Ethics and Policy Implications for Inclusive Intelligent Transportation Systems

Aaron Steinfeld
Robotics Institute
Carnegie Mellon University
5000 Forbes Ave
Pittsburgh, PA 15213

***Abstract* – Research experiments and product deployments of QoLT technologies for independent transportation have unique and profound ethics and policy concerns. Experimenters who run field studies can easily recount anecdotes involving real (e.g., crashes) and hypothetical (e.g., participant questions) scenarios where personal privacy concerns and legal requirements come into tension. Product deployment brings a new set of issues due to the absence of IRB protections. Examples include, but are not limited to, tracking people as they use transit systems or drive around town, liability for semi and fully autonomous vehicle actions, and variable driving risk based on geographic location.**

I. INTRODUCTION

Intelligent transportation systems provide significant benefits to end users but often include new ethics and policy dilemmas due to the increased use of sensing, tracking, and real-time behavior evaluation. In some cases, the lines of responsibility are also blurred due to automated decision-making, warnings, and vehicle control.

The large populations and often steep infrastructure costs associated with transportation technology place a premium on systems that exhibit universal design principles. Inclusive approaches are inherently preferable in that they support spontaneous travel, social participation, and increased familiarity with disability among members of the public unfamiliar with disability. There are also significant financial motivations for independent mobility within the community. Lack of transportation (29%) was only second to a lack of appropriate jobs being available (53%), as the most frequently cited reason for being discouraged from looking for work [1]. A one-month delay in nursing home admissions could save $1.12 B annually [2] and the loss of independent transportation is likely a major trigger for why some older adults move to nursing homes.

Many of the intelligent transportation systems discussed in this paper are mainstream technologies that can have a direct impact on the quality of life of people with disabilities and older adults through inclusive design. Therefore, mainstream concerns about ethics and policy become the same concerns for people who need accessible solutions.

A. *Institutional Review Board*

It is important to note the influence of Institutional Review Boards (IRB) on the ethics of research. Researchers at organizations which utilize IRB, like universities and other Federally funded organizations, often need to adhere to more stringent levels of conduct than what is found in typical commercial settings. IRB includes the notion of "informed consent" which involves making all risks, including loss of confidentiality, known to the participant. Consent is typically obtained through a signed document detailing these risks.

Since some of the cutting-edge technologies discussed in this paper are drawn from university research settings, it is important to note that this added layer of responsibility subsequently biases some of the observations in this paper. In the context of transportation, IRB is most often focused on the privacy and safety of the end user. Therefore these two topics are highlighted in their own sections. Having said this, liability is often king, even in the ivory tower.

II. LIABILITY AND OTHER COSTS

B. *Liability*

As implied, liability concerns can override all other factors. This is obvious in an industry context and a major reason for the relative conservative outlook of many transportation industries when compared to the software industry. For example, adaptive cruise control (ACC) was initially marketed in the United States as a convenience feature. Companies did not want the fact that ACC systems automatically slow the car to match speed with the leading vehicle to be interpreted as a relinquishing of responsibility by the driver. This fear is not unfounded – hypothetical scenarios where ACC could theoretically lead to a more severe collision due to overreliance have been crafted and debated [3].

In many research settings these sorts of critical scenarios are cataloged and used to develop action plans. If the vehicle with the experimental collision warning system is in a crash, what should the researchers do? Aside from retrieving the expensive sensor on the ground, should the driver also take steps to preserve the data? If the data should be safeguarded, how can an evidentiary trail be maintained? Should it?

Unexpected events occur and hard decisions need to be made on the fly. During a panel on ethics and privacy for on-road data collection [4], one researcher described two events recorded and discovered during a study. The first event involved the driver, alone on a rural road, casually steering into the oncoming lane in order to cut the corner of the intersection at high speed – including going off and back on the road. In the second case, a non-consented passenger was recorded planning threatening and potentially harmful acts to a third party. Should the researcher pick up the phone and notify the local police?

In the end, many of these issues may be overshadowed by concerns about liability. For example, if the non-consented passenger followed through on their plans, the third party could conceivably sue the university for failure to act. The risk of a multimillion-dollar lawsuit can be a powerful factor in the decision making of upper level administrators. To some degree, researchers and developers should keep their organization's lawyer on speed dial during field research.

A. *Costs*

Aside from exposure to risk, there are other costs that can affect engineering design decisions in a strong, clear manner. The street cameras used to manage traffic congestion are a good example. Some states prohibit the use of street camera data as legal evidence. However, others do not. During a site visit to a traffic management center, it was revealed that no video data was stored specifically because no such law existed. The center consistently received queries from lawyers trying to prove fault during crash cases and travel paths during divorce proceedings. There was a valid concern that employees would spend large quantities of time providing video data and be frequently called to the witness stand.

B. *Determination of Fault*

Aside from traffic cameras there are many intelligent transportation systems that can be used to discern fault during a crash. Whether consumers realize it or not, many cars now have short duration black box recording for speed and other engine data. Some of this data is transmitted to centralized servers in real time for emergency response service (e.g., OnStar). Some commercial vehicles and aftermarket products also include video recording.

Video data is widespread for transit vehicles. These are similar to security cameras in that there is a limited buffer of stored content and the content is typically only examined in the event of a critical incident. Examples include vandalism, threatening behavior, fights, falls, and crashes. There are serious financial motivations for these cameras – for example, being able to prove fraud by a passenger during a fall can forestall expensive legal procedures and potentially steep settlements. Surprisingly, fraudulent falls and claims of being on a bus during a crash are large costs for transit agencies. Fraud is such a problem that some agencies utilize additional procedures to ensure proof of ridership after critical incidents (e.g., closing the door and counting passengers, handing out cards to riders, etc).

In research settings, participants are often very attuned to the fact that such data is being collected and may ask how such data can be used for determination of fault in the event of a crash or potentially illegal act. It is becoming increasingly common for informed consent documents to include clear wording regarding what will happen if the organization is served with a subpoena for the data.

III. PRIVACY

A. *Expectations*

Within the transportation domain, privacy is really about expectations. People know they are in public but expect a certain level of privacy for the mode of travel they are using. (How many people pick their nose in the car?) Problems typically occur if a user expects a certain level of privacy and discovers it is actually much lower. Due to the nature of IRB, HIPAA, financial regulations, and the efforts of privacy advocates, scenarios where privacy really matters have mechanisms for remedying inadequate privacy. In many scenarios people have the ultimate option of not participating in an experiment or not using a product.

Disability and degree of functional assistance directly impact acceptance of privacy loss [5]. This is not surprising given that people with severe disabilities often enlist, or rely, on caregivers, transit providers, and other members of society to accomplish tasks and activities. To a degree there is an expectation that some privacy must be sacrificed to achieve certain goals.

This negotiation can be handled through strictly regulated methods or through the informal social norms of society. A good example of the former is the TTY relay system where government funded operators translates between text and speech when people who are deaf need to make a phone call. Regulations impose strict confidentiality rules due to the frequent transmission of very private data (medical information, credit card numbers, etc). Conversely, Golan [6] refers to "Nearest warm body" model when making phone calls before TTYs in public settings became prevalent. Being deaf, this involved enlisting the help of whichever passerby was willing to make a call on his behalf. Societal norms suggest an inherent agreement that the passerby provides some modicum of confidentiality when helping.

Similar expectations are present in transportation. Transit riders assume the same security camera use models they have come to expect in retail stores. Transit users with alcohol on their breath assume the operators and fellow riders will not reveal this information to others. Car drivers assume the RFIDs in their electronic toll collection devices (e.g., E-Z Pass) will not be used for speed enforcement between tollbooths. When these expectations are violated, either for real or imagined reasons, then end users may react strongly. Therefore, it is important to properly gauge the level of expected privacy and design systems accordingly.

B. *End User Privacy Control*

If some degree of privacy must be sacrificed, it is preferable to use an opt-in model rather than an opt-out approach. Opt-in is used in some RFID transit farecard (aka smartcard) systems. For example, both the Washington Metropolitan Area Transit Authority and Massachusetts Bay Transportation Authority allow riders to load smartcards using cash. Registration is optional and only necessary if riders want the ability to recover money stored on lost cards. Riders with significant privacy concerns can still pay fares in cash.

Some forms of opt-in are implicit in the interaction. OnStar users initiate phone calls to operators by pushing a button. While calls after airbag deployment and crashes can occur without driver action, operators do not listen to conversations in the car whenever they desire.

User determination of privacy levels does not need to be binary. There has been increasing interest in user control over levels of privacy, both through learned models and explicitly settings [7]. Similar methods can be used in transportation settings by tying privacy to location and travel modality. For example, a transit rider with a cognitive disability may want a caregiver or coach to be able to track movements and call in with corrective feedback [8].

C. *Data Handling*

Researchers familiar with IRB processes know that the easiest way to protect privacy is to avoid collecting identifiable data. This is often accomplished by either not matching participant identity to collected data or by using a confidential lookup table. Whenever possible, the goal is to collect inherently anonymous data.

These steps are often required for HIPAA data but can also be useful for non-research scenarios. There are very few reasons for sharing information matching a transit rider to their smartcard and access can be controlled.

Likewise, it is often best to only collect the data needed for the task at hand. Researchers working on projects where participants are tracked using GPS will often filter out data outside the geographical region of interest. They may also elect to not collect data in the participant's immediate neighborhood, thereby concealing the participant's address.

Collecting at an abstraction layer above the raw data is also possible. Automatically aggregating over a larger population conceals identities. For machine learning applications, it is often possible to only save coefficients and cost functions rather than storing raw data.

It is worth noting that privacy may be protected at the raw data level, but unprotected when combined with other data. For example, linking datasets containing mobile phone tracking and anonymous smartcards allows pinpointing paired data and specific individuals.

D. *Authenticity and Transparency*

The ability for the general public to convey information to transportation decision makers and service providers is a critical element of policymaking and ensuring high quality of service. While there are obvious scenarios where anonymity is important due to retribution or other risks, it is often important to include some method for ensuring the data is authentic. These mechanisms protect against negative practices like spamming, ballot stuffing, and astroturfing.

System designers should consider whether a middle layer can broker authenticity or if user identities need to be passed all the way to the data consumers. The latter can be done by third parties (e.g., consultants conducting focus groups) or through compartmentalization where the data collection unit of the transportation agency does the verification before passing anonymous data along to data consumers. For example, a transit customer service representative may collect a rider's name and contact information but not include the identifying data when passing a complaint to the relevant group within the agency.

General expectations of behavior suggest that the receipt of information should be acknowledged and, if possible, feedback should be provided to the consumer. For example, many web form systems send an automated email indicating confirmation of receipt and some include a tracking number and instructions on how to access the case should a response not be obtained. This transparency is important for preventing a "black hole" phenomenon where end users feel like their contribution is being ignored. The black hole problem can lead to low perceived benefit for engaging with the transportation agency (e.g., [9]).

IV. SAFETY

A. *Models of Operation*

There are two prevailing approaches to improving safety in the transportation community, each with their own policy implications. Knipling, et al [10] describe this in terms of a distribution of risk where there is a long tail beyond an unsafe risk threshold. One can attempt to "cut off the tail" (p. 35) through interventions or move the distribution towards safer behavior, thereby reducing the tail. The former include collision warning systems (e.g., [11, 12]) while the latter is focused on programs like seat-belt campaigns and commercial driver sleep regulations.

Shifting the distribution is particularly attractive when working with populations that have reduced capability. This is similar to the decisions some older drivers already make when they perceive loss of capability (e.g., not driving at night). By self-selecting out of difficult driving scenarios, these drivers shift their distribution. Recently there has been growing use of driver monitoring systems to provide objective measurements of behavior and encourage safer habits. Some systems can be paired with real-time alerts when systems detect hard accelerations and fast speeds.

Such systems are not uncommon in fleet vehicles and are starting to be used by the regular public [13]. Monitoring and coaching must walk a fine line; drivers may perceive the loss of privacy to outweigh the benefits. Systems with poor user interaction models run the risk of being perceived a nuisance. Work in drowsy driver monitoring [14] suggests that driver coaching systems that employ a "trusted advisor" interaction model can provide effective information in a manner that drivers will accept.

B. *Safety Interventions*

When designing systems that intervene during a safety critical scenario it is important to consider the ethical concern that the intervention may make things worse. This negative impact can either come in the form of confusion or overreliance.

Confusion can occur if the intervention is not understood by the user and distracts attention away from the critical incident. This problem is well documented in aviation (e.g., [15]) and has led to efforts standardize warning signals within personal vehicles [16].

There are specific trust and liability concerns related to intervention warnings. One issue uncovered during a transit collision warning system project was the concern that warnings intended for drivers might be misunderstood by riders or used as a "starting gun" for fraudulent rider falls [11]. The former centered on the belief that riders might loose trust in the driver's skills if they observed a large quantity of warnings.

An excellent example of how overreliance on a feature beneficial to drivers with reduced capabilities can lead to problems throughout the population is backup warning systems. These are warnings issued as a result of the vehicle sensing the presence of an object behind the vehicle during rearward motion. In a report to Congress, the National Highway Traffic Safety Administration found the reliability of some systems to be poor and, worse, in some case misleading [17]. This, paired with high driver confidence in such systems [18], is problematic and demonstrates a challenging ethical quandary for designers and producers of these systems.

V. SOCIETAL FACTORS

A. *Personal Benefit vs. the Greater Good*

Personal vehicles and transit have numerous cases where ethical debates occur on personal benefit vs. the greater good. Some of these debates have direct impact on the transportation independence of people with disabilities and older adults. Examples include, but are most certainly not limited to, defining older driver licensing regulations, dedicating more funds to improve paratransit service quality, and setting thresholds in vehicle safety regulations.

Innovative technologies are being explored to mitigate the divide between parties. Research on more efficient routing and vehicle dispatching is a good example of how better paratransit service might be achieved at lower cost levels.

B. *Trust in Government and Industry*

An organization's desire to avoid certain activities and/or business practices have a direct impact on the viability and design of a proposed technology. This often manifests in clear boundaries of what an organization is willing to do, privacy policies, and codes of conduct. While these policies may not be explicitly based on the notion of consumer trust, they often manifest in this manner. The famous Google "Don't be evil" motto [19] is a well-known example of a technology organization establishing consumer trust as a result of internal policies.

The idea that internal policies can affect trust is present in intelligent transportation systems too. For example, during the course of a research project on interventions for drunk driving, one state Department of Transportation reported their traffic camera system could not be used for enforcement. The research team had inquired about the idea of using the traffic cameras to automatically detect drunk driving behavior and notify the state police for intervention. This resistance was based on the concern that participation in enforcement activities would put their roadside employees at risk. Contacts reported that it was not uncommon for drivers upset with construction to throw objects at roadside workers. There was concern that similar behavior might be employed as a direct result of participation in enforcement.

C. *Regulations*

The transportation realm is filled with regulations that can intersect with technology development and impact design choices. The Americans with Disabilities Act has had enormous impact on transportation independence within the transit sector. It is conceivable that the popularity of low floor buses, which are inherently inclusive for all riders due to the lack of stairs, can be traced to policies enacted by the ADA and similar laws.

In some cases regulations are well known to end users and directly affect their acceptance of technology. For example, older drivers know that doctors can request license revocation and are required to report patients they deem to be unfit to drive. This knowledge manifested in survey data on who should have access to various personal data. There was a dip in acceptance for doctors when comparing driving data to vital signs, medications, toileting, etc [5]. Driving data followed comparable patterns to the other data when discussing data sharing with family members and researchers.

Wiretap regulations can also affect technology design decisions and research projects. Some states prohibit audio recordings of people without their consent. The example of the non-consented driver planning ill will occurred in a state where such recordings were legal. In another state, no audio would have been recorded and the plans would never have been recorded.

VI. EXAMPLES

This section explores the ethical and policy issues associated with a few selected examples of intelligent transportation systems designed to support quality of life through inclusive design. *DriveCap* is a project within the Quality of Life Technology Center (QoLT) focused on measuring driver capability and providing trusted advice to the driver so they can make informed judgments on their driving habits. The same technology could also be used to assess driver capability during driver rehabilitation therapy. The subsection on *Crowdsource Transit Information* is focused on research being conducted in the Rehabilitation Engineering Research Center on Accessible Public Transportation (RERC-APT) on mobile rider information systems. Both sets of technology are focused on universal design solutions where end users may or may not be people with disabilities or older adults.

A. *DriveCap*

As mentioned earlier, driver monitoring systems are becoming increasingly common. Most systems are focused on relatively broad behaviors and are not suitable for measuring driver capability. This project is looking ahead to when better sensing will be present in all cars, not just luxury vehicles. For example, a luxury car may already have a forward range sensor for ACC, GPS for OnStar, and assorted accelerometers for various other functions. Some of these systems are already present in low and mid-range cars. By combining data from these sensors it is already possible to examine following behavior (tailgating), turn handling, and speed control.

The team is pursuing the trusted advisor model for two reasons – both touched upon in earlier sections. First, there is the clear issue of liability. Sensing human capability is a noisy and challenging task. Even Certified Driver Rehabilitation Therapists (CDRS) will sometimes cycle through the same scenario during on-road evaluations in order to discern actual driver performance. It is very difficult to make consistent, accurate judgments using low-cost sensors. Therefore, the team is focusing on reporting data and leaving judgments to the driver and/or CDRS.

Second, by serving as an advisor to the driver, rather than an automated insurance or government reporter of driver safety, collected information becomes owned and managed by the driver. This accounts for the findings that sharing of driving data with people outside the immediate family is less desirable [5].

Having said this, one potential application is to use monitoring to manage drivers with specific capability weaknesses. While largely underutilized, it is possible for governments to maintain transportation independence through graduated licensure rather than revocation at the first sign of trouble. Graduated licenses, often used during teenage years, can also be used for older drivers on a case-by-case basis [20]. Example limitations include nighttime, highway, and geographical area restrictions. Governments might be more open to using graduated licensing if they have more insight on actual driver capability and information on which restrictions are appropriate for each driver.

B. Crowdsource Transit Information

A major factor for accessible travel through public transit systems is information. The ADA and other laws stipulate that transit should be accessible to riders with disabilities yet in many cases barriers exist solely due to the scale and complexity of the transit system. Agencies lack the resources to canvass their entire system and document barriers. Riders need to know if elevators are broken, buses are too full for a wheelchair, and a whole collection of other small yet important details.

The team believes that two-way feedback between riders and providers is the key to supporting best practices and propose that technology can be used to streamline this interaction. In particular, there is real promise in the use of citizen science – the application of rich media evidence to civic advocacy [21].

There are many examples that demonstrate the value of using this form of data collection. Major network news channels, accident reconstruction teams, courts, and law enforcement routinely utilize information obtained by citizens on camera phones and camcorders. The popularity of YouTube and similar sites demonstrates the potential for using these methods as a means of civic engagement and public discourse. For example, YouTube videos of transit bus features are regularly produced by amateurs and popular enough to accumulate thousands of views each.

ParkScan.org is an example where this model has led to positive improvements. In 2007 alone, ParkScan had 425 registered users, 1,531 observations, and 68% of the issues identified by end users were addressed by the City [22]. Likewise, Pittsburgh and other municipalities now have iPhone applications for reporting problems directly to city offices (e.g., iBurgh).

However, there is evidence that transit systems may require additional features to support large-scale reporting habits. Interviews and interaction concept testing by the team [23] has revealed that riders rarely encounter infrastructure problems that meet the perceived cost-benefit threshold for reporting. The aforementioned black hole effect has suppressed the perceived benefit of reporting compared to the perceived cost of pausing and filing a report while moving through the system. As a result, the team's view is that observation reporting should be part of a larger system that includes valuable, frequent information (e.g., arrival times, vehicle fullness, and dynamic route changes), thereby streamlining the infrequent desire to report observations and lowering the cost. This approach gives riders many different reasons to remain engaged with the system – hopefully increasing the rider's willingness to collaborate with the agency – and supports pre-loading of important real-time details (e.g., current location, route, etc).

In fact, riders with disabilities have reported real-time information about the arrival time of nearby buses as being especially important. This knowledge helps mitigate exposure to inclement weather, reduces risk of theft, and provides insight on if a bus is even on the way. This information is also helpful for riders with cognitive disabilities [8]. Along a similar lines, riders who use wheelchairs want to know if the bus they are waiting for has enough room for their wheelchair or if the ramp/lift is broken.

Accurate arrival time is information all riders want, not just people with disabilities. Some agencies report ridership increases as high as 40% on specific routes when providing real-time predictions [24]. Real-time information about bus arrival is typically accomplished using automatic vehicle location (AVL) systems. Unfortunately, such systems are expensive and sometimes encounter institutional barriers within transit agencies. Due to this gap, the team is developing a system to use GPS data from riders' mobile phones to generate AVL data. This clearly introduces ethical concerns about tracking and privacy. The team has approached this from the perspective on an opt-in model and is designing the system to only log movements between bus stops (i.e., within the transit system). Such filtering is also useful from the perspective of keeping walking data out of the vehicle arrival estimation calculations.

VII. CONCLUSIONS

These observations are only a small window on the ethical and policy implications of introducing inclusive intelligent transportation systems. These examples show how mainstream concerns about ethics and policy in the transportation domain become the same concerns for people who need accessible solutions. This highlights the importance of using universal design approaches when resolving ethical and policy concerns.

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