013) ‘Responsible research and innovation: The role of privacy in an emerging framework’, *Science and Public Policy*, 40(6), pp. 708–716. doi: 10.1093/scipol/sct067.

Stahl, B. C. *et al.* (2014) ‘From computer ethics to responsible research and innovation in ICT: The transition of reference discourses informing ethics-related research in information systems’, *Information & Management*, 51, pp. 810–818. doi: 10.1016/j.im.2014.01.001.

Stahl, B. C. *et al.* (2016) ‘The Ethics of Computing: A Survey of the Computing-Oriented Literature’, *ACM Computing Surveys*, 48(4), pp. 1–38. doi: 10.1145/2871196.

Stahl, B. C., Eden, G. and Jirotka, M. (2013) ‘Responsible Research and Innovation in Information and Communication Technology: Identifying and Engaging with the Ethical Implications of ICTs’, in *Responsible Innovation: Managing the Responsible Emergence of Science and Innovation in Society*. Wiley-Blackwell, pp. 199–218. doi: 10.1002/9781118551424.ch11.

Warren, S. D. and Brandeis, L. D. (1890) ‘The Right to Privacy’, *Source: Harvard Law Review*, 4(5), pp. 193–220. Available at: http://www.jstor.org/stable/1321160 (Accessed: 24 March 2018).

Wilson, J. R. and Scheutz, M. (2015) ‘A model of empathy to shape trolley problem moral judgements’, in *Affective Computing and Intelligent Interaction (ACII), 2015 International Conference on*, pp. 112–118. Available at: http://affectivecognition.com/docs/empathy\_trolley.pdf (Accessed: 15 November 2018).

Wiltshire, T. J. (2015) ‘A Prospective Framework for the Design of Ideal Artificial Moral Agents: Insights from the Science of Heroism in Humans’, *Minds and Machines*, 25(1), pp. 57–71. doi: 10.1007/s11023-015-9361-2.

Wiseman, Y. and Grinberg, I. (2018) ‘The Trolley Problem Version of Autonomous Vehicles’, *The Open Transportation Journal*, 12(1), pp. 105–113. doi: 10.2174/18744478018120100105.

# **Appendix A**

# **Appendix B**

# **Appendix C**

1. A platinum mine [↑](#footnote-ref-1)
2. A coal mine [↑](#footnote-ref-2)
3. An iron ore mine [↑](#footnote-ref-3)
4. Phakisa means swiftly or accelerate [↑](#footnote-ref-4)