AUTOMATED VEHICLES (AV) STRATEGIC ECONOMIC ANALYSIS

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Abstract

This paper was commissioned to provide a strategic economic analysis to support the current work of the Law Commission for CCAV on proposals to regulate Automated Vehicles (AV).

This paper:

- **Discusses the rationale for AV regulation**
- **Provides a framework for assessment of proposed regulations and**
- **Outlines potential economic impacts of AV and how they could be further assessed**

Automated Vehicles (AV) strategic economic analysis

This paper was commissioned to provide a strategic economic analysis to support the current work of the Law Commission for CCAV on proposals to regulate Automated Vehicles (AV).

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Executive Summary

This paper was commissioned to provide a strategic economic analysis to support the current work of the Law Commission on regulating Automated Vehicles (AV).

The paper:

- **Discusses the rationale for AV regulation and appraisal options**
- **Provides a framework for assessment of proposed regulations**
- **Outlines potential economic impacts of AV and how they could be further assessed**

Key findings:

1. Uncertainty over legal responsibilities provides the key economic justification for regulatory intervention in AV. Having clear legal responsibilities will contribute to ensuring safe use.

2. Having appropriate regulations will act as an enabler to allow an AV market to develop.

3. The base case against which the Law Commissions' proposals should be assessed is changing over time. A pragmatic approach is suggested, based on a descriptive assessment comparing the Law Commissions' proposals against the existing body of relevant legislation.

4. The paper outlines a framework to enable proposed AV regulations to be further assessed. The framework is based on five criteria: certainty, proportionality, transparency, safeguarding equity and alignment with wider government goals.

5. The paper describes potential economic benefits from AV. However the emergent nature of the AV market makes detailed assessment of its growth and future benefits problematic.

6. Any economic assessments of potential benefits of AV (as such) will, by their nature, be speculative. Using a theory of change approach would enable assumptions and potential benefits to be set out and tested. The theory of change approach can be revisited as more data becomes available.

7. Data requirement considerations to enable future evaluation of AV are outlined.

Introduction

Context

Automated Vehicles (AV) are a new technological development potentially allowing "driverless" travel. UK law does not currently adequately address this area. Without a clear legal framework in place, there is a fundamental uncertainty over who is responsible for the safe operation of the AV, and in what circumstances. These issues have been extensively investigated and consulted upon jointly by the Law Commission for England and Wales and the Scottish Law Commission[1]. A final report from the Law Commission is due in the last quarter of 2021. In addition, the Law Commission is currently preparing an Impact Assessment for consultation, which will set out the areas of likely costs and benefits of its proposals in greater detail.

Purpose

This paper was commissioned to provide a strategic economic analysis to support the current work of the Law Commission[1] on regulating Automated Vehicles (AV)[2]. The aim of such regulation is to provide a clear legal framework, (where one does not currently exist), to enable a market for AV to develop in Great Britain[3].

The paper's strategic focus is intended to consider key economic issues raised by AV and how they can be addressed. It does not cover every topic that has been examined to date by the Law Commission, nor attempt detailed assessment of options or specific issues which are more appropriately covered by the Law Commission's Impact Assessment.

The economic case for establishing a legal framework for AV is primarily based on addressing the uncertainty around legal liability: who is responsible for the safe operation of AV? Is it the AV manufacturer, the vehicle owner/provider, or the driver? While this fundamental uncertainty remains, the full potential benefits of developing AV are untapped or constrained.

Structure of paper

Table 1 Structure of Paper

This paper sets out:

[1] The AV work is being conducted jointly by the Law Commission for England and Wales and the Scottish Law Commission. The use of the term "Law Commission" in his paper therefore refers to the joint work of both Law Commissions.

[2] In line with the Law Commission work, this paper refers throughout to Automated Vehicles (AV), also variously known as autonomous, self-driving or driverless vehicles. "Automated vehicles" is a general term, used to describe vehicles containing an automated driving system which are able to perform the dynamic driving task. These vehicles can overlap with Connected and Autonomous Vehicles (CAV) (also known as Cooperative Intelligent Transport Systems (C-ITS)). Connected Vehicles refer to vehicles with increasing levels of connectivity which allows them to communicate with their surrounding environment. [51]

[3] The scope of the Law Commissions' AV work and proposals are limited to Great Britain (i.e. England, Wales and Scotland). This paper has therefore attempted to adopt a similar scope. However, evidence cited is drawn from a mixture of sources, covering GB, UK and other jurisdictions. While the focus is on GB, wider economic impacts from AV could be experienced across the whole UK.

1. The economic rationale for regulatory intervention in AV.
2. Potential issues and options for intervention (including a discussion of the base case to compare Law Commission proposals against and what constitutes appropriate regulation).
3. A framework and criteria for evaluating proposed AV regulations.
4. An outline of the potential economic impacts of AV and how they could be further assessed.

This paper sets out economic rationale for establishing a legal framework for AV. This is not the same as attempting to provide a detailed analysis of the potential economic benefits of AV as such. However, having a clear and appropriate legal framework provides the necessary structure to enable the future development of AV and its subsequent economic benefits.

The paper discusses options for intervention and includes a framework and criteria that could be used to assess the provisions of AV regulatory proposals.

The paper outlines the potential economic benefits from AV. It does not attempt a detailed quantification of these impacts but outlines how an assessment of the future benefits of AV could be carried out, using a theory of change framework.[4] A theory of change approach can be adopted to set out and test potential benefits and assumptions.

The paper concludes with a summary of findings.

[4] See the "Value of law reform" report.[57].

The economic rationale for regulatory intervention: Why is a legal framework required for AV?

The importance of the rule of law

The rule of law underpins the operation of the market economy. At its most fundamental level, the legal system enables property rights to be established and enforced (rights to both physical and intellectual property). These legal rights enable trade to take place. Markets are unlikely to function, or at least not function efficiently, where ownership of resources is unclear. With ownership often come various responsibilities, also enshrined in law.[2]

Market failure and the law

In addition to defining property rights, laws and government intervention are often enacted to address what economists describe as market failure.

Table 2 Market failure

According to the Treasury Green Book:[5] **"Market failure** occurs where, a market is unable to function fairly according to the economic ideas of efficient markets, from a Green Book perspective which looks beyond simply economic efficiency this means the market is unable to provide satisfactory levels of welfare efficiency". (Treasury Green Book p 133) [3]

There is potential for market failure where conditions for an efficiently functioning market are not met.[4] Market failure is traditionally associated with provision of public goods, externalities, abuse of market power and informational asymmetry. (See table below for further details).

Table 3 Examples of market failure

Examples of some of causes of market failure include: Public goods: Many aspects of the environment can for example be described as public goods, for instance the benefits of clean air. When provided it is unavoidably available to all. It is non-excludable in supply and once provided, it matters little how many people enjoy it. It is therefore non-rivalrous in demand. These features make clean air impossible to supply on a commercial basis. Imperfect information: Well-functioning markets require buyers and sellers to both have perfect information about what is on offer and about the other bargains being struck in the market, that is about quality and price. An imbalance in the information available known as information asymmetry confers an unfair advantage on the side that possesses it. Externalities: These occur when an activity imposes costs or produces benefits for economic agents not directly involved in the deal. For example, pollution not covered by regulation may be profitable for a perpetrator but impose real costs on others who are not directly involved in the market. Market power: This results from insufficient actual or potential competition where either sellers or buyers have an unfair advantage. It can arise from too few buyers or sellers, as occurs with

[5] The Treasury Green Book is the main central Government guidance on appraisal and evaluation.

monopoly and oligopoly among sellers or through collusion by sellers in anti-competitive behaviour. Problems can also arise from monopsony, i.e., where there is effectively only one dominant buyer. Barriers to market entry and exit can also cause a concentration of market power.
(Treasury Green Book p25) [3]

In practice, no markets are fully efficient. (For example, the assumption that buyers and sellers are equally well informed is unlikely to hold, since obtaining information is not costless)[6].[5] The decision for Government to intervene is therefore a balance between identifying the costs of market failure and the extent to which intervention can reasonably be expected to successfully address the identified failure. Poorly designed or inappropriate intervention risks potentially making the situation worse, rather than better. (This situation has been coined as "government failure")[6].

Government regulatory intervention can take many forms[7]. However, regulations can be seen as falling into two broad classifications: [8,9]

- Regulations aimed at *protecting* the consumer from the consequences of market failure;
- Regulations aimed at *preventing* the market failure from happening in the first place.

The development of the AV market faces imperfect information, due to the uncertainty over legal liability. Potentially there could be a "missing market"[10] for AV– a market that is desirable, but is held back, in this case by the lack of a clear legal framework. Timely intervention could therefore be seen as a taking a preventative approach to market failure, by ensuring an appropriate legal framework exists. Having clear legal responsibilities and an appropriate regulatory framework will contribute to ensuring safe use and would enable the market to develop (or to develop faster), bringing economic benefits but without attempting to guarantee or constrain exactly how the future market will develop.

The law and AV

There is a considerable body of law concerning motor vehicles. This includes both the regulation of vehicle design (which is largely derived from international standards) and laws on driver behaviour (which are largely decided at national level). However, new technological developments offer the opportunity to move from vehicles with increasingly sophisticated levels of driver assistance technology to potentially allowing "driverless" travel, with the vehicle taking full control, "driving itself" and the law does not currently adequately address this[7]. Without a clear legal framework in place, there is a fundamental uncertainty over who is responsible for the safe operation of the AV, and in what circumstances[8]. When can a vehicle be considered "safe" to drive itself? Is it safe and appropriate to remove the driver responsibilities and liabilities? Who is liable, should things go wrong? These issues have been extensively investigated and consulted upon jointly by

[6] There is an extensive literature on this topic and its implications for policy intervention. See for example the discussion around Coase Theorem. [60]

[7] The Automated and Electric Vehicles Act (2018) which recently came into force includes some AV provisions. See section "Driver insurance and AV"

[8] See, for example, the debate over whether a vehicle equipped with Automated Lane Keeping Systems (ALKS) should be considered as capable of "driving itself".[14]

the Law Commission for England and Wales and the Scottish Law Commission. The coverage of the consultation papers is outlined below. A final report is due in the last quarter of 2021.

Table 4 Law Commission AV Consultation Papers

The Law Commissions' proposals for AV are still in development. The preliminary consultation paper identified the following objectives[9]:[11]

a. The key objective is assuring safety.

Secondary objectives are:

b. to provide a clear allocation of responsibility and liability; (both civil and criminal law)
c. To remove any remaining blocks which might otherwise delay the benefits of driving automation, expected to arise through improvements in mobility and productivity. Driving automation technologies can enable new ways for those with visible and non-visible disabilities to get around.

The preliminary consultation paper noted additional objectives may emerge from work on subsequent stages of the AV review. The second consultation paper, on highly automated road passenger services (HARPS) covered the regulation of remotely operated fleets of automated vehicles and their relationship with public transport.

The proposals in consultation paper 3 develop a safety assurance scheme for the approval and deployment of AVs, safety and criminal liability. They include:

- In any particular set of operational conditions (the 'operational design domain', in SAE[10] terminology) a vehicle may be classified for lawful use in one of two ways. The vehicle can be used in that ODD[11] only with a 'user-in-charge' on board; or it can be used without a 'user-in-charge'. For example, AVs that only drive themselves on the motorway be classified as 'user-in-charge' (UIC) only as an element of human driving may be required to complete a journey. Alternatively, a 'no-user-in-charge' vehicle could complete a whole journey unaided and without any human in the vehicle at all (such as a freight vehicle, or remotely operated taxi fleet travelling empty between trips).
- Proposals to enhance safety, for the deployment of AVs on roads in Great Britain roads and during their lifetime. This covers vehicle approval as well as software updates and cybersecurity risks. It includes a shift away from the criminal enforcement of traffic rules towards a new no-blame safety culture including a new range of regulatory sanctions.
- New legal roles to reflect legal responsibilities arising from automated driving: for developers and manufacturers of AVs, users of AVs that are less than drivers but more than passengers (the user-in-charge), and AV fleet operators[12].

[9] Note: CCAV, who commissioned the Law Commission's AV work, has three core objectives for Connected and Autonomous Vehicles, covering road safety and security, access to transport and UK productivity.

[10] SAE = Society of Automotive Engineers International: The society which established the levels of automation of vehicles from 0 to 5 in their technical document J3016.

[11] ODD = Operational design domain: The domain within which an automated driving system can drive itself. It may be limited by geography, time, type of road, weather or in some other way.

AV and market failure: uncertainty over legal responsibilities

The overriding economic rationale for intervention in AV is due to market failure- without clear legal rights being assigned, there is ongoing uncertainty over who bears legal responsibility for the safety of operating AV. (Or, alternatively, government failure- from failing to regulate adequately, in a timely or appropriate manner).

While manufacturers are responsible for safe vehicle manufacture, vehicle owners (whether organisations or private individuals) have traditionally been legally responsible for use-maintaining and driving the vehicle. With AV, depending on the use case for self-driving e.g. motorway leg of a journey through to full (i.e. door to door) there may be no human driver, for at least some of the journey. Who is therefore responsible, should some road traffic violation or accident occur? Without clarity over this responsibility, the lack of certainty risks stifling the development and uptake of AV, and with it the potential for improved well-being for wider society[12]. Legal clarity provides greater confidence for the public to accept AV technology, leading to the potential uptake and growth of the market. Safe deployment of AV would be expected to further improve public acceptability and uptake, leading to the fuller realisation of the benefits from AV. This would also be expected to attract investment into the AV market and bring wider benefits to the economy.

Additionally, there are some parallels with the wider economic literature on informational asymmetry and quality uncertainty. Quality uncertainty refers to situations where it is difficult for the consumer to know the quality of goods or services being marketed. This can, over time, lead to only poorer quality goods or services being traded, to the detriment of both the potential buyers and sellers. The historic example in the literature is the market for used cars,[13] but quality uncertainty is often the rationale for codes of practice or other forms of regulatory oversight of a market and intended to ensure and reassure consumers about the quality and safety of goods and services. For example, in aviation, both aircraft production and operation are regulated to agreed standards to ensure safety on a "level playing field". Any incidents are rigorously investigated. Additionally, a "no blame" culture is encouraged to ensure potential problems are shared with the regulatory authorities, to avoid compromising the safety of operations. The system relies on trust between the manufacturers, operators, and regulatory oversight bodies.[14] [15] While existing laws already cover many aspects of motoring, the new and evolving nature of the AV market suggests quality uncertainty is likely to be an issue and could be addressed through a safety assurance scheme, covering the approval and deployment of AVs, safety and criminal liability.

The regulatory framework also has an important role in enabling better evidence-based policy making for AVs. It is important to put in place a system to collect data so it can be analysed and accessed by key players; and inform future standards so the quality of regulation can be improved as the regulatory scheme and technology matures. The Law Commissions' proposals therefore include a scheme enabling the collection of data for in-use monitoring. Identifying the most useful metrics and standards can be used by regulators to assess claims made in the safety case and allow for benchmarking that is meaningful and allows comparisons between different AVs and with non-AVs (conventional human-driven vehicles). The information may not otherwise be shared in the public

[12] See later section "Assessing the potential benefits of AV"

domain due to uncertainty over its value and desire to keep it confidential so it can be monetised once new use cases may emerge. Being able to demonstrate that AV technology is safe is reported as a key factor in gaining public acceptance of the technology.[16]

Clear legal responsibilities and an appropriate regulatory framework would therefore contribute to ensuring safe use of AV and act as an enabler for the market to develop.

Appropriate regulation or no regulation?

Appropriate regulation of AV will reduce uncertainty- providing legal clarity will enable the development, or the faster development, of the AV market, together with a range of other potential benefits.[13] Alternatively, not having regulation could delay AV and its potential benefits. "Doing nothing" therefore risks significantly hindering the potential economic benefits of developing the technology.

Identifying market failure is a "necessary but not sufficient" condition for government intervention. In addition to identifying a problem, it is important to consider whether intervention options are likely to lead to greater benefits to society than the costs they impose and can be devised in a way that address their objectives, while avoiding imposing additional costs which do not add any further value (known as "gold plating")[3]. (See table below).

Table 5 Potential risks of under and over regulation

Potential risks of under-regulation	**Potential risks of over-regulation ("Gold plating"**
A poorly conceived or designed regulation risks being ineffective in adequately addressing the identified market failure or imposing costs while failing to meet its intended objectives[14].	Over-regulation may address the identified market failure, but risks imposing additional costs that do not bring additional benefits to society and may also distort the market in other ways.

Appropriate regulation will therefore seek to address the underlying market failure, while avoiding the risks of from either under or over regulation.

The potential risks and benefits of different approaches to AV regulation are set out below:

Table 6 Potential risks and benefits of approaches to AV regulation

Potential (high level) risks of not having AV regulation: "Doing Nothing"	**Potential benefits of appropriate AV regulation:**[15]	**Potential risks (from government failure) if regulation is ill-designed:**
On-going uncertainty	Removes uncertainty	If regulation is poorly

[13] See elements in Value of law reform framework[57]

[14] For AV, under-regulation risks leaving the legal uncertainties unresolved, delaying the development of the market with implications for road safety and other potential benefits, as outlined in table 6.

[15] Further assessment of potential benefits of AV is shown in Table 11.

over issues of legal liability: Which delays development of a market for AV and thus potentially prevents or hinders economic benefits of AV to GB from being realised.	over legal liability. Which enables benefits of AV to be unlocked or brought forward (or realised to a greater extent): (e.g.) Improved safety Reduced congestion Lower stress for vehicle occupants Productivity improvements - ability to work while in AV Greater mobility and opportunities for vulnerable users Wider Potential impacts e.g. land use changes (such as reuse land from car parking facilities) Wider economic impacts to GB economy from investing in AV technology Potential gains from "first mover" advantage Potential trade and competitiveness impacts	conceived or designed: Ineffective in addressing market failures Overly costly on business Constraint on innovation Risk of "path dependency" – locking into "wrong" solution. There is a risk of either **under** (ineffective), or **over** ("gold plated") regulation: (see Table 5). Ineffective regulation risks imposing additional costs but without achieving its intended objectives. Over regulation risks imposing additional cost burdens, in excess of what is needed to address the identified market failure.
Example of specific risk (drawing on data collection proposals):		
Failure to collect information about how	Minimum requirements	Standards are imposed that are

AVs are performing in the real-world environment. Data that is collected is in different formats making interoperability difficult.	regarding data mean that data sets are more interoperable and usable. Which addresses: 1. Difficulties benchmarking and comparing AV performance between different providers. 2. Difficulties taking appropriate action in response to near misses and incidents.	onerous or quickly obsolete or not relevant to different technologies at the risk of stifling innovation.
Ensuring key consumer interests are met by recommending user-centric standards	Addresses potential loss of consumer confidence at early stages of deployment, which could compromise long-term prospects of the technology	Stifling innovation by making erroneous assumptions about user needs.

Driver insurance and AV

Historically, the law has required drivers to have insurance, to provide compensation for third parties for personal injury or property damage due to a driving related incident. The Automated and Electric Vehicles Act 2018 ("the AEV Act") [17] recently came into effect and extended the insurance principle to automated vehicles. The intention of the legislation was to emphasise that, if there is an insurance 'event', (accident) the compensation route for the individual remains within the motor insurance settlement framework, rather than through a product liability framework against a manufacturer. This is intended to encourage manufacturers to develop transport technology in the UK, with the confidence that they will be able to exploit market opportunities.[18–20]

Providing that liability is clear, and the risks are quantifiable, the insurance market should be able to function and provide suitable coverage. However, moving along a sliding scale between driver in control and fully autonomous does potentially lead to significant grey areas. Some commentators have stated that the industry might find it easier to move to developing automated vehicle use cases where there is no element of manual driving at any stage of the journey, to avoid the liability issues that come with shared driving responsibility.[21] [16]

[16] The AEV Act creates a new form of liability for accidents caused by AVs when driving themselves. Under the AEV Act, the insurance policy must cover both the human driver and the Automated Driving System (ADS) and imposes a new form of direct liability on insurers. Broadly speaking, the AEV Act requires the insurer to pay a

Insurance markets require access to data to fulfil their obligations under the Automated and Electric Vehicles (AEV) Act 2018, which regulation can support. The Law Commission proposed that victims of uninsured AVs need to be compensated also (which is beyond the current provisions). There are considerable grey areas in how the Act will apply. Insurance markets may seek to deal with grey area through exclusions, potentially undermining the scope/effectiveness of the insurance.

The consultations conducted by the Law Commission to date have demonstrated that there is significant support for the principles behind the AEV Act, coupled with concerns about some of its details[17]. This suggests that the AEV Act does not provide a complete set of answers to questions of civil liability surrounding AVs, however, it achieves the primary aim of ensuring that those who suffer damage caused by AVs are able to be rapidly compensated. The concerns raised will need to be reviewed in the light of experience of how the Act works in practice.

Unintended consequences

Regulation of the AV market and the subsequent use of AVs needs to consider potential unintended consequences that may arise,[18] for example as a result of moral hazard (e.g. other drivers driving aggressively, or pedestrians "jay walking" in front of AV, on the assumption that the self-driving vehicle will always stop). The potential for unintended consequences to arise from regulatory action is relevant for the responses of users and manufacturers / suppliers of AVs. It will be important to keep the emerging evidence of behavioural responses to AV under review.

Table 7 Moral Hazard

Moral Hazard occurs when an individual changes their behaviour and takes risks because they are protected from negative consequences and someone else bears the costs. (Treasury Green Book p 133) [3]

The next section considers potential options and their assessment.

Potential options for intervention and related issues

Do nothing- (Allow things to develop)

Every proposal needs to be compared against its alternatives, including a 'base case"[19] -what would happen in the absence of an intervention- if things are simply left alone? Doing

victim for any damage caused by a vehicle when driving itself. While the AEV Act aims to facilitate quick and smooth compensation for victims, final responsibility for AV accidents may be allocated by the insurer bringing a secondary claim against anyone else responsible for the accident.

[17]See discussion of civil liabilities and the AEV Act in Chapter 16 of the AV Consultation Paper 3 [14]

[18] The so-called "**law of unintended consequences**" suggests that actions – especially those of government—distort behaviour and can lead to effects that are unanticipated or unintended. (In hindsight, the responses can be seen as logical, but were unforeseen at the outset).

[19] The base case is sometimes referred to as "**option zero**".

nothing risks on-going uncertainty and delaying the development of a market for AVs. However, working out what to compare against is not straightforward. "**Do Nothing" is not stationary, as the nascent AV market is rapidly evolving**, due both to rapid technical change (including the increasing application of various "driver assistance" type features) and because other countries are also working on AV regulations.

It is therefore difficult to predict how, and at what speed, the future AV market will change. Similarly, estimating the likely impact of proposals on the rate of change to the nascent AV market is fraught with difficulty. Both are uncertain and dependent on assumptions. However, until clear legal rights are assigned, there will be ongoing uncertainty over who bears legal responsibility for the safety of operating AV.

Defining an appropriate "base case" comparator for assessing AV proposals

The difficulty inherent in attempting to quantify and predict how the AV market is likely to develop suggests a pragmatic approach is required to assess the economic impact of Law Commission AV regulatory proposals. The starting point in such an assessment is to compare the Law Commissions' proposals against the existing body of relevant legislation and describe how the proposals address gaps and risks that have been identified through the Law Commissions' work. (The assessment can be further developed with relevant evidence gathered from stakeholders from consultation exercises, which may potentially identify a degree of convergence on some issues). However, as noted, the base case will not be stationary, for the reasons outlined above.

Alternative options

In addition to the proposed regulations, it is necessary to identify what alternative options have been considered and articulate why these have not been taken forward. For example, the Law Commissions' consultation paper outlines on-going developments on AV legislation in other jurisdictions (notably Germany and Japan), but these differ significantly from the Law Commissions' proposals in how they treat driver criminal liability.[14] Other jurisdictions or related regulatory systems may also be able to provide some useful comparators for elements of the Law Commissions' proposals.

Having identified a base case, an economic assessment will aim to identify and compare the benefits and costs of the proposals against the existing body of relevant legislation (or against an alternative base case which has minimal changes made to it). The current Law Commission proposals are outlined and discussed below.

Options for intervention

The Law Commissions' AV work is still under development, but the current package of proposals broadly addresses three main themes:

1. Having a clear procedure for deciding when a vehicle can safely drive itself without the need for human monitoring.
2. Where that threshold is met, removing both criminal and civil liability from the human in the driving seat (changing their status from a driver to a "User-in-charge").
3. Replacing driver liability with a system of regulatory sanctions on the entity behind the vehicle (such as the manufacturer).

In addition, the proposals also deal with important issues of learning and evaluation, covering in-use monitoring, based on collecting data that can be used for benchmarking purposes and assessing real world performance, to build more evidence-based standards as the framework and technology gets more mature.

The Law Commission's proposed safety assurance process for AVs may be used to determine if it is safe to delegate the dynamic (or total) driving task to the vehicle but in effect also sets an approach to ensure and monitor safety of the AV before approval for use and during use. Having clear legal responsibilities will contribute to ensuring safe use.

The Law Commissions' proposals on legal responsibility

The current Law Commission proposals aim to address the uncertainty over legal liability for AV. While the consultation proposals are highly detailed, the key issue for the question of liability is that when a vehicle is driving itself, the person in the driving seat would no longer be considered a driver but a "User-in-charge" while the automated driving system is engaged. The user-in-charge would therefore have no responsibility for the way the vehicle behaves in traffic while it is in automated mode. However, the user-in-charge would retain responsibility for the responsibilities of a driver that do not arise from dynamic driving. These include important duties relating to maintenance of the vehicle, securing loads, making sure children wear seatbelts and reporting accidents, for example. The user-in-charge would not continue to have the responsibilities of a driver in terms of monitoring and controlling a (self-driving) vehicle. Instead, the criminal liability would shift- the proposals would move the responsibility to an entity responsible for the automated driving system (referred to as the Automated Driving System Entity or "ADSE" and driving offenses would be a regulatory matter to be resolved between the ADSE and a safety assurance regulator. The proposals also call for a specialist incident investigation unit to be established, to analyse data on collisions involving automated vehicles and recommend safety improvements. This would be like the UK investigation branches for aviation, rail, and maritime incidents. It would also promote a culture of safety without allocating blame.

AV could potentially operate as a privately owned vehicle, a leased vehicle or as an on-demand service- (with different legal implications and potentially different economic impacts, depending on the extent to which AV became used as a service (on demand travel, like hiring a taxi) rather than seen as a private good (where the AV was owned (or leased) and used by an individual or family).

Proposed Legal liability for AVs- Automated Driving System Entity (ADSE)

Irrespective of the internal structures of organisations that develop, manufacture, bring to market or deploy AV, the regulatory proposals in the Law Commissions' consultation[22] addresses the issue of liability by specifying that a single legal entity The Automated Driving System Entity (ADSE) be responsible for the putting vehicles forward for categorisation as "safe for self-driving".

Table 8 The role of the Automated Driving System Entity

The role of the ADSE
8.64 Our proposal is that all self-driving systems should be backed by an Automated Driving System Entity (ADSE). The ADSE will need to register with the safety

assurance scheme. Previously, we have described the ADSE as the manufacturer or developer which puts an ADS forward for approval. We have now developed our thinking and it would be more accurate to say that the ADSE puts the vehicle forward for categorisation as safe self-driving.

8.65 A wide variety of organisations may work together to develop self-driving vehicles. They may also use a variety of structures to manufacture vehicles, bring them to market or deploy them on the roads. Whatever the internal structures, we think it is important that a single entity is registered with the safety assurance scheme as the first point of reference in the event of problems.

8.66 In most cases we think that the ADSE will be the manufacturer. However, we recognise that it might also be a software developer; or a partnership between developer and manufacturer. As the industry is still developing, we have sought to remain flexible in our approach.

8.67 However, we need to be clear about the ADSE's responsibilities. The ADSE must put its name to the safety case. It will need to show that it has been sufficiently involved in assessing safety and writing the safety case to vouch for the information in it. If the information in itis inaccurate, the ADSE might be guilty of a serious criminal offence, as discussed in Chapter 14.
P137 [22]

Proposed financial resource requirements

The Law Commission proposals also require the ADSE to have sufficient financial resources to meet regulatory sanctions if things go wrong (e.g., meeting obligations from improvement notices through to a requirement to recall its vehicles). The ability for an overseeing authority to impose such regulatory sanctions draws on existing systems of regulation in other areas. The requirements for total funds held, and how it is held, are not prescribed at this stage. [14]

Future benefits will depend (in part) on the form the regulations eventually take – particularly if they impose a structure that restricts the way the AV market can develop ("gateways"). This issue of gateways is discussed next.

Keeping the potential pathways open - Gateways to AV implementation

There are essentially two ways (or gateways) by which AV as a fully autonomous, self-driving vehicle could be implemented: - either:

- a gradual improvement of the automation in the current stock of vehicles – where vehicles continue to have a driver, but as the AV technology evolves, the human driver will be able to increasingly give over control of the car to a computer.

Or alternatively:

- allowing the use of driverless vehicles in defined areas and gradually increasing the areas in which they are used. (The occupant – if any - is simply a passenger, rather than the driver).

There are clearly legal and philosophical implications of the two different approaches. The first approach can broadly be seen as based around extending the capabilities of the vehicle as a "good", while the second is more akin to a "service", potentially providing "on demand" (driverless) transport. The second approach could be compared to developments in other sectors of the economy, where renting a service (e.g., music and video streaming services) have grown rapidly to challenge a traditional market based around ownership (e.g., buying physical copies of music, films as CDs, DVDs etc).

A wide variety of organisations are working on developing self- driving vehicles, either in collaboration or in competition[23]. These include both established and more recent car manufacturers and software developers.

Any regulatory system will therefore need to remain flexible, as the industry develops, to allow the AV market to evolve, which could involve either (or both) of the above paths[20].

The Law Commission recommendations are designed to create a flexible system to allow for the safe development of the AV market. The approach of the Law Commission is to establish a broad framework with several components, not all of which will be implemented at the same time. These recommendations accommodate both development paths, through regulation supporting user-in-charge vehicles and no-user-in-charge vehicles. Some of these recommendations involve the continual monitoring and updating of AV regulation in light of practical experience and as the AV market develops.

Path dependency and real option theory

Path-dependent risks arise when pursuing the wrong path would involve wasting large sums of resources.[24] Real option theory[21] may also suggest delaying a difficult and uncertain decision, (in order to retain flexibility). However, failure to agree a regulatory framework for AV is likely to delay the development of the market and potentially prevent or hinder the economic benefits of AV to GB/UK from being realised. Other countries are currently considering AV regulatory frameworks[22]. It is important to consider the potential consequences of the UK being left behind.[21]

There is therefore a potential trade-off as technology and the AV market internationally continue to evolve over time, but also continuing uncertainty about exactly how, and at what speed, the AV market will progress.

Better regulation considerations

New regulations and laws are likely to impose new costs on business, either directly or indirectly, to achieve compliance. The better regulation framework provides guidance on dealing with such considerations.[25] However in the case of AV, the potential gains from devising appropriate regulations will be to enable a new and dynamic market to develop. As with other countries, the UK

[20] Some developers may use both paths in the one vehicle. For example, a User-In-charge (UIC) vehicle may also go and park itself and therefore be a Non-UIC vehicle.

[21] **Real option theory or analysis** is used to estimate the benefit of delaying a decision by retaining flexibility in situations with high levels of uncertainty but where knowledge is increasing significantly over time. [3](p134)

is grappling with the problems inherent in regulating an emergent technology, for a market that does not yet exist, but for which the technology is rapidly developing. [21]

Better regulation and the current Law Commission proposals

The table below briefly outlines some of the potential "better regulation agenda" considerations raised by the current AV proposals, using the proposed ADSE requirement as an example.

Table 9 Better Regulation considerations using ADSE as an example

New regulatory burdens	**Rationale**	**Costs and benefits – comments**
Setting up an ADSE	Clearly defines who has legal responsibility for AV	New legal entity cost (unclear) (e.g. familiarisation, set up and ongoing costs) Needs to be in UK or jurisdiction that recognises UK legal judgements Cost estimates currently unclear- Consider information from possible comparators? Benefit: enables new market in AV to rapidly develop, without restricting its overall form. Companies able to trade and grow in AV market.
Appropriate financial standing requirement of ADSE	Ensures that any legal obligations can be met.	Requirements for total funds held and how it is held is not prescribed at this stage. (Would likely be in regulations/ guidance, not in the legislation). Requirement draws on approach adopted in other

		regulatory systems (e.g., coach operators) but details not specified.
Impact on Small businesses		Financial standing requirement could be addressed through insurance market. (i.e. not necessarily by having to hold funds directly).

The Law Commission will produce and consult on an impact assessment covering its AV proposals, which will allow the regulatory issues and impacts of AV to be examined and commented upon in greater detail. (Currently in preparation, at the time of writing this paper).

A framework for assessing provisions of AV regulatory proposals

A well-designed regulatory framework would enable the potential economic benefits of AV to be unlocked, or potentially brought forward, by clarifying the uncertainty over legal liabilities. However, other dimensions or criteria are also likely to be relevant in assessing AV regulatory proposals. The framework below has been drawn up as a potential means to help assess the benefits of any regulatory proposals for AV that emerge from the Law Commissions' work. The framework scope is intended to be broad enough to apply to provisions in a future bill reflecting the Law Commission reforms. It could be used for internal scoping or future refining of options, either for comparing options with one another or against a base case.

Proposed assessment framework - suggested criteria, rationale and metrics

The suggested criteria for the framework cover: **certainty, proportionality, transparency, safeguarding equity** and **alignment with wider government goals**- all of which will underpin an effective regulatory system. Rationale for each of the suggested criteria are also given, together with a selection of metrics that could be further expanded to form the basis of their assessment.

Table 10 Potential framework for assessing provisions of AV regulatory proposals

Criteria	Rationale	Possible Metrics
Creates certainty /clarity/ removes ambiguity	Provide clarity where legal responsibility lies, and in what circumstances. (Especially role and	Clarity over roles, responsibilities, and liabilities, in what circumstances. Vehicle safe to be deployed. (Design-

	responsibilities of AV "user" vis a vis manufacturer/ service provider).	type approval) Vehicle safe in use (maintenance and operation).
Proposed regulation is proportionate (Sufficient and efficient).	Focused on addressing identified issues from Consultation Papers and views of stakeholders, while avoiding excessive burden.	Does not impose undue burdens (e.g., addresses potential barriers to entry or to the future development of AV market). Considers costs of compliance. (Compared to potential benefits*) Considers distributional impacts e.g., potential effects on business (Small-Medium Enterprises etc). Incentivises (does not hinder) innovation. Seeks to align/ build on existing international/ national frameworks, where appropriate.
Operates transparently and responds flexibly	Legal requirements and any on-going regulatory supervision framework are well understood and open to scrutiny.	Clear how framework operates and how issues will be dealt with. Focus on ends (identifying and achieving overall objectives) not overly on means (seek to be flexible

		on process by which compliance is achieved). Operation of system encourages rapid disclosure and sharing of information (e.g., risks and issues) to enable potential concerns to be addressed. (Build culture of trust).
Safeguarding equity	Equity, accessibility, and vulnerable user considerations	Protects or enhances access for vulnerable users.
Aligns with wider government objectives	Fit with wider public policies	Contribution towards sustainability goals, and other relevant goals/ objectives.

*See section further below on assessing potential benefits of AV.

Distinguishing between assessing a regulatory framework for AV and the potential benefits of AV

Assessing a regulatory proposal for AV is not an assessment of the potential economic benefits of AVs *as such*[22]. Assessing the economic benefits of AV is extremely difficult to quantify, given the nascent nature of the AV transport market, combined with the dynamic nature of the developments of AV technology.[26] Yet not having a clear set of regulations in place could stifle the development of AV in the UK. On the other hand, even if a perfect set of regulations could be devised, there are other issues, (including the impact of COVID), that may adversely impact the development of AV.

Appropriate regulation (revisited)

Any regulations need to be appropriate- too much regulation and AV won't develop (or at least not in the UK) while too little could potentially result in high profile collisions that undermine public trust in the technology, again affecting investment and potential wider benefits. It could also delay the timeline for regulators developing a sufficient evidence-base for improving regulation of the technology, an understanding of its performance, and enabling more use-cases through more interoperable standards. What is required is clear, unambiguous regulation that provides a middle path, with regulation that is both sufficient and efficient. (i.e. regulation that clearly addresses the

[22] The future potential economic benefits of AV are, by their nature, difficult to assess as the technology and market is rapidly evolving. Attempting to assess the impact of AV regulatory proposals on the "rate of change" of the market and its benefits to society adds an additional layer of uncertainty and complexity. Further complexity arises in any attempt to assess the extent to which regulation enables additional, wider benefits to the GB economy (i.e., including benefits which may not have otherwise arisen here at all, without the market being enabled by an appropriate regulatory framework).

identified issues, without being excessive in its requirements). Getting the balance right should enable the potential benefits of AV to be realised.

The following sections discuss the potential (key) benefits of AV and how the benefits could be assessed in the future, in both the short and longer term.

Assessing the potential benefits of AV

Given that a significant AV market does not currently exist, any estimate of its benefits will, by its very nature, be highly speculative. Early estimates of take up of AV have proven premature. There is therefore uncertainty attempting to predict the future benefits of AV, in terms of their potential scale, scope and timing.

Yet depending on the degree and speed with which AV technology is developed and adopted, AV does potentially offer a range of benefits that could have wide ranging economic impacts, including accident reductions, greater productivity, and changes to land use, among others. (All depending on the extent and level of AV adoption)[27][28].

Potential impacts of AV- a descriptive assessment

The Law Commission's proposals, in conjunction with other enabling factors, will facilitate the development of the AV market.[23] This section gives a descriptive assessment of the range of potential impacts of AV.

For transport users, AV offers a wide range of potential benefits, for example, safer travel, while allowing time spent in transit to be better utilised, e.g., the potential to work as a "passenger", (rather than needing to pay close attention to a vehicle's surroundings).

AV could potentially have wider impacts in network capacity (by enabling efficient vehicle platooning for passenger and freight traffic, for example) and land use- from alternative use of land currently used car parks etc, (in the case of the most automated form of AV) [29] together with wider benefits to the UK economy. A transition to AV would also be expected to lead to sectoral shifts within the economy, e.g., affecting demand in driving occupations, vehicle (crash) repairs, vehicle insurance and related activities.

A range of potential benefits from AV are set out below, together with a brief narrative assessment of the impacts.

Table 11 Potential benefits of AV

Potential benefits of AV (types of identified impacts)	**"Snapshot" narrative assessment**
Direct transport benefits	

[23] The potential initial and on-going costs directly associated with the Law Commission's proposals and their distributional impacts will form part of the Law Commission's Impact Assessment. A detailed examination of other potential enabling factors and their costs, (such as changes to transport infrastructure), are beyond the scope of this paper.

to passenger/users:	
Improved road safety	Many potential safety benefits are expected from AV. (Due to reduction in human error, the overwhelming factor in road accidents). [30] Beneficial impact of "driver assistance" is already seen by those driving cars with such features.[30] [31] Studies (simulations) give a wide range of estimates of AV's potential to reduce chance of a vehicle crash, (e.g., 33%[32]-90%[33]). One study estimated AVs could reduce road traffic fatalities by 25% by 2025. (From 2018, when the study was produced - assuming outstanding technological, practical and liability challenges are addressed).[34] By way of comparison, The Department for Transport estimates annual road traffic accidents currently cost around £ 33.5 bn (in 2019).[35]
Impact on congestion/environment- from passenger travel	Overall impact of AVs on congestion (travel time) is unclear, since: Increasing AVs will enable vehicle to vehicle (V2V) communication, creating the opportunity for smoother traffic flows and higher capacity and less congestion. (Depending on degree of AV uptake). However, AVs could also increase demand for travel, due to AV offering increased accessibility (a benefit to those currently unable to drive) and potential reduction in travel costs [36]. (Rebound effects). There is also uncertainty over AV in "real world" driving conditions, e.g., including the reaction of other road users.
Benefits to freight operators from AV	Potential savings in freight service operations- (freight platooning etc, depending on uptake), but unclear about overall congestion freight operators will face on the network. (For reasons noted above).
Lower stress for vehicle occupants	Assumed uptake of full AV will lead to lower stress (as the vehicle "driver" becomes a "passenger" and no longer needs to concentrate on the vehicle and its surroundings, freeing them up to do other things while traveling). [30] Such benefits are also linked to what use is made of the time.
Productivity- ability to work /undertake other activities while in AV	In addition to impacting on journey times, network capacity and congestion, AV will crucially change what people can do while travelling, by freeing up significant amounts of time previously dedicated to driving. Changing both the quality of the journey and the opportunities for alternative use of that time is expected to have significant economic impacts. (But extremely difficult to predict with any precision).[34]
Access to transport: Greater mobility for vulnerable users /social	AV offers great potential to improve access and mobility, potentially at lower cost than currently available alternatives[37]. Distributional impacts to disadvantaged and

inclusion	vulnerable groups are therefore likely to be significant, with benefits in terms of improved access to opportunities for employment, education, health care and recreation. [38]
Potential Wider/ indirect benefits:	
Land use changes (such as reuse land from car parking facilities)	AV could sharply reduce the need for parking in core urban areas – either through "drop off" of passengers and remote parking, or, in the form of AV as a driverless taxi service, moving on to collect the next passenger. Significant benefits could arise from redevelopment /reuse of land.[29] [39] [40]Over time, AV could support greater dispersion, if relocation occurs [30](As AV reduces the "opportunity cost" of time spent travelling).
Wider economic impacts to UK economy from investing in AV technology.	AV is expected to have wider economic impacts, e.g. on the upstream automotive vehicle supply chain and potentially in a wide range of related industries, including IT, electronics, and growing market of digital services, generated from in-car data. [41] [42]Wider economic impacts could be very diverse and include completely new services and products.
Potential gains from "first mover" advantage[24]	Having appropriate "AV-ready" systems in place sooner rather than later could benefit the GB economy by attracting firms seeking to take early advantage of favourable conditions to develop AV. "AV Readiness" factors include having appropriate regulatory systems, infrastructure, and consumer acceptance. [41,43–45]. Being first mover in setting the regulatory framework can also influence the standards subsequently adopted by others. [46–48]
AV leads to new (related) industries etc. Potential trade and competitiveness impacts	Although difficult to quantify, developments in the technology associated with AV could have wide ranging potential spill-overs into other areas, generating opportunities for new economic activity[34]. The size of the potential AV market is expected grow rapidly, offering potential opportunities for GB trade.[49]

Potential impacts of AV- a summary of quantified results

A summary of a selection of AV studies with quantified benefits is briefly outlined here to provide an indication of both the potential types and estimated scale of economic impacts of AV. The selected studies cover different geographical locations and adopt differing methodologies.[25] For example, a study commissioned by CCAV estimates the UK self-driving vehicle market is set to be worth nearly £42bn by 2035,[50]with the manufacture of CAVs worth £6.3bn Gross Value Added (GVA) p.a. to the

[24] **First mover advantage** refers to a firm's ability to be better off than its competitors by being first to market in a new product category or first to do so on a large scale.

[25] Further details of these studies can be found in Annex 3

UK (by 2035) [51]. User benefits and other impacts beyond the CAV manufacturing market were explicitly excluded from the coverage of this study. Another study, commissioned by the Society of Motoring Manufacturers and Traders (SMMT), [41] forecast the net economic benefit of Connected and Autonomous Vehicles to be worth £62 bn pa by 2030. (This study included estimated impacts on consumers, producers, and wider impacts on digital services). A study in the US quoting the results of transport modelling work found public benefit (in US alone) of more than $800bn pa in 2030. [29] The latter study also noted that not all second-round effects are ambiguously positive-from disruption to insurance industry, energy consumption rising, as self-driving cars tap latent demand, and the estimated impact on vehicle taxes and fees.

As AV is a new technology it is difficult to forecast timings or exact scale of impacts - but these could be substantial. However, any figures that are quoted in studies need to be treated with caution, since they are all driven by a series of assumptions- and are therefore best seen as "illustrative" of the potential impacts, rather than taken as statements of fact.

Potential impacts of AV- wider alignment with Government objectives

AV also aligns with wider government objectives, including accessible mobility, [52]road safety[53], carbon emission reduction[54] and seeking opportunity to develop the UK's trading and economic competitiveness. [55][56] AV appears to offer a wide range of potential benefits, despite the difficulties raised in their quantification.

On the longer term, this could herald a potential future where AV are seen as providing an "on demand" accessible transport service, supplanting the traditional view of the car as a private consumer good.

Future testing of potential benefits (and assumptions) of AV using a theory of change approach

Any current economic assessments of benefits of AV will, by their nature, be speculative. A descriptive approach is therefore a prudent way of setting out the potential benefits enabled by the Law Commissions' current proposals.

It would however be possible to attempt a more detailed assessment of AV at a future date, using a theory of change approach. This could potentially be applied to the finalised proposals and could help to determine what evidence is needed to evaluate the longer-term impacts of AV.

Table 12 Using a Theory of Change approach

The potential benefits of AV to GB can be described using a logic model, or **theory of change**[26], to set out the possible impacts and the underlying assumptions. Transparency in describing the steps and assumptions can allow the robustness and realism of the paths and assumptions to be assessed, helping to identify the data or evidence to enable future evaluation to take place. Estimates of the potential scale of future impacts can be particularly difficult to assess where change may be rapid and the impacts potentially widespread and of a non-marginal nature, moving away from previously established norms or trends.

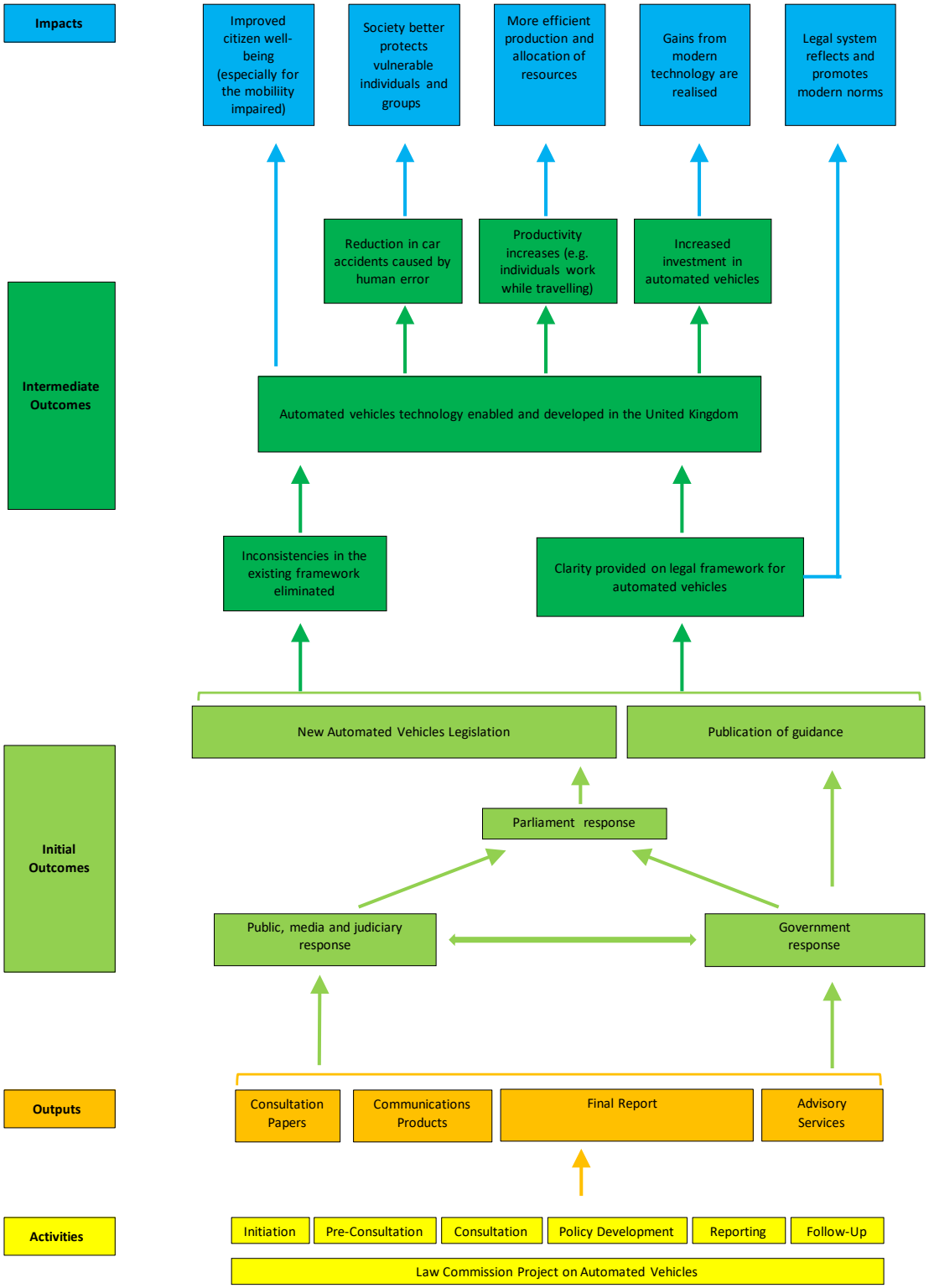
[26] See Annex 1 for an example of a theory of change framework.

A theory of change is a process by which a set of logical steps can describe how an identified problem or issue can be addressed and the assumptions made at each step in the process, (in terms of activities or inputs, outputs, outcomes and, finally, impacts). A theory of change approach can help clarify the assumptions that are made in at each step in the process, even in situations that are prospective in nature (such as AV) where the benefits are essentially scenarios, based on a set of underpinning assumptions.

A theory of change approach has already been used to briefly examine the potential economic benefits of AV, as one of a series of case studies in a 2019 report on the value of law reform.[57] The theory of change shown in the Table below was applied to assess the work of the Law Commission on AV.[27]

Table 13 Law Commission AV work Theory of Change

[27] See Annex 2 for the full AV case study from the Value of Law reform report[57]



A theory of change approach to assessing the economic benefits of AV would focus on the assumed intermediate outcomes and impacts stages.

An extract discussing the potential economic benefits of AV identified in the Value of Law Reform case study [57]is cited in the Table below. The case study attempted to assesses the contribution of the Law Commissions' work to AV. Setting a clear legal framework acts as an enabler for AV, for which the estimated potential benefits are significant, as reported here:

Table 14 AV case study economic benefits (extract)

AV case study – extract

There is a large potential opportunity from developing AV technology. Providing legal clarity offers a way to help unlock these benefits or advance their timing.
In addition, having a clear UK legal framework in place could potentially attract global research and funding for the development of the technology associated with AV to the UK, together with bringing forward benefits to users in terms of road safety, greater mobility (particularly for the disabled), and wider benefits in terms of increased productivity and reduced pollution.[28] While such benefits are difficult to estimate, a recent study by Mckinsey[29] predicted that, if readily adopted, the benefits of autonomous vehicles could exceed $800bn pa in the US alone:

- Nearly one-third of the benefit was estimated to arise from the public sector's redevelopment of unnecessary parking spaces into more productive commercial or residential property. (For context, the amount of land taken up by car parking in Los Angeles is more than 17 million square meters—equivalent to nearly 1,400 soccer fields[30].
- About 15 percent would accrue annually to workers in the form of more productive commuting time. Further, McKinsey anticipated a yearly benefit of about one-half of 1 percent (somewhat less than $4 billion) in the form of reduced environmental damage, since, for example, more efficiently utilized vehicles idle less than others do.
- Finally, more than half of the benefits would stem from safer roadways and the avoidance of the millions of fatal and nonfatal accidents caused each year by human error. A comparable analysis of Germany found that by 2040, self-driving vehicles could save the country €1.2 billion a year through lower costs for hospital stays, rehabilitation, and medication alone.

It is difficult to assess the contribution of the Law Commissions' work on AV, since the current review is at an early stage and the Commissions' proposals, which have still to be developed, will apply to a rapidly developing area that could potentially revolutionise the future of travel. The Law Commissions' review is intended to provide a clear legal framework and thus be an important enabler for AV, since in the right conditions, transport experts predict AV has the capacity to grow rapidly and offer significant and widespread benefits.

AV is expected to enable widespread economic gains, but the benefits are difficult to quantify with any degree of certainty. However, an assessment of the benefits (and costs) could be revisited, with a more detailed theory of change style assessment. This could include any new evidence from consultation exercises or other sources. It could be applied to the finalised proposals and help to determine the evidence needed to evaluate the longer-term economic impacts of AV.

[28] (KPMG, 2019)

[29] (McKinsey, 2019)

[30] See (Peters, 2017)

Capturing data to enable the potential benefits of AV to be monitored and evaluated

It will be important to identify sources of evidence that can be used to evaluate the impact of AV. These are discussed below:

Costs and benefits associated with AV regulation

The Law Commissions' proposed regulatory scheme will itself have an active role in ensuring aspects of evidence are collected and evaluated, e.g. data from the relationship between the ADSE and the regulator.

The ADSE is anticipated to trade and profit from the developing AV market as a result.

Transport user benefits

In terms of anticipated transport user benefits, road traffic accidents are already the subject of detailed reporting. It should therefore be possible to collect data to monitor changes in accident statistics and assess the impact of increasing levels and uptake of AV, moving from further development and wider uptake of current driver assistance technologies through to movement towards "full" AV and its adoption. Such analysis will also be important to address any public concerns about the roll out of such technology.

Additional information will need to be collected to assess the future impact of AV on driver / user-in-charge behaviour. This will require assessing both the extent to which the AV saves driver time (i.e., does AV reduce overall journey times?) and identifying what use (or changes in use) are made of the time spent in the vehicle. These impacts would be expected to change over time, as the technology and its use became more widespread.

It is unclear to what extent AV may unlock "latent demand" for travel, leading to additional journeys being undertaken. AV is anticipated to reduce the cost of making journeys (either in terms of monetary cost from owning or accessing an AV, or, alternatively, in terms of the "disutility"/discomfort involved in travel). Overtime, the number, frequency of journeys and distances travelled may change significantly. To assess such impacts will require access to detailed information on travel patterns to track changes in behaviour. Widespread adoption of AV as a transport "service" could also have significant implications for the use of public transport.

Data is also needed to understand and assess distributional issues, including the impacts AV in providing enhanced accessibility and mobility.

In the longer term, it is entirely possible that AV could induce significant travel and land use changes, with longer journeys being undertaken, (or relocation further from work), if driver commuting time or in vehicle travel time generally ceases to be considered a "deadweight" and travel time can be put to alternative uses.

Other impacts: changes in land use, sectoral shifts, and wider economic impacts

As noted, over time AV could lead to significant changes in patterns of land use. Widespread adoption of AV would also have significant sectoral impacts- e.g., potential reduction in demand for jobs involving driving, lower use of services related to vehicle crash repairs, reduced demand for car parks (in the case of the most automated forms of AV) and changes to the car insurance market (to reflect the lower risk of accidents). New and expanding markets, related to servicing the demand for

AV are widely anticipated to grow substantially. Having a clear regulatory system should create the opportunity for attracting AV related economic activity to the UK. Details of changes to these (and other) markets will need to be monitored carefully to assess AV's impact/contribution.

Key Findings

Key findings from the paper are set out below:

Table 15 Key Findings

1. Uncertainty over legal responsibilities provides the key economic justification for regulatory intervention in AV. Having clear legal responsibilities will contribute to ensuring safe use.

2. Having appropriate regulations will act as an enabler to allow an AV market to develop.

3. The base case against which the Law Commissions' proposals should be assessed is changing over time. A pragmatic approach is suggested, based on a descriptive assessment comparing the Law Commissions' proposals against the existing body of relevant legislation.

4. The paper outlines a framework to enable proposed AV regulations to be further assessed. The framework is based on five criteria: certainty, proportionality, transparency, safeguarding equity and alignment with wider government goals.

5. The paper describes potential economic benefits from AV. However the emergent nature of the AV market makes detailed assessment of its growth and future benefits problematic.

6. Any economic assessments of potential benefits of AV (as such) will, by their nature, be speculative. Using a theory of change approach would enable assumptions and potential benefits to be set out and tested. The theory of change approach can be revisited as more data becomes available.

7. Data requirement considerations to enable future evaluation of AV are outlined.

Conclusions

This paper was commissioned to provide a strategic economic analysis to support the current work of the Law Commission on regulating Automated Vehicles (AV).

The analysis has covered a wide range of topics, starting with the economic rationale for regulatory intervention in AV (based around clarifying the uncertainty over legal responsibilities). It discussed potential issues and options for intervention, including the "base case" to compare Law Commission proposals against and what constitutes appropriate regulation. A framework and criteria have been included to assist with evaluation of any proposed AV regulations. The paper has also outlined the

potential economic impacts of AV and how they could be further assessed, using a theory of change approach to test potential benefits and assist with future evaluation.

In the right conditions, AV is predicted to grow rapidly and offer significant and widespread benefits. The Law Commissions' review is intended to provide a clear legal framework and be an important enabler for AV.

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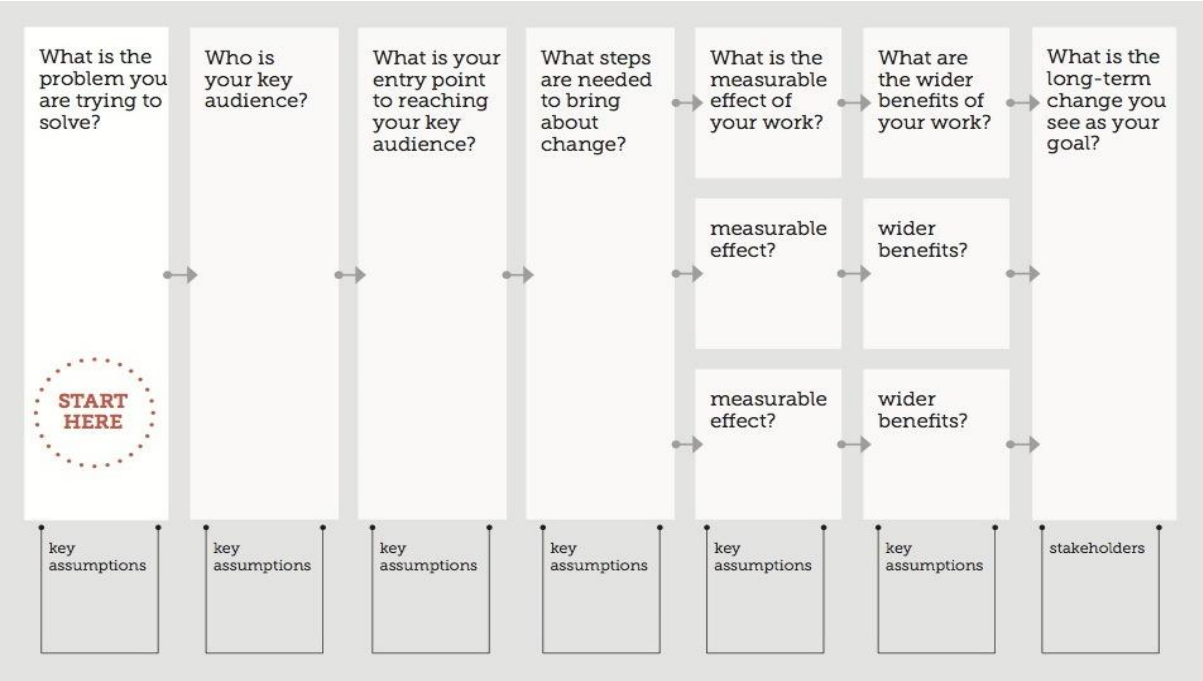
Annexes

Annex 1: Example Theory of Change Framework



Source: NESTA
[58]

Annex 2: Case study On the Law Commissions' work on AV, reproduced from "The Value of Law Reform" Report (2019)

Legal Framework for Automated Vehicles [57] [31]

Background

The Centre for Connected and Autonomous Vehicles (CCAV) asked the Law Commission of England and Wales and the Scottish Law Commission to undertake a far-reaching review of the legal framework for automated vehicles, and their use as part of public transport networks and on-demand passenger services[32].

Automated vehicles (AV) refer to vehicles that are capable of driving themselves without being controlled or monitored by an individual for at least part of a journey. While it is difficult to predict the future pace and impact of new technology, one recent study suggested AV could add over £62bn pa to the UK economy by 2030.[33] The Law Commission[34] is considering issues arising at the boundary between self-driving vehicles and widely used driver assistance technologies such as cruise control.

This is the first time that the Law Commission has been asked to recommend how the law should be adapted to circumstances that (in the main) do not yet exist but are in prospect. This requires the Law Commission to anticipate what might happen. The challenge is to regulate appropriately and at the right time. Premature intervention could stifle innovation, while late intervention could jeopardise safety. The Law Commission is therefore undertaking a series of consultations to test ideas and respond to developments over the next three years.

1. In November 2018 the Law Commission launched a three-month consultation on safety assurance and legal liability. An analysis of responses and interim findings was published in June 2019.

2. A second consultation paper on automated road passenger services will be published later this year, covering the regulation of remotely operated fleets of automated vehicles and their relationship with public transport.

3. A third consultation, in 2020, will draw on responses to both previous papers to formulate overarching proposals on the way forward.

4. Final recommendations will be published in 2021.

Objectives

Currently the Law Commissions' proposals for AV are still in development. The preliminary consultation paper identified the following objectives:[35]

a. The key objective is assuring safety.

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[31] NOTE Annex 2 (and the annex 2 footnotes below) are reproduced directly from the 2019 Value of Law Reform report [57]. The text has been amended slightly to reflect the geographical scope of the AV work of the Law Commissions (covering GB, i.e. England, Wales and Scotland).

[32] Law Commission Automated Vehicles Webpage

[33] (Frost & Sullivan, 2019)

[34] For the AV review case study, the term "the Law Commission" refers to the joint work being carried out by the Law Commission for England and Wales and the Scottish Law Commission.

[35] See (Law Commission, 2018) section 1.3.

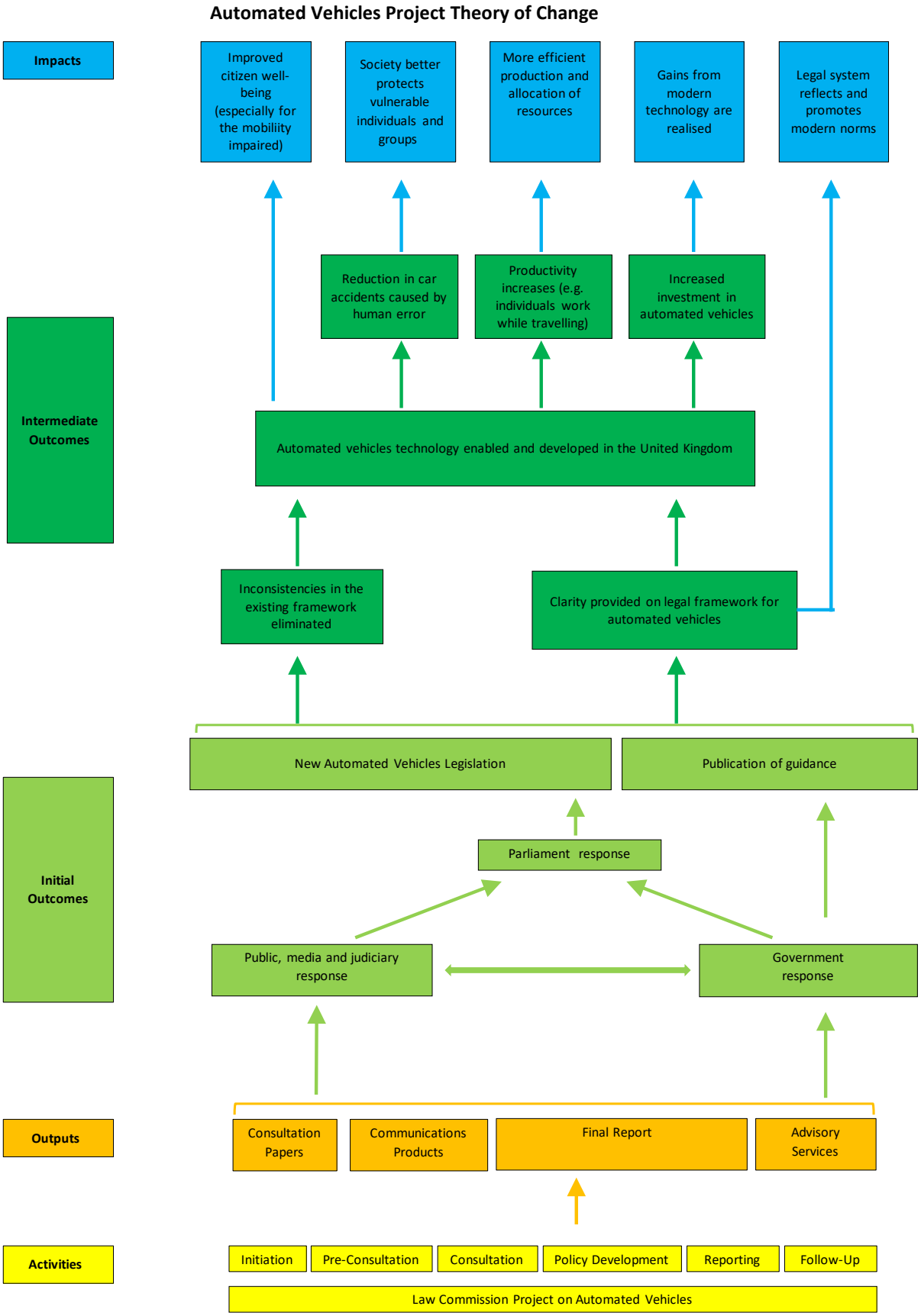
Secondary objectives are:

b. to provide a clear allocation of responsibility and liability; (both civil and criminal law)
c. To remove any remaining blocks which might otherwise delay the benefits of driving automation, expected to arise through improvements in mobility and productivity. Driving automation technologies can enable new ways for those with visible and non-visible disabilities to get around.

Additional objectives may emerge from work on subsequent stages of the AV review.

Theory of Change and Applicable Themes

The general theory of change framework set out in section **Error! Reference source not found.** is applied to the Law Commissions' proposals on Automated Vehicles in the diagram that follows. This illustrates the potential causal pathways from the Law Commission's work to wider impacts.
The potential key themes arising in this project are as follows:
Harm prevention –The key objective of the Law Commissions' review of the legal framework around automated vehicles is to ensure safety in the use of AV. The technology offers the potential to reduce the number of road accident fatalities and injuries that result from human error. More efficient driving, leading to reductions in vehicle emissions, would also bring additional environmental and human health benefits.
Well-being improvement – the development of AV offers the potential opportunity for enhanced mobility for those with disabilities.
Efficiency gains- the development of AV offers the potential to increase productivity. e.g., through the ability to work while travelling in the vehicle and to free up resources for alternative uses. The potential scale of opportunity of downstream impacts arising from AV appears substantial.
Technology driven growth –Having a responsive legal system that keeps up to date with technology enables wider gains from technology to be realised, encouraging UK investment. The introduction of appropriate "future proofed" AV legislation, following extensive consultation, should make suppliers more confident about investing in AV related technology and products and increase the UK's standing as a hub for technology development. Early adoption potential brings advantages to UK economy through first mover advantage.
Modernising the legal system – Updating the legal system to keep it up-to-date with technological norms can help to ensure that the legal system remains relevant and appropriate.



Contribution Claims

The next step is to consider whether the Law Commission's outputs will be effectively realised, resulting in the outcomes predicted by the theory of change. The first claim to assess is whether the Law Commission's recommendations will be successfully implemented:

CC1 The Law Commissions' review of AV will result in greater legal clarity over use of AV in England and Wales.

The second claim to assess is whether the implementation of the Law Commission's recommendations will make a difference as predicted:

CC2 The Law Commissions' review and recommendations on AV will make a difference to citizens of England and Wales.

CC2a: The review and recommendations on AV will contribute to harm prevention in England and Wales through the scope to improve road safety.

CC2b: The review and recommendations on AV contribute to well-being improvement through the potential opportunity for enhanced mobility for those with disabilities.

CC2c: The review and recommendations on AV offers potential efficiency gains-by clarifying the law which reduces legal uncertainties and may encourage development of AV, potentially increasing productivity.

CC2d: The review and recommendations on AV offers greater potential for technology driven growth.

CC2e: The review and recommendations on AV modernise the legal system.

Findings

The findings in relation to each of the contribution claims in this case are as follows:

Contribution Claim 1: The Law Commissions' review of AV will result in greater legal clarity over use of AV in England and Wales.

Test	Finding	
Assumption: The Law Commission will complete its review and publish its recommendations.	The Law Commissions' review is due to be published in 2021. Results for from the preliminary consultation were published in June 2019. Given the Law Commissions' proven expertise in consulting with stakeholders on proposed legal reform, there seems little reason to doubt the review will be completed and published.	
Assumption: The Law Commission proposals will provide greater legal clarity over AV	At this early stage and without the Law Commissions' final recommendations to review, it is difficult to evaluate this assumption. However, the preliminary consultation strongly supported the view that the Law Commission has carefully considered the legal issues raised by AV in its work on the topic to date, outlining ways in which the law could be amended to provide greater legal clarity over issues of AV safety assurance, regulation and criminal and civil liability. The on-going process of consultation undertaken by the Law Commissions is extremely valuable for bringing together and seeking the views of a wide range of stakeholders. The complexity and interconnectedness of AV issues, and the importance of the Law Commissions' work for obtaining legal clarity is also evident in the recently produced Zenzic UK Connected and Automated Mobility Roadmap to 2030.[36]	

[36] (Zenzic, 2019)

Assumption: The Law Commission proposals will be broadly supported and accepted.	It is not possible to evaluate this assumption ahead of Law Commission completing its review and publishing its proposals. However, the central finding from the preliminary consultation obtained strong support, namely that the Government could begin work to establish a safety assurance scheme, building on its existing work in the Code of Practice, to allow for the commercial deployment of highly automated driving systems. The safety assurance scheme is required to prohibit unauthorised systems and to support the implementation of the Automated and Electric Vehicles Act 2018. Stakeholders strongly support its creation before automated vehicles reach the market. While the Government has yet to respond to the preliminary findings, Government policy (e.g. DoT's Future of Mobility Urban strategy) makes clear the government's desire to see the UK embrace the future opportunities arising from innovative transport technology. While it therefore seems likely that the Law Commissions' proposals, when published, will be well evidenced, broadly supported and are likely to be accepted, it is currently too early to evaluate this assumption.	

Contribution Claim 2: The Law Commissions' review and recommendations will make a difference to citizens of England and Wales.[37]

Test	**Finding**	
Assumption: legal clarity over AV will increase the opportunities for the benefits from AV to be realised.	At this early stage, without the Law Commissions' final recommendations to review, it is difficult to evaluate the potential impact of Law Commissions' work on AV and how it may affect the speed or nature of future AV development. However, there is a large potential opportunity from developing AV technology. Providing legal clarity offers a way to help unlock these benefits, or advance their timing. In addition, having a clear legal framework for Scotland, England and Wales in place could potentially attract global research and funding for the development of the technology associated with AV to GB, together with bringing forward benefits to users in terms of road safety, greater mobility (particularly for the disabled), and wider benefits in terms of increased productivity and reduced pollution.[38] While such benefits are difficult to estimate, a recent study by Mckinsey[39] predicted that, if readily adopted, the benefits of autonomous vehicles could exceed $800bn pa in the US alone: • Nearly one-third of the benefit was estimated to arise from the public sector's redevelopment of unnecessary parking spaces into more productive commercial or residential property. (For context, the amount of land taken up by car parking in Los Angeles is more than 17 million square meters—equivalent to nearly 1,400 soccer fields[40]. • About 15 percent would accrue annually to workers in the form of more productive commuting time. Further, McKinsey	

[37] At this early stage, the key themes have been considered together under the single heading of contribution claim 2.

[38] (KPMG, 2019)

[39] (McKinsey, 2019)

[40] See (Peters, 2017)

	anticipated a yearly benefit of about one-half of 1 percent (somewhat less than $4 billion) in the form of reduced environmental damage, since, for example, more efficiently utilized vehicles idle less than others do. • Finally, more than half of the benefits would stem from safer roadways and the avoidance of the millions of fatal and nonfatal accidents caused each year by human error. A comparable analysis of Germany found that by 2040, self-driving vehicles could save the country €1.2 billion a year through lower costs for hospital stays, rehabilitation, and medication alone. It is difficult to assess the contribution of the Law Commissions' work on AV, since the current review is at an early stage and the Commissions' proposals, which have still to be developed, will apply to a rapidly developing area that could potentially revolutionise the future of travel. The Law Commissions' review is intended to provide a clear legal framework and thus be an important enabler for AV, since in the right conditions, transport experts predict AV has the capacity to grow rapidly and offer significant and widespread benefits.	

Conclusion

The Law Commissions are currently in the process of developing proposals around AV. Assessing the potential outcomes is especially difficult, given the prospective nature of the work, dealing with a new and rapidly developing technology. However, as a result of detailed consideration of the issues and the extensive ongoing process of consultation, the Law Commission will seek to develop well evidenced recommendations that provide a clear legal framework for AV that ensures public safety without stifling innovation, to enable the considerable potential benefits of AV to develop.

Annex 3 Economic assessments of AV

(Tables begin on next page)

Annex 3 Economic assessments of AV

This annex briefly summarises information on economic assessments, taken from a selection of AV related studies. The results are intended to be indicative of the potential economic impacts of AV. It is not an exhaustive or systematic review of the AV literature.

Title/ Source	**Geographic coverage**	**Benefits (type)**	**Quantified Value?**	**How Assessed? (Assumptions set out or not?)**	**Comment**	**Quotes and notes**
Connected Places Catapult[51] (2020)	UK	UK GVA, (Gross Value Added) employment from CVA industry, market forecast to 2035	UK self-driving vehicle market set to be worth nearly £41.7 bn by 2035. £6.3 bn GVA pa for CAV to UK (2019 prices)	Qualitative and quantitative. Assumptions and scenarios set out. (Appendices)	Scope: UK market forecast for industry impact of Connected and Autonomous Vehicles. Other impacts, e.g., on consumers, safety, productivity etc. explicitly ruled out of scope. (p43) Report prepared for CCAV.	"UK self-driving vehicle market set to be worth nearly £41.7bn by 2035." Notes: Prepared pre COVID and before UK Government announced bringing forward phase out date for new vehicles powered by Internal Combustion Engines (ICE).
Connected and Autonomous Vehicles[41] (2019)	UK	Economic impact from CAV on UK £62 bn: Of which: £46 bn consumer impact, (mainly from more use of time in vehicle) £2bn producer impact (growth in profits related to CAV) £18 bn wider impacts (related to upstream automotive and digital services) £4 bn increased tax (from increased economic activity) £2 safety (via ADAS an AV technology) with additional costs of £10 bn from infrastructure and road maintenance.	£62 bn pa by 2030, potentially £145 bn by 2040	Reports findings from "custom economic model" and "CAV deployment Index". Few details of underpinning economic model - summary style report.	Uses "CAV Deployment Index" Scope: UK, "economic impact" Report prepared for SSMT.	"UK economic Impact £62 bn pa by 2030." Notes: Prepared "while Brexit is still unresolved".
Mobility's Autonomou	US	Quotes public benefits findings: Mix of Safety (over 50%)	Public benefit (in US alone)	Summary paper-	McKinsey Centre for Future Mobility - Authors quoting results from	Quote "The global revenues associated with AVs in urban

s future McKinsey (Centre for future mobility)[29](2019)		Redevelopment of unnecessary parking spaces into commercial or residential property (nearly 1/3rd) More productive commuting time (15%) Notes that not all second-round effects are ambiguously positive-disruption to insurance industry, energy consumption rise as self-driving cars tap latent demand, impact on vehicle taxes and fees.	would exceed $800bn pa in 2030	describing overall results, (no further details /assumptions set out).	modelling 40+ transportation use cases.	areas could reach $1.6 trillion a year in 2030… As important as these revenues would be for the providers of end-to-end mobility equipment and services, the effects on society would be more transformative still. If the United States, for example, fully adopted autonomous vehicles, the benefit to the public would exceed $800 billion a year in 2030" p2 [29,59]
The economic and social impact of Fully Autonomous Vehicles (KPMG) [36] (2020)	US and NL	Summary of economic and societal impacts from various AV studies	Could result in an annual societal benefit of more than $750 billion in the US alone.	Summary citing results from other studies- (not underlying assumptions)	Coverage includes impacts from variety of source on accident savings, improved use of time during travel, impact on jobs, Greenhouse gas emissions.	"The number of vehicle crashes could be reduced, and travel time can be used more effectively which could result in an annual societal benefit of more than $750 billion in the US alone." "Although AVs have the potential to improve energy use of vehicles and therefore reduction in carbon emissions, rebound effects could mitigate this effect due to uptake in use of road vehicles." "There will be a shift of jobs between different sectors. This effect may result in an annual cost of more than $350 billion annually in the US alone. Transitioning the skillsets of the affected groups is therefore key to avoid such societal costs".
Autonomous Vehicles Readiness Index	International comp	"Readiness" for AV	Country readiness rank and score, not monetised	Series of readiness indicators Methodology	Ranking and scoring exercise, with country/ jurisdiction level commentary on developments.	Quote "Although it drops two places overall, [to 9th] the UK retains its second place on the Policy and Legislation pillar, with

KPMG Global Report[43][44][45] (2018-2020)	arisons. 2020 report covers 30 countries and jurisdictions.		values.	set out. 30 countries and jurisdictions assessed on 28 different measures, gathered into four pillars — policy and legislation, technology and innovation, infrastructure, and consumer acceptance	Latest results include comment on UK preparation for AV, including current review of AV legislation. Notes "The World Health Organization estimates that there are 1.35 million road deaths and 50 million injuries annually. With human error responsible in around 95 percent of cases, AVs have the potential to reduce these casualties dramatically". (p4)	the government continuing to make substantial progress in this area over the past year. Building on 2018's Automated and Electric Vehicles Act, UK Government launched its second consultation paper in a three-year review of the UK's regulatory framework for automated vehicles."(p20)[45]
Marketplace of change: Automobile insurance in the era of autonomous vehicles (KPMG) [37](2015)	US	Potential changes from AV, with emphasis on implications for US auto insurance: reduction in accidents and consequences for insurance claims/ insurance industry.	Covers a range of scenarios and market impacts-falling insurance premiums.	Reports changes in market, results from actuarial models and implications from range of scenarios. (Few details of underlying models)	Synthesis of work carried out to study potential impacts of AV, with emphasis on potential implications for the (US) insurance industry.	Potential large reduction in insurance premiums, impact on insurance market/industry. Suggests AV could cut cost of "mobility vehicle" services by around 50% (from US 82c to US 43c) per mile. (p14) [37] "Accident frequency could drop by 80%" (p30)