HOW DO CLEAN ENERGY AND AUTONOMOUS VEHICLES IMPACT THE CLIMATE RISK PROFILE OF ROAD TRANSPORTATION? IMPLICATIONS FOR WINTER ROAD MAINTENANCE

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Summary

As part of a large body of work on clean energy and equitable transportation, this paper starts to explore whether a transition to electric and autonomous vehicles will improve the winter resilience of road transport. Although future winters will be milder, climate change means that vehicles will need to navigate an increasingly extreme range of conditions. This research illustrates that the different characteristics of clean energy vehicles will also result in an altered weather risk profile. This presents both new challenges, and opportunities, for the winter road maintenance sector.

Introduction

CLean Energy and Equitable Transportation Solutions (CLEETS) is an ambitious project that brings together climate, energy, data science, and transportation experts to establish a global center for climate change, clean energy, and clean transportation research (https://www.cleets-global-center.org/). It aims to accelerate use-inspired decarbonised road transportation pathways via partnerships with government, private sector, industry and end-user communities. The founding members are based in the UK and USA with plans to expand the geographical remit and international collaboration far beyond. The scale of the funding matches this ambition with £6m and $5m currently allocated to academics working on three research themes related to the center:

1. Clean & Equitable Transport: Studying the impact of transportation choices as well as the pace of equitable clean energy transportation adoption
2. Transport Energy Infrastructure: Investigating the coupling of electricity, transportation, water, petrochemical, and mineral resources, to avoid shifts in emission sources and optimize resource allocation.
3. Climate Change: Exploring the implications of climate change on the adoption of new transportation solutions along with related consequences (e.g. air quality)

This paper reports on an element of work currently being undertaken in the third theme which is exploring the potential impact of climate change on connected electric and autonomous vehicles.

Are electric and autonomous vehicles climate resilient?

Future changes to our climate are increasingly understood. It is highly likely that vehicles will need to navigate in more severe weather conditions than today, with big implications for safety - a key underlying tenet of car design. A modern electric vehicle is very different in capabilities and specifications to a vehicle manufactured just 10 years ago. Autonomous vehicles even more so, as driving technology becomes even more integral to the design. However, the successful development, implementation, and adoption of autonomous vehicles will entirely depend on their ability to safely, efficiently, and reliably operate in all weather conditions and across climate hazards [1]. This leads to the question of whether electric and autonomous vehicles are more, or less, weather and climate resilient than their fossil fuel based predecessors. If this can be better understood, then adaptations can be made so that vehicles, and associated interdependent infrastructure, can safely operate in the full climate envelope. To begin to explore this question, a desktop analysis was conducted to explore how the features of clean energy and autonomous vehicles will impact on their weather and climate resilience (Table1).

As Table 1 shows, the weather and climate risk profile for transport has the potential to look quite different as we move towards an increasingly electrified and autonomous future. Existing risks on the road network will persist (i.e. flooding, road melting), but these are also joined by a new set of challenges which will need consideration. Although technological improvements in the vehicle fleet (e.g. driver assistance systems) will help to mitigate both existing and emerging risks, adaptations will still be required to ensure the resilience of road transport. In particular, the increasingly interdependent nature of the electricity and transport networks comes into much sharper focus and is an area which is in urgent need of attention. Fundamentally, all road maintenance functions will need to adapt to deal with this new risk profile, including winter road maintenance, which makes for an interesting case study.

Table 1. Weather risks and considerations associated with electric vehicles and autonomous vehicles

	Electric / Connected Vehicle Risks	**Additional Issues for AV**	**Considerations / Mitigations ***
Low temperatures	Reduced battery performance and range (up to 36%). Compounded by the increased need for cabin heating. Batteries take longer to charge Heavier vehicles can cause more damage to the road in freeze-thaw cycles (potholes) Increased demand on energy grid for heating may impact supply.		Preconditioning to warm the vehicle while it's plugged in Ecological driving to increase range in adverse conditions.
High Temperatures	Reduced range due to cabin cooling Melting roads will impact roll resistance also reducing range Increased cooling of components requiring further drain (overheating risks) Battery degradation in heat, reducing their lifespan Increased demand on energy grid for cooling may impact supply.		Battery thermal management systems may help, but will also require increased power. Parking / charging in covered areas during extreme weather, Preconditioning to cool the vehicle while it's plugged in Ecological driving to increase range in adverse conditions.
Rain / Fog / Visibility	Communication challenges in poor weather	Reduced sensor performance (especially LIDAR) Extreme rainfall (e.g. Freezing Rainfall) may be beyond training envelopes. Hail can damage on-board vehicle sensors	
Flooding	Water ingress into electric systems. Charging infrastructure and substations susceptible to flooding.	Shallow floodwater can obscure lane markings, deep floodwater can hide hazards.	Lack of an air-intake potentially increases wading depth, therefore increasing resilience
Snow and Ice	Accretion of snow on wheel arches may reduce efficiency and range Frozen charging infrastructure. Accretion of snow and ice may impeded energy generation and supply. Communication challenges in poor weather	Snow obscure / obstruct sensors Snow on road infrastructure can impact navigation (lane markings and signs) Interactions with winter maintenance fleet may be challenging. Rapidly changing weather conditions can be challenging for AV algorithms	Trends to move to AWD by manufacturers will increase resilience Heavier vehicles with a lower centre of gravity will increase traction Better engine torque Reduced risk of skidding from regenerative breaking Simpler mechanics promote resilience. Data from sensors will facilitate improved real-time decision making
Wind & Storms	Impact on aerodynamics and energy consumption Gusts may impact vehicle stability Charging infrastructure susceptible to flying debris Storms may impact electricity supplies Low winds will impact on renewable generation		

*Real-time data integration and advanced forecasting capabilities can help AVs anticipate and respond to changing weather conditions effectively (e.g. real time routing)

Implications For Winter Road Maintenance

Against a backdrop of climate change which is seeing many countries experience increasing milder winters, we are already seeing how the rise of the connected vehicle is improving winter service (e.g. real-time friction measurements [2]), but the benefits do not end there. The latest generation of electric vehicles are also generally better equipped to deal with snow and ice. Heavier electric vehicles with a lower centre of gravity increase friction, whereas improved torque and regenerative braking further lower skid risk. The rise of driver assistance systems towards greater autonomy also reinforce safer braking, distance control etc. Taken together, vehicle developments should result in improved performance and safety in winter conditions, which coupled with a changing climate, could present an opportunity to reduce elements of winter service (e.g. marginal climates may no longer be marginal; a 'white-road' policy may become more feasible elsewhere).

However, autonomous vehicles presently do not perform well in snow and ice. The obscuring of lane markings and other signage is a significant risk (especially with a 'white-road' policy) as are transitional surface states (i.e. melting snow). Although, there is potential for this problem to be overcome with increasingly precise navigation systems based on quantum technology, this will not prevent sensor issues (e.g. LIDAR) during snow events which may render driver assistance and autonomous driving functions unusable.

The transition from fossil fuels to electric will also cause issues. For a range of reasons cold weather has a significant negative impact on range and has the potential to lead to stranded vehicles obstructing ploughing operations. Finally, the interdependency between energy supply and transport needs consideration. For example, distances between charging stations will need to be less in colder regions. A key question is whether the duty of care for winter road maintenance should be partially extended to this additional infrastructure network.

Conclusions

The move to an increasingly electric and autonomous future is already here and has implications for weather and climate risks on interdependent infrastructure networks. There is potential for the changing nature of the risk profile, coupled with a warming climate, to potentially be used to justify cuts in winter service delivery. However, the uncertainties surrounding how the technology will perform under various winter weather conditions is a crucial counter-argument for maintaining a good level of winter service into the future. The sector can also position itself to readily evolve to embrace the technology via an autonomous gritting and ploughing paradigm [1, 3].

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References

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