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

AJ Louw (53031377)

Abstract

The trend to automate cars and trucks is a very topical subject today. It is hotly debated in the media and in academic circles. Driverless haul trucks have not seen as much popularity in the media or in academic circles. Replacing the drivers of the haul trucks, on open pit mines, can have drastic consequences to those involved. Some of the potential benefits include improved safety and greater profitability for the mines. Unfortunately, automation in this sector can also lead to job losses for the drivers of these haul trucks. South Africa has not been immune to this trend of automated or driverless haul trucks. The first prototype has completed its initial phase on an unnamed South African open pit mine. Meaning, South Africa is set to feel the blessings and the curse of this new technology. This research proposal aims to present a research project that will assess the impact of driverless haul trucks onto South African open pit mines.

ADRIAAN LOUW (53031377)

Table of Content

1   Introduction

The South African mining industry is facing many challenges. At the beginning of 2016 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 also remain many regulatory risks (PWC, 2014, p. 15). Labour relations also remain strained and is a major risk to mining operations (PWC, 2014, p. 15). 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 trucks onto South African open pit mines are in its initial phases. The international telecommunications company Cisco completed the 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 on Western Australia can earn $A100000 per annum. Which would equate to significant savings 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 benefits from driverless haul trucks. The roads these driverless trucks require need not be as wide as roads 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 of 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. Therefore, how it affects the people involved, needs to be studied.

2   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] and Grootegeluk Mine[2]. In the Northern Cape there is Sishen[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.

The focus will be primarily on how the miners of these mines are affected.

3   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 influence driverless haul trucks have had, has been studied in the Australian context (Bellamy and Pravica, 2011). The study maintains that with driverless haul trucks, workers with greater skill level will be required. Thus, creating more highly skilled jobs, but the number of unskilled jobs will be reduced. Safety on the mines will also be increased for

---

[1] A platinum mine
[2] A coal mine
[3] An iron ore mine

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], created by the Presidency, had difficulties in involving the trade union AMCU (Association of Mineworkers and Construction Union) (Hermanus, 2017, p. 815).

How the miners on South African open pit mines will be affected by the automation of haul trucks remain an open question.

4   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.

5   Research sub questions

The first research sub question will be:

---

[4] Phakisa means swiftly or accelerate

How will the safety of 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?

6 Research objectives

The objective of this study is to gather data that will be able to show how miners on South African open pit mines have been affected by driverless haul trucks. From a utilitarian point of view, this will be able to show whether the implementation was ethical.

7 Literature Review

7.1 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 produced the 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 systems 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).

7.2 Definition of Ethical Computing

The Cambridge Dictionary of Philosophy defines ethics as "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.

The field of computer ethics was first pioneered in the seminal work (1985). There are a few competing ethical theories used in the field of 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 can be classified as either 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 described as doing the most amount of good to the largest amount of people (Stahl *et al.*, 2016, p. 4).

Deontology holds that the intention of agent doing the action determines whether it is ethical or not (Stahl *et al.*, 2016, p. 4). The name is 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).

The "trolley problem" is a thought experiment that is used often in computer ethics literature to discuss some of the problems related to self-driving vehicles (Hevelke and Nida-Rümelin, 2015; 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.

ADRIAAN LOUW (53031377)

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 et al. (2016) is a study into what would be people's 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 et al. (2016) suggests that a potential solution is government regulation. 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.

SAE International, an international, professional and standards organization for 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.

The socio-economic implications of driverless vehicles are discussed frequently in the (Bellamy and Pravica, 2011; Sousa *et al.*, 2017; Abbot and Bogenschneider, 2018; Levy, 2018). These effects are usually discussed in terms of driverless automobiles, road going trucks or automation in general. While literature does exist on the socio-economic implications of automation of South African hard rock mines (Gumede, 2018), no literature can be found on automation of haul trucks on South African open pit mines.

7.3   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 (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 the 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.

7.4 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". The development process requires that ethical issues be brought up early. The earlier in the development life cycle 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.

The most discussed topic in computer ethics literature is privacy (Stahl *et al.*, 2016, p. 22). One form of privacy is Data Protection. 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 will be enforced through the new General Data Protection Regulation (GDPR). According to Stahl (2013, p. 712) these regulations prove that technological issues can be regulated by using the democratic process.

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).

7.5 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.

8   Research strategy

This study will use the epistemological stance of objectivism. Thus, believing nature of reality can be found and is not relative to how or what we think. We will use objective data gathered from mines and miners that are not open to interpretation. 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, 2007). Quantitative methods will be used since the surveys will ask quantifiable questions that are not rooted in opinion or experience. The data will be used to show a correlation between the amount of driverless haul trucks on the mine and the various ethical consequences mentioned. This will also be a longitudinal study, because how driverless haul trucks affect miners will be a process that will take many years to complete. Given that the first prototype trail was only recently conducted, this study will require some time. Provisionally we aim for a study that will last 5 years. That should be sufficient time for the implementation of driverless haul trucks on South African open pit mines.

9   Data collection

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

This study will not include asking trade unions for input. This study focusses on the miners and does not focus how well these miners are represented. Also, it is known that it is very difficult to get involvement from some of the South African mining trade unions (Hermanus, 2017, p. 815; Gumede, 2018, p. 8).

9.1   Data collection from mines

A 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 mine's 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 do the mine currently employed? This is to establish how many driver jobs were lost in the period surveyed.

- How many haul truck maintenance and operational personnel do the mine employ? It is believed that new jobs will be created during the automation process (Gumede, 2018, p. 3). These metrics will help to determine the job creation that took place on the mine.

- 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.

- The mine will be asked several safety related questions. How many haul truck 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). This is one of the key motivations for implementing this form of automation.

9.2   Data collection from miners

Miners will be given a standardized questionnaire relating to how driverless haul trucks have affected them. They will be given the same questionnaire annually for a period of 5 years. The mines will be asked several questions including the following:

- Is the mine worker still employed on the mine, and if not, why? The worker can leave the mine for various reasons. They could leave for personal reasons, they could be dismissed due to misconduct or retrenched due to being replaced by driverless haul trucks.
- What is the miner's position on the mine? It needs to be established if this person's job description is related to haul trucks and the moving of earth on the mine. This can also be very illuminating in the case where haul truck drivers are moved to new positions. If the miner's position changed, they will be asked if it is due to their job being replaced by a driverless haul truck.
- What is the mine workers current annual salary? This information might be more difficult to collect since not all miners might remember what their annual salary is at the time.

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.

10   Data analysis

This study will be able to determine how much more viable the surveyed mines have become due to automation. It will not be able to gather information on mines, that were closed due to not being economically viable and 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.

The sampling error needs to be computed for all the data compiled from all the miners for each year as described in Sapsford (2007).

The following variables will be used for data analysis and will be directly from the surveys:

- The number of driverless haul trucks on a mine (N_d).
- The number of haul trucks on a mine (N_h).
- The number of surveyed miners on a mine (N_m).
- The salary of each miner (S).
- The number of haul truck related accidents on a mine (A)
- The number of maintenance and operational staff working with haul trucks on the mine (N_O).
- The mine viability (V) which will be the number of years until the mine is projected to be closed.

These variables will be calculated

- The median salary of the surveyed miners on the mine (S_m). The median salary is used to protect against outliers. Calculating the mean is very sensitive to outliers (Ali and Bhaskar, 2016).
- The proportion of driverless haul trucks to haul trucks on a mine (P). This normalization protects the analysis against variations in production. The number of haul trucks a mine uses may be influenced by production issues that are independent of the usage of driverless haul trucks. For example, more trucks are added due to a sudden spike in the price of the commodity the mine in mining.

Descriptive statistics will be applied to this data (Ali and Bhaskar, 2016). We then calculate mean, median and mode for this data.

From the literature, it is shown that automation affects the socio-economic situation of miners and the safety of the mines. This dependence needs to be shown for our data. The ANOVA (Ali and Bhaskar, 2016) method will be used for this. More specifically repeated measures ANOVA, because data will be collected at 5 different points in time and the conditions may vary.

Finally, the proportion of driverless haul trucks per mine (P) will be plotted against the median salary per mine (S_m), the viability of the mine each mine (V) and the number of maintenance and operational staff (N_O). This should show how much driverless haul trucks affect miners socio-economically.

The proportion of driverless haul trucks per mine (P) will be also plotted against the number of accidents per mine (A). This will show how safety on the mines has been affected.

11 Data verification

Most of the literature included in this proposal, when relating to automation, relates to driverless cars and trucks (Fröhlich *et al.*, 2018; Hyder, Siau and Nah, 2018). The problem of driverless cars will affect many more people than driverless haul trucks due to the sheer number of vehicles on the road contrasted to the relatively low amount of haul trucks on mines. Which would to a certain extent explain the difference in the amount of literature available.

Haul trucks differ from cars and road going trucks in 3 main aspects.

- Haul trucks tend to be much larger than cars or road going trucks (CAT, 2018).
- The maximum speeds involved in haul trucks are lower than those of cars and road going trucks. For instance, the CAT 793F has a maximum speed of 60km/h (CAT, 2018).
- Haul trucks operate in large mines with fewer other vehicles and pedestrians.

The trolley problem still affects haul trucks because they are still vehicles driving at speed in an environment with other vehicles and pedestrians. Also, their automation will mean that there is less of a need for haul truck drivers. Just as automating cars mean fewer driving jobs.

A system of double entry will be used to store the data, ensuring accuracy. Additionally, proofreading of the data by the researchers will also be done.

12 Ethical consideration

Sensitive information regarding miners financial and medical status will be gathered by this study. The mines will also be giving sensitive information in the form of layoffs etc. 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 anonymised. Only then can the data be analyzed or published. Interviewers will facilitate the answering of 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.

The rights of the University of South Africa (UNISA) needs to be protected. This will be achieved in several ways. The School of Computing Ethics sub-committee will have to give clearance for this research. The university will also retain the right to cancel this research project at any point. Also, each step of the research process will be under the strict guidance of a research supervisor, appointed by the university.

To maintain scientific integrity the researchers will declare any previous contact or conflict of interest with the miners or the mining companies. As previously stated, the personal data of the miners will be kept in a safe location with minimal access. At no point will any of the researchers contact the media to promote the research or, hand the raw data over for public consumption. This research will only be published in reputable peer-reviewed journals.

13 Conclusion

Driverless haul trucks have the potential to have drastic effects on South African open pit mines. Safety is set to increase with the automation of haul trucks, reducing the amount of human interaction, therefore reducing the number of fatalities these mines. Large scale lay-offs are a distinct possibility for many haul truck drivers. In a country with severe joblessness, a large amount of job losses cannot be ignored. How these miners are affected needs to be studied and understood.

14 Completed references list

Abbot, R. and Bogenschneider, B. (2018) 'Should Robots Pay Taxes? Tax Policy in the Age of Automation', *Harvard Law & Policy Review*, 12. doi: 10.2139/ssrn.2701092.

Ali, Z. and Bhaskar, S. B. (2016) 'Basic statistical tools in research and data analysis', *Indian journal of anaesthesia*. Medknow Publications & Media Pvt Ltd, 60(9), pp. 662–669. doi: 10.4103/0019-5049.190623.

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., Andersson, U., Dadhich, S., Uhlin, E., Marklund, U. and Häggström, D. (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.

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).

CAT (2018) *793F Mining Truck*. Available at: https://www.cat.com/en_ZA/products/new/equipment/off-highway-trucks/mining-trucks/18092621.html.

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.

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).

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).

Fröhlich, P., Sackl, A., Trösterer, S., Meschtscherjakov, A., Diamond, L. and Tscheligi, M. (2018) 'Acceptance Factors for Future Workplaces in Highly Automated Trucks', in *Proceedings of the 10th International Conference on Automotive User Interfaces and Interactive Vehicular Applications*. New York, NY, USA: ACM (AutomotiveUI '18), pp. 129–136. doi: 10.1145/3239060.3240446.

Group World Bank (2016) *Commodity Markets Outlook, January 2016*. Washington, DC. Available at: https://openknowledge.worldbank.org/bitstream/handle/10986/23680/CMOJan2016FullRep ort.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.

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.

ADRIAAN LOUW (53031377)

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.

Levy, F. (2018) 'Computers and populism: artificial intelligence, jobs, and politics in the near term', *Oxford Review of Economic Policy*, 34(3), pp. 393–417. doi: 10.1093/oxrep/gry004.

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.

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(5), 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).

Sapsford, R. (2007) 'Survey Research'. London: SAGE Publications, Ltd, pp. 13–48. doi: 10.4135/9780857024664.

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).

Sousa, N., Almeida, A., Coutinho-Rodrigues, J. and Natividade-Jesus, E. (2017) 'Dawn of autonomous vehicles: review and challenges ahead', *Proceedings of the Institution of Civil Engineers - Municipal Engineer*, 171(1), pp. 3–14. doi: 10.1680/jmuen.16.00063.

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., 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.

Stahl, B. C., Timmermans, J., Daniel, B. and Mittelstadt, B. D. (2016) 'The Ethics of Computing: A Survey of the Computing-Oriented Literature', *ACM Computing Surveys*, 48(4), pp. 1–38. doi: 10.1145/2871196.

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).

ADRIAAN LOUW (53031377)

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.

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

15 Appendix A

ADRIAAN LOUW (53031377)

16 Appendix B

Plagiarism Pledge
HPCOS81

1. I have read Unisa's plagiarism policy.
2. I understand Unisa's plagiarism policy.
3. I agree to abide by Unisa's plagiarism policy.
4. All academic work, written or otherwise, that I submit is expected to be the result of my own skill and labour.
5. I understand that, if I am guilty of the infringement of breach of copyright/plagiarism or unethical practice, I will be subject to the applicable disciplinary code as determined by Unisa.
6. I understand that I must use Turnitin to check submitted research for copyright, plagiarism and/or similarity of existing written information.
7. The supervisor has the right to return any work to be revised if plagiarism is detected and that this may impact on my mark.

Student name: _ADRiaan Louw_

Student number: _5303/377_

[signature]
Student Signature

_29/11/2018_
Date

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

17 Appendix C

ADRIAAN LOUW (53031377)