Article

Autonomous Rail Technologies: Diffusion, Risk Perception & Public Acceptance

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Currently, autonomous-vehicle technology is in the nascent stages of its public debut, only recently gaining widespread attention amongst average consumers. And while isolated examples of autonomous transport have existed for decades,[1] the possibility of a broadly implemented driverless-vehicle network will force consumers, for the first time, to grapple with conventional adoption choices that accompany the roll out of most disruptive innovations.

While public comfort and willingness to adopt has important consequences for all forms of driverless-transport technology, this aspect of social determination will play a particularly unique role in the context of autonomous freight-rail transportation, where the general public will face not the option to use or reject the technology, but rather some degree of involuntary exposure to it. Public comfort with this exposure will be critical for railroads as they work to transition to autonomous operations, especially given the significant scrutiny this shift will receive from regulators, who are highly attuned to public fears and safety concerns surrounding new technology.

1. *See* Carl Franzen, *Why Don't We Have Driverless Trains Yet?*, MOTHERBOARD (Jan. 8, 2015) (noting that "the first completely automated subway train went into service in New York in 1961, and a crewless freight train system was tested in Canada a year later").

As such, this paper first provides an overview of the literature addressing factors that affect diffusion of and risk tolerance for new technologies – especially those where safety concerns add significant dimensional complexity – with the goal of highlighting how autonomous freight-rail operations might attain a level of public acceptance broad enough to reorient the regulatory outlook from its current state of resistant apprehension to a more dynamic, forward-looking mindset open to technological progress and collaboration. Second, it touches on the extent to which new innovations, and in particular IoT technologies such as PTC, can become a platform for further advances not anticipated at inception.

I. Diffusion, Risk Perception, & Public Acceptance of Autonomous Technologies

Given that public acceptance of autonomy will be a key factor in the railroad industry's ability to adopt autonomous technology, especially vis-à-vis regulatory oversight and approval of the technology's development and eventual deployment, it is important to understand what might drive that acceptance. Since Everett Rogers's seminal 1962 work, *The Diffusion of Innovations*,[2] substantial literature has addressed this question. Accordingly, this section will first provide an overview of that literature and examine a potential path for adoption and diffusion of autonomous-passenger-vehicle technology amongst the general public. It will then describe how public adoption, coupled with other salient factors, could sway societal risk perception such that the public would be willing to accept exposure to driverless freight-rail operations, thereby minimizing the possibility that social angst over autonomous technologies might irrationally prejudice regulators.

A. Factors Influencing Adoption of Autonomous Passenger-Vehicle Technologies

A significant number of vehicle manufacturers and transportation providers have indicated their intent to offer autonomous passenger transportation in the very near term, with numerous commitments to provide autonomous-vehicle technology for mass-market consumption in the next two to five years.[3] While there are many considerations that might

2. Everett M. Rogers, Diffusion of Innovations (3d Ed., The Free Press 1983) (1962).

3. *See, e.g.*, *Autonomous 2021*, Ford, https://corporate.ford.com/innovation/autonomous-2021.html (last visited June 7, 2018); *Toyota Announces New Company Devoted to Self-Driving Cars*, The Wall Street Journal (Mar. 2, 2018), https://www.wsj.com/articles/toyota-announces-new-company-devoted-to-self-driving-cars-1519976923; *GM: Self-Driving Cars Are Our Next Big Thing*, CNN (Nov. 30, 2017), http://money.cnn.com/2017/11/30/technology/gm-autonomous-

affect an individual's willingness to adopt this new technology, literature keying off of Rogers's research indicates that five factors will likely play a key role: (1) relative advantage; (2) compatibility; (3) complexity; (4) trialability; and (5) observability.[4]

Recent surveys indicate that consumer perception of self-driving cars aligns favorably with these factors. For example, several surveys indicate that consumers perceive multiple relative advantages of autonomous vehicles over manually operated vehicles, with safety enhancements ranking most highly.[5] Further, autonomous vehicles are compatible with consumer needs,[6] are not overly complex (at least with respect to overt functionality),[7] easily lend themselves to consumer testing and trials (e.g., dealership test drives, experience with driverless taxis),[8] and can be easily observed in action on the road. Of course, were technical problems to arise, such issues could significantly diminish any perceived safety benefits, perhaps even converting this factor to a relative disadvantage. Discrete catastrophic events could especially amplify this issue.[9]

B. Innovation-Diffusion Theory Applied to Autonomous Passenger-Vehicle Technologies

Assuming no major safety incidents, however, innovation-diffusion theory, coupled with public opinion surveys, suggests conditions may exist for swift diffusion of autonomous-vehicle technology. The heart of in-

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cars-2019/index.html?iid=EL; *BMW Plans to Take on Mercedes by Releasing a Fully Driverless Car by 2021*, Business Insider (Mar. 17, 2017), http://www.businessinsider.com/bmw-to-rival-mercedes-with-level-5-driverless-car-in-2021-2017-3; Philip E. Ross, *CES 2017: NVidia and Audi Say They'll Field a Level 4 Autonomous Car in Three Years*, IEEE Spectrum (Jan. 5, 2017), https://spectrum.ieee.org/cars-that-think/transportation/self-driving/nvidia-ceo-announces.html.

4. *See, e.g.*, Evan T. Staub, *Understanding Technology Adoption: Theory and Future Directions for Informal Learning*, 79 Rev. of Educ. Res. 625, 630 (2009); *see also* Rogers, *supra* note 2, at 15-16.

5. *See* Prateek Bansal, Kara Kockelman, & Amit Singh, *Assessing Public Opinions of and Interest in New Vehicle Technologies: An Austin Perspective*, 67 Transp. res. Part C: Emerging Tech. (2016); Nikhil Menon, *Consumer Perception and Anticipated Adoption of Autonomous Vehicle Technology: Results from Multi-Population Surveys*, Scholar Commons: Univ. S. Fla. (2015) (with respondents also noting "more productive use of time" and "less stressful driving experience" as key benefits).

6. *See id.*

7. *See* Bansal et al., *supra* note 5, at 8 (indicating that only 7% of survey respondents were apprehensive about learning to use an autonomous vehicle).

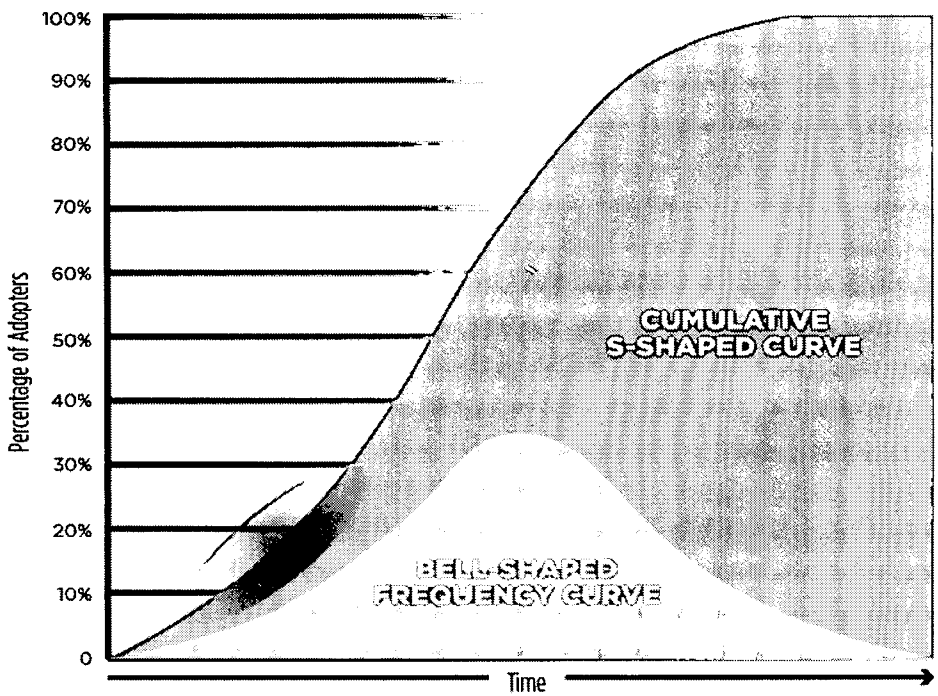
8. *See, e.g.*, Paul Goddin, *Uber's Plan for Self-Driving Cars Bigger than its Taxi Disruption*, Mobility Lab (Aug. 18, 2015), https://mobilitylab.org/2015/08/18/ubers-plan-for-self-driving-cars-bigger-than-its-taxi-disruption.html (noting that Uber, which operates in 300 cities worldwide, plans to have an entirely driverless fleet ready for consumers by 2030).

9. *See* Younghwan Kim, Wonjoon Kim, & Minki Kim, *An International Comparative Analysis of Public Acceptance of Nuclear Energy*, Energy Pol'y 475, 480 (2014) (noting that "the stigma effect from catastrophic events . . . can considerably reduce public acceptance" of existing technologies).

novation diffusion is peer-to-peer communication about a new technology, near-peer modeling of that technology, and imitation by potential adopters.[10] The pace at which diffusion occurs is thus determined by how quickly this interactive process prompts individuals to adopt a new technology over time.

Importantly, Rogers and many other social scientists have observed that the frequency of adoption over time follows a bell-shaped curve that closely approximates normality,[11] as shown in *Figure 1.* And if the cumulative number of adopters over time is plotted, the result is a standard s-shaped curved,[12] as also shown in *Figure 1.*

FIGURE 1



Given that adopter frequency distributions mimic the normal curve, innovation-diffusion theory posits that distinct adoption groups can be estimated by using simple dispersion around the mean, i.e., standard-

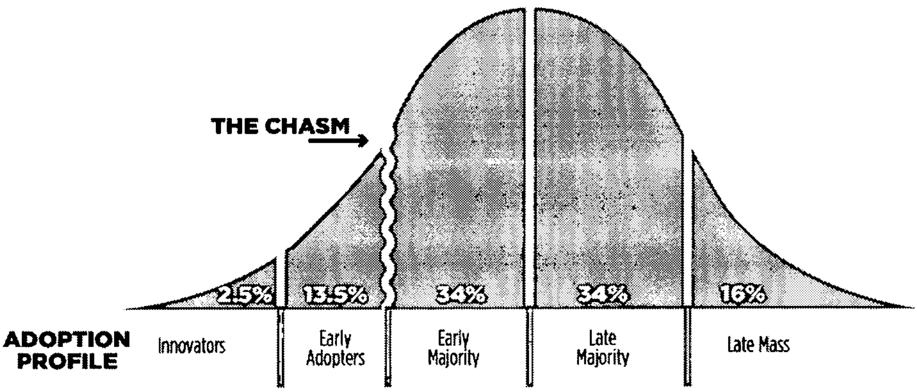
10. ROGERS, *supra* note 2, at 293.

11. *Id.* at 243.

12. *Id.* Note that both curves in *Figure 1* are for the same data – the bell-shaped curve shows these data in terms of the number of individuals adopting at each point in time, whereas the s-shaped curved shows these data on a cumulative basis.

deviation analysis.[13] Based on this observation, Rogers sorted adopters into the distribution groups listed in *Figure 2* below.

FIGURE 2



As shown in *Figure 2*, preliminary adoption occurs among innovators and early adopters and is driven primarily by a sense of adventure and a desire to innovate.[14] Of those two groups, early adopters are the key to diffusion, as they: (1) are more integrated into the social system than innovators; and (2) have the greatest degree of opinion leadership (i.e., potential future adopters look to early adopters for advice and information about the innovation).[15]

Once early adopters have reached a critical mass, the diffusion process reaches what some social scientists have referred to as "the chasm" – the divide an innovation must cross to initiate adoption amongst the early majority, who represent the mainstream market and whose adoption-motivations are tied much more to the positive experiences and examples of early adopters than to a pure desire to innovate.[16] *Figure 2* illustrates this divide, noting the differences in adoption motivation between those individuals on either side of the chasm. Based on this dichotomy, adoption levels close to the 16% mark (or more generally, in the 10%-20% range) typically signal that an innovation has established a toehold amongst the early majority. And at this level of market penetration, diffusion tends to accelerate rapidly.[17]

The shaded oval in *Figure 1* above represents this so-called "tipping point" where the slope of the cumulative adoption curve dramatically in-

13. *Id.* at 246-47.
14. *Id.* at 248-49.
15. *Id.* at 249.
16. *See* GEOFFREY MOORE, CROSSING THE CHASM (3d Ed., Harper Business 2014) (1991).
17. ROGERS, *supra* note 2, at 243, 304.

creases, signifying rapid diffusion. At this point, eventual diffusion to the late majority is often a fait accompli, as the inertia of convenience, economic necessity, and a desire to conform with social norms steer more conservative holdouts towards adoption.[18]

Regarding autonomous-vehicle technology, recent survey data indicates that once autonomous vehicles are available to the mass market, enough adoption willingness may already exist such that diffusion reaches tipping-point level in very short order. For example:

JD Power surveys of vehicle owners in 2012, 2013, and 2014 revealed that 20%, 21%, and 24% of respondents, respectively, would buy an autonomous vehicle at their next car purchase, even assuming an additional $3,000 cost for the autonomous features.[19]

A 2013 Carinsurance.com survey indicated that approximately 20% of drivers would buy a fully autonomous vehicle if one was available.[20] When told that an 80% discount would be provided on car insurance, 34% of the respondents indicated that they were "very likely" to purchase an autonomous vehicle, with an additional 56% willing to "consider the option."[21]

A 2014 survey by Kyriakidis et al. noted that 20% of respondents had a willingness to pay more than $7,000 to add autonomous capabilities to their next vehicle.[22]

A 2016 Kelley Blue Book survey found that by 2020, 26% of individuals would be willing to purchase a car with Level 4 autonomy features, i.e., a car that could operate independently in all standard roadway settings.[23]

In sum, this early evidence indicates that autonomous passenger vehicles may even now have crossed the "chasm" to the point where, once available, they will meet the threshold for accelerated adoption by the early majority.[24] And given that once a technology begins diffusion across the early majority (i.e., approaches the 20%-30% adoption range), even-

18. *Id.* at 245. (observing that "[t]he area of the diffusion curve after about 10 percent adoption and up to 20 or 25 percent adoption is the heart of the diffusion process. After that point, it is probably impossible to stop the further diffusion of a new idea, even if one wishes to do so").

19. Jeff Youngs, *Automotive Emerging Technologies Study Results*, J.D. POWER (May 5, 2014), www.jdpower.com/cars/articles/jd-power-studies/2014-us-automotive-emerging-technologies-study-results.

20. Mark Vallet, *Survey: Drivers Ready to Trust Robot Cars?*, FOX BUSINESS (Mar. 5, 2016), www.foxbusiness.com/features/survey-drivers-ready-to-trust-robot-cars.

21. *Id.*

22. Miltos Kyriakidis, Riender Happe, & Joost de Winter, *Public Opinion on Automated Driving: Results of an International Questionnaire Among 5,000 Respondents* (Oct. 7, 2014).

23. *See Future Autonomous Vehicle Driver Study*, KELLY BLUE BOOK (September 2016), www.mediaroom.kbb.com/future-autonomous-vehicle-driver-study.

24. *See* David Galland, *10 Million Self-Driving Cars Will Hit the Road by 2020*, FORBES (Mar. 3, 2017), www.forbes.com/sites/oliviergarret/2017/03/03/10-million-self-driving-cars-will-

tual diffusion across the late majority is highly likely, general acceptance could occur as early as the mid-2030s.[25]

Finally, technology adoption rates have been rapidly increasing over the past century.[26] While standard telephones took over 35 years to saturate the U.S. market, smart phones took only four.[27] Accordingly, Rogers's traditionally s-shaped diffusion curve has become increasingly steep as consumers have moved into the new millennium.[28] Thus, while the original diffusion of automobiles took decades, the modern trend of rapid technology diffusion supports the notion that there may already be a tipping-point-sized group of consumers willing to purchase driverless vehicles.

C. Risk Perception and Acceptance of Autonomous Freight-Rail Operations

Unlike their ability to choose to buy an autonomous passenger vehicle, the general public will not be able to exercise choice over whether it is exposed to autonomous freight-rail operations and any potential attendant risk. Rather, railroads themselves will make the choice of whether and when to implement autonomous operations, subject to signoff from regulatory bodies. Given, however, that social opinion regarding autonomous technology in general will significantly affect regulators' willingness to approve development and deployment of such technology in the rail space, widespread public acceptance of autonomous-passenger-vehicle technology would represent a significant strategic victory for railroads.

That said, public perception of risk is not entirely rational.[29] One

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hit-the-road-by-2020-heres-how-to-profit/#1e0cb0407e50; *see also* Bansal, *supra* note 5 (finding that "[m]ore than 80% of survey respondents are interested in owning Level 4 AVs").

25. *See Evolution, Disruption, Growth, Emerging Themes: Autonomous Vehicles*, Morgan Stanley (2018) (noting that "it is not outside the realm of possibility that a child born today may never need a driver's license"); Johana Bhuiyan, *The Complete Timeline to Self-Driving Cars*, Recode (May 16, 2016), www.recode.net/2016/5/16/11635628/self-driving-autonomous-cars-timeline (estimating that most new cars will be fully automated by 2025-2030 and that automakers will stop manufacturing non-automated cars by 2030).

26. *See* Rick Rieder, *Tech Adoption Rates Have Reached Dizzying Heights*, Market Realist (Dec. 24, 2015), www.marketrealist.com/2015/12/adoption-rates-dizzying-heights; Rita McGrath, *The Pace of Technology Adoption is Speeding Up*, Harvard Business Review (Nov. 25, 2013), www.hbr.org/2013/11/the-pace-of-technology-adoption-is-speeding-up.

27. *See* Rieder, *supra* note 26.

28. *See* Jeff Desjardins, *The Rising Speed of Technological Adoption*, Visual Capitalist (Feb. 14, 2018)

29. *See* Nidhi Gupta, Arnout Fischer, & Lynn Frewer, *Socio-Psychological Determinants of Public Acceptance of Technologies: A Review*, Public Understanding of Science (Oct. 21, 2012), (summarizing the literature on risk perception and noting that "[a]ll of these studies imply that people's attitudes towards technological risks and benefits are influenced by risk dimensions that have little to do with the possible consequences of the technology," "showing that cognitive

might assume that if consumers were comfortable placing themselves in driverless vehicles, or at least sharing the road with them, they certainly would be comfortable with autonomous trains, which run on a separate guideway that is more physically distant and has far less potential for variability. Yet while comfort levels with an analogous, consumer-chosen technology may go a long way towards assuaging safety concerns related to driverless freight trains, several factors could heighten public concern over autonomous trains.

First, a risk that is perceived as involuntary in terms of personal exposure tends to be more threatening than one that is perceived to be voluntary, even if the probability of harm is the same, or possibly even less.[30] Second, the public tends to fear potentially catastrophic hazards more than those which affect a similar number of individuals but at different times.[31] And third, the public tends to view exposures as riskier when there is a lack of trust and confidence in both regulatory institutions overseeing and companies promoting a technology.[32]

Although such responses may seem irrational and misaligned with technical risk estimates,[33] failing to acknowledge and address them can cause significant damage to a technology's image.[34] Accordingly, the industry should be prepared for at least some public apprehension over autonomous freight-rail operations, even with potential ubiquity of autonomous-passenger vehicles. As such, railroads will need to take affirmative steps to bolster public confidence in the unique safety benefits derived from autonomous rail, including the following:

evaluation and emotional response do not necessarily align"), *available at* www.ncbi.nlm.nih.gov/pmc/articles/PMC3546631/.

30. *See* L. Frewer, J. Lassen, B. Kettlitz, J. Scholderer, V. Beekman, & K.G. Berdal, *Societal Aspects of Genetically Modified Foods*, Food and Chemical Toxicology 42, 1183 (2004) (noting that "a risk that people perceive to be involuntary in terms of personal exposure is more threatening than one that that is perceived to be voluntary, even if the probability of harm is the same, or possibly even less").

31. *See* T. Katsuya, *Public Response to the Tokai Nuclear Accident*, Risk Analysis 21, 1039-1046 (2001); Frewer et al., *supra* note 29.

32. *See* Kim et al., *supra* note 9 (indicating in the context of nuclear plants that "trust in inspection authorities is a necessary condition for attracting opinions of reluctant acceptance"); M. Siegrist, *A Causal Model Explaining the Perception and Acceptance of Gene Technology*, Journal of Applied Social Psychology 29, 2093-2106 (1999) (explaining that "trust in companies and scientists conducting research in the area of gene technologies has a strong effect on the overall levels of risk and benefit perceived to be associated with those technologies").

33. *See* Frewer et al., *supra* note 29, at 1183 (noting that in the case of genetically modified foods, the public outrage that has plagued this technology was primarily driven by perceptions that exposure to potential risks, however small, was involuntary, uncontrollable, and opaquely regulated); *see also* Gupta et al., *supra* note 28.

34. *See* Robin Gregory, James Flynn, & Paul Slovic, *Technological Stigma*, 83 American Scientist 220, 222 (1995) (observing that "[t]he stigmatization of products has resulted in severe losses stemming from consumer perceptions that the products were inappropriately dangerous").

Inform and Educate. Railroads should keep the public, customers, and politicians constantly apprised of the safety, productivity, and efficiency advantages of transitioning to autonomous operations.[35] Industry communications should also emphasize the significant comparative advantages of autonomy in the rail network as compared to highways, underscoring that there are considerably fewer interactions between trains and the general public, as well as the fact that railroads face far less network variability due to the fixed nature of track and the predictability of train movements.

Initiate Public Relations. Given widespread media coverage discussing the benefits of self-driving cars,[36] the industry should reach out to third-party sources now to encourage the authoring of similar pieces addressing the development and benefits of autonomous trains.

Build an Inclusive Coalition. An effective campaign to shape public perception and influence policymakers on autonomous trains will require a concerted effort amongst the railroads, as well as the involvement of other stakeholders, e.g., customers and vendors.

Encourage Experimentation. Railroads should request that FRA follow the lead taken by other groups in the U.S. Department of Transportation[37] and set up a permissive framework for safe, controlled experimentation with autonomous rail technologies.

Renew Intellectual Capital. Railroads would also benefit from third-party studies supporting safety benefits. Because there is little academic research on these topics, the industry could consider providing seed funding for academics to tackle these issues in a way that meets the industry's needs.

Pursue Additional Safety-Enhancing Technologies. Railroads should continue to look for ways to invest in incremental automation to improve safety and reduce liability. Adoption of small-scale automated tools will allow introduction of automation at a modest pace, allowing regulators and the public to develop confidence in the technology. Similarly, railroads should pursue technologies that eliminate public concerns about autonomy[38] and inform the public that such technology exists or could be

35. To be effective, author Simon Sinek suggests that messaging begin by answering the "why" question. *See* SIMON SINEK, START WITH WHY (2009) (explaining that consumer communication is most effective when it focuses first on *why* a new technology is needed before explaining *what* the technology is and *how* it works).

36. *See* note 3 *supra.*

37. *See, e.g.*, *Automated Driving Systems 2.0: A Vision for Safety*, NATIONAL HIGHWAY TRAFFIC SAFETY ADMINISTRATION (Sept. 2017).

38. *See, e.g.*, Jason Kuehn & Juergen Reiner, *A Driverless Future for Freight, Transportation, & Logistics* (2016), http://www.oliverwyman.com/our-expertise/insights/2009/apr/oliver-wyman-on-transport-logistics.html (discussing some of the unique operational and safety challenges that autonomous trains will face).

readily developed.[39]

Work with Other Modes on Autonomous Operation. Autonomous technologies are affecting many other modes of transportation, all of which share a similar interest in creating public confidence in the safety of driverless operations. Railroads should be open to working with other industries to promote this common goal.

In addition, research shows that public willingness to accept exposure to a risk-imbued technological process will greatly hinge on public confidence in the existence of competent, transparent regulation.[40] And the industry must acknowledge that FRA will not allow autonomous operations to proceed without some mechanism for oversight. That said, the industry has the chance for a fresh start with regulation of this technology by encouraging FRA to pursue performance-based regulation rather than its traditional command-and-control approach.[41] Such regulation should aim to promote, not restrict, technological advancements that make railroads safer and eliminate opportunities for human error. Relying on this framework, railroads should continue to encourage FRA to maintain strong oversight but to "regulate for results rather than adherence to prescribed means under prescriptive regulations or adherence to specified technologies,"[42] creating a transparent process for reviewing safety performance while also allowing railroads maximum flexibility to experiment and optimize the benefits of autonomous operations.

Finally, an unforeseen safety issue, if not properly addressed, can forever stigmatize a technology, even despite immediate correction and significant improvement thereafter.[43] And in the case of autonomous rail operations, a major safety event on either rails or the roads could irrationally enhance the perceived risk surrounding driverless trains, regardless of arguments explaining why risk might still remain slight when

39. For instance, one of the greatest public concerns over autonomous trains will likely be how a locomotive approaching an obstruction will know to stop or blow its whistle. However, a mature technology called Light Detection and Ranging (LiDAR), which is already used in many different fields (including terrain mapping/surveying, weather forecasting, marine navigation, obstacle avoidance) and which is a key component of driverless cars, could likely be adapted for obstacle detection in locomotives. *See* Devin Coldewey, *WTF is LiDAR?*, TECHCRUNCH.COM (Feb. 12, 2017), https://techcrunch.com/2017/02/12/wtf-is-lidar/. .

40. *See* Frewer et al., *supra* note 29, at 1184; Kim et al., *supra* note 9, at 476.

41. A logical starting point would be to ask FRA to port the National Highway Traffic Safety Administration's autonomous vehicles guidance to the rail environment. *See Automated Driving Systems 2.0: A Vision for Safety*, *supra* note 37.

42. *See* Peter J May, *Performance-Based Regulation and Regulatory Regimes: The Saga of Leaky Buildings*, 25 LAW & POLICY 381, 384 (2003).

43. *See* Gregory et al., *supra* note 33 (indicating that "[t]he impetus for stigmatization is often some critical event, accident or report" that "sends a strong signal of abnormal risk"); Kim et al., *supra* note 9 (noting that "the stigma effect from catastrophic events . . . can considerably reduce public acceptance" of existing technologies).

compared to the totality of operations. Fortunately, much of the technology used to implement driverless trains will be built on the PTC foundation, which is expressly designed to eliminate some of the most common causes of accidents. Nevertheless, PTC is not a safety cure-all, and as full-scale autonomous operations move closer to reality, the industry should develop an on-the-shelf communications strategy focused on immediate, accurate transparency[44] for publicly addressing any significant issues encountered when implementing automated technology, whether they occur as a result of freight-rail operations or highway transportation.

In sum, although diffusion of autonomous cars should help, railroads cannot rely purely on public comfort with driverless cars as a panacea to neutralize regulatory concerns. Rather, the industry must strategically and thoughtfully address the potential risk-perception challenges that will likely accompany attempts to automate rail operations. Taken in tandem with high levels of public acceptance towards autonomous passenger technology in the consumer market, such action could lead to an environment where the sheer social inertia of autonomous operations would be difficult to oppose.

Leveraging the Benefits of IoT Technologies

Finally, when promoting autonomous operations to various stakeholders, the industry should keep in mind that it will likely discover many currently unforeseen ways to leverage PTC and other elements of autonomy-enabling technology, leading to unanticipated, and potentially material, benefits for multiple stakeholders.[45] This is especially true given that autonomy-enabling technologies will operate primarily through the so-called "Internet of Things" (the "IoT"), a term coined to describe the growing network of internet-connected objects able to collect and exchange data using embedded sensors.[46]

Though unexpected windfalls are often realized from new inventions,

44. *See* Kim et al., *supra* note 9 (observing that severe trust erosion and stigmatization occurred after the Fukushima nuclear accident due to the government's initial release of inaccurate and unreliable information); Gregory et al., *supra* note 33 (advocating for the adoption of more open and transparent communication and decision processes regarding potentially stigmatizing technology and events). *See generally* Paul Slovic, James Flynn, & Mark Layman, *Perceived Risk, Trust, and the Politics of Nuclear Waste*, Science 254 (1992) (noting that trust follows the asymmetry principle, in terms of its development and durability or duration, i.e., the pace of trust formation is very slow, but that of its erosion is quick).

45. *See* Geoffrey A. Fowler, *iPhone User's Lament: Can't Live With You, Can't Live Without You*, Wall St. J. (June 22, 2017) at B1 ("A decade ago, Steve jobs said you were 'three revolutionary products' in one. He was wrong. You've already displaced so many more: alarm clocks, guitar tuners, pocket calculators, atlases, Filofaxes, Dictaphones and weathermen (sorry Al Roker), to name a fraction.").

46. *See* Andrew Meola, *What is the Internet of Things (IoT)?*, Business Insider (Mar. 10, 2018), http://www.businessinsider.com/internet-of-things-definition.

this potential can be significantly heightened for new IoT devices and processes that, like PTC, can collect, analyze, and leverage external data. Thus, while a traditional invention might lend itself to one or two unintended uses (e.g., WD-40 (originally for displacing water in nuclear missiles), Rogaine (originally for treating high blood pressure), and Play-Doh (originally for cleaning wallpaper)) due to some accidental characteristic of the invention,[47] innovations tied to the IoT often lend themselves to a far broader universe of unexpected uses that derive not from their innate properties, but the situational aspects of their use and the data to which they have access.[48]

Accordingly, railroads are only beginning to discover the many potential uses to which they can put the real-time sensory data collected through the PTC network. While PTC was built to transmit information necessary to prevent the unsafe operation of trains, the placement of various sensors and transmitters throughout much of the rail network will likely have significant data-collection-and-analysis upside that could translate into better, cheaper service for customers, as well as safety and efficiency gains that could appeal to regulators. And as PTC is further upgraded into a platform for fully autonomous operations, the opportunity for real-time data collection, and the many uses to which it can be parlayed, will only increase.

Thus, as the rail industry develops and implements technology to further automate operations, it must at all times remain alert for opportunities to leverage ancillary data-collection efforts and "smart" processes. If railroads are able to capture these secondary enhancements, they will likely yield material operational efficiencies that will not only benefit the company, but could also serve as additional ammunition in the fight to convert external stakeholders and critics to the cause of autonomy.

Conclusion

Based on current development of and public opinion about driver-

47. *See Our History*, WD-40, https://www.wd40company.com/who-we-are/our-history/ (last visited June 7, 2018); Jenny Bryan, *How Minoxidil Was Transformed from an Antihypertensive to Hair-Loss Drug*, The Pharmaceutical Journal (Jul. 20, 2011), https://www.pharmaceutical-journal.com/news-and-analysis/news/how-minoxidil-was-transformed-from-an-antihypertensive-to-hair-loss-drug/11080942.article; Davin Hiskey, *The Shocking Story Behind Playdoh's Original Purpose*, Business Insider (Sep. 20, 2015), http://www.businessinsider.com/the-shocking-story-behind-playdohs-original-purpose-2015-9.

48. *See* Michael Chui, Markus Löffler, & Roger Roberts, *The Internet of Things*, McKinsey & Co. (Mar. 2010); Andrew Meola, *Internet of Things Devices, Applications, & Examples*, Business Insider (Dec. 19, 2016), http://www.businessinsider.com/internet-of-things-devices-applications-examples-2016-8; Roger Ordman, *IoT and Unexpected Use Cases: Examining Overt, Covert Uses of Connected Devices*, Innovation Insights (Aug. 7, 2014), http://insights.wired.com/profiles/blogs/iot-unexpected-use-cases-examining-the-overt-and-covert-use.

less passenger vehicles, innovation-diffusion theory and current trends in tech adoption suggest that autonomous vehicles could gain widespread acceptance in the next 20 years. Given these prospects, it seems increasingly plausible that regulators may soon face circumstances where irresistible social momentum and incontrovertible safety benefits render obsolete any opposition to autonomous trains.

Yet railroads cannot rest purely on the laurels of public acceptance in the passenger-vehicle arena, especially since driverless trains implicate both involuntary exposure and the potential, however small, for catastrophic loss. Thus, the industry should take affirmative steps to minimize any lingering public concern by: (1) promoting the safety benefits of an autonomous rail network; (2) working with regulators to achieve performance-based regulation that will bolster public confidence and allow for maximization of efficiencies through operational flexibility; and (3) pursuing indirect enhancements available via IoT concepts to implement technologies that will inure to the benefit of many. When paired with public acceptance of driverless vehicles, these efforts may be the key to neutralizing any residual safety-based criticisms, clearing the tracks for the pursuit of full automation.