An Economic Analysis of the Legal Liabilities of GNSS

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Abstract

GNSS (Global Navigation Satellite System) technology is widely used presently and many private as well as national actors are entering the market. While national actors such as the United States in the case of GPS are generally exempted from both tort and contractual liability, private actors, such as Galileo in the EU and QZSS in Japan, are generally not immune from liability. In order to enhance private GNSS businesses, there is an international debate as to whether it is necessary to set up a new treaty on the liability of GNSS managers. This paper provides a basic economic analysis of the legal liability of the various parties. While the international debate focuses on the strict liability of GNSS managers and the exclusive channeling of liability, this paper argues against these ideas. It is well known in the literature that strict liability schemes are desirable in unilateral care cases, while negligence liability schemes are desirable in bilateral care cases. Since most of the cases in which GNSSs raise liability issues involve bilateral care in the sense that GNSS receiver makers and consumers, as well as GNSS managers, need to engage in precautionary behavior, it is socially optimal to adopt negligence-based liability schemes in general. Strict liability schemes would cause insufficient precaution on the part of GNSS receiver makers and consumers and would result in increasing the number of GNSS-caused accidents. In contrast, negligence liability schemes would provoke effective precautionary behavior on the part of GNSS receiver makers and consumers as well as GNSS managers and would thus deter GNSS-caused accidents efficiently.

I. Introduction

GNSS (Global Navigation Satellite System) technology is widely used presently. The most popular GNSS is the GPS (Global Positioning System) of the U.S., and innumerable services rely on GPS, such as automobile navigation services, ship navigation services, smartphone applications, and time adjustment services. While GPS is operated by the U.S., many other countries are also entering the GNSS market: GLONASS of Russia, Galileo of the EU, BeiDou and Compass of China, QZSS of Japan, DORIS of France, and IRNSS of India.

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GNSSs are expected to send out signals regularly, but it is not possible to send out accurate signals all of the time: space debris may hit GNSS satellites, causing their malfunctioning; solar storms may change the state of the ionosphere and influence the accuracy of GNSS signals; some components of GNSS satellites may come to the end of their product lifetimes and stop working; operators on the earth may send wrong instructions to GNSS satellites; and persons on the earth may be using GNSS jammers or other equipment that causes nearby receivers to malfunction. When signals from GNSS satellites are inaccurate, receivers can show considerable errors. For example, on January 2, 2004, one of the GPS satellites sent out incorrect signals that caused errors of up to 600km.

When GNSSs send out incorrect signals and GNSS receivers cannot acquire exact position or time information, such errors can lead to a variety of accidents. Automatically driven cars may go out of lane, drones may crash into buildings, aircrafts may crash while attempting to land, the coast guard may not be able to search for and rescue people on wrecked ships, and high-frequency traders may lose earning opportunities because of their inaccurate clocks. In such cases, the injured parties are expected to require the GNSS operators or the receiver manufacturers to compensate them for their losses.

In the case of GPS, which is operated by the U.S. government, the solution is simple. As Gabriel (2011) explains, the U.S. government basically does not assume liability under U.S. law. Only the receiver manufacturers may face liability against the injured parties. However, other GNSS operators such as Galileo and QZSS are not state operators, and nor are they governed by U.S. law. These "private" GNSS operators, unlike GPS of the U.S. government, are not exempted from civil liability against the injured parties.

Because most GNSS services are provided without a fee, the risk of civil liability may deter private GNSS operators from providing general GNSS services. At the same time, the need to compensate victims and to achieve efficient precaution is apparent. In order to balance these conflicting factors, there is an international debate on the third party liabilities of GNSS services (UNIDROIT (2013)). However, the debate so far lacks an economic analysis of the issue. This paper provides the first attempt to analyze economically the issue of third party liability of GNSS services.

The paper proceeds as follows. First, section II describes a situation in which an inaccurate signal from a GNSS service causes an accident. The illustration is necessary in setting up an analytical framework to examine the third party liability in GNSS services. Next, section III provides an economic analysis of the issue. Building on this analysis, section IV critiques the UNIDROIT[1] debate. Finally, section V concludes.

1 UNIDROIT (the International Institute for the Unification of Private Law) is an independent intergovernmental organization, whose purpose is to study needs and

II. Illustration

As mentioned above, GNSS services are not expected to send out accurate signals at all times. Some of these risks are predictable beforehand and can be controlled by GNSS operators, while others are unknown and are beyond their control. It is impossible to ensure the accuracy of GNSS signal 100 percent of the time under current technology and GNSS operators usually offer Interface Specifications (IS) and Performance Standards (PS), which provide users with information such as the interface and service performance specifications required to develop GNSS receivers and applications.

Specifically, most GNSS services recognize the possibility of incorrect signals and try to inform receivers about the status of GNSS signals by sending alert flags and integrity status flags. When a receiver picks up an alert flag, it regards the sending satellite as unreliable and drops its signal from the position/time calculation. IS and PS define the lag between the status change of a satellite and the sending out of flags. During the lag, receivers cannot recognize that the signal is wrong and may miscalculate position and time. When flags are sent out in timely fashion as the IS and PS specify, the risk of miscalculation is relatively small. However, when the sending of flags is delayed, the risk can become substantial.

When such miscalculations occur, GNSS-navigated objects, such as drones, cars, and aircrafts, can invite accidents. The victims of accidents require compensation from the owners of the GNSS-navigated objects, the manufacturers of the GNSS-navigated objects, and the GNSS operators. The owners, who pay compensation to the victims, in turn require compensation or indemnification from the manufacturers and the GNSS operators. When a victim sues multiple defendants, it is a joint tort and we need to consider how the liability is shared among the joint tort feasors. When a victim sues only the owner, then we need to consider whether and how the owner can claim compensation from the manufacturers and the GNSS operators. In both cases, the important legal issue is how the loss is allocated among the victims, the owners, the manufacturers, and the GNSS operators.

III. Economic Analysis

In this section, we want to provide an economic analysis of the case depicted in section II. The basic assumption of our economic analysis is that the main purpose of tort law is to deter GNSS-related accidents and to achieve socially optimal levels of care and activity (Shavell (2004)).

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methods for modernizing, harmonizing and coordinating private law and to formulate uniform law instruments, principles and rules.

III.1. Level of Care

We first discuss how the liability system affects the level of care of various parties. As noted above, it is impossible for a GNSS service to send out accurate signals 100 percent of the time under current technology. If we wanted to avoid GNSS-related accidents completely, we would need to stop using GNSS technology, which would be socially inefficient. GNSS technology brings benefits to society and we need to balance its cost and benefits. The goal is to achieve socially efficient levels of accuracy of GNSS signals.

In order to achieve a socially efficient level of accuracy, we need to consider which liability system provides the most efficient level of precaution to reduce GNSS-related accidents. Understanding the multiple layers of GNSS-related accidents is helpful in analyzing the incentive issue.

The first layer of GNSS-related accidents is at GNSS operator level. If a GNSS operator increases the integrity of its GNSS service, the service becomes more reliable and the social benefit increases. In addition, the sending of timely alert and integrity status flags helps GNSS receivers to avoid miscalculations and leads to fewer accidents. Therefore, a GNSS operator can control the risk of GNSS-related accidents at a certain level. However, most GNSS operators are already exercising sufficient precaution and it is difficult for them to decrease the probability of incorrect signals even further.

The second layer of GNSS-related accidents is at manufacturer level. Because the fact that GNSS signals are not always accurate is widely known at manufacturer level, a manufacturer can reduce the risk of GNSS-related accidents by embedding a fail-safe system or avoiding the use of GNSS technology in the first place. For example, most car navigation systems rely on map data and gyroscopes as well as on GNSS technology. When the GNSS signal is inaccurate and tells a car navigation system that the car is going out of a road lane, the car navigation system stops relying on the GNSS signal and relies on map data instead. Most drones employ not only GNSS technology, but also cameras and sensors in order to avoid hitting objects. ICAO rules require an aircraft not to rely solely on GNSS technology while attempting to land, but to employ other technologies such as ground-based radars. However, ICAO rules do allow an aircraft to rely solely on GNSS technology while cruising. These rules are based on the idea that landing is a high-risk activity and that the reliability of GNSS is not sufficient by itself to support landing.

Given the incompleteness of GNSS signals, receiver manufacturers are the most important layer in deterring GNSS-related accidents. They can produce safer receivers by installing fail-safe systems and by limiting the use of GNSS technology. They can also tell purchasers of their products that these products are not perfect and that purchasers need to use them according to the instructions from the manufacturers.

The final layer of GNSS-related accidents is at owner level. Even when a manufacturer provides a receiver with fail-safe systems and detailed instructions, its purchaser (owner) may not use it in a proper manner. For example,

she may purchase a receiver of poor quality without a fail-safe system and climb a snow-covered mountain in winter, finally losing her way. She tries to send a distress call, but her receiver sends incorrect position information because the GNSS signal is unfortunately inaccurate and her receiver cannot interpret the position information correctly. The rescue team cannot reach her and she dies. If she had purchased a more expensive, high-quality receiver, she would not have died. Thus, owners can reduce the risk of GNSS-related accidents by acquiring the appropriate receivers for their particular situations and following the manufacturers' instructions.

Thus, in order to reduce the risk of GNSS-related accidents, it is necessary to let GNSS operators, manufacturers, and receiver owners take precautions. It is not sufficient to incentivize only GNSS operators, but to incentivize all relevant parties. A GNSS-related accident is not a unilateral care case, but is a bilateral, or more precisely, a multilateral care case. What type of liability system induces more efficient precautionary behavior in this case?

It is well known in the law and economics literature that strict liability does not achieve an efficient outcome in bilateral care cases. In contrast, strict liability with contributory negligence and negligence liability can achieve an efficient outcome. The reason why strict liability does not lead to efficient outcomes is that strict liability only requires one party to take precautions and allows the other parties a free ride, while strict liability with contributory negligence and negligence liability can induce all parties to take optimal levels of care in the equilibrium. In other words, strict liability gives no incentives to victims, which leads to socially suboptimal outcomes.

The next step is to consider whether strict liability with contributory negligence or negligence liability is better. The main difference between the two liability systems is that the former puts the residual risk on GNSS operators and manufacturers, while the latter puts the residual risk on owners. Another difference is that a negligence-based system, whether it is contributory negligence or negligence liability, can only influence the actor as long as she knows that all the relevant factors will be taken into consideration when judging her potential negligence. If particular factors that can influence this incentive and change the risk of GNSS-related accidents are not taken into account, a negligence-based system cannot induce optimal behavior.

Comparing the risk attitude of GNSS operators, manufactures, and owners, it is reasonable to assume that owners, who in general own the least in terms of personal assets, are the most risk-averse party, while GNSS operators and manufacturers are more risk-neutral parties.[2] Then the strict liability with contributory negligence under which GNSS operator or manufacturer is the

2 There are exceptions. For example, airline companies, which are owners of GNSS receivers and own large assets, can be regarded as risk-neutral.

residual risk bearer is more desirable than negligence liability under which the owner is the residual risk bearer.

Finally, we need to decide which party is the most efficient residual risk bearer under strict liability with contributory negligence. It should be considered that most GNSS operators are already doing their best to make their GNSS services more reliable. This is because GNSS operators are competing with each other and the reliability of their service is the most appealing point for their customers. GNSS operators already have sufficient incentive to reduce the risk of GNSS-related accidents even without the threat of civil liability. In contrast, manufacturers may not have sufficient incentive to take precautions, because consumers (owners) presumably do not have complete information about the risks of GNSS receivers and competition in the product market tends to be incomplete. Thus, under strict liability with contributory negligence, the manufacturer should be the residual risk bearer.

III.2. Levels of Activity

Next, we discuss the activity levels. In the case of GNSS-related accidents, we do not need to consider the activity level of GNSS operators. GNSS operators are sending signals to their target area and they cannot vary the quantitative rate of signals they provide. If a GNSS operator stopped sending a signal during a certain period each day, customers would not use its signal, instead relying on signal from other GNSS operators. A GNSS operator can control only the level of care – the quality of its signal.

In addition, it is also meaningless to consider the activity level of manufacturers. Of course, a manufacturer can decide how many receivers to produce and sell. However, the amount of sales depends on many other factors, such as the number and quality of competitors and demand from consumers. It is difficult for a manufacturer to control its activity level. Rather, its activity level is decided by the consumers (owners). A consumer can decide whether he purchases a GNSS receiver and how often he uses it. Thus, the only party that can control its activity level is the owner, not the GNSS operator or the manufacturer.

Based on this assumption, what type of liability system will achieve efficient activity levels? It is well known in the law and economics literature that strict liability achieves optimal activity levels of the tort-feasor, but excessive activity levels of the victim, while negligence liability achieves optimal activity levels of the victim, but excessive activity levels of the tort-feasor (Shavell (2004)). This is because those parties that bear the residual risk of accidents have an incentive to adjust their liability levels, while others do not have such an incentive. Then strict liability (with or without contributory negligence) puts the residual risk onto GNSS operators or manufacturers and causes inefficient activity levels of owners. In contrast, negligence liability puts the residual risk on the owner and induces optimal activity levels of owners. Because GNSS operators and manufacturers cannot change their activity levels, negligence liability does not cause excessive activity for them.

Therefore, when we consider achieving socially optimal levels of activity, negligence liability is the most desirable scheme. Strict liability, with or without contributory negligence, would cause excessive activity levels of owners. Owners may use GNSS receivers inappropriately too often under strict liability.

III.3. Price and Risk Evaluation

In order to analyze the relationship between manufacturer and owner, it is also necessary to observe the price levels of products (Shavell (2004)).

First, when consumers' knowledge about the risks of GNSS receivers is perfect, the liability system does not matter. Under any liability system, the level of care of the manufacturer becomes socially optimal and the amount purchased by the consumer also becomes optimal. This is because the level of risk a consumer assumes is reflected in the product price. For example, even if a manufacturer assumes no liability and exercises suboptimal precaution, the product price becomes higher and the manufacturer cannot maximize its profit.

Second, under more realistic settings, consumers' knowledge about the risks of GNSS receivers is not perfect. Consumers do not know how much risk they are assuming nor do they evaluate the amount of risk involved. When consumers' knowledge is not perfect, the risks assumed by consumers are not reflected in the product price; and manufacturers without liability to consumers do not have incentives to provide safer products. In order to induce efficient care on the manufacturers' side, it is necessary for manufacturers to assume liability (either strict liability or negligence liability).

In addition, manufacturers' liability can induce efficient transmission of risk information. Under strict liability with contributory negligence, a manufacturer can reduce the risk of assuming liability either by providing safer products or by providing risk information to consumers. Negligence liability also gives manufacturers incentives to provide risk information to consumers.

Among various liability systems, negligence liability puts the residual risk on consumers and can bring about inefficient purchasing behavior on the part of consumers, because consumers cannot evaluate the risks they are assuming. In contrast, strict liability with contributory negligence puts the residual risk on manufacturers and all that consumers need to do in order to achieve optimal purchasing behavior is to observe the market price. Thus, considering the amounts purchased by owners (consumers), strict liability with contributory negligence is the most desirable liability system.

III.4. Effect of Insurance

Finally, it is necessary to analyze the effect of insurance. While the use of insurance may not be popular among owners,[3] most GNSS operators and manufacturers are likely to purchase liability insurance. The existence of

3 There are some exceptions. For example, airline companies usually purchase insurance that covers liability against third parties.

liability insurance can change the incentives of various parties (Abraham (1986)).
Whether liability insurance can change the incentive of GNSS operators and manufacturers depends on the content of thier insurance policies. When an insurance company sets effective categories and charges different insurance premiums, its liability insurance can induce efficient behavior on the part of GNSS operators and manufacturers. In contrast, when the categories are coarse and the insurance company cannot differentiate among the insured parties, these parties engage in suboptimal behavior. Thus, it is desirable for insurance companies to control the insured parties through insurance policies.

IV. Critical Analysis of the UNIDROIT Debate

IV.1. Strict Liability vs Negligence Liability

There is a strong argument for strict liability in the UNIDROIT debate. It is argued that GNSS services can invoke serious and broad ranges of losses including disasters like nuclear power plant accidents, which should be deterred as much as possible by imposing strict liability on the GNSS operator.
However, GNSS operators argue against this idea and support their exemption from liability. They argue that the GNSS service is usually provided without a fee and that any imposed liability on GNSS operators would reduce the supply of GNSS services to a socially suboptimal level.
From the viewpoint of economic analysis, both arguments are wrong. First, whether the losses caused by GNSS services are serious or not does not influence the choice of liability system, apart from the bankruptcy-proof issue. The important point is establishing which factors we need to control in order to reduce the likelihood of GNSS-related accidents. Such accidents can be reduced by changing the precaution levels of GNSS operators, manufacturers, and owners. They can also be reduced by changing the activity levels of owners. Strict liability cannot control the precaution levels of owners, nor their activity levels. Therefore, strict liability of GNSS operators is not socially optimal. In contrast, strict liability with contributory negligence and negligence liability can control the precaution levels of multiple parties at the same time.
Second, because GNSS operators can reduce the risk of GNSS-related accidents, complete exemption of liability would cause inefficient precaution on the part of GNSS operators.[4] For example, GNSS operators can employ more reliable satellites and can emit an alert flag and integrity status flag as soon as possible when a GNSS satellite becomes unreliable. The possibility of liability, even quite a limited one, can induce efficient behavior in GNSS operators.

4 However, the argument against strict liability is appropriate in that the GNSS operator should not be the residual risk bearer.

IV.2. Exclusive Channeling of Liability

In the UNIDROIT debate, there is an argument that exclusive channeling of liability to the GNSS operator is desirable. The argument relies on the idea that GNSS receiver manufacturers may not have sufficient funds to compensate victims of GNSS-related accidents, while the magnitude of liability caused by GNSS-related accidents can be quite large.[5]

However, exclusive channeling of liability does not achieve a socially efficient outcome. Exclusive channeling of liability is another version of vicarious liability. When liability is exclusively channeled to a GNSS operator, it first compensates the victims and then files a claim for recovery against the manufacturer of the receiver. If the amount of the recovery claim exceeds the solvency of the manufacturer, the GNSS operator is forced to incur the remaining amount. Thus, exclusive channeling of liability to the GNSS operator has the same function as vicarious liability by the GNSS operator.

Whether vicarious liability is desirable or not depends on how effectively a principal can control the behavior of an agent (Shavell (2004)). When the principal can effectively control the agent, the former can induce the efficient behavior of the latter. In case of a GNSS-related accident, the GNSS operator cannot control the behavior of manufacturers in general. It is true that most GNSS operators publish IS and PS and request manufacturers to follow them. However, most manufacturers do not have contractual relationships with GNSS operators; they use GNSS signals unilaterally and do not have contractual obligations to comply with the requests of GNSS operators. Therefore, vicarious liability of GNSS operators cannot induce efficient behavior in manufacturers.

There are other legal techniques to overcome the problem of insolvency. For example, imposing minimal asset requirements, mandatory insurance, or direct regulation of manufacturers can achieve optimal behavior of manufacturers. Considering the possibility that GNSS signals diffuse across national borders, some of these regulations may not be implementable. However, others may still be implementable through import controls and may prove more effective than exclusive channeling of liability.

V. Conclusion

This paper analyzes the third party liability problem of GNSS services from an economic viewpoint. When we consider controlling the level of care as the most important factor, and where the risk-averse nature of owners is significant, strict liability with contributory negligence – where manufacturers of GNSS receivers are the residual risk bearers – is the most desirable liability

5 For example, when a GNSS-navigated aircraft crashes with the loss of life of all passengers and the destruction of ground ojbects, the overall losses will amount to billions of dollars.

system. However, when we want to control the activity levels at the same time, negligence liability becomes the most desirable option. The difference between the two alternatives is the allocation of residual risk. Whether we stress the risk-averse behavior or the control of activity levels determines the choice of alternatives.[6]

Considering the fact that most countries adopt optimal deterrence as the main purpose of tort law,[7] the economic analysis of this paper is expected to correspond to the interpretation of tort law in most countries, although there may exist subtle differences such as strict liability with contributory negligence versus negligence liability. When laws of most countries basically coincide and their content is expected to be socially optimal, there is little need to employ an international treaty to achieve harmonization of law. The decisions of the ICAO and UNIDROIT not to take any initiatives for making an international instrument for the moment are appropriate.[8]

References

Abraham, Kenneth S., 1986, *Distributing Risk: Insurance, Legal Theory, and Public Policy* (New Haven: Yale University Press).

Fried, Charles, and David Rosenberg, 2003, *Making Tort Law: What Should be Done and Who Should Do It* (Washington, D.C.: The AEI Press).

Gabriel, Henry Deeb, 2011, "The Global Positioning System: United States Government Liability – Real and Potential," *Paper* available at http://www.unidroit.org/english/workprogramme/study079/presentations/gabriel.pdf (Accessed September 4, 2015).

Shavell, Steven, 2004, *Foundations of Economic Analysis of Law* (Cambridge: Belknap/Harvard University Press).

UNIDROIT, 2013, "Third-Party Liability for Global Navigation Satellite System (Gnss) Services: The Proposed Unidroit Project," available at http://www.unidroit.org/work-in-progress-studies/studies/civil-liability/96-about-unidroit/workprogramme/530-third-party-liability-for-global-navigation-satellite-system-gnss-services-the-proposed-unidroit-project (Accessed September 4, 2015).

Widmer, Pierre (ed.), 2005, *Unification of Tort Law: Fault* (Hague: Kluwer Law International).

6 In general, the control of activity seems to be the more important problem and the negligence liablity tends to be desirable.

7 See Fried and Rosenberg (2003) and Widmer (2005).

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