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The Existing Dilemmas and Optimization Approaches of Infringement Liability in Autonomous Driving

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Abstract. With the rapid iteration and practical application of autonomous driving technology, its advantages in reducing human driving errors and improving traffic efficiency are becoming increasingly prominent, while also giving rise to new challenges of traffic accident infringement liability . Under the current legal framework, autonomous driving tort liability faces core dilemmas such as vague definition of liability subjects, conflicting application of attribution principles, and inadequate mechanisms for compensation and risk sharing. This paper, in light of the classification standards of autonomous driving technology and their legal significance, analyzes from a theoretical perspective the diverse doctrines for identifying liability subjects and the coordination paths for liability principles, and proposes strategies for improving the supporting institutional system, with the aim of providing effective relief for victims and laying a solid legal foundation for the healthy development of the autonomous driving industry.

Keywords: autonomous driving, tort liability, subject toliability, attribution principles

1. Background and significance of the study

The deep integration of artificial intelligence and the automotive industry has driven the development of autonomous driving technology to move from concept to reality at an unprecedented speed. While the research and application of autonomous vehicles bring many benefits, the traffic accidents they cause have raised doubts about the stability and safety of the technology. The "data black box" feature of autonomous driving makes it difficult to determine product defects and prove causality in accidents, often leaving victims in a situation where they cannot provide evidence due to the inability to obtain vehicle operation data [1]. The traditional traffic legal system is built around human driving behavior and is difficult to adapt to the technical characteristics of autonomous driving. The infringement liability issues caused by it cannot be comprehensively resolved within the existing legal framework. Therefore, exploring the adaptation path between autonomous driving technology and the current legal system, clarifying the allocation rules of infringement liability for autonomous driving, is not only a practical need to resolve judicial disputes, but also an inevitable requirement to promote the standardized development of the autonomous driving industry, which has significant theoretical value and practical significance.

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2. The classification of autonomous driving technology and its legal significance

2.1. Global authoritative classification standards for autonomous driving technology

The currently widely adopted classification standards globally mainly consist of two: the SAE J3016 standard developed by the Society of Automotive Engineers (SAE) and China's national standard GB/T 40429-2021 "Classification of Automotive Driving Automation" [2]. Both classify driving automation into 0-5 levels, with the core division based on the executing subject of dynamic driving tasks (DDT), limitations of the designed operating range (ODD), and the response strategies in the event of system failure. The national standard for "Classification of Automotive Driving Automation" in China was released in August 2021, and the Chinese GB/T 40429-2021 standard was implemented on March 1, 2022. Its core logic is consistent with SAE J3016 and has been adjusted specially take into account the traffic and road conditions in China. The SAE J3016 standard (revised in 2021) is the most widely applied standard for autonomous driving classification worldwide, and its core definition is as shown in Table 1:

Table 1. The SAE J3016 standard (revised in 2021) and its core definition

Level	Definition	Core features	Dynamic driving task execution subject	Human character
L0	No Driving Automation	It only provides instantaneous warnings or interventions, without continuously controlling the vehicle.	Human driver.	Responsible for the entire process, the system only assists in early warning.
L1	Driver Assistance	The system can control either the lateral (steering) or longitudinal (acceleration/braking) movement.	Human driver as the main driver, system assisted single control.	Continuously monitor the driving environment and be ready to take over at any time.
L2	Partial Driving Automation	The system can simultaneously control both horizontal and vertical aspects.	Human drivers are the main force, with the system providing assistance for multiple controls.	Continuous monitoring must be carried out and a state of readiness for takeover must be maintained. This is the legal responsibility of the entity.
L3	Conditional Driving Automation	The system fully executes the dynamic driving tasks within the specified design operating range.	The system is primary, with humans as the backup.	It can be disconnected from the monitoring system, but it must immediately take over when the system requests it. In case of system failure, it will execute the strategy with the least risk.

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Table 1. (continued)

L4	High Driving Automation	The system fully executes DDT within the specified design operating range and can independently handle all situations.	The system is fully responsible.	There is no need for human intervention. It can be equipped with security personnel. The system itself is the main responsible party.
L5	Full Driving Automation	The system fully implements DDT under all road and environmental conditions.	The system is fully responsible.	No human intervention is required. There are no traditional control devices such as steering wheels or pedals.

2.2. The legal significance of classification of autonomous driving technology

The development of autonomous driving technology has completely broken the traditional "human driven" mode, and the technical classification provides a factual basis for the application of legal regulations. Its legal significance lies in redefining the scope of the "actual vehicle operator", replacing the traditional responsibility determination and regulatory model centered only on human drivers with new rules such as "who controls the risk bears the responsibility", "multiple parties share the responsibility", and "full-process supervision". The classification of autonomous driving technology is not to set differentiated legal regulations, but rather a tool for determining "who is actually operating the vehicle" and "under what road conditions the vehicle can be driven". It aims to achieve scientific and reasonable regulation of autonomous driving technology behaviors.

3. The core legal dilemma of liability in autonomous driving

Autonomous vehicles are not merely an upgraded version of conventional transportation means; they are intelligent mobile robots with the capabilities of environmental perception and decision-making. This technical characteristic means that the liability issues arising from this technology cannot be satisfactorily resolved within the traditional "person-car" binary framework. Whether it is the legal status disputes at the front end, or the failure of the attribution principle at the middle stage, ultimately they will inevitably be transmitted to the end stage of damage compensation and risk allocation, forming a series of interlinked legal dilemmas.

3.1. The problem of defining the responsible party

Regarding the issue of liability arising from autonomous driving, clearly defining the responsible party is the prerequisite and foundation for handling disputes related to autonomous driving liability, which has sparked numerous debates.

3.1.1. The controversy over the legal personality of autonomous driving system

It is definitely believed that to address the responsibility challenges posed by highly autonomous artificial intelligence, it may be advisable to grant limited legal personality or "electronic personality" to advanced autonomous systems such as L4/L5 level autonomous vehicles. The

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European Union proposed in a related proposal to establish an "electronic personality" for highly autonomous robots and required owners to purchase mandatory liability insurance. This idea provided a reference for the affirmative view. The negative view is also known as the tool/object view and currently holds the mainstream position. This theory holds that autonomous vehicles are essentially "objects" or "products" in the legal sense and do not possess independent will or civil liability capacity. The tort liability caused by them should still belong to the human subject behind it. Professor Liangfang Ye also pointed out that artificial intelligence does not have the ability to form intentions or bear responsibility and cannot be an independent subject [3]. In the first domestic case of an L2-level assisted driving tort case, the court clearly determined that the system was merely an auxiliary tool, and the driver was primarily responsible for failing to fulfill the monitoring obligation, which confirmed the practical value of the negative view.

The compromise proposal attempts to reconcile the two previous viewpoints and, within the current legal framework, classifies the autonomous driving system as "the driver" in terms of functionality. The National Highway Traffic Safety Administration (NHTSA) of the United States stated in an early reply to Google's letter that vehicles controlled by the autonomous driving system can consider the system itself as a "driver" in the context of federal regulations [4]. In the L4-L5 level fully autonomous driving scenarios, the system becomes the actual controller, and placing full responsibility on the human subject is unfair, but directly granting it legal personality would also exceed the current legal framework. Regarding this, we should be achieved through mandatory insurance or compensation fund mechanisms, with the ultimate risk still being anchored on the human subject."

3.1.2. The complexity of responsibility allocation involving multiple stakeholders

The research, production and operation of autonomous vehicles involve a wide range of aspects, and the rules for allocating responsibilities among multiple parties also have significant differences, which makes the single responsibility entity model unsustainable.

In traditional automotive accidents, liability is mainly attributed to the driver and the manufacturer. However, the development, production, and operation of autonomous vehicles involve multiple entities such as car manufacturers, algorithm software providers, data service providers, vehicle owners/users, and operation enterprises. The extension of the liability chain makes it extremely difficult to accurately identify the source of liability. Additionally, there are blurred areas of responsibility during human-machine interaction, especially in the case of L3 level conditional autonomous driving, where issues such as the timing of system takeover requests, the clarity and timeliness of takeover prompts, all become points of contention in liability determination. If the system fails to prompt timely for takeover, resulting in an accident, the attribution of liability becomes unclear. Moreover, the traditional liability determination standards centered on "operation control" and "operation interests" have separated in the context of autonomous driving. The autonomous driving system holds the actual operation control rights, while vehicle users enjoy the operation interests. Directly applying the traditional standards to determine liability entities can easily lead to unfair liability distribution.

In conclusion, the determination of the liability entity for accidents involving autonomous vehicles has fallen into a dual predicament of "unclear legal status and diversified liability entities", and it is urgently necessary to conduct systematic improvements at both theoretical and institutional levels.

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3.2. The selection and application of the principle of liability

The principle of liability attribution is the core of determining tort liability ,which directly affects the protection of the rights and interests of the victims. The traditional tort liability system for motor vehicles in China mainly adopts the principle of fault liability, with the principle of no-fault liability serving as a supplement. However, this system is difficult to meet the requirements of the autonomous driving scenario.

The application difficulties of the fault liability principle mainly apply to traditional motor vehicle traffic accident liability, with the core being to investigate the driver's driving mistakes. However, for accidents caused by system failures or other reasons in the autonomous driving scenario, victims cannot obtain the core data of the algorithm and thus have difficulty proving that the carmaker or technology supplier is at fault. If` human users are still regarded as the core for liability determination, it may result in the victims being unable to receive compensation, which is not conducive to protecting the rights and interests of the victims.

To overcome the limitations of the liability for fault, our country has stipulated the no-fault liability of the vehicle owner in certain circumstances, also known as the liability for danger. Some scholars advocate that autonomous vehicles fall under highly dangerous operations and should apply the no-fault liability principle. The car manufacturers should bear the main responsibility, and the victims do not need to prove the fault of the infringer. However, the application of the no-fault liability principle also has obvious controversies: on the one hand, it may increase the burden on the car manufacturers, affecting the development of the autonomous driving industry; on the other hand, in accidents with complex causal relationships, it is difficult to determine the responsibility proportion of each liability subject.

Therefore, when it comes to accidents involving autonomous vehicles, should we follow the principle of fault liability or adopt the principle of no-fault liability? No conclusion has been reached yet.

3.3. The intelligent improvement of damage compensation and risk sharing mechanisms

When an autonomous vehicle causes an accident, determining who is responsible is only the first step. How to ensure that the victims can smoothly receive compensation and prevent the related enterprises from going bankrupt due to a single accident requires a well-established mechanism , which currently faces great challenges.

3.3.1. Traditional insurance "does not match the illness"

On the one hand, insurance is the most important tool for risk sharing. The current compulsory insurance is purchased by car owners to cover the risks they face as drivers. However, in the case of autonomous driving mode, the real risk creators are the car manufacturers and software providers [5]. It is unreasonable for drivers to buy insurance for the defective products they provide. On the other hand, insurance companies do not know how to set premiums. Traditional auto insurance considers factors such as age, driving experience, and violation records of the driver [6]. But the risks of autonomous driving depend on the reliability of the algorithm, the accuracy of the sensors, and so on. Insurance companies do not have historical data to assess new risks, and thus cannot set premiums accurately.

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3.3.2. The absence of a "safety net fund" to deal with major accidents

In the event of a serious accident involving multiple people, the compensation amount could be extremely high, and a single automaker may not be able to bear it. Currently, our country has not established a public compensation fund for the entire autonomous driving industry. As a result, victims may face a situation where "the companies can't afford to compensate and they have nowhere to turn for help."

3.3.3. The risk-sharing entity is single

So far, the compensation liability for autonomous driving accidents has mainly been borne by drivers or car manufacturers. The responsibilities of technical suppliers and other entities have not been fully reflected. The risks are overly concentrated on a few entities, which is not only detrimental to providing multiple channels of relief for the victims, but also not conducive to the sustainable development of the industry. In summary, the current predicament is as follows: It is difficult for victims to prove their defects. Traditional insurance wrongly insures the wrong parties and cannot set the price. And there is no mature liability allocation mechanism in terms of the maximum risks.

4. Analysis of liability for infringement in autonomous driving

After sorting out the practical challenges such as the identification of liability subjects, the adaptation of liability principles, and the damage compensation mechanism in the field of autonomous driving infringement, the research on autonomous driving infringement liability needs to analyze the core issues such as the composition of liability and the basis for liability attribution from a legal perspective.

4.1. Analysis of the theories and paths of determining the responsible party

Regarding the determination of the liability entity in cases involving autonomous driving, there are various theories in the legal field. The core controversy lies in whether artificial intelligence can and should become a legal subject, and how responsibility should be allocated under different levels of automation. At present, the "negative theory" is the mainstream position, strictly follows the binary division of legal entities and objects, and defining the autonomous driving system as a "thing" or product in the legal sense. The advantage of this approach is that it maintains the stability of the legal system, but when dealing with highly automated systems, traditional product defect liability or fault liability rules may lead to ambiguous attribution chains or insufficient relief for victims. The "positive theory" has proposed a more forward-looking "electronic personality" concept, aiming to combine "electronic personality" with compulsory insurance or compensation funds. This approach attempts to respond to the system's autonomy in a formal sense while distributing the economic compensation risk in a substantive manner. As a compromise, the "moderate theory" adopts a more functionalist and pragmatic improvement path. It focuses on interpreting and supplementing within the current liability system, essentially constructing a hierarchical liability model: the autonomous driving system assumes the initial responsibility as the behavior controller, and through institutional arrangements, the compensation burden is ultimately allocated to the risk creators and beneficiaries. This view combines legal stability and technical compatibility, and is more in line with the current legal needs of the ruler of law in China.

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Based on the above analysis, the determination of the liability entity for autonomous driving infringement should take into account the technical characteristics, current legal rules and social development needs. Based on the classification of autonomous driving technology and application scenarios, and drawing on the strengths of various theories, a composite liability system with flexibility and operability should be constructed.

4.2. Conflict and coordination of attribution principles

The highly autonomous decision-making capability of the autonomous driving system has led to a gradual shift of the control center of vehicles from traditional vehicle drivers to the developers and producers of the system. The liability system based on human driver's faults and duty of care has fallen into a predicament. As the producer providing the autonomous driving system, the product liability of the producer shows a trend of replacing the driver's liability [7]. If producers are allowed to claim exemption by citing "the technological level at the time of product release was unable to detect the defect", it will seriously harm the rights and interests of the victims. Moreover, the scope of liability subjects has also expanded due to the complexity of technology, and algorithm designers, software suppliers, high-precision map service providers, etc. may all be included in the scope of liability investigation. The complexity of internal liability division has been significantly increased.

To address the above-mentioned attribution dilemma, the application of attribution principles can be dynamically adjusted according to the different levels of autonomous driving. For low-level assisted driving, the traditional rules based on driver fault liability can still be applied; while for high-level autonomous driving, the core is to strengthen product liability, along with special evidence rules. For example, for producers, the "burden of proof reversal" can be applied, requiring them to prove that the product is defect-free, thereby balancing the litigation capabilities of both parties and compensating for the weak evidentiary position of the victim.

4.3. The establishment of the mechanism for distributing responsibilities and risks

Facing the potential huge claims resulting from the risks of autonomous driving systems, the excessive burden on producers, and the lengthy litigation procedures, a single insurance model is unable to cover the complex responsibilities arising from the transition from assisted driving to fully autonomous driving systems [8]. The current mainstream academic viewpoints and comparative legal practices have paid significant attention to the "double-layer insurance framework" composed of "compulsory liability insurance + product liability insurance". The first layer of this framework involves transforming the existing motor vehicle accident liability compulsory insurance to cover the tort liability of autonomous vehicles, providing rapid and basic protection for the victims. The second layer is to establish an autonomous vehicle product liability insurance, specifically targeting the product liability risks of producers, to disperse the tort compensation liability caused by system design flaws, algorithm errors, etc., and ensure the sufficiency of compensation funds. This is the key innovation in the double-layer framework. This framework not only provides timely protection of the rights and interests of victims but also offers a risk buffer for the development of the autonomous driving industry, and is an effective path to balance rights protection and industrial innovation [9].

In conclusion, the implementation of liability for autonomous driving cannot be achieved without the corresponding risk-sharing mechanism. The multi-level relief system is not only a "safety net" for the rights and interests of the victims, but also a "stabilizer" for the sustainable development of

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the autonomous driving industry. Ultimately, it will achieve a dynamic balance between safety and innovation within the framework of the law.

5. The construction path of the liability system for autonomous driving in our country

The legal issues brought about by autonomous driving are wide-ranging and highly technical. Patching them piecemeal is no longer sufficient. Therefore, a comprehensive approach is needed to establish a set of responsibility systems that can balance technological innovation and rights protection. This will ensure that victims can receive timely and fair compensation in case of accidents.

5.1. Definition of responsibility entities: establish a hierarchical framework for identifying responsibility entities

Abandoning the all-or-nothing debate on legal personality, based on technical classification, a dynamic and hierarchical framework for identifying responsible entities is constructed. For L0 to L3 level autonomous vehicles, the system is defined as a driving assistance tool and its independent legal personality is not recognized. According to the actual ownership of "operation control" and "operation benefits", combined with the specific circumstances of human-machine interaction, the responsibilities of car manufacturers, technology suppliers, vehicle owners/users are divided; for L4 and L5 level highly autonomous vehicles, through legislation, the functional "driver" status of the system is clarified, and it assumes the initial liability for compensation. At the same time, the ultimate liability is anchored in the human subject behind it, namely car manufacturers, algorithm software suppliers, etc. The ultimate liability for compensation is divided based on their degree of fault and risk control ability.

In light of the feature of multiple stakeholders' participation, the liability allocation rule of "initial compensation + final recovery" is established. The vehicle owner/operating party shall bear the initial compensation liability to the victim, ensuring that the victim receives timely relief. After the compensation, the vehicle owner/operating party can, based on the final liability determination result, pursue recovery from the responsible auto manufacturers, technology suppliers, etc., to achieve the final reasonable allocation of responsibilities.

5.2. Selection of liability principle: establishing a dual liability system and a system of reversing the burden of proof

In terms of the principle of liability attribution, a dual system centered on product liability is established. Based on the cause of the accident, the principles of no-fault liability and fault liability are reasonably applied, and the reverse burden of proof rule is also implemented to balance the litigation capabilities of both parties. For accidents caused by the inherent defects of the system, the no-fault liability principle is given priority, and the burden of proof is shifted to the producer. The victim only needs to prove the occurrence of the accident, the damage consequences, and the causal relationship between the two. For accidents caused by improper intervention, abuse of the autonomous driving system, failure to fulfill reasonable duty of care, etc., due to human factors, the fault liability principle is applied, and the party at fault shall bear the corresponding tort liability. The liability ratio shall be determined based on the degree of fault.

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5.3. Damages compensation and risk assumption

A socialized and multi-level guarantee mechanism for damage compensation and risk sharing should be designed. It is required that automobile manufacturers and suppliers of autonomous driving systems purchase sufficient product liability insurance to cover compensation for product defects. After an accident occurs, the compulsory insurance should be prioritized for compensation within the liability limit. The remaining part can then be covered by the product liability insurance [10]. When the insurance company makes the compensation, if the accident is ultimately determined to be caused by the product defect of the producer, the insurer of the compulsory insurance has the right to claim compensation from the insurer of the product liability insurance of the producer. Through the combination of "product insurance + compulsory insurance industry fund", the risk can be effectively dispersed among producers, consumers and the entire industry, ensuring the relief of victims, and promoting the sustainable development of technology.

6. Conclusion

The research on the liability issues of autonomous driving reveals the profound impact of technological innovation on the legal system. Through a systematic analysis, this paper shows that the core legal dilemma of autonomous driving stems from the transfer of control rights from human drivers to algorithm systems and product manufacturers due to its technical characteristics. This transfer has led to problems such as blurred liability entities and difficulties in proving causality. Therefore, through a systematic analysis, this paper proposes to establish a liability system oriented towards risk control and applicable in a hierarchical manner. The core of this system lies in flexibly adjusting the proportion of application of the principle of fault liability and the principle of product liability according to the different levels of autonomous driving (L0-L5), and including producers, algorithm providers, etc. as liability entities. This study also recognizes that the technology of autonomous driving is evolving rapidly, while legal research has a certain lag and is difficult to fully cover the legal problems brought about by higher-level autonomous driving in the future. Moreover, the proposed institutional conception has an implementation process full of practical challenges. Therefore, the legal research on the liability issues of autonomous driving must maintain openness and dynamics, closely follow technological evolution and judicial practice, and promote China from the adaptive revision of current laws to the formulation of clear rights and responsibilities, effective regulation design, and a complete chain of production, operation, and law provisions, laying a solid legal foundation for the intelligent mobility era.

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