// FREIGHT AUTOMATION //

Dangers, Threats, and Opportunities for Health and Equity

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Regional Asthma Management and Prevention

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Moving Forward Network

The Moving Forward Network (MFN) is a national environmental justice coalition of community-based organizations, advocates, scientists, researchers, faith-based organizations, and others committed to reducing the public health harms our country's freight transportation system creates. The Network comprises more than 50 organizations and academics across the country where large ports, rail yards, and other freight corridors reside. Building strong frontline communities and community-based solutions for national policy change is central to the protection of our health, environment, and our communities. Led by port and freight communities, MFN is an important part of the grassroots-led movement infrastructure necessary to build power and win community-relevant and impactful policy change. MFN is a project of the Urban & Environmental Policy Institute at Occidental College. www.movingforwardnetwork.com

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Community Advisory Committee

This report would not be possible without the perspectives, knowledge, and wisdom of the following individuals comprising the Community Advisory Committee:

- P. Qasimah Boston, Tallahassee Food Network
- Roberto Clack, Warehouse Workers for Justice

- Kim Gaddy, Clean Water Action
- Theral Golden, West Long Beach Neighborhood Association
- Vivian Malauulu, International Longshore and Warehouse Union Local 13 Registered Longshore Worker and Benefits Officer
- Jimmy O'Dea, Union of Concerned Scientists
- David A. Rahn, University of Kansas
- Regina Townes, ILA, Local 1233, Port of New York and New Jersey

Additional Contributions

The report was also strengthened by the input, knowledge, and stories shared by the following:

- John Bagakis, San Pedro small business owner
- James, railroad conductor*
- Maria, Amazon warehouse worker*
- Jeff S. Johnson, former director of global thought leadership at Dell Technologies
- Dr. Rob Laumbach, Associate Professor, School of Public Health, Rutgers University
- Jesse Marquez, Coalition for a Safe Environment
- Jorge Mayorga, veteran port truck driver
- Wendell Mitchell, over-the-road truck driver
- Veronica Roman, San Bernardino community member
- Buddy Smith, President, Local 1233, International Longshoremen's Association

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* Due to fear of employer retaliation, the interviewee requested the use of a pseudonym.

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// EXECUTIVE SUMMARY ////

People: the heart of the freight system.

The freight transportation system in the United States is a fundamental part of our economy, infrastructure, and environment. Sprawling ports, large rail yards, train tracks cutting through sparse deserts and dense urban centers, millions of miles of roads, massive warehouse complexes and more: the system delivers grapes from Chile and electronics from China to our neighborhood stores–if not our doorsteps.

If steel is the bones and diesel fuel is the blood of the freight system, people who move our goods and work incredibly hard are its heart. People like Maria, whose warehouse work often requires her to carry boxes as heavy as 60 pounds. People like Wendell Mitchell, a 25-year veteran big-rig driver who knows the global positioning system (GPS) can get you lost in a minute. People like James, a railroad conductor who has had to work with his crew to reboot a train blocking an intersection during rush hour. Many of the freight system's frontline workers work incredibly hard in arduous conditions, yet receive low wages and limited benefits.

Frontline freight workers aren't the only ones who know the intricacies of the freight transportation system: fence-line communities know them as well. Where there's freight, there are people living and working close by–typically people with low incomes and people of color. Often, they are remarkably close, both physically and economically, to trains, warehouses, ports, and busy truck routes. For example, there's John Bagakis, a small business owner whose 52 employees regularly make pizza deliveries to a nearby port. Then there's Veronica Roman, whose dining room shakes when the trains go by her home, and whose family cannot consider leaving the windows open overnight due to the noise and soot.

Wendell Mitchell, over-the-road truck driver / Vivian Malauulu, International Longshore and Warehouse Union Local 13 Registered Longshore Worker and Benefits Officer

Freight automation: it's here and growing.

Although people are still key to making the freight system move, technological change is coming. In some corners of the freight system, it's already here. Various forms of freight automation, where some or all human labor is replaced by machines, are already operational or in different stages of development and testing. In addition to technological advances, the future of freight automation will be determined by negotiations and disputes between workers and employers. Below are sector-by-sector snapshots of what freight automation looks like now and how it may look over the next 5 to 15 years.

Trucking

Driver-assistance technologies for big-rig trucks, such as automated breaking and blind-spot detection, are widely available now, and the next 5 years will likely bring a substantial increase in the use of these technologies. Companies and drivers are also likely to put platooning–where technology enables a string of trucks to drive at proximities that would otherwise be unsafe to do without computer assistance–into widespread use. Within 5 to 15 years, trucks that self-drive–meaning with no driver intervention, and possibly with no driver in the cab at all–will likely be commercially deployed on some freeways and highways, likely first in the Southwest, because of its better weather and long stretches of road.

Warehouses

Extensive warehouse automation is in place right now, with autonomous robots and automated guided vehicles taking the place of humans. Yet, the presence of automation is limited to a smaller portion of early adopters across the sector. Over the next 5 to 15 years, warehouse-related automation is likely to increase. Although slim profit margins make automation investments difficult, factors such as a tight labor market and the ever-increasing demand for e-commerce suggest the sector is moving toward an ever-more automated future.

Rail

Many automated technologies that complement or replace worker's responsibilities are already widely in use, such as train "cruise control" to save fuel, as well as safety systems such as Positive Train Control technology. Higher levels of train automation, including reducing the number of crew members working on trains partially or fully, are technologically feasible now in certain conditions and may become feasible in broader conditions in the near term. In early 2020, the nation's largest freight railroads and unions representing more than 125,000 workers launched a contract negotiation process, and crew size and automation will be at the heart of the likely multiyear negotiation.

Ports

Significant port automation is in place right now. For example, at the twin ports complex of Los Angeles and Long Beach in southern California, several terminals are human-free zones

as computer-controlled equipment and vehicles hum around the terminals. Such automation in the United States is not widespread. Whether that changes substantially in the next 5 to 15 years will depend on economic and labor factors. Upfront costs to automation investments are very high, and productivity gains can be uncertain. As for workers, automation will likely be one of the central and contentious issues for labor and port employers to negotiate when two major labor agreements in the United States end in 2022 and 2024.

COVID-19'S UNCERTAIN IMPACT ON FREIGHT AUTOMATION

About midway through writing this report, the coronavirus pandemic surged across the globe, killing more than two million people, sickening tens of millions, and wreaking havoc on local and global employment and economies. The United States has been particularly affected, with more cases and deaths than any other country. The spread of COVID-19 is impacting the freight transportation system, too: trucking jobs have declined, and some ports have seen a record-setting surge in traffic.

Many questions remain about the pandemic's implications for the state of freight automation in the United States. Will COVID-19 ultimately speed up or slow down the pace of automation? Will we see different types of automation and an increase in e-commerce develop because of the impact of the virus? Because the United States continues to struggle with the coronavirus, and because the path of the virus is anything but clear, the answers to these questions are uncertain.

In the near term, community residents and advocates have expressed concern that the pandemic will result in less-transparent decision-making processes, not only for automation but for freight decisions in general. Longer term, there's some industry sentiment that the pandemic will ultimately speed up freight automation to reduce human-to-human interactions (and thus help prevent contagion) or to reduce human involvement entirely so that future upheavals like COVID-19 have less of an impact on the freight system.

The counterargument to the view that COVID-19 will speed automation rests on matters of money and the heart. First the money: ever increasing levels of automation are more expensive. Given the fallout in the US economy in 2020, the freight transportation system will also need time to recover. Then there's the heart: Throughout the pandemic, the public and policymakers have hailed frontline essential workers as heroes of the moment as they've kept supplies on shelves and food delivered to our doors. Policymakers can build on that sentiment to protect and enhance workers' experience—not simply replace it with automation. ■

A critical window of opportunity.

The extent to which freight automation replaces traditional workers is not an "all or nothing" proposition. Nor can freight automation, however it's conceived, be implemented immediately across the vast and complex freight transportation systems. In light of the timelines described above, there is a critical window of opportunity: policymakers, industry stakeholders, frontline workers, fence-line community members, and the public have time to better understand the implications of freight automation. More importantly, they can make decisions, through policies and programs, that promote health and equity for frontline workers and fence-line communities.

Bracing for impact: increased freight automation will have significant and largely negative health and equity effects on frontline workers and fence-line communities.

Better understanding and addressing the implications of freight automation on frontline workers and fence-line communities are essential. As this analysis details, increased freight automation will have significant, and largely negative, health and equity impacts on frontline workers and fence-line communities. Through extensive literature review and in-depth interviews with key stakeholders, this report details the anticipated effects of freight automation related to various social determinants of health, including employment, air quality, traffic safety, and noise and vibrations. Within each of these determinants, the report details current freight-related dangers, future automation-related threats, and possible beneficial opportunities.

Absent a concerted effort from policymakers and other stakeholders, automation will likely result in the following:

Employment: Automation has already and will likely continue to cut jobs for frontline workers, and wages and benefits may also decline. With less income to spend in communities, local economies closely tied to freight infrastructure will consequently experience negative ripple effects. In addition, automation has and will likely continue to negatively affect frontline worker safety through increased workload and pace of work. All these impacts will inequitably affect lower-wage workers and workers of color.

Air quality: Air pollution from freight transportation currently creates significant health problems, especially for fence-line communities. In limited scenarios, automation may slightly reduce pollution through efficiency gains, but caution is warranted: more real-world testing is needed, and such reductions may be negated by changes in trucking operations. If automation proceeds without electrification and decarbonization, air pollution and related health risks will continue unabated, further affecting frontline workers and fence-line communities. Adopting zero-emission technologies, with or without automation, would provide much more significant pollution reductions.

There is a critical window of opportunity. Policymakers, industry stakeholders, frontline workers, fence-line community members, and the public can make decisions—through policies and programs—that promote health and equity.

Noise and vibrations: The noise and vibrations from freight transportation are significant and have negative health consequences. To the extent that freight automation permits freight facilities to run for longer periods, including during more traditional "off-hours," the burden of noise and vibrations for frontline communities may increase. Although automation itself will have little impact on noise and vibrations, electrifying freight with zero emission technologies would reduce noise and vibrations.

Traffic safety: Similar to air pollution, collisions involving freight trains and trucks cause deaths and serious injuries across the United States. Automation that complements or augments some truck and train driver labor holds significant promise for improving traffic-related safety. Automation may also play a helpful role in safety inspections of freight equipment. However, automation that replaces most or all truck and train driver labor may worsen traffic-related safety in some situations; overall much more research is needed.

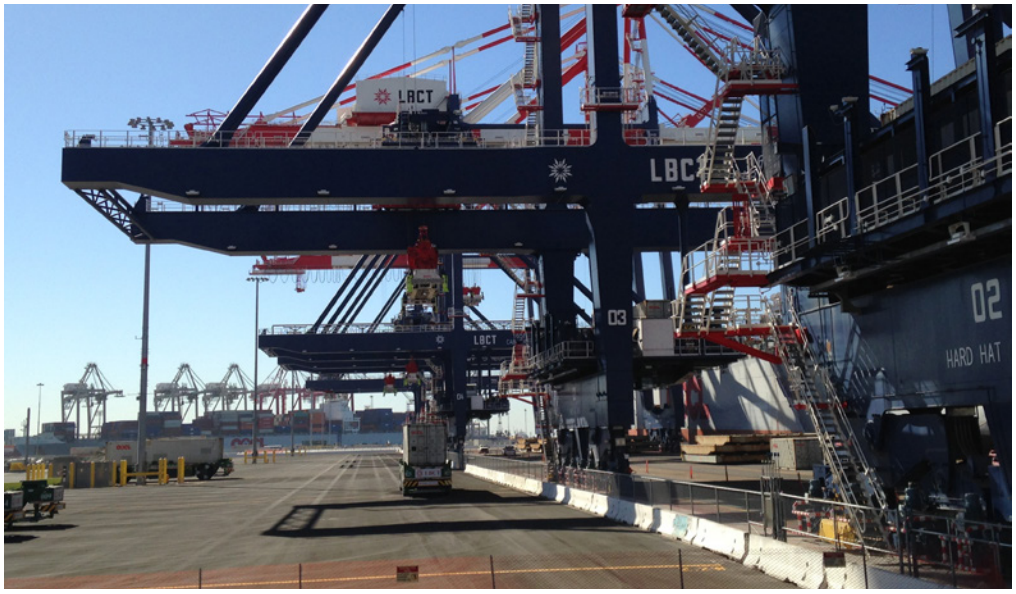
Freight automation is at an inflection point. We have the opportunity to deploy technology to create healthier, more equitable workplaces and communities. But policymakers need to make the right choices.

Implemented thoughtfully, freight automation can improve the health and safety of the low-income workers and communities of color who make up substantial portions of the freight workforce and nearby neighborhoods. For example, an automatic braking system that reacts far faster than any human to prevent collisions makes our highways safer. With proper training, a forklift operator can transition into a job fixing an automated forklift. Tying zero-emissions technology to automation will greatly reduce air pollution (and associated greenhouse gases) and noise far more than automation can alone. Where freight automation supports these types of changes, it can be a tool to advance public health, workers' rights, racial justice, and a "just transition" to a carbon-free economy.

But freight automation only realizes improvements in the livelihoods and lives of frontline workers and fence-line communities when those same people are prioritized in decision-making. Job losses, the decline in workplace benefits and working conditions, and erosion of environmental quality could all occur if freight automation is implemented without placing people at the center. The freight transportation system is trending toward an ever-more automated future, but decisions about if, when, and how to use automation will determine its effects. Some of those choices will happen at the organizational level. For example, when Boxed, a bulk retailer, automated one of its warehouses in Union, New Jersey, company leaders decided to retain warehouse staff, shifting many of them into new roles through training and additional support.

Although such decisions should be celebrated, automation-related choices cannot and should not be left to individual companies. Public policies and programs enacted by decision-makers at multiple levels of governance are critical to ensure that the future of freight automation promotes health and equity rather than sustaining and worsening problems inherent with the freight system. Policies and programs should not only help mitigate current harms created by a system that relies heavily on low-wage workers and creates pollution, noise, and safety problems for nearby communities; new hazards and harms need to be prevented as well.

Equally important, policies and programs need to reflect the input, knowledge, and experiences of frontline workers and fence-line communities who bear the brunt of freight's current effects and who have the most to lose from decisions that amplify those effects. Also, policies and programs needed for freight automation should not undercut solutions to current problems that can be enacted now: an overworked warehouse employee shouldn't have to wait for tomorrow's automation to spare her back when helpful changes like rotating task stations can be put into practice today.



Policy and Program Recommendations for Health and Equity

These policy and program recommendations orient freight automation to support health over harm, and equity over injustices, for frontline workers and fence-line communities.

Engage frontline workers and fence-line communities in automation decisions.

- Decision makers at all levels of government should ensure that automation-related policy and program decisions reflect the input and perspectives of frontline workers and fence-line communities.
- Leaders in businesses considering automation should also engage workers in thinking through automation-related decisions and impacts.

Support frontline workers.

- Plan for automation that advances frontline workers, not just technology.
- Strengthen workers' rights to organize for fair wages, benefits, and a say in automation-related decisions.
- Enforce and improve safety standards for workplace conditions to prevent the negative effects of automation on worker safety and health.
- Reinvigorate and expand programs to meet the needs of frontline workers displaced by automation.
- Correct worker-status misclassification of truck drivers and other freight workers to promote livable wages and benefits.
- Implement broader policies and programs that address automation's impact across the entire US economy.

Support frontline workers and fence-line communities.

- Require Automation Impact Reports (AIRs) to better understand and mitigate automation's effects on health and equity.
- Prohibit the use of public funding for any freight automation that may have negative effects on worker and community health.
- Accelerate efforts to shift freight transportation to a zero-emission system through incentives, regulations, and permitting decisions.
- Implement federal policies to prioritize the safety of freight drivers and other road users.

Finally, where there are still questions about the health and equity consequences of freight automation, additional research is needed.

// INTRODUCTION ////

Automation of the freight transportation sector will fundamentally transform the sprawling ports, large rail yards, millions of miles of roads, and massive warehouse complexes that make up a significant part of our built environment and economy. This transformation could also have profound effects on the millions of people who work and live most closely to the freight system.

Freight's frontline workers and area residents face many struggles.

Maria, a resident of San Bernardino, CA, works at an Amazon Fulfillment Center, a large warehouse that helps move vast quantities of goods from supplier to customer. Her work is physically demanding: often she carries boxes as heavy as 60 pounds. Sometimes she has a small team to help her, but other times she's on her own. She feels she doesn't have the option of not picking up heavy boxes, because it would hold up her line.

The intense work has meant stress and physical pain, and the risk of injury. According to Maria, management doesn't provide back support braces, gloves, or other protective gear; it's up to workers to get the support they need. Once she hurt her hip because of the job's demands, but like many of her coworkers, she decided not to report the injury. Why not?

"[W]hen people get hurt on our job they don't get paper cuts, they don't get headaches. When people get hurt on the docks they lose limbs or they lose lives."

– Vivian Malauulu, ILWU Local 13 Registered Longshore Worker and Benefits Officer

"Porque no te van ayudar. Es tan común que no te ponen atención." [*Because they won't help you. [Injuries] are so common that they don't pay attention to you.*]

The COVID-19 pandemic has also amplified Maria's stress. She says management was slow in getting workers masks and other personal protective equipment. Although workers can now miss work by letting management know when they don't feel well, there's no paid time off. Even with the temporary extra $2 per hour during the pandemic, people are afraid to go to work because of the virus.

Outside, diesel trucks rumble to and from the warehouse. With other warehouses, industrial and commercial facilities, a railyard and a freeway, residents of San Bernardino face intense levels of air pollution. Maria's two daughters have asthma, as do many of her coworkers. She's very aware of the risks. "La realidad es que hay una necesidad de trabajo y por el otro lado es lo que te está perjudicando, la salud tuya y de tu familia." [*The reality is that there is a need to work and on the other hand the work is hurting you, your health, and your family.*]

Maria's daughters are now 12 and 14 years old. The schools they attend are close to freeways and the railyard, so there is often a lot of truck traffic. There is also a community center and park with a daycare facility right next to the railyard. The school installed air filters in the classrooms, but students still go outside to play. There's a truck ban by her house, but it's not enforced. She is also a school crossing guard and has noted an increase of trucks in her neighborhood. She has participated in truck counts with a community organizer from the Center for Community Action and Environmental Justice, a nonprofit organization based in Jurupa Valley, CA, and she was shocked at the findings: "Me vine sorprendidísima que vine contándole a mi esposo y más preocupación me dio mis hijas que…tienen asma y yo tengo alergias. Pues que triste que en una hora hayamos contando más de 600 camiones por casas y escuelas." [*I left there astonished that I came home telling my husband and I'm more worried about my daughters who…have asthma and I have allergies. It is so sad that we counted more than 600 trucks in 1 hour so close to homes and schools.*]

When Maria's older daughter was a 14 months old, she was hospitalized for 4 days because of her asthma. Now the children know how to monitor their own symptoms and can use their inhalers. Maria links their asthma to the pollution exposure in San Bernardino. She considered moving to Fresno, CA, thinking there was better air quality given the number of farms. But her research showed the air quality was just as bad there. She also looked into moving to Long Beach, CA, but its port and freight infrastructure mean the air pollution is bad in that community too.

Maria's experience is all too common. For the frontline workers and communities closest to the US freight transportation system, the hours are long, the work is hard and sometimes dangerous, the pay is often low, and the impacts are significant and inequitable.

For more than 35 years, Jorge Mayorga has driven short- and long-haul trucks both as an employee and an independent contractor. He describes the pride he takes in his work, and the struggles he has faced to make ends meet:

> En los tiempos de navidad, tenía mi camión que con todo el esfuerzo había comprado verdad y si me dio satisfacción porque era una manera de cómo sobrevivir. … [U]na semana antes de la Navidad, se me quebró el motor y tuve que reparar todo el motor. … (P)ero el gasto, se me hizo más de lo que yo creía o de lo que me dijo el mecánico y tuve que hacer préstamos para poder arreglar el camión. Lo más triste es que llegamos el 24 en la noche cuando todo mundo está cenando—nuestra costumbre es de celebrarse el 24 y el 25—el 25 alrededor de los apartamentos ver a los niños con sus juguetes y yo no pude. No alcancé, no alcancé para darle ese regalo a la niña, no alcancé para llevar el alimento que siempre comíamos.
>
> [*During Christmas time, I had my truck that with all the effort I had bought, right, and it gave me satisfaction because it was a way to survive. … [A] week before Christmas, my engine broke and I had to repair the whole engine. … [B]ut the expense was more than I thought or what the mechanic told me and I had to take out loans to fix the truck. The saddest thing is that on the 24th [Christmas Eve] when everyone is having their dinner—our tradition is to celebrate the 24th and 25th—and on the 25th around the apartments you see the children playing with their toys and I couldn't. I did not have enough, I did not have enough to get a gift for my little girl, I did not have enough to buy the food we always ate.*]

For longshore worker Vivian Malauulu, port work is dangerous work. "[W]hen people get hurt on our job they don't get paper cuts, they don't get headaches. When people get hurt on the docks they lose limbs or they lose lives." She also fears what automation in two terminals at the Ports of Long Beach and Los Angeles has already done to employment:

Prior to automating, and on their busiest days…each of these terminals ordered approximately 500-800 jobs out of our Dispatch Hall. Today, on the same busiest days, these terminals will only order approximately 200 jobs, if that. That equates to a significant job loss of almost 500 jobs daily at each terminal, and 1,000 jobs daily combined at both terminals. It is important to note that in addition to these job losses, there are also much longer delays,

such as container-delivery wait times, due to constant deficiencies in technology. There are also increased accidents for the same reason. Some of these accidents have resulted in injuries to labor and independent truck drivers, as well as damage to equipment.

When asked to describe the freight system, Jesse Marquez, the founder of the Coalition for a Safe Environment based near the Ports of Los Angeles and Long Beach, summed it up as follows: "The ports and freight transportation industry have a significant negative impact on my life, that of my family, and environmental justice community." He listed the following negative influences:

- Increased air pollution
- Increased noise
- Increased ground vibration
- Increased traffic congestion
- Increased accidents
- Increased multiple public health problems, costs
- Increased premature deaths
- Increased public safety risks
- Increased insurance costs
- Increased blight
- Property depreciation

Frontline workers and fence-line community members echo these stories across the US freight transportation infrastructure. They often work in low-paying jobs with few benefits. The neighborhoods through which freight rumbles are typically low-income communities and communities of color. The country's freight transportation delivers goods—and fosters inequities.

Against the backdrop of these inequitable burdens comes automation.

Just a few years ago, a fully autonomous tractor-trailer carrying Budweiser beer drove more than 100 miles on an interstate from Colorado Springs to Fort Collins, CO. While a person was in the vehicle monitoring the trip, he spent most of the time in the truck's sleeper cab and did not drive.[1] Guinness World Records later designated the milestone as "the longest continuous journey by a driverless and autonomous lorry [semitrailer truck]."[2]

Highway restriping and multiple test runs preceded the trip; the truck was also escorted by state troopers.[3,4] Still, the test sponsors lauded the trip for its technological accomplishment. Anheuser-Busch Companies, the producer of Budweiser beer, said, "As we continue to partner with long-haul carriers to ship our beers, we hope to see this technology widely deployed

across our highways to improve safety for all road users and work towards a low-emissions future."[5] The Colorado Department of Transportation claimed the event was "[a] monumental step forward in advancing safety solutions that will help Colorado move towards zero deaths on our roads."[5]

Although truck automation is still in its nascent stage, port automation is not. At southern California's Ports of Los Angeles and Long Beach, one of the busiest port areas in the United States, some portions are largely human-free zones as computer-controlled equipment and vehicles hum around docks. Meanwhile, in freight warehouses adjacent to the nation's commerce arteries, driverless forklifts move pallets, and robotic arms select items from bins for processing.

Proponents of freight sector automation describe an array of benefits, including relief for congested roads, air quality improvements for nearby communities, safer streets, and new high-paying jobs for many. Certainly such benefits are needed; a system that can deliver grapes from Chile and electronics from China currently has extremely high costs. Fence-line communities bear the brunt of the impacts of the freight sector, including noise, vibrations, pedestrian collisions, air pollution, and pollution-related health conditions like asthma, cancer, and heart disease. Employment within the freight sector, such as warehouse workers, short-haul drivers around ports, and many others, is often of low wage, with minimal benefits, and, at times, very dangerous.

Are the promises of automation real? Will improvements benefit the workers and communities that need them the most?

This report explores freight automation and the related public health and equity implications—positive and negative—for Maria, Jorge, Vivian, and Jesse (featured at the beginning of this section) and other freight workers and fence-line community members across the United States. For example, will automation-related efficiency gains lead to improved air quality? Or will pollution increase as more and more trucks jam crowded roads? Where automation leads to the reduction of jobs, will new jobs be ready and available for the same workers?

OUR FOCUS

TRUCKS, TRAINS, WAREHOUSES AND PORTS

Trucks, trains, ships, planes, and all manner of facilities—from mega-ports to a small truck stop—are each an integral part of the freight system, and automation is leaving few areas untouched. This report focuses primarily on trucks, trains, warehouses, and ports for two reasons. First, these vehicles and facilities make up a substantial portion of the freight system in the United States. Second, these are some of the components of the freight system that involve both many workers and are close to communities experiencing health burdens. Because of time and resource constraints, and guidance from the Community Advisory Committee, this report doesn't cover every aspect of automation in the freight system; for example, ships and air cargo are not included. Although examining the health and equity implications of automation in every component of the freight system isn't in the scope of this report, our hope is these can be addressed soon. ■

For years, community and environmental justice advocates, public health allies, forward-thinking policymakers, and some industry representatives have pursued a vision in which, for example, communities near the port of New York and New Jersey no longer subsidize, with their health and well-being, the cost of a cheap television sold in Colorado. This report aims to add to that larger discussion of health and equity by exploring how freight automation can contribute to a built environment that is healthy rather than harmful, and that creates economic security for the freight system workforce. By identifying automation-related issues, assessing their potential impacts, and providing policy and program recommendations, our principal objective is to shape future technology and infrastructure investments in automation that result in healthier, more equitable communities.

Conventional thinking tends to equate technological change with societal improvement. In this project, we take the view that freight automation *might* promote public health and equity. Where it does, we recommend ways to accelerate that progress. Where it doesn't, we recommend ways to prevent or mitigate problems.

In this report, we

1. Review the state of US freight automation, such as different technologies, use in different sectors, and pace of change, with an emphasis on the next 5 to 10 years
2. Examine the public health and equity implications of freight automation in the areas of air quality, workforce and economic development, traffic-related safety, and noise and vibrations
3. Provide broad policy and program recommendations to promote health and equity within freight automation

Lessons learned from the current struggle for health and equity within the freight system only reinforce the urgency of exploring these issues. Although fence-line communities have known for years about the system's negative impacts, only more recently has there been widespread understanding to fuel the political will for cleanup efforts. In the meantime, ports have expanded. Warehousing complexes have mushroomed. Truck volumes have increased. Pollution control technologies have offered only modest air quality improvements; because of the technologies' upfront investment costs, they delay the use of more effective technologies in the future. More recently, the COVID-19 pandemic has brought disruption and uncertainty into the freight transportation system. It's still very early; however, there are indications the pandemic may accelerate, rather than decelerate, freight automation.

KEY TERMS AND DEFINITIONS

Automation: Technology that augments or replaces human labor, either incrementally or fully. This includes, for example, software and artificial intelligence programs that manage vast amounts of information and driverless vehicles and robots. Automation encompasses both digital and physical approaches.

Fence-line communities: People living in immediate or close to ports, rail yards, truck routes, warehouses, and other components of the freight system. These communities are predominantly low-income communities and/or communities of color.

Freight transportation: The infrastructure–including ports, rail yards and trains, long- and short-haul trucks, warehouses, and other modes of transit–that moves physical goods across the country. Also called the goods movement system, the logistics industry, and other terms.

Frontline workers: People working most closely to the freight system's physical infrastructure. These include truck drivers, port workers, train conductors, and warehouse workers, many of whom are low-income workers and/or people of color.

Health equity: Everyone has a fair and just opportunity to be as healthy as possible. To achieve this, we must remove obstacles to health (e.g., such as poverty, discrimination, deep power imbalances) and their consequences, including lack of access to good jobs with fair pay, quality education and housing, safe environments, and health care.

Racial justice: The creation and proactive reinforcement of policies, practices, attitudes, and actions that produce equitable power, access, opportunities, treatment, and outcomes for all people, regardless of race.

Social determinants of health: The social, environmental, and economic conditions in which people live, work, and learn that affect health outcomes. ■

// THE CURRENT STATE OF AUTOMATION IN THE FREIGHT INDUSTRY ////

A tractor-trailer loaded with beer traveling over 100 miles of freeway without a human driver. A port terminal with no dockside workers. Warehouses with more robots than people. Given the type of automation already underway across the nation's freight system, the most pertinent question isn't *if* freight automation will happen but *to what extent* and *when* freight automation will occur.

In this section, we characterize the current state of freight automation as well as the pace of its development. Although our focus is primarily on the near term, especially the next 5 to 10 years, the longer-term horizon is critical to keep in mind, because increases in automation serve as stepping stones to potentially more significant automation later.

Freight automation is not an all-or-nothing proposition: levels of automation can range from making a worker's job easier and safer to eliminating the need for a human being entirely. Similarly, automation may shape the entirety of the freight system or be concentrated in a portion of it.

COVID-19'S UNCERTAIN IMPACT ON FREIGHT AUTOMATION

About midway through writing this report, the coronavirus pandemic surged across the globe, killing more than two million people, sickening tens of millions, and wreaking havoc on local and global employment and economies. The United States has been particularly affected, with more cases and deaths than any other country. Naturally, the spread of COVID-19 is impacting the freight transportation system too.

In April 2020, for example, more than 88,000 trucking jobs evaporated, "wiping out four years of trucking employment growth in one month."[6] But, by later in the year, the Ports of Long Beach and Los Angeles saw a surge of traffic due to increased e-commerce from consumers ordering more online.[7]

Many questions remain about the pandemic's implications for the state of freight automation in the United States. In the near term, community residents and advocates have expressed concern that the pandemic will result in less transparent decision-making processes, not only for automation but for freight decisions in general. In Joliet, IL, for example, residents were able to successfully slow the development of a massive warehousing facility. The coronavirus changed that: "With much of the nation sheltering in place and ramping up the need for home deliveries, supporters of the warehouse project have used the pandemic as a reason for government officials to quickly approve the development. And opponents…have felt hamstrung to fight back, because COVID-19 is forcing government meetings to be held virtually,"[8] which prevents a more robust city hall presence.

For the longer term, there is concern that the pandemic will ultimately speed up freight automation. For example, concerns about spreading the virus through physical interactions, like handing a paper document from a driver to a warehouse operator, has accelerated freight companies' interest in digitalizing their operations.[9] Such digital platforms, in turn, are foundational to broader automation efforts. Others see human-beings' vulnerability to something like COVID-19 as the impetus for more automation. As one freight analyst put it:

> The supply chain is, at heart, physical. It moves large amounts of physical goods around, and at almost every step of the way it is propelled by human labor. Truck drivers. Crane operators. Workers loading and unloading containers. Stevedores. Seafarers. As the pandemic spreads…we will see a decline in the availability of all these people. Some fall ill themselves, others need to stay home to care for their family. … Just as with digitalization, automation of the physical part of the industry has also been under way for several years and as such the pandemic is not a game changer, but will serve to accelerate the development. We will see a more rapid uptake in remote-controlled technology that enables the use of skilled

people without a physical presence at a specific location. We will likely also see an acceleration in the use of fully autonomous equipment in settings where this can be practically incorporated.[10]

The counterargument to the view that the coronavirus will speed automation rests on matters of money and the heart. First the money: ever increasing levels of automation are more expensive. Given the fallout in the US economy in 2020, the freight transportation system will need time to recover. McKinsey & Co., for instance, predict a "full recovery will take about three to five years, a rough patch in which companies will be severely tested."[11] During this time, it may be difficult for companies to invest in increased automation. Then there's the heart: Throughout the pandemic, the public and policymakers have hailed frontline essential workers as the heroes of the moment as they've kept supplies on shelves and food delivered to our doors. That sentiment could be leveraged so their work is protected, enhanced, and made safer–not simply replaced with automation. ■

Predictions are fallible, of course. Apart from technological uncertainties, external factors–legal, economic, political, public sentiment–may also play a major and, at times, unpredictable role in shaping the pace and scope of freight automation. The complexity of these types of factors add a great deal of variability to identifying freight automation trends.

With the above caveats in mind, following is a sector-by-sector breakdown of freight automation, including where things stand now and what's likely ahead.

TRUCKING

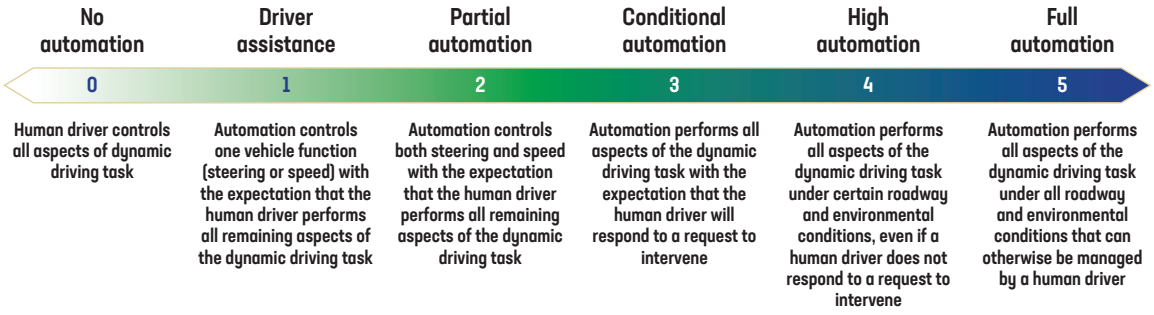
It's difficult to overstate the significance of trucking to the country's freight transportation sector. Trucks handled more than 11 billion tons of freight in 2019–greater than 70% of the domestic total.[12] More than 3.5 million people work as truck drivers, and between 2012 and 2016, trucking businesses grew at a rate that outpaced total industrial growth. More than half of trucking businesses are considered long distance, shuttling goods from one corner of the country to the other and beyond.[13] In 2017, the American Trucking Associations estimated that all registered trucks traveled more than 297 billion miles,[12] which equates to more than 60,000 round trips to the moon.

The extent of truck automation

Truck automation is varied. In some instances, the driver is in complete and total control. In others, the truck may not even be built with a steering wheel or space for a human occupant. Between these two extremes are more nuanced levels of automation, where a human may

still control some specific driving functions (e.g., steering but not braking) or portions of a journey (e.g., more complicated roadways). The US Department of Transportation categorizes six levels of driving automation, from none (zero) to full automation (five).[14]

Levels of Driving Automation Used by the Department of Transportation



Source: GAO analysis of U.S. Department of Transportation information (GAO-19-161)

Driver-assistance technologies are a major category of truck automation. Examples include automatic braking for emergency situations and technologies like lane-departure warnings and blind-spot detection, neither of which automates driving functions, but they provide alerts to the truck driver.* Another example is adaptive cruise control, which automatically adjusts the vehicle speed to maintain a safe distance from traffic.

Freight and technology stakeholders see automation efforts focused first and foremost on long-haul trucks (i.e., those traveling hundreds of miles on a single route). Those automation efforts generally fall under one of three different scenarios:

- *Platooning*: Linked by various communication technologies, one or more trucks follow behind a lead truck at distances that are much closer than would be safe without automation. Should the lead truck brake quickly, the remainder of the trucks would brake nearly instantaneously. A more advanced platooning variation has a human driver in a lead truck followed by one or more "drones"—driverless trucks that track the lead truck's speed and movement.
- *Self-driving a portion of a route*: Also called exit-to-exit automation, trucks would have high or full degrees of automation, but only on certain predetermined portions of a long-haul route. For example, a driver might steer a truck to a freeway on-ramp and then engage the automation system, reclaiming control at the appropriate off-ramp.
- *Self-driving a full route:* From the local roads near freight warehouses to the open highway, an automated truck would handle it.

* Technically, warning systems aren't typically classified as automation. We include them here, however, because of their increasing prevalence and because they're foundational to more advanced types of automation.

The timing of truck automation

As different truck automation scenarios unfold, the time frames in which various forms of automation happen will vary considerably. Although these time frames can be uncertain, there are clear trends.

Time Frame and Technologies	Anticipated Deployment
0-5 years: Driver-assistance technologies	Adaptive cruise control, automatic braking for emergency situations, and other technologies like lane-departure warnings and blind-spot detection are commercially available now for new and older trucks. Market demand for these types of technologies is "quite strong,"[15] so their use will grow considerably in the future.
Platooning	A range of platooning technologies is commercially available now. More basic are those where the following drivers are responsible for steering but not for speed or braking. More advanced forms are in the precommercial state of development but are close to commercial use.[15] Given what we have now, "platooning will likely deploy within the next 5 years and will be the first automated trucking technology to be widely available."[14] Others estimate an even faster deployment.[16]
5-15 years: Self-driving a portion of a route	Per one comprehensive summary, "Automated trucks that are self-driving for part of a route may become available for commercial use within the next 5 to 10 years, according to several stakeholders, including technology developers."[14] Other researchers and reports make similar estimates. An important caveat: this type of highway-centric automation will likely be concentrated at first in the "southwest United States because of its good weather and long highways,"[14] such as interstate highways I-10 and I-40. Such automation will likely then spread over 10-15 years to other "key freight lanes nationally on a seasonal basis."[16]
≥20 years: Self-driving the full route	It will likely be several decades "before driverless trucks will be able to routinely navigate local streets packed with cars, pedestrians, cyclists, road work, and other unexpected challenges. Humans will also be needed to handle the many non-driving tasks—coupling tractors and trailers, fueling, inspections, paperwork, communicating with customers, loading and unloading, etc.—that drivers currently perform."[16]

WAREHOUSES

Warehouses occupy a critical nexus between the creation of a good or product and the delivery of that product. Also known as distribution centers, warehouses are "responsible for the storage, flow and rerouting of goods to consumers or retailers."[17]

There are nearly 17,000 warehouses in the United States,[18] generally clustered around major population centers and close to the nation's transportation thoroughfares. This includes places like inland southern California, the greater Chicago area, Dallas–Fort Worth, and the New York–New Jersey area.[17] Driven in part by the explosive growth of e-commerce, both the number and size of warehouses have increased over the past two decades. The average size of warehouses built between 2012 and 2017 increased by 143% (184,693 sq. ft.) compared with warehouses built between 2002 and 2007.[19] In the Inland Empire of California, the average size of new warehouses is approximately 338,000 sq. ft.[19]—equivalent to nearly six football fields.

More than one million people were employed in the warehousing and storage sector in 2018, a number that excludes warehouse workers hired through temporary staffing agencies.[20] Typical warehousing activities include unloading and putting away goods; storing them until they are needed elsewhere; "picking," or selecting items for later shipment; and shipping, including preparing orders and loading goods.[17]

The extent of warehouse automation

Warehouse automation starts with increasingly sophisticated warehouse management systems (WMS) – software that helps control and manage day-to-day operations as goods flow to and from the warehouse. On their own, WMS are typically used to increase operational efficiencies and reduce user error.

Warehouse management systems also serve as a foundation for more hardware-focused automation. The range of automation applications is rather diverse; below are examples of foundational and/or significant advances in warehouse automation, as captured by a recent comprehensive report.[17]

- **Automated guided vehicles:** Technology-enabled material moving vehicles…that transport goods along preset routes in a facility
- **Robotic picking:** A robotic arm is equipped with hand-like or suction-cup grippers that can reach into a pick location, grasp an item, and place it into a tote.
- **Goods-to-person systems:** Goods-to-person systems bring items to the worker for order picking. This can, for example, take the form of a shelf mounted on a robot that makes its way to the picking station…or a hanging bag sorter that brings individual items to a worker via an overhead-mounted pouch.

- **Voice-directed systems:** Workers wear a headset that provides instructions on what items to pick or put away and where they are located, and workers confirm the location and items by speaking standardized commands.
- **Autonomous Mobile Robots (AMRs):** Automated carts that travel around a warehouse, moving items for orders between picking and sorting or packing locations. Two subcategories exist: "relay" carts and "follow-me" carts. Relay AMRs can work with most picking processes; the order picker selects the items for the order, places them in the cart or tote, and the AMR delivers the tote to the next task station. A follow-me AMR leads a worker through the warehouse, setting the pace and directing the worker to select particular items.
- **Sensors:** Sensors have many applications in the warehouse, from dynamically tracking inventory, to monitoring the movements of workers, to controlling energy usage.

The timing of warehouse automation

Significant warehouse automation is already in place now. For example, across Amazon's 175 fulfillment centers worldwide, 26 have "robots and people working together to pick, sort, transport, and stow packages."[21]

Generally, the presence of such automation is limited to a smaller portion of early adapters across the warehouse sector. For example, WMS, which help control and manage day-to-day operations as goods flow to and from the warehouse, are "considered to be a fundamental building block for the adoption of other technologies," but an estimated 33% of warehouses do not use one.[17] Even for the majority of warehouses that do use WMS, that doesn't mean that incorporating additional automation happens readily or quickly.

There are significant barriers to full adoption of automation within the warehouse sector, including that the "industry is characterized by slim profit margins and cost-sensitive competition, which leads to a cautious approach to technology adoption."[17] That isn't likely to change much in the next 5 to 10 years. A variety of other factors comes into play too. For example, companies' heavy reliance on outsourcing warehousing services to third-party logistics companies acts as a brake on automation. Outsourcing contracts tend to be relatively short (e.g., 3-5 years), thus making it difficult for a third-party logistics company to realize an automation-related return on investment. There's also the question of how advanced automated technology is versus how advanced it needs to be for large-scale adoption. As one warehouse manager put it, "'I struggle to find the robot that will be able to handle a bag of plaster of Paris, a bit for a jackhammer, a galvanized steel garbage can, a saw blade, and a five-gallon bucket of paint. Oh, by the way, what happens when that [plaster of Paris] bag ruptures? How does the robot know that the bag is ruptured?'"[17]

In contrast, labor dynamics and conditions act as powerful tailwinds to support automation. Between a very low national unemployment rate (albeit prior to the COVID-19 pandemic) and low wages within the warehouse sector, the warehouse sector has had a difficult time meeting its labor needs, a dynamic that intensifies during the holiday season when e-commerce spikes. Another issue is the rising cost of real estate. Rents are increasing as vacancy

rates are on the decline, putting more cost pressure on the sector, which creates the need for cost cutting. Last, there's the ever-increasing push to deliver goods more rapidly. Within the industry, automation is seen as a potential way to address these cost and efficiency factors.* Indeed, one 2019 industry survey indicated that 39% of respondents anticipated investing in some level of automation technology within the next 5 years.[22]

These factors make it difficult to predict exactly when large-scale warehouse automation will occur. Still, on balance the warehouse sector is moving toward an ever-more automated future: "Over the long term, in the absence of major shifts in the economy or context of firms' technological adoption strategies, the increasing use of technology points to a labor reduction."[17]

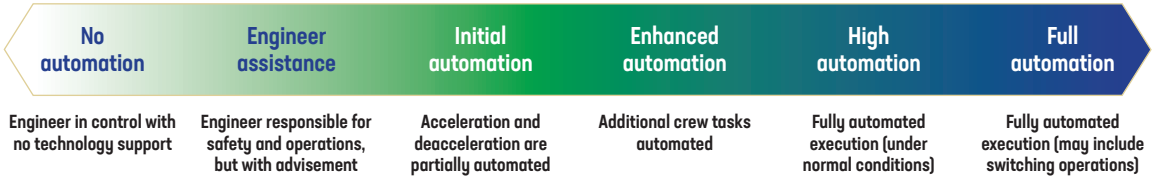
RAIL

Composed mostly of large national rail lines, approximately 140,000 miles of track, and anchored by sprawling rail yards in each region of the country, freight railroad companies haul fuel, agricultural products, manufacturing components, consumer goods, and more—57 tons of goods per American per year.[23] Over the past several decades, the rail industry has grown more integrated with the rest of the freight system: the American Association of Railroads estimates that nearly half of its carloads are intermodal, meaning the trains carry containers designed to be transferred to other forms of transportation, such as trucks and ships. More than 160,000 people are employed by rail companies.[24]

The extent of rail automation

Much like the trucking sector, train-related automation is varied and can easily be thought of along a spectrum ranging from zero automation, where humans are in full control of all operations, to full automation involving no human input. In between are levels of semiautomation whereby portions of an operating crew's workload are either supported or replaced by specific technologies. The Association of American Railroads (AAR), an industry group representing major railroad companies, recommends the following taxonomy[25]:

Automated Rail Taxonomy



* For an-depth overview of the factors facilitating and constraining warehouse automation, see this publication by Beth Gutelius and Nik Theodore: *The Future of Warehouse Work: Technological Change in the U.S. Logistics Industry*. UC Berkeley Labor Center, Working Partnerships USA; October 2019.

Currently, all types of automation on this spectrum are technologically feasible. There is fuel and energy management technology (think cruise control but for trains), train sensor data and alarms to provide crews situational awareness while in operation, and positive train control (PTC) technology to prevent collisions by controlling train speeds and movements.[26] Although there is no fully autonomous freight rail service commercially operating in the United States, it's not because of lack of technology: the mining company Rio Tinto uses fully autonomous trains to shuttle iron ore on approximately 1,000 miles of track through the Australian Outback.[27]

The timing of rail automation

Many of the mid-spectrum automated technologies for trains, particularly those related to fuel use and safety, are in place already. Various technologies have been implemented piecemeal by different railroad companies as "add-ons." In other instances, automated systems have been adopted at a system-wide level. For example, after a 2008 freight and commuter train collision in Los Angeles, CA, that killed 25 people when an engineer missed a stop signal, Congress mandated the adoption of PTC technology. Twelve years and $10 billion dollars later, the safety system is mostly in place.[28] Automated technologies are also being put to use to inspect wheels and tracks.[29]

Full automation under limited or all conditions is rare. There is the example of Rio Tinto, and also a successful test in Colorado in 2019, when "three locomotives and 30 loaded wagons carrying [5,208 tons] were moved without human intervention along a 48-mile test track."[30] Beyond these examples, it is hard to predict the next 5 to 10 years, because of opposing political perspectives.

Opponents of high levels of train automation frequently raise safety and employment concerns. The Transportation Division for the Sheet Metal, Air, Rail, and Transportation Union has stated: "In valuing safety as the highest priority, it is important to understand the essential roles that human employees play in the safe operation of trains. There are countless essential functions that humans perform, using their perception and judgment that cannot be replaced by automation, especially on America's vast rail system that covers an incredible geographical and weather diversity."[31] The Union also emphasized the role onboard workers can play in "thwarting hostile actors and terrorism," [31] and cited concerns about cyberattacks in which a fully autonomous train could be taken over with no onboard worker to intervene. The Union has expressed strong worries about job loss: "The automation of train operations has the potential to cause the loss of tens of thousands of good paying union jobs across America. The potential for the dislocation of workers in the event automated rail operations become common practice is extreme."[31] The Union was not alone in its concerns: the Federal Railroad Administration's call for comments on rail automation received more than 3,300 comments and, by one estimate, 99% of them were in opposition.[28]

In contrast, the AAR, a proponent of increased train automation, has said: "If railroads are to continue to improve their efficiency, increase their capacity to transport their customers' freight, further reduce congestion on the highways, use less fuel to get goods to their

RAIL YARD AND INTERMODAL RAIL AUTOMATION

At rail yards across the country, a substantial number of switching and other operational activities have already been automated. Complex computer systems help manage the flow of rail cars in and out of yards, flag certain cars for inspection, and even help heat rail lines and equipment in extremely cold conditions.

More fully automated systems are being developed and deployed. For example, in 2019, Canadian National Railway introduced an "automated inspection portal, a machine that relies on artificial intelligence that can evaluate 120 cars in the same time it takes a worker to check a single car."[36] Canadian National Railway would like to use the portals in the United States. Elsewhere, at least one company is using drones and artificial intelligence programs to inspect rail yards and tracks for safety concerns.[37]

Intermodal rail automation (e.g., automating portions of a facility where a container might be transferred from a train to a truck) is yet another area poised for implementation. That's not surprising; for example, much of the automated cargo-handling equipment in ports has similar functions to operations within intermodal and rail facilities.

Still, in-depth information about the broad extent and timing of future automation within rail yard and intermodal facilities isn't readily available. It's an area worth additional exploration. ■

destination, and, most importantly, make the industry even safer than it is today, a paradigm shift is required. Automation is that paradigm shift."[25] The AAR acknowledged concerns such as cyberattacks, but framed them as a "challenge, but not an obstacle, to autonomous rail operations [that] can be addressed through proper design and constant vigilance."[25] The AAR also promotes increasing rail automation as a job generator: "the development and deployment of PTC [technology], for example, has created numerous new jobs on the railroad, and has employed and will continue to employ many people,"[25] and warns that without automation, rail is unlikely to remain competitive with other modes of transportation, which will result in substantial job losses.

These differing perspectives are reflected in various regulatory and legislative actions. For example, at least five states currently mandate a minimum of two-person crews on trains, and another 21 states are actively considering similar legislation.[32] At the federal level, Congressional bills would require a minimum of two-person crews, although no bills have advanced substantively.* In addition, the Federal Railroad Administration's more recent actions may have tipped the regulatory and legal scales in automation's favor: whereas in

* Specifically, S. 1979 sponsored by Senator Markey and H.R. 1948 sponsored by Representative Young.

2016 it proposed setting a two-person train crew mandate, it rescinded that proposal in 2019 and summarized that "no regulation of train crew staffing is necessary or appropriate for railroad operations to be conducted safely at this time."[33] Such moves may support legal efforts to overturn state crew mandates on the grounds they interfere with interstate commerce.[34]

In early 2020, the nation's largest freight railroads and unions, representing more than 125,000 rail workers, launched a contract negotiation process, and crew size will be at the heart of the likely multiyear negotiation.[35] Predictions about rail automation will likely become much easier to make once that negotiation is finalized.

PORTS

From massive, sprawling complexes to relatively smaller facilities, waterside ports are another significant hub for the nation's freight infrastructure. Connecting ships with trucks and trains, and vice versa, the top 25 maritime ports in the United States handled 1.88 billion tonnage in 2018.[38] If all of the containers that went through these ports were lined up, they would circle the earth more than 43,371 times.

The extent of port automation

Similar to warehousing, software-based decision-making tools, tracking and tracing programs, and analytical supports serve as both the brain and central nervous system of all automated port operations. These digital technologies provide the foundation for a wide range of port equipment that moves containers from ships to docks to trucks and vice versa. These include:

- **Quay cranes,** which move containers from ships to the dock
- **Straddle carriers,** which transport containers from the quay cranes to storage areas within the port
- **Yard cranes,** which stack containers within the yard for storage and later retrieval
- **Gates,** where containers are loaded and unloaded from short- and long-haul trucks

Similar to other freight transportation sectors, automated technologies span a spectrum that includes assisting human-performed tasks to fully replacing them. For example, although automated quay cranes may not have an operator located on the physical crane, and although some of its movements may be computer controlled, a remote operator may still be monitoring its performance and may step in to handle certain tasks. Straddle carriers, in turn, guided by underground magnets, may move about without any human involvement.[39]

The timing of port automation

Extensive port automation is currently in place in the United States. Both the TraPac terminal at the Port of Los Angeles and the Long Beach Container Terminal (LBCT) at the Port of Long

Beach are mostly automated. For example, the LBCT has 48 stacking cranes. "In a traditional terminal, workers operate them from booths on top, but in the LBCT, four people can control all 48 cranes at once" from a remote location.[40] The Global Container Terminals in New York and New Jersey and the Virginia International Gateway terminal in Norfolk, VA, are two other terminals that are semiautomated: container stacking is automated, whereas the "horizontal transportation of moving containers from the berth to the stacks in the yard is performed by conventional yard tractors driven by longshore workers."[41]

Still, this level of automation is limited. The LBCT, for instance, is only one of 22 terminals at the site; the others are conventionally operated.[40] The use of automation at ports in the United States is less than what is used at many ports in Asia and Europe. For example, the Port of Shanghai launched a fully automated terminal in 2017, and the automated terminal in Rotterdam, the Netherlands, launched in the early 1990s.

Although technological feasibility would suggest high levels of port automation, economic and labor factors have created an uncertain future. McKinsey & Company note that "the up-front capital expenditures are quite high, and the operational challenges…are very significant… [W]hile operating expenses decline, so does productivity, and the returns on invested capital are currently lower than the industry norm."[42] An analysis by Moody's raised similar concerns.[43]

Among the factors influencing the future of port automation, labor plays an outsized role. Dock jobs are some of the most highly compensated heavy-labor work in the United States, and the workers and the unions that represent them are concerned about how port automation has already cut into workforce levels. The International Longshore and Warehouse

Union (ILWU), which represents West Coast dockworkers, "estimates that two-thirds of the longshore jobs at LBCT have disappeared due to automation."[40] Moody's analysis notes "labor-saving is a key feature of automated terminals, which may have between 40 and 70 percent lower labor requirements than traditional facilities."[43]

Although the pace of port automation in the United States is currently difficult to predict, that likely won't be the case in a few years. Automation will be a central and contentious issue for the ILWU and the Pacific Maritime Association, which represents terminal operators and owner companies, when they negotiate the current labor agreement that ends in 2022.[44] On the East and Gulf Coasts, the current labor agreement (which ends in 2024) coupled productivity targets with limits on terminals' ability to automate.

The current state of freight automation offers a window of opportunity.

Any amount of automating of the freight system will not happen overnight, nor will it replace all workers with new technology. Automation happens with an array of decisions and choices, which affords policymakers, industry stakeholders, frontline workers, community members, and the public time to better understand the implications of freight automation. More importantly, they can make decisions to enact and support policies and programs that promote health and equity for frontline workers and fence-line communities.

The next sections of this report take a closer look at several health and equity implications of freight automation.

// FREIGHT AUTOMATION'S IMPACTS ON THE ECONOMIC SECURITY, HEALTH, AND SAFETY OF FRONTLINE WORKERS ////

Current dangers:

- Automation has resulted in fewer available jobs for some frontline freight workers, as well as decreased income for some contract workers who experience automation-related work slow-downs.
- Automation in warehouses has resulted in worker injuries and death.

Future threats:

- Automation will likely generate job losses and decrease the total number of jobs available for frontline workers across multiple freight sectors. Given automation's likely effects on other, nonfreight industries, finding new employment may be difficult.
- Job wages and benefits in existing and new positions will also likely decline due to the expansion of the gig economy.
- Working alongside automated technologies such as robots will likely continue to negatively affect worker safety and health.
- Low-income workers and workers of color will be disproportionately affected if employment and workplace impacts unfold as expected.
- Local economies will experience ripple effects from job loss, because people will have less income to spend in communities.

Opportunities:

- Automation will likely create new employment opportunities for current frontline workers, though for how many is unclear.

Summary Trends: What Freight Automation Means for Frontline Workers' Economic Security and Safety

"I look at automation as a short-term fix for the financial health of the country. Automation eliminates jobs which eliminates the ability for people to buy goods and services."

– Buddy Smith, President, Local 1233, International Longshoremen's Association

"Health and safety is an issue. Because the pace is increasing [with automation], are we going to see more accidents and injuries or even heart attacks? We've had a couple members at Amazon have strokes."

– Roberto Clack, Associate Director, Warehouse Workers for Justice

"Every industry is being impacted [by automation], which presents a lot of danger to our industry because when people get hurt on our job they don't get paper cuts, they don't get headaches. When people get hurt on the docks they lose limbs or they lose lives."

– Vivian Malauulu, ILWU Local 13 Registered Longshore Worker and Benefits Officer

Given the outsized role that the freight transportation system and its workers play in the USeconomy, it is no surprise that automation holds the potential for significant—and in many cases, negative—impacts.

Automation has already negatively affected the health and well-being of freight's frontline workers.

Automation in the freight industry is already impacting the livelihood, health, and safety of workers across the country. A recent report found that the rate of serious injuries at an Amazon warehouse facility in Tracy, CA, almost quadrupled after robots were introduced.[45] At seaports, slowdowns occur from clogged automated systems causing drivers to wait hours longer for their workloads and reducing their wages, because they get paid by the load, not by the hour.

Increased automation may bring job losses and lower benefits, and worsen many worker conditions, especially for low-income workers and people of color.

Job loss and a reduction in the number of jobs available are potential side effects of automation in the freight system. In addition, these job losses will likely happen in an economy where automation will simultaneously be increasing unemployment across a variety of

nonfreight sectors: some estimates predict that up to 30% of workers may need to transition to different occupations by 2030 as a result of automation.[46] Automation may create some new employment opportunities for current frontline workers, but for how many is unclear.

Because income and economic security are key social determinants of health, job loss and economic insecurity can lead to negative health outcomes, such as chronic illness and premature death. Such economic losses would also have ripple effects in nearby communities.

Some models predict that automation will contribute to fragmentation of worker benefits like health care. Automation also can, and already has, increased the workload and pace of work, with consequences for employee safety.

These automation impacts are likely to be concentrated among low-income workers and people of color, who are overrepresented in various freight sectors compared with the overall population.

A Closer Look: Sector-Specific Examples

Sectors within the freight industry will feel the effects of job losses differently.

Trucking: Within the long-haul trucking sector, one recent report found that without policy intervention, up to 294,000 long-distance driving jobs could be eliminated with automation.[16] Another report estimates that between 300,000 and 900,000 trucking jobs could be lost over the next 10 to 20+ years to automation, out of a total of nearly 1.9 million heavy and tractor-trailer truck driver jobs.[14] These estimates vary considerably in part because, as noted previously under *State of Automation in the Freight Industry*, there are still considerable uncertainties related to automation's deployment.

Ports: A limited number of ports already have automated terminals, and others are under development. Given the technological feasibility of automating port operations now, it's clear the employment impacts can be significant. For example, the LBCT, which opened April 2016, has two-thirds fewer employees than do traditional terminals.[40] A recent study in Canada may also be illustrative for the United States. The authors found that automation at the Ports of Vancouver and Prince Rupert could reduce dockworker jobs by 50% if the ports semiautomate, and up to 90% if the ports fully automate.[47] The adjacent table shows examples of the number of workers used at three ports with varying levels of automation.

Conventional Terminal[a]	Semiautomated Terminal[b]	Fully Automated Terminal[c]
525 workers	213 workers	150 workers
1 million TEU[d]	1.6 million TEU	1 million TEU

[a] Prince Rupert terminal (British Columbia, Canada). [b] Port Botany terminal (New South Wales, Australia). [c] Victoria International Container Terminal (Melbourne, Australia).] [d] TEU: 20-foot equivalent unit, a common measurement of cargo capacity.

Warehouses: In some warehouses across the country, workers are already working alongside automated robots. But researchers predict that automation within warehousing will not likely cause widespread job loss for at least the next 5 to 10 years.[17] There are already cases of automation resulting in job loss, though: in Japan, clothing company Uniqlo cut their staff by 90% at their Tokyo warehouse when they automated.[48] In contrast, leaders at retailer Boxed chose to retrain workers to run the new automated equipment instead of laying them off.[49]

Rail: Although automation advances such as PTC technology has helped set the stage for reducing the number of workers operating a train, whether it happens is a different story. The debate is a key part of the negotiations taking place between labor and the major railroad companies over the next several years.

Job losses within freight transportation are likely to occur against a backdrop of significant job losses driven by automation across a wide range of sectors within the US economy. "[F]uture waves of disruption may impact a wide variety of industries and occupations at the same time, making it more difficult for disrupted workers to find a stable industry or occupation into which to transition."[50] One report estimates that between 16 and 54 million US workers, which is 10% to 32% of the workforce, may need new occupations by 2030.[46] Another group of researchers estimates that approximately 9% of US jobs are at risk of being lost to automation.[51] Estimates differ; however, the consensus is that jobs across multiple employment sectors will be affected, including but not limited to retail, sports, law, hedge funds, and the freight industry.

Interested in more in-depth information about automation and job displacement? For a closer look see:

"A Future That Works: Automation, Employment, and Productivity" by McKinsey & Company (https://www.mckinsey.com/~/media/McKinsey/Featured%20Insights/Digital%20Disruption/Harnessing%20automation%20for%20a%20future%20that%20works/MGI-A-future-that-works_Full-report.ashx)

Unpacking Skill Bias: Automation and New Tasks, which addresses automation's historical contributions to income inequality (https://www.aeaweb.org/articles?id=10.1257/pandp.20201063) ■

Automation may also cause reduced wages for workers in the freight industry. For example, some truck drivers get paid by the load, so they get paid less when they can't complete as many trips due to workflow inefficiencies and delays at ports. Such delays have been caused by automation, according to stakeholder interviews. Stakeholders report stalled operations when the computer system cannot locate a certain container load for a truck driver, and there have been times when outside truckers have had to wait for hours because a computer-directed machine "decked" the container in the wrong yard spot, or because the computer

is unable to locate the container in the yard pile where it was assigned, or because it was incorrectly delivered to the wrong driver.

Remaining freight jobs may see a decline in employee wages and benefits, and access to newly created jobs may be difficult.

Automation-related job losses may happen along with some job growth within other freight industry sectors. For example, the Bureau of Labor Statistics estimates a modest increase in the need for diesel service technicians and mechanics through at least 2029.[52] Growth in e-commerce-related jobs is also expected, which is likely to increase the new job opportunities for women, who are "more likely to be employed in e-commerce warehouses than in traditional ones."[17]

But the quality and stability of these jobs may not be strong. Many jobs will be part of the gig economy, meaning workers are independent contractors without the rights and benefits of employees. Misclassification is already a significant problem that affects the wages and benefits of many within the freight sector. Jorge Mayorga, a veteran port truck driver, notes, "Unlike employees, independent workers usually have no access to unemployment benefits, disability pay or workers' compensation. In many cases, trucking companies also pass costs on to drivers, including expenses for fuel, maintenance, repairs, insurance, permits and truck leases." This problem is likely to be exacerbated by automation, particularly in e-commerce warehouses.[17] Similarly, as automation works its way further into the trucking sector, newer jobs will mostly be local driving and "last-mile" delivery jobs that, without policy intervention, risk misclassification as independent contractor jobs with lower income and fewer protections.[16]

Interested in more in-depth information about trucking misclassification? For a closer look see:

Big Rig Overhaul: Restoring Middle-Class Jobs at America's Ports Though Labor Law Enforcement, from the Economic Analysis and Research Network (EARN) (https://earn.us/publications/the-big-rig-overhaul-restoring-middle-class-jobs-at-americas-ports-though-labor-law-enforcement/) ■

New jobs will emerge, including automated equipment service and maintenance jobs; technology repair specialists; software, computer programming, and electrical engineering positions; jobs with firms that map the nation's highways; and jobs related to technology development, financial analytics, and patent infringement law.[53] With policy and program interventions, current freight workers could be retrained to take over some of these newer jobs. For instance, a forklift mechanic could undergo training in the controls of automated guided vehicles.[54]

"Latinx and Black workers are overrepresented in the industry compared with the total U.S. workforce: both groups are employed in warehousing at twice the rate of all other industries."

– Beth Gutelius and Nik Theodore
(*The Future of Warehouse Work: Technological Change in the U.S. Logistics Industry;* 2019[17])

But for other jobs, such a transition might be more difficult, particularly if the skills needed for newer positions aren't aligned with existing skills. The percentage of displaced freight workers who will be able to transition into new positions that are created by automation is unclear and unpredictable; this is an area ripe for additional research.

Automation can significantly change workplace conditions.

"Trying to figure out a way to have a one-man road freight train... Can you imagine being by yourself in a train for 12 hours, 9 o'clock in the night to 9 o'clock the next morning? Going to the desert by yourself from LA to Yuma, Arizona. That's just ridiculous especially what happens if the train breaks down too? Too much to put it on one guy."

– James, railroad conductor

Automation can create changes in workplace conditions, including increased worker isolation and reduced ability of workers to make decisions. In warehouses, robots and productivity software can cause work speed-ups which push workers to move faster,[45] and workers also face direct interaction with robots that roam warehouse floors more freely.[55]

Driver-assist automation has already changed truck driver's experiences. For example, automatic braking can react faster than a driver can. Changes will depend in part on how automation unfolds. Even with increasing levels of automation, a driver may still need to be "on call" to instantly take over if needed. Meanwhile, a fully automated truck self-driving a portion of a route may not require any driver oversight. In instances where drivers are still required to be in the cab, they may have longer driving shifts. As one researcher observed, without policy intervention, "the nation could easily end up with a model of autonomous trucking where humans are simply poorly paid attendants to robots, working in cramped and lonely conditions, with little sleep, and few prospects."[56]

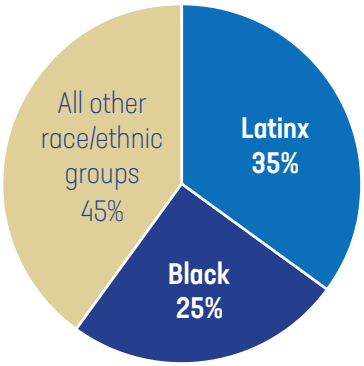
How Freight Automation's Impacts on Employment and Workplace Conditions Will Affect Health and Equity

Job losses will inequitably affect low-income workers and workers of color.

Without policy and program interventions, the impact of automation on job loss and accompanying economic insecurity will have significant health effects and will disproportionately impact low-income, lower-skilled, and less-educated workers.[51] Workers who are young, male, Latinx, and Black are overrepresented in the warehousing industry; for example, workers of color make up 66% of warehousing industry workers.[17] As such, automation's impacts will disproportionately affect these workers.

Frontline Warehousing Jobs, by race/ethnicity

(Adapted from Gutelius and Theodore[17])



In addition, Black workers are greater than 1.5 time more likely to work in easily automated jobs, including freight movers. The employment category "laborers & freight, stock & material movers, hand" employs 1,900,000 people, of whom 378,000 are Black employees. This category of work makes up 1.8% of the total Latinx workforce and 2.1% of the Black workforce,- both more than the 1.2% of the White workforce employed in this area.[57]

Black people are overrepresented as drivers in the trucking industry; a greater proportion of truck drivers are Black compared with their proportion within the US population.[58] One estimate predicts that without policy intervention, automation could "increase the African American unemployment rate from 7.5 percent to over 20 percent"[57] due to the number of Black workers in jobs that are at high risk of elimination due to automation.

Lower-wage jobs are at greater risk from automation. The White House Council of Economic Advisors found that "83 percent of jobs making less than $20 per hour would come under pressure from automation," compared with only "4 percent of jobs making above $40 per hour."[57]

Joblessness is a health risk.

Losing a job can have consequences on a worker's physical and mental health and influence how long they live. [59] For example, a displaced worker's mortality rate in the year after displacement is 50% to 100% higher than would be expected.[60] Once displaced workers are

re-employed, they experience improved physical functioning and mental health.[59] Job loss can also make it hard for families to afford food, utilities, medications, and housing.[61]

Loss of access to health care harms health.

Accompanying job loss is a loss in health care, which also harms health. Having access to health insurance improves health by increasing the likelihood that an individual will access and use health care.[62] People who are uninsured are less likely to get preventive care and are more likely to die earlier than people who have health insurance.[63]

Automation changes to workplace conditions can risk worker health and safety.

Automation can considerably change workplace conditions for frontline workers. What follows are the wide range of health and safety implications of those changes.

Injuries and illness: Automated technologies can cause work speed-ups that push workers to move faster than is safe, leading to injuries.[45] Workers also face potential harm from robots that roam warehouses floors more freely, which is much different than previous iterations of robots that were behind cages for the safety of workers.[55] Warehouses with robotics often have higher injury rates than warehouses without robots; for example, all five of the Amazon warehouses with the highest number of injuries in 2018 had robotics in the facilities.[45]

Interested in more in-depth information about warehouse worker safety? For a closer look see:

Behind the Smiles, published by Reveal from the Center for Investigative Reporting (https://revealnews.org/topic/behind-the-smiles/). ■

Workplace stress from a variety of factors, such as increased pace of work, also likely plays a role in the development of illnesses. According to the National Institute for Occupational Safety and Health, "evidence is rapidly accumulating to suggest that stress plays an important role in several types of chronic health problems—especially cardiovascular disease [and] musculoskeletal disorders."[64]

It's critical to note that injuries and illnesses aren't inherent to automation. Proper planning, training, and oversight can ensure technologies don't harm workers.[55] Also, workers can and should be protected from workplace injuries without any automation at all. For example, supervisors can rotate warehouse workers to different positions to reduce repetitive stress injuries.

In contrast, low levels of automation for truck drivers may reduce physical injuries. Currently, professional drivers are 10 times more likely to be killed on the job and nearly 9 times more

likely to be injured than the average worker.[65] Automation that makes truck driving safer, such as automatic braking, will support driver health. As for increased levels of automation, including reducing the need for a driver at all, the safety implications are much less certain. Please see the section, *Freight Automation's Impacts on Traffic and Health*, for more information.

Mental health: Workers with less control, decision latitude, and agency over their work environment have worse mental health than those with greater control,[66,67] including higher rates of depression, anxiety, insomnia, and exhaustion.[66,68] In contrast, the physiological stress experienced by workers was reduced as they gained more agency on the job.[69]

OF LITTLE LEAGUE TEAMS AND BALLET CLASSES

John Bagakis

John Bagakis is a San Pedro small business owner who works near one of the most massive port complexes in the United States. Before the LBCT was automated, his restaurant made 12 to 15 deliveries a week to the facility. Now, they only receive one order every 2 weeks. If APM Terminals Pier 400 becomes automated, John's business would be affected even more. Currently, he makes 4 to 5 deliveries per day to Pier 400 Maersk and its approximately 500 employees. If the terminal automates, they could go down to zero deliveries, and John would most likely have to lay off workers and delivery drivers. So, in addition to the roughly 500 employees at Pier 400 Maersk, the effects would reverberate out, impacting the entire community. "We small businesses give back a lot to our communities. Whether it's a local little league team, or whether it's a fundraiser for someone battling an illness … We give money to that, we give food donations to that… If there's less money coming into our business, that's less money for us to funnel back into the community."

Vivian Malauulu

Vivian Malauulu, a registered longshore worker with ILWU Local 13 in Southern California, shares similar perspectives. "We're not completely against automation. We're only against automation that replaces human labor. If you're going to introduce automation, do so with a conscious effort to preserve a job that allows for somebody to pay taxes, that allows for somebody to buy a home, to contribute to the community, to eat at a local restaurant, to shop at a local store, to send their kids to ballet. Because if you automate terminals and you take away the jobs and the human factor, that's less revenue, less taxes, less payroll, less going back into the community, and a reduced quality of life for families." ■

Increased isolation: Loneliness can create a greater risk of cardiovascular disease, increased risk of depression, compromised immunity, and even a shorter lifespan.[70]

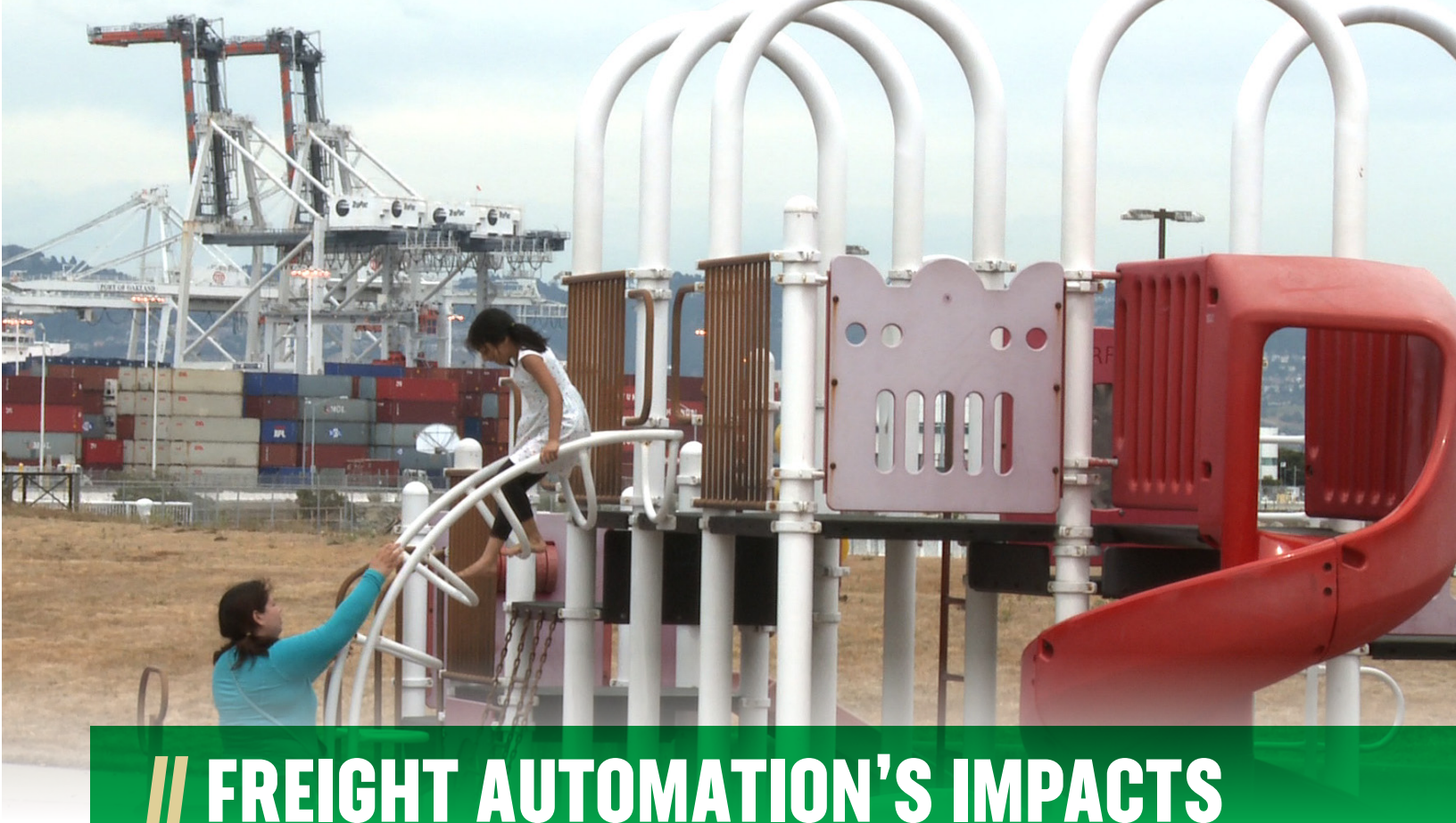
Concerns about impacts of 5G on health: Stakeholders interviewed as part of this project shared concerns over the impacts of the radio waves that are used to power 5G and other technologies that make automated equipment run. Although there is evidence that 5G is not harmful to health,[71] companies owe workers research and transparency on the full spectrum of effects new technologies will have on worker health before installing and running automated technologies at workplaces.

Automation's impacts on economic security will have a ripple effect on communities.

The freight industry is massive, and increased automation leading to job losses will have ripple effects across the local economies that are tightly intertwined with the freight system. Take the more than 600,000 people working in the marine cargo industry. These workers generate economic activity in their communities via "re-spending" and local commerce and consumption. Marine cargo worker spending was estimated at $139.2 billion in 2018 alone.[72] One study found that for every additional industrial robot introduced into a local labor market, an average of 6.2 workers in that labor market lost their jobs. These losses include direct factory job losses as well as indirect losses, particularly in the construction, business services, wholesale, service, and retail industries.[50] If ports continue to semi- or fully automate, the impacts on local businesses and economies would be sizable. If trucking and warehousing continue to automate, the effects will ripple out through the many local communities across the country that are hubs for freight industry workforces.

AREAS FOR EXPLORATION

- What percentage of displaced freight workers will be able to transition into new positions created by automation?
- Which current positions might translate easily to a more automated industry? Which will be more difficult?
- Is there any emerging evidence indicating 5G's effects on health? ■



// FREIGHT AUTOMATION'S IMPACTS ON AIR QUALITY AND HEALTH ////

Current dangers:

- Air pollution from freight transportation creates significant health problems, especially for fence-line communities.

Future threats:

- If automation proceeds without electrification and decarbonization, air pollution and related health risks will continue unabated.
- Where automation improves vehicle efficiency, pollution reductions may be negated by changes in trucking operations.

Opportunities:

- In limited scenarios, automation may slightly reduce pollution through efficiency gains, although more real-world testing is needed.
- Adopting zero-emission technologies provides much more significant pollution reductions than adopting automation alone.

"Ya hay muchos niños con cáncer, asma, problemas respiratorios, y pensar agregar otro proyecto a la comunidad es mucho." [There's already a lot of kids with cancer, asthma, respiratory health, lung issues, and to add another large project it is too much for our community.]

– Veronica Roman, San Bernardino community member

Summary Trends: What Freight Automation Means for Air Quality and the Health of Frontline Workers and Fence-Line Communities

"Here in the United States the main source of black carbon emissions is diesel engines. … We're talking about freight and transportation. But even in the freight industry, there's also off-road diesel, which includes the port equipment and vessels. … Everybody's affected by diesel."

– Dr. Robert Laumbach, Associate Professor, School of Public Health, Rutgers University

A clear and present danger of the freight transportation system is the air pollution it produces. Run largely on diesel and other petroleum-based fuels, freight contributes significantly to our country's pollution and global climate change. Because of long-standing racial and economic segregation, air pollution and its attendant health effects particularly harm frontline workers and fence-line communities.

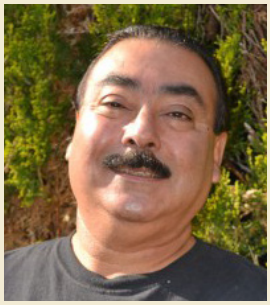
Without electrification, increased automation could lead to increased air pollution and negative health impacts.

Automating an electric engine provides substantial emission reductions, whereas automating a diesel combustion engine does not. Without electrification, automation may lead to more pollution, because operational efficiencies can allow for increased use of vehicles over the long term. In the shorter term, automation may provide some marginal reductions in air pollution for certain narrow segments of the freight transportation system. For example, some estimates have found that using automated computer-based "cruise control" or fuel management systems in freight trains offers fuel savings between 3% and 5%, with some estimates

as high as 14%.[73,74] Similarly, there is evidence that allowing trucks to travel closer together via platooning could reduce fuel use, which, in turn, could reduce air pollution.[75] The risk, however, is that efficiency gains will lead to changes in trucking operations and increased pollution, which will outpace any pollution reductions. On its own, automating diesel-run machines in ports, warehouses, and on the roads will not make a meaningful dent in air pollution.

In contrast, with electrification, whether it happens with automation or not, air pollutants like particulate matter, nitrogen oxide, ozone precursors, and greenhouse gas emissions will decline. The benefits of any pollution reduction will directly affect the communities closest to the sources of pollution: low-income communities and communities of color.

DOES AUTOMATED EQUIPMENT MEAN EMISSION-FREE EQUIPMENT? THIS TECHNOLOGY TRACKER IS SKEPTICAL



Jesse Marquez

Jesse N. Marquez is a resident of Wilmington in Los Angeles, CA, and the founder and executive director of the Coalition for a Safe Environment. "I have lived in Wilmington all my life. Most of my 60+ years. I grew up living in East Wilmington, literally two blocks away from the Alameda Corridor, an oil refinery and two blocks is the BNSF Watson railroad yard." He and community partners started working on freight in 2001 with a lawsuit over the China Shipping Terminal, a $400 million project that industry stakeholders were trying to build with minimal community notice.

Jesse is also part of Trade Health and Environment Impact Project, a region-wide, community and academic collaborative formed in 2006. The collaborative's work is to change the debate and ensure that *health* is no longer a forgotten word when discussing growth of the ports and the goods movement industry. The collaborative shared studies on the adverse health, community, and labor impacts of freight transportation going first into the Ports of Los Angeles and Long Beach and then being transported on trucks and trains to San Bernardino and Riverside County warehouses, highlighting the freight industry's regional impacts. They also hosted several national conferences that provided policy recommendations for freight-affected communities.

"One of the specialty areas of what our organization does is researching clean alternative technologies. Zero emission freight transportation vehicles, trains, ships, cargo handling equipment and construction equipment. Of that list none of the technologies include automation." In Jesse's experience, zero emission technologies are automated through special custom-order designs. ■

HOW DOES FREIGHT CURRENTLY AFFECT AIR QUALITY?

Most of the freight transportation system now runs on diesel. The US Environmental Protection Agency has called the movement of freight "a major public health concern at the national, regional and community level" due to the emissions of particulate matter, nitrogen oxides, hydrocarbons, and other air toxics in diesel exhaust.[76]

This pollution harms the health of children and adults alike, and is inequitably concentrated in fence-line communities.

The freight industry currently contributes greater than

- 50% of the nation's nitrogen oxides emissions
- 30% of volatile organic compound emissions
- 20% of particulate matter (PM) emissions[77]

"We live where we can live and not where we want to live."

Veronica Roman

Veronica Roman's time in southern California started in the early 1990s in Santa Monica and Inglewood. High rents pushed her east to San Bernardino. "Uno vive donde puede y no donde uno quiere." *[We live where we can live and not where we want to live.]*

Veronica's community faces a variety of freight impacts, including two Amazon warehouses, the Burlington Northern Santa Fe (BNSF) Railyard, an airport, and freeways. "Yo creo que aquí tenemos un poco de todo como, ahora sí como un tipo ensalada, pero las bodegas están creciendo muchísimo aquí en San Bernardino. Hay mucha, mucha bodega…y ahora ya están al lado de las escuelas y hogares." *[I think we have a little bit of everything here, it's like a type of salad [you can pick and choose from all these freight facilities], but the warehouses are growing so much here in San Bernardino. There are many, many warehouses…and now they are next to schools and homes.]* According to the American Lung Association's State of the Air report, San Bernardino County received failing grades for its ozone and PM levels.[78]

Veronica previously worked as a community organizer with the Center for Community Action and Environmental Justice (CCAEJ). They did a truck count right outside the railyard where the streets have only one lane each way. They counted 500 trucks at one intersection in 1 hour. There are schools close to that railyard; CCAEJ did a study with Loma Linda University that found higher levels of asthma for the kids in the area due to the pollution. Her oldest daughter has a 5-year-old son with asthma. "Ya hay muchos niños con cáncer, asma, problemas respiratorios, y pensar agregar otro proyecto a la comunidad es mucho." *[There's already a lot of kids with cancer, asthma, respiratory health, lung issues, and to add another large project it is too much for our community.]* ■

A Closer Look: Sector-Specific Examples

Zero-emission electrification can improve air quality whether it's coupled with automation or not.

The clearest way to improve air quality is through electrification. Where electrification happens, with or without automation, the pollution reductions can be impressive, though combining automation and electrification can come with other job-related consequences, which we discuss below.

Take the LBCT at the Port of Long Beach in southern California. Unlike the other 21 docks at the port, this one is highly automated, with self-driving vehicles and large stacking cranes controlled remotely by less staff than used for traditional cranes. Critically, this equipment is zero-emission. As a result, the terminal "emits 85 percent less diesel soot, 58 percent less nitrogen oxide (a component of smog), and 33 percent less carbon dioxide than a traditional dock at the ports."[40] In this case, it's not the automation that created reductions in pollution, it was the decision to automate using zero-emission equipment.

"You can upgrade these machines, that the longshoremen are operating, to clean air, but they can still be controlled, or manned, by a human. … What they're doing is upgrading these machines to clean air–which is great–but they're also making them unmanned. Why can't they upgrade them to clean air and still keep them manned?"

– John Bagakis, San Pedro small business owner

Although the decision to couple automation with electrification at the LBCT resulted in air quality improvements, it also resulted in job losses. By one estimate, two-thirds of the high-paying jobs at the LBCT disappeared because of automation.[40] Changes to employment, and the subsequent health effects, due to automation is a critical dynamic to understand. See the section *Freight Automation's Impacts on the Economic Security, Health, and Safety for Frontline Workers* for more information. ■

Automation that improves fuel efficiency provides limited air pollution reductions.

Where automation happens without electrification, air quality can improve in limited contexts. For example, using automated, computer-based "cruise control" or fuel management systems in freight trains offers fuel savings between 3% and 5%, with some estimates as high as 14%.[73,74]

Current automation trends strongly suggest we'll see more trucks platooning in the near future. By making braking and acceleration smoother and reducing drag-platooning, configurations offer a more efficient use of fuel, which cuts down on the quantity of pollutants released. On the basis of results of demonstration projects and tests, researchers estimate that platooning can create fuel savings of 4% to 15%.[15,75] Researchers have estimated that as fuel consumption goes down, diesel-related air pollution will also decrease.[75] This is an area in need of more research to better understand the nature of the relationship on platooning and reduction in air toxics.

Nonplatooning automation technologies may also improve fuel efficiency. In some tests, applications such as predictive cruise control and eco-driving feedback systems have shown modest fuel improvements in the 2% to 5% range, although a few were as high as 11%.[15]

With automation, trucking operation changes may negate air pollution–reduction gains.

An important dynamic that may potentially undermine air quality improvement is the degree to which any pollution reductions are outweighed by changes to trucking operations, including the increased presence or use of trucks. One risk is that trucks may travel additional miles by "going out of the way to create a truck platoon [which] could undermine the fuel savings and environmental benefits."[15] In addition,: "If collision mitigation systems and higher levels of truck automation improve safety to the point that policymakers and the public accept faster highway travel, this could pose a risk to long-haul fuel economy as driving faster uses more fuel"[15]—a risk that, in turn, would endanger any air pollution reductions. Finally, evidence suggests that "as platooning technology enables safe operation at close following distances, more efficient use of road space could result."[15] That additional road capacity could then potentially induce demand, leading to increased truck traffic and pollution, like how building bigger roads actually increases traffic by making it easier for people to take more trips. "Businesses that rely on roads will swoop into cities with many of them, bringing trucking and shipments."[79]

Even as trucking's share of total freight tonnage will decrease slightly, the American Trucking Associations estimates tonnage will continue to grow over the next decade.[80] Such growth could result in more trucks on the road. Depending on the number of trucks and the air pollution they produce, gains from automation-related fuel efficiencies could be more limited or canceled. Furthermore, even if the increasing number of trucks run on cleaner engines, air pollution could still increase from brake dust and tire wear—major contributors to PM pollution. Overall, this is an area that warrants far more study.

How Freight Automation's Impacts on Air Pollution Will Affect Health and Equity

Diesel pollution is a public health risk.

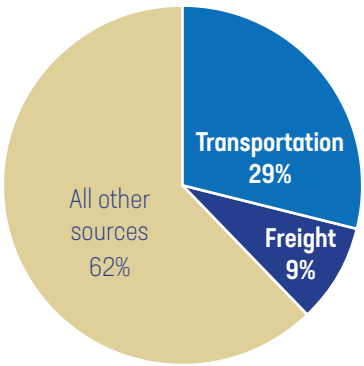
Independent of automation, diesel pollution *currently* is a clear public health risk with considerable impacts. Diesel exhaust includes:

- **Black carbon or soot,** which is associated with respiratory and cardiovascular problems, low birth rates and cancer.[81]
- **Organic substances,** including benzene, formaldehyde, and acetaldehyde, which are carcinogenic[82]
- **Volatile organic compounds,** which can cause cancer, damage to the central nervous system and organs, and, when inhaled, can create difficulty breathing, cause nausea, and irritate the eyes, nose, and throat[83]
- **Nitrogen oxides,** which contribute to ground-level ozone that reduces lung capacity and has been linked to increased hospital admissions for respiratory problems and asthma[84]
- **Particulate matter,** which comprises very small particles that can cause cancer, heart problems, respiratory issues, cardiopulmonary- and lung cancer–related deaths, premature death, and can trigger asthma attacks.[84-87] Exposure to fine PM is estimated to be responsible for three to four million deaths from air pollution worldwide.[88] Particular matter includes fine particulate matter (PM2.5) and coarse particulate matter (PM10).[85]

Although all of these pollutants are important, PM stands out: nearly two-thirds of all PM emissions from US transportation sources comes from diesel-powered vehicles and equipment.[89] In addition to being released through diesel exhaust, it's also created by nonexhaust sources like dust from tire, clutch, and brake wear on the roads.[90]

Freight transportation pollution also contributes significantly to climate change. After the production of electricity, the transportation industry is the second largest producer of climate change–inducing greenhouse gas emissions in the United States.[91] Almost one-third (29%) of all emissions come from transportation[92] and 9% of total greenhouse gas emissions are from the freight industry.[77]

Sources of Greenhouse Gas Emissions in the United States



Air pollution disproportionately affects fence-line communities.

Because of their proximity to freight infrastructure, low-income communities and communities of color are disproportionately burdened by air pollution from PM-producing facilities.[93] Across the country, communities of color are also disproportionately affected by the harms of transportation-related pollution.[88,94] For example, Black, Latinx, and Asian American Californians are exposed to much higher rates of vehicle-produced PM than are White Californians, and people living in households with low incomes (<$20,000/year) had 25% more PM exposure than did the highest-income groups.[95] In the Northeast and Mid-Atlantic, on average, Latinx residents are exposed to 75% higher air pollution; Asian American residents are exposed to 73% higher air pollution than White residents; and Black residents are exposed to 61% higher air pollution from vehicles than are White residents.[88]

Racial and economic segregation is associated with greater air pollution exposure and health inequities.

Although the Civil Rights Act of 1968 made housing discrimination based on race illegal, segregation continues today; housing discrimination affects people's health and is a fundamental cause of health inequities.[96] Researchers have found that people who live in racially segregated areas have higher exposures to cancer-causing ambient air toxics.[97] Another study found that in areas that were historically redlined (i.e., neighborhoods where there was systemic denial of mortgage loans to people of color), people had much higher rates of emergency room visits for asthma attacks.[98]

For health and equity, electrification is critical, whether it happens with automation or not.

If the freight sector is deliberately electrified, be it in combination with automation or on its own, the air quality and related health improvements could be meaningful, particularly for frontline workers and fence-line communities already facing an inequitable burden of air pollution. Smaller improvements may be possible without electrification where automation allows for more efficient fuel use. However, if freight automation is *not* simultaneously coupled with electrification, we are likely to see a continuation of the high and inequitable levels of air pollution, along with all the health risks they bring, in communities most burdened by the freight system.

As detailed above, people living close to air pollution already face negative health consequences. In addition, for some workers in the freight system, high levels of air pollution can be a burden that adds to other automation-related stresses, such as increased pressure to meet productivity quotas. According to Roberto Clack, associate director at Warehouse

"When [there are] changes [and] improvement in air quality, there's improvement in health."

– Dr. Robert Laumbach, Associate Professor
Rutgers University School of Public Health

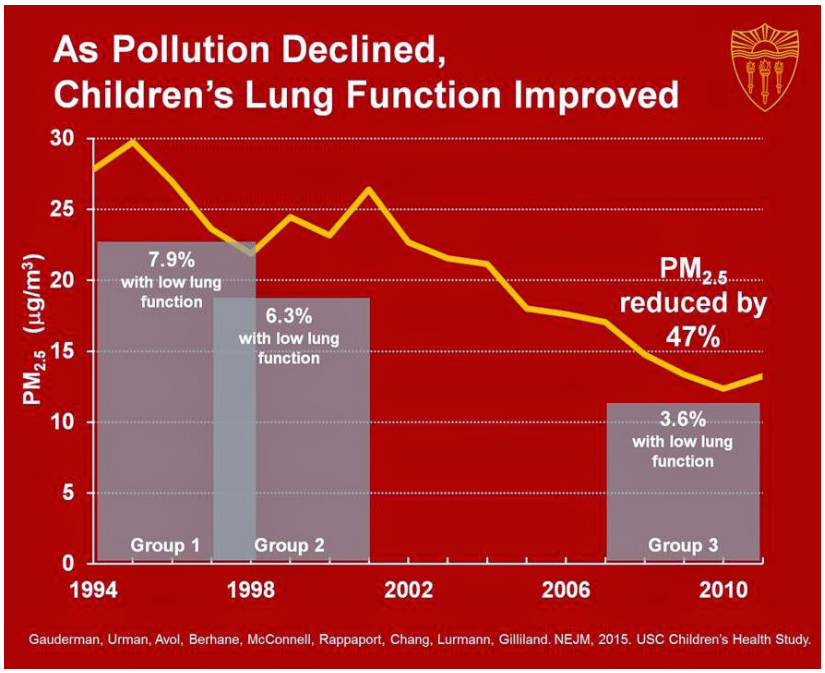
Workers for Justice, "Air quality is an issue. And that has an impact on respiratory [health] and hypertension. Are you creating a situation where people are working harder than ever [due to automation], and the air quality is bad? I could imagine automation even contributing to something like that."

Better health depends on cleaner air.

According to Dr. Robert Laumbach, Associate Professor at Rutgers University's School of Public Health, "When [there are] changes [and] improvement in air quality, there's improvement in health." For instance, studies show that children who grow up in more polluted areas face increased risk of reduced lung development.[99] One study found that living close to a railyard increases the number of asthma emergency room visits by children, and asthma risks were higher for children living near the top five pollution-emitting rail yards.[100] Asthma episodes in children cause sick days, lost school days, and lost learning.[143] Studies have also found that living in areas with high levels of PM was associated with an increased risk of preterm birth.[101–103] Again, these impacts are not equally distributed: low-income children and children of color face significantly greater disease burden as a result of exposure to air pollution.

In this context, the story of Maria is both moving and unsurprising. Originally from Mexico, Maria moved to San Bernardino about 20 years ago and recently started working at the Amazon Fulfillment Center. This Amazon facility, combined with other warehouses, industrial and commercial facilities, a railyard, and a freeway, have resulted in high levels of air pollution in San Bernardino. Maria's two daughters have asthma, as do many of her coworkers. "La realidad es que hay una necesidad de trabajo y por el otro lado es lo que te está perjudicando, la salud tuya y de tu familia." [*The reality is that there is a need to work and on the other hand the work is hurting you, your health, and your family.*]

Maria's daughters are now 12 and 14 years old. The schools they attend are close to freeways and the railyard, so there is often a lot of truck traffic. There is also a community center and park with a daycare facility right next to the railyard. Though the school did install air filters in the classrooms, students still go outside for recess. By her house, there is a ban on trucks passing through, but it's not enforced. Maria is also a school crossing guard and has



USC Environmental Health Centers

noted an increase of trucks in her neighborhood. She has participated in truck counts with a community organizer from the Center for Community Action and Environmental Justice, and was shocked at the findings: "Me vine sorprendidísima que vine contándole a mi esposo y más preocupación me dio mis hijas que como te dije tienen asma y yo tengo alergias. Pues que triste que en una hora hayamos contando más de 600 camiones por casas y escuelas." [*I left there astonished that I came home telling my husband and I'm more worried about my daughters with asthma and I have allergies. It is so sad that we counted 600 trucks in one hour so close to homes and schools.*]

When Maria's older daughter was about 1 year old, she was hospitalized for 4 days because of her asthma. Maria links her children's asthma to the pollution exposure in San Bernardino. She considered moving to Fresno, CA, thinking there was better air quality given the number of farms. But her research showed that, in part due to freight transportation, the air quality was just as bad there and in other places like Long Beach, CA, where she also considered moving. Ultimately, Maria came to realize "la solución no es moverme, la solución es que hagan algo para que aquí no haya tanta contaminación." [*The solution isn't to move, the solution is to do something so that there isn't as much pollution here.*]

Maria doesn't see a choice between jobs and the environment. "Yo se y entiendo que nosotros necesitamos esos camiones porque nos traen los bienes a nuestra ciudad o los llevan. Eso es indispensable, lo entiendo. Pero pueden modificar y hacerlos eléctricos para que no contaminen más." [*I know and understand that we need these trucks because they bring us goods or take them. This is indispensable, I understand. But they can modify and make the trucks electric so they don't pollute more.*]

If freight automation is not simultaneously coupled with electrification, then we'll likely see high and inequitable air pollution in fence-line communities.

Electrification, with or without automation, will help prevent climate change.

Electrification, whether it happens in conjunction with automation or not, is necessary to halt the increase in and consequences of climate change. Left unchecked, climate change will cause significant harms for communities across the country, especially those who are already most vulnerable including "the poor, the elderly, those already in poor health, the disabled, and indigenous populations."[104] These harms include more frequent and intense wildfires, which increase levels of health-harming PM in the air[105]; longer and more frequent heat waves; and greater risks from flooding and intense storms.[104] Coupling automation with electrification can make a positive difference with regard to climate change. For example, electric trucks have zero tailpipe emissions, and switching to electric semi-trucks and school buses can cut global warming emissions by half. [92]

AREAS FOR EXPLORATION

- What amount of pollution can be reduced with the widespread use of platooning?
- To what extent will the increased use of platooning result in more trucks on the road, which, in turn, could counteract any pollution reductions?
- Will the increased use of platooning result in faster-traveling trucks, which risks fuel and pollution reductions? ■

NOISE AND VIBRATIONS:

Current Health Risks Best Addressed Through Electrification, Not Automation

The freight transportation system is extremely noisy, particularly for frontline workers and fence-line communities.

Heavy-duty trucks rumble down streets. Trains growl as they move slowly through a rail yard. Shipping containers clang and screech as they're settled onto metal frames. The system for transporting goods also creates vibrations that literally shake all that is nearby.

Similar to air pollution, the health impacts of noise from the freight industry disproportionately affect frontline workers and communities where heavy-duty vehicles and machines operate.[106] Homes, schools, parks, senior centers, and more are affected in urban, suburban, and rural environments. That these impacts are felt inequitably across race and class lines is not accidental: systemic racism has shaped a long history of planning and policy decisions so that freight transportation's impacts are inequitably felt most acutely in communities of color and low-income communities.

Noise and vibrations are a serious health issue.

Veronica Roman is a resident of San Bernardino, CA. She and her family live right next to the truck-laden I-215 freeway, and they're close to freight warehouses and the Santa Fe BNSF Railyard. "Cuando yo me moví aquí, me pregunté porque se mueve todo mi comedor, y mi hijo me dijo no es que aqui cada que pasa el tren todo se menea y toma un buen rato. Es como si estuviera temblando muy seguido." *[When I moved here, I wondered why my whole dining room moves, and my son told me that here every time the train passes everything shakes and it takes a good while to pass. It's like it is often trembling here.]*

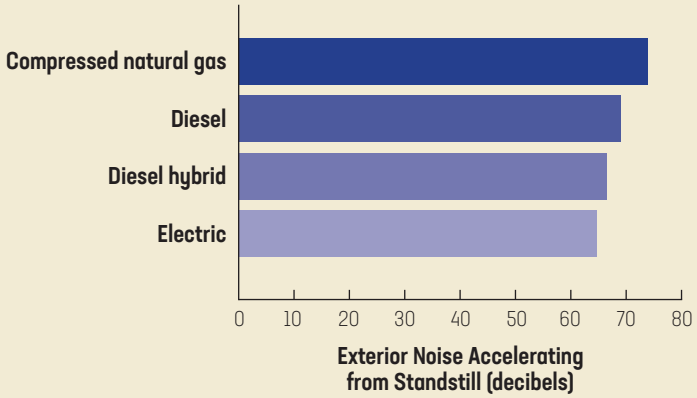
Noise pollution is more than a nuisance, and it can create serious health problems for frontline workers and fence-line communities. Workers who are exposed to vibration and noise at the same time are more likely to suffer hearing loss than workers exposed to the same level of noise alone. Exposure to both vibration and noise also increases musculoskeletal problems.[107] Chronic low-level noise, like constant sound from a nearby freight corridor, can interfere with people's ability to hear well, concentrate, and communicate. Multiple studies have found that unwanted noise from road traffic, aircrafts, railways, and industrial areas can disturb sleep, as well as lead to the development of cardiovascular diseases like arterial hypertension, ischemic heart disease, heart failure, arrhythmia, and stroke.[108,109] Noise pollution can also impact mental health; a study found that adults exposed to higher levels of noise annoyance had increased risk of depression and anxiety.[110] Freight also generates low-frequency noise and vibrations, which can lead to headaches, irritation, sleep disturbance, a feeling pressure in the head, pain in arms and legs, and dizziness.[111]

Children's ability to learn and concentrate in school is also affected by noise pollution. Research has found that noise pollution from aircraft impaired students' reading abilities and long-term memory.[112] In another study, researchers found that higher levels of noise in the community corresponded to decreased mental health in elementary schoolchildren.[113]

Reducing noise and vibration is best accomplished through zero-emission technologies, not automation.

Zero-emission technologies (e.g., a battery-powered truck) have far fewer moving parts, which significantly reduces operating noise and associated vibrations. One analogous example is the exterior noise of an all-electric bus accelerating from standstill, which is notably lower than alternatives such as compressed natural gas, diesel, and diesel hybrid buses.[106]

Electric Buses are Quieter Compared to Other Fuel Types



Implementing zero-emission technologies, be they automated or not, have limits to promoting peace and quiet: as the accompanying chart indicates, an electric vehicle is *quieter*, not quiet. In addition, the predicted overall growth of the freight system, along with the associated noise and vibrations, will likely outpace noise and vibration reductions achieved through adopting any electrification alongside automation. Finally, to the extent that freight automation permits freight facilities to run for longer periods, including during more traditional "off-hours," the burden of noise and vibrations for communities will increase.

// FREIGHT AUTOMATION'S IMPACTS ON TRAFFIC AND HEALTH ////

Current dangers:

- Truck-related collisions cause serious injuries and deaths across the United States.
- Train-related collisions, while far rarer, can be catastrophic and cause death and injuries.

Future threats:

- Automation that replaces most or all truck and train driver labor may worsen traffic-related safety in some situations.
- The safety-related consequences of fully automated trucks self-driving portions of a route are unclear and require more research.

Opportunities:

- Automation that complements some truck and train driver labor holds significant promise for improving traffic-related safety in many situations.
- Automation may play a role in inspecting train tracks for safety problems.

Summary Trends: What Freight Automation Means for Traffic and Health

"We all know GPS [global positioning system] will get you lost in a minute. So you are going to have to be able to read a map, have to be able to navigate some systems in order to get you where you're going, because there's always construction, there's always roads down, there's always accidents. So you're going to have to be able to cut that machine off and just drive this thing manually."

– Wendell Mitchell, over-the-road truck driver

Sensors and software can detect and respond to traffic-related risks far faster than a human could, and offer an opportunity to reduce the considerable burden of freight-related traffic collisions. As with many different aspects of freight automation, however, the context is important.

Near-term, driver-assistance automation that complements truck and train driver labor is likely to reduce traffic collisions and related injuries and fatalities.

For truck drivers, collision reductions are likely to benefit Black drivers particularly, who are overrepresented among truck drivers nationally.[58] Reducing traffic collisions brings other benefits, too, such as reducing congestion that occurs after an incident.

Longer term, automation that replaces most or all of truck and train driver labor may worsen traffic-related safety in some situations. Additional research is needed.

For example, some automated systems require human monitoring and potential intervention at a moment's notice; maintaining such vigilance may be difficult. Other types of automation, such as a truck or train that self-drives a portion of a route, are simply too new to provide definitive data regarding their safety.

A Closer Look: Sector-Specific Examples

Various driver-assistance technologies hold significant promise for improving truck- and train-related safety.

As use of automatic braking, lane-departure warnings, blind-spot detection, and adaptive cruise control grows, traffic-related safety will likely improve. A study by the Insurance Institute

HOW DOES FREIGHT TRAFFIC CURRENTLY AFFECT SAFETY?

Big rigs carrying thousands of pounds of materials. Trains more than 1 mile long. The laws of physics dictate that collisions between trucks and trains and other vehicles have significant health consequences: big rigs are involved in thousands of crashes annually, which resulted in 4,119 deaths in 2019, a 31% increase since 2009. Eleven percent of annual roadway fatalities occur in crashes involving large trucks.[114] Class 1 trains, the primary movers of freight throughout the country, were involved in 5,376 incidents in 2019, a number that has stayed relatively flat over the past 10 years. Fatalities totaled 546 in that same year, an increase from the previous 10 years, when fatalities hovered between approximately 400 and 450 per year.[115]

The freight transportation system often stretches through crowded residential areas, so these crashes aren't limited to long stretches of congested highways or rail lines stretching through deserted landscapes. Veronica Roman, a resident of San Bernardino in southern California, notes that her community sees truck and train traffic associated with nearby warehouses, a rail yard, and freeways. As warehouses continue to multiply closer and closer to homes and schools, truck traffic and related crashes have increased. Now, families need to leave earlier to get kids to school, and for those who walk to school, it is less safe to cross the streets. Roberto Clack, the associate director at Warehouse Workers for Justice in the Chicago area, sees similar challenges. "There's so many fatalities and there's so much traffic involving the trucks locally. Fatalities have definitely risen, and most of the fatalities involve semi-trucks." ■

Roberto Clack

for Highway Safety suggests that the combination of side-view assist, forward collision warning and mitigation, lane-departure warning and prevention, and adaptive headlights-on passenger vehicles might prevent or mitigate as many as 1,866,000 crashes each year, including more than 10,000 fatalities.[116] Such promise with passenger vehicles bodes well for using similar technologies with trucks. Indeed, a more narrowly focused study concluded "equipping large trucks with forward collision warning and automatic emergency braking (AEB) systems could eliminate more than 2 out of 5 crashes in which a large truck rear-ends another vehicle."[117] An assessment by a business consulting firm concluded automated trucks could reduce truck-related collisions from 222 truck crashes per one million vehicle-miles (in 2000) to only eight truck crashes per one million vehicle-miles by the year 2040.[118]

"Equipping large trucks with forward collision warning and automatic emergency braking (AEB) systems could eliminate more than 2 out of 5 crashes in which a large truck rear-ends another vehicle."

– Insurance Institute for Highway Safety

There has been significant uptick of safety-related technologies in trains, with train sensor data and alarms providing many crews with situational awareness while in operation.

After a 2008 freight and commuter train collision Los Angeles, CA, that killed 25 people when an engineer missed a stop signal, Congress mandated the adoption of PTC technology "to prevent train accidents by automatically controlling train speeds and movements if a train operator fails to take appropriate action in certain operational scenarios."[119] That system has now almost fully been implemented nationally. In reviewing incidents that could have been prevented by PTC, the Federal Railroad Administration (FRA) estimates reduced fatalities and injuries, damage to track and equipment, and hazardous material cleanup, among other benefits, will save $90 million annually.[120]

PERSPECTIVES FROM THE DRIVER'S SEAT: AUTOMATIC BRAKING

Wendell Mitchell has been driving trucks for over 25 years. "Truck drivers, you know, we're the heart of America." He currently drives from Orlando to Fort Lauderdale, FL. Is driving stressful? "Aww man, stress isn't the word for it... You got a lot of cars on the road now, and a lot of people aren't really thinking about safety. When you don't think about safety, you have accidents." One thing that makes Wendell feel safer: his new Volvo 2020 truck, which has automatic braking that kicks in when the truck senses a car slowing down quickly in front of it.

Jorge Mayorga is a truck driver with over 35 years of experience. He appreciates the help of an automated brake. But he's also quick to point out the many scenarios on the road where automation alone wouldn't cut it. "Yo he tenido que sacar el camión del carril y meterme donde no está designado para poder evitar un accidente y eso no lo puede hacer un camión solo." *[I have had to merge out of the lane and get onto the shoulder in order to avoid an accident and the truck alone cannot do that.]* ■

Lower levels of truck automation that complement driver labor may result in new safety risks.

Take platooning, for example, where one or more trucks follow a lead truck at distances that are much closer than would be safe without automation. As technological advances permit trucks to platoon at ever-closer distances to one another, how will other nearby vehicles handle navigating in proximity to these lengthy caravans? One researcher noted, "interactions between truck platoons and cars may be problematic, because drivers may need to speed in order to change lanes around the platoons of trucks following each other closely."[14]

The safety-related impacts of fully automated trucks self-driving portions of a route are unclear.

Fully automated trucks regularly self-driving portions of a route aren't likely viable for at least another 5 to 15 years. The technological issues alone are daunting. Jeff S. Johnson, former director of Global Thought Leadership at Dell Technologies, described a self-driving car in these terms: "Research shows that in order to make an autonomous car 80% as efficient as a human driver you would need 15 billion miles of data. It's going to take several years before that kind of data is collected." Car-maker Tesla's experience—and fatal problems with ever-more automated passenger vehicles[121]—offers a cautionary tale, albeit not with a freight vehicle, about the likely safety challenges inherent to increasingly automated freight. Research shows risks particularly increase when drivers are required to actively monitor an automated system:

> When automation is used to relieve a human operator of task duties, the operator is not relieved of work. Instead, the nature of the work changes. Human-automation interaction typically requires that an operator remain alert and attentive so that they can monitor one or more automated systems and be prepared to intervene should automation fail. This monitoring role is highly monotonous and requires that an operator be ready to respond to rare, seemingly random automation failures. … Unfortunately…human operators are limited in their ability to maintain vigilance. The longer operators are required to monitor automated systems, the more likely they are to demonstrate the vigilance decrement, that is, to miss or respond too slowly to a critical automation failure.[122]

Even as self-driving trucks requiring no human supervision on board become technologically feasible, there are also questions about how they will behave in real-world situations like traffic jams, road construction, closures, and hazardous road conditions (e.g., ice, which may require longer braking distances) and what this will mean for traffic safety. Higher levels of automation also come with more potential vulnerability to cyber attacks.[14]

If safety concerns can be addressed, higher levels of automation may ultimately reduce the risks of incidents: with a less-active driver or no driver at all, trucks will be able to drive more during off-peak hours and have less interaction with other cars and people.[53] Of course, any

PERSPECTIVES FROM THE DRIVER'S SEAT: PEOPLE ARE ESSENTIAL TO FREIGHT AND TRAFFIC SAFETY

Jorge Mayorga

"Al llegar al puerto tiene que ir a buscar ese chasis, ósea la plataforma, conectarlo, y después bajarse para la seguridad del público, para la seguridad de las personas, para la seguridad hasta de la misma compañía porque el chofer tiene que asegurarse que el chasis este en buenas condiciones. Que las llantas están buenas. Que no haiga un liqueo de aire porque esos tractores ya conectados tienen que ponerlos a trabajar con el chasis conectado con el tractor con aire y si hay un liqueo de aire es casi algo fatal que puede ocurrir y que no lo puede checar el camión. Tiene que revisar las luces porque si no pueden pasar unos accidentes si el camión no da las señales correctas. Si no están en buenas condiciones, puede ser un peligro para el público. Estoy casi seguro que pueden pasar muchos accidentes y eso no lo puede hacer solo el camión, se necesita a una persona. Después de checar todo el equipo tienen que ir a otra máquina a que le pongan el container. Y cuando le ponen ese container el chofer tiene que bajarse del camión y asegurarse que los cuatro esquinas de los container se aseguren por medio de un pin de seguridad porque si no en una vuelta ese container se cae. Entonces el camión solo no lo puede hacer. Incluso conectar las mangueras de la luz, del aire no lo puede hace el camión. No lo van a poder hacer sin una persona." *[When you arrive at the port you have to go find the chassis, that is, the platform, connect it, and then get off for the safety of the public, for the safety of people, for the safety of even the company itself because the driver has to make sure that the chassis is in good condition. That the tires are good. That there is no air leaking because when the tractor is connected they have to work with the chassis connected (via air hoses) to the tractor and if there is air leaking it is almost something fatal that can happen and that the truck cannot check (on its own). You have to check the lights because accidents will happen if the truck does not give the correct signals. If they are not in good condition, it can be a danger to the public. I am almost certain that many accidents can happen and the truck alone cannot do that [i.e., check the truck], it takes a person. After checking all the equipment, they have to go to another machine to place the container. And when they place that container, the driver has to get off the truck and make sure that the four corners of the container are secured by means of a safety pin because if not, in one turn that container will fall. So the truck alone cannot do it. Even connecting the hoses for the lights and for the air, the truck can't do that. They won't be able to do it without a person.]*

– Jorge Mayorga, veteran port truck driver ■

marked shift to off-peak hours may also have implications for drivers who do remain in the cab; see the section *Freight Automation's Impacts on the Economic Security, Health, and Safety for Frontline Workers* for more on worker conditions.

There is no consensus on the safety impacts of reduced train-crew size due to automation.

Industry stakeholders are currently engaged in a contentious struggle about the number of crew members that should be required on most trains. One core question: will reducing the number of crew members from the typical two crew members per train to one affect safety? The question is complex because it's often difficult to uncouple concerns about safety with other motivations. For example, railroad companies interested in reducing costs often look to labor reductions, whereas railroad workers want to protect well-paying jobs.

In 2016, the FRA issued a Notice of Proposed Rulemaking to establish minimum train-crew size requirements for various operations. In 2019, the FRA rescinded that Notice, stating that "no regulation of train crew staffing is necessary or appropriate for railroad operations to be conducted

A RAILROAD CONDUCTOR LAUDS THE STRENGTH OF CREW MEMBERS WORKING TOGETHER

James has worked in rail for 16 years, including as a railroad conductor with Union Pacific. In California in about 2006, Union Pacific started switching over to a remote-control engineer, taking the engineer out of the driver's seat and reducing the crew from three to two people. James took the 13-month remote-control conductor training, but he didn't use it. He doesn't support crew reductions for a variety of reasons. "I'm against remote control because I think it takes away from the jobs for other guys at the railyards and it tends to move slower. I just didn't like the way it operates."

James believes trains run more efficiently with more crew members. "When you have two guys working together everything is a lot smoother. … [For the long-distance trains, rail companies] have been trying to figure out a way to have a one-man road freight train. Which is ridiculous. Can you imagine being by yourself in a train for twelve hours, nine o'clock in the night to nine o'clock the next morning? Going to the desert by yourself from L.A. to Yuma, Arizona. That's just ridiculous, especially if the train breaks too. What happens then? [That's] too much to put it on one guy. And then with one guy on the cab imagine walking 10,000 feet for a train that is two miles long to repair it." He raises security concerns, too, because with less crew members it would be easier for someone to board the train.

James does think drones could play a helpful role in rail operations, specifically inspecting the tracks to prevent train derailments because, he notes, there has been a cut in track-labor workers for track inspections. ■

safely at this time."[33] In its explanation of the withdrawal, however, the FRA noted that a workgroup assigned to examine the issue "was unable to reach consensus on any recommendation or identify conclusive, statistical data to suggest whether there is a *safety benefit or detriment* from crew redundancy [emphasis added]."[33] In addition, the FRA's own review of collision-related data "could not determine that any of the accidents/incidents involving a one-person crew would have been prevented by having multiple crewmembers" while noting that data limitations made it "impossible" to compare the relative safety of one-person crews to two-person crews.[33]

The FRA also responded to stakeholders who cited the value that two-person crews have in mitigating environmental hazards after an incident, for example, or being able to decouple a train blocking a rail crossing in order to allow emergency personnel through. Specifically, the FRA found these "indirect connections" didn't warrant train-staffing minimums, and such challenges could be addressed through other safety procedures.[33] The absence of data indicating a benefit or a detriment isn't particularly conclusive at this point and warrants additional careful study to determine likely outcomes.

Automation may help with inspecting train tracks for safety problems.

In 2018, the FRA suspended various requirements related to track inspection so that BNSF Railway could test an automated track-inspection system. Echoing the debate about train crew sizes, unions and the train company have divergent perspectives on the safety-related implications of such automation.

The Brotherhood of Maintenance of Way Employees Division of the International Brotherhood of Teamsters, a national union, supports new technology to increase safety, but its leaders are "alarmed that the testing of this new automated system of track inspection could potentially fail because BNSF Railway has reduced the number of visual track inspections that are crucial in catching any errors that the new system makes."[123] BNSF counters with the technological advantage provided by the new system. "We know that inspecting through the technologies we're using provides us with better data than visual inspections. So, while the number of visual inspections may change, the inspections we're adding actually provide better inspection data than in many cases the human eye is capable. … To date, key performance metrics judging the success of the pilot have surpassed expectations."[124]

How Freight Automation's Impacts on Traffic Affect Health and Equity

When collisions are reduced, health improves.

It's a fairly simple equation: where automation that complements driver labor reduces traffic collisions, there will be a corresponding decline in injuries and fatalities.

The aforementioned analysis by the Insurance Institute for Highway Safety concluded "equipping large trucks with forward collision warning and automatic emergency braking (AEB) systems could eliminate more than 2 out of 5 crashes in which a large truck rear-ends another vehicle."[117] Another aforementioned study found that various warning and automatic braking systems implemented on passenger vehicles might prevent or mitigate as many as 1,866,000 crashes each year, including more than 10,000 fatal crashes.[116]

Although all truck drivers stand to benefit from these improvements, that's particularly true of Black drivers, who are overrepresented among truck drivers nationally; that is, a greater proportion of truck drivers are Black compared to their proportion of the US population.[58]

There are other benefits when the number of collisions is reduced as a result of automated technologies, including reductions of injuries, injury severity, and property damage.[125] Other benefits include a reduction in spills caused by collisions and resulting environmental hazards, and reducing congestion that occurs after a big crash and causes stress to other drivers.[126]

Conversely, if automation that replaces some or all driver labor to an ever-greater degree worsens traffic-related safety, we would expect to see a corresponding increase in injuries and fatalities. Given the uncertainties, this is an area that requires additional research to better assess the outcomes. This research not only needs to happen in the short term, because technological advances allow vehicles to operate with less and less human supervision on freeways and highways; it's also needed if and when automation moves off freeways and into freight-congested, fence-line neighborhoods.

AREAS FOR EXPLORATION

- **How will platooning trucks and passenger vehicles interact? Do the chances of collisions increase?**
- **What are the health and safety issues where humans are still required to monitor and engage with higher levels of truck automation?**
- **What are the safety implications of trucks self-driving in ever-more complicated roadway conditions?**
- **How would the reduction in train-crew size affect traffic safety in a variety of real-world conditions?** ■

// PUTTING PEOPLE FIRST: POLICIES AND PROGRAMS FOR HEALTH AND EQUITY WITH FREIGHT AUTOMATION ////

Automation in the freight industry has already affected the economic security and health of frontline workers in warehousing, trucking, rail, and at ports across the country. Such impacts will only accelerate as automation grows. Automation will also significantly affect the lives and livelihoods of frontline communities, who are primarily communities of color, because the expanding technology will create ripple effects with consequences for the health, safety, and economic security of communities across the country. Policymaker choices will determine whether current and future impacts are positive or negative.

POLICY RECOMMENDATIONS

Engage frontline workers and fence-line communities in automation decisions.

- Decision makers at all levels of government should ensure that automation-related policy and program decisions reflect the input and perspectives of frontline workers and fence-line communities
- Leaders in businesses considering automation should also engage workers in thinking through automation-related decisions and impacts.

Support frontline workers.

- Plan for automation that advances frontline workers, not just technology.
- Strengthen workers' rights to organize for fair wages, benefits, and a say in automation-related decisions.
- Enforce and improve safety standards for workplace conditions to prevent the negative affects of automation on worker safety and health.
- Reinvigorate and expand programs to meet the needs of frontline workers displaced by automation.
- Correct worker-status misclassification of truck drivers and other freight workers to promote livable wages and benefits.
- Implement broader policies and programs that address automation's impact across the entire U.S. economy.

Support frontline workers and fence-line communities.

- Require automation impact reports to better understand and mitigate automation's effects on health and equity.
- Prohibit the use of public funding for any freight automation that may have negative impacts on worker and community health.
- Accelerate efforts to shift freight transportation to a zero-emission system through incentives, regulations, and permitting decisions.
- Implement federal policies to prioritize the safety of freight drivers and other road users.

Support additional research on employment, air quality, and traffic safety impacts. ■

We have the opportunity to deploy technology to create healthier, more equitable communities if stakeholders make choices centered on health and equity.

When warehouse worker Maria observes her community, she sees industrial and commercial facilities, a railyard, and a freeway. She notes her two daughters have asthma, as do many of her coworkers. "La realidad es que hay una necesidad de trabajo y por el otro lado es lo que te está perjudicando, la salud tuya y de tu familia." [*The reality is that there is a need to work and on the other hand the work is hurting you, your health, and your family.*]

It's also the reality that it doesn't have to be this way. Policymakers and industry stakeholders made policy and program decisions that have shaped a large portion of the pollution, accidents, and other freight impacts Maria sees day in and day out. Where choices have created problems such as health inequities, different choices can create healthier, more equitable solutions. Implemented thoughtfully, some types of freight automation have the potential to support the health and safety of low-income workers and people of color who compose significant portions of the freight workforce and fence-line communities. For example, an automatic braking system that reacts far faster than any driver to prevent collisions makes our highways safer. If coupled with zero-emissions technology, automated freight equipment can reduce air pollution and noise that fills worksites and adjacent communities. Where freight automation supports these types of changes, it can serve as a tool to advance public health, workers' dignity and rights, racial justice, and a "just transition" to a carbon-free economy. These benefits serve frontline workers and fence-line communities and the broader public.

Some of these choices will happen at the organizational level; when automation eliminates jobs, management can choose to retain and retrain staff for new roles. However, we cannot and should not leave the future of automation's impacts to individual companies. Public policies and programs enacted by decision makers at multiple levels of governance are critical to ensuring the future of freight automation is one that promotes health and equity rather than sustaining and worsening problems inherent with the freight system.

Policies and programs should help mitigate current harms created by a system that relies heavily on low-wage workers and creates pollution, noise, and safety problems for nearby communities; new harms need to be prevented as well. In addition, policies and programs needed for freight automation should not undercut solutions to current problems that can be enacted now: an overworked warehouse employee shouldn't have to wait for tomorrow's automation to spare her back when helpful changes like rotating task stations can be put into practice today.

To that end, we propose a series of recommendations to address identified impacts and mitigate harms. Paramount across all of these recommendations is particular attention to the needs of the people and communities of color who are most affected by freight automation, either as frontline workers or as residents in fence-line communities.

Our recommendations are divided into three interconnected sections:

- The critical role of community engagement in policy and program decision-making
- Policy and programs focused primarily on frontline workers
- Policy and programs that will benefit *both* frontline workers as well as fence-line communities

These recommendations are geared toward a broad category of policymakers responsible for freight automation, including elected and administrative officials at local, state, and federal levels of government.

Engaging Frontline Workers and Fence-Line Communities in Automation Decisions

Automation-related policy and program decisions should reflect the input and perspectives of frontline workers and fence-line communities who bear the brunt of freight's current impacts, and who will continue to be most affected by decisions that shape future automation. Such input will promote government and corporate accountability and help ensure healthy and equitable outcomes.

Decision makers at all levels of government should ensure that automation-related policy and program decisions reflect the input and perspectives of frontline workers and fence-line communities.

Although public decision-making processes typically include some method by which stakeholders can share their opinions, they often do not account for the fact that some community members face significant barriers to engaging fully, including language differences, access to relevant information, limited ability to participate in public meetings held during traditional work hours, and more. Policymakers need to surmount these barriers to ensure that workers and community members are meaningfully involved in decision-making processes.

Across the country, policymakers and community leaders are demonstrating what this engagement can look like. At the state level, in California, policies require government agencies to pursue various environmental justice principals in their decision-making, including "[a]t a minimum, the meaningful consideration of recommendations from populations and communities most impacted by pollution into environmental and land use decisions."[127] In addition, in 2017, the state adopted legislation (Assembly Bill 617) to establish the Community Air Protection Program. Designed to reduce pollution in the most heavily affected communities, the Program mandates stronger connections between regional air-quality agencies and community organizations.[128] Although advocates point out the intended community engagement has been very uneven across the state, there are bright spots. For instance, in heavily industrialized West Oakland, the Bay Area Air Quality Management District and the West Oakland Environmental Indicators Project collaborate on all aspects of the program, and leadership and decision-making are shared.[129] These approaches can and should serve as models for the type of worker and community engagement needed in automation-related decisions.

Leaders in businesses considering automation should also engage workers in thinking through automation-related decisions and impacts.

Some of this engagement, of course, is a requirement (e.g., the negotiations that take place between labor unions and management). In other circumstances, however, business leaders have a choice in the matter and should choose to engage workers early and often.

James, who has about 16 years of experience working in rail, including as a conductor with Union Pacific, thinks that questions related to automation should receive much more input from workers who are closer to the issues in play:

> I don't think the people further up have a clue because they don't see it. [There are] people way above making decisions that don't have a clue what is going on at the bottom. It has to be someone closer to the workers for them to know what is actually happening. For instance, they hire people straight out of college; like I said nothing against them, I support everyone going to school to get their education, but if you haven't worked out there before or actually been out there before, then you don't know, it doesn't work that way. They think they can figure out a faster way to do things. Everything is about speed out there; they want to move stuff as fast as possible. But their way is not the best way. We are out there and us workers know how to do things most efficiently.

Policy and Programs to Support Frontline Workers

"If you automate terminals and you take away the jobs and the human factor, that's less revenue, less taxes, less payroll, less going back into the community."

– Vivian Malauulu, ILWU Local 13 Registered Longshore Worker and Benefits Officer

Millions of people could lose their jobs if freight automation displaces human workers. Wages and benefits in remaining jobs may decline. Worksite injuries due to freight automation are already happening, and may increase as automation spreads. All these impacts will be felt disproportionately by the workers of color who are predominately represented in the freight industry. To counter the host of possible risks posed by escalating use of freight automation, we recommend the following policies to uplift the economic security, health, and overall well-being of frontline workers.

Plan for automation that advances frontline workers, not just technology.

At the national level, policymakers should create a National Council in Innovation and Freight Employment to bring together diverse stakeholders across the freight sector, including workers, employers, engineers, frontline community members, policymakers, and technology experts. The Council should develop and implement an action plan for "career pathways and training/job-matching programs for incumbent, dislocated and future workers."[16] The plan should also have a strong racial equity component to ensure, for example, that high-paying automation-related jobs benefit workers of color and current low-income workers.

States can also take aggressive action to plan for automation in ways that support frontline workers. For example, in California, Governor Gavin Newsom created a Future of Work Commission tasked with identifying and addressing how new technology will affect employment and economic forces, as well as the physical and social needs of workers who are losing human connection and interaction because of increasing automation in their industries.[130] Transportation planning also needs to highlight automation: the *California Freight Mobility Plan 2020*, for example, briefly notes some of the positive and negative impacts of increased automation.[131]

Both federal and state efforts should also have a strong stakeholder education component that alerts workers, communities, and industry to trends in automation and their potential effects on workers and communities.

Strengthen workers' rights to organize for fair wages, benefits, and a say in automation-related decisions.

Some of the pitfalls of automation can be prevented by ensuring a strong voice for workers in automation decisions. The most effective way to ensure a strong voice is to strengthen workers' abilities to organize and shape business operations. Specific policies to focus on include restricting so-called right to work laws, increasing penalties for employers who violate current labor laws, and expanding National Labor Relations Act protections to include currently excluded workers, such as independent contractors. Other policies worth exploring and implementing, such as those proposed in *Clean Slate for Worker Power: Building a Just Economy and Democracy*,[13] include federal and state actions to:

- Create a system of collective bargaining across industrial sectors (rather than by organizations)
- Increase worker-selected representation on corporate boards
- Require that corporations attend to the interests of workers in addition to shareholders
- Expand the types of issues covered by collective bargaining, such as environmental and community impacts

These policies will help build the "collective economic and political power necessary to build an equitable economy,"[132] where business decisions reflect and respond to a wider range of critical stakeholders.

Enforce and improve safety standards for workplace conditions to prevent the negative effects of automation on worker safety and health.

The increased pace expected of workers laboring alongside robots and automated equipment has resulted in and will likely result in more accidents, deaths, and the onset of other chronic medical conditions. There is a clear role for federal and state policymakers to protect frontline workers. Examples of actions for the federal and state governments include:

- Creating and improving workplace safety standards
- Enforcing those standards in a timely and effective fashion
- Protecting workers who report unsafe conditions
- Funding research and interventions to eliminate occupational-related health disparities

Another recommendation is to enact state and federal policies that hold companies responsible when entities with whom they subcontract or outsource for workforce support violate the health and safety of their workers.[133] Such policies would be particularly helpful across the freight sector, which often relies on such third-party arrangements. Finally, policymakers should address the potential for technological malfunctions with automation applications.

Reinvigorate and expand programs to meet the needs of frontline workers displaced by automation.

Workers need retraining so they are prepared for jobs that may emerge due to automation. The National Council in Innovation and Freight Employment, noted above, should also focus on "the creation of safety-net programs to support transitions within and out of the industry, including work-sharing initiatives [ie, short-term, limited reductions in worker hours combined with unemployment benefits to prevent permanent layoffs], supplemental and flexible unemployment insurance, and retirement packages."[16] Given the inequitable consequences workers of color are likely to face due to displacement from automation, these efforts should have a strong racial equity component.

Correct worker-status misclassification of truck drivers and other freight workers to promote livable wages and benefits.

Workers in the freight industry deserve employee rights and just wages. Workers erroneously categorized as independent contractors are denied basic labor protections because various standards do not apply to them. States and the federal government should address misclassification through a combination of better enforcement of existing laws as well as developing new ones.[134] These approaches are particularly critical to support workers in the trucking industry, where many drivers are currently misclassified as independent contractors—a trend that automation risks exasperating. Properly classifying drivers as employees, rather than independent contractors with limited labor protections, can serve as a backstop against this trend. It can also help reduce pollution and other environmental harms. As one researcher noted, drivers classified as employees create "economic incentives for trucking firms to use their labor efficiently. With less time wasted idling engines, and paired with clean electric trucks, this approach would reduce congestion and pollution in surrounding communities."[16]

Implement broader policies and programs that address automation's impact across the entire US economy.

Job losses and other employment changes within freight transportation are likely to occur against the backdrop of automation-driven changes across a wide range of sectors in the US economy. Although the aforementioned interventions need to be targeted for the freight sector, they will be more effective when coupled with state and federal policies and programs designed for these large-scale, cross-sector changes.

Examples of such broader policies, as identified by the Aspen Institute's Future of Work Initiative,[135] include federal and state actions to:

- Promote employer engagement and investment through a worker-training tax credit, expansion of apprenticeships, and new sector and regional workforce partnerships
- Encourage employers to adopt a multistakeholder approach to automation decisions by promoting new forms of worker voice and ownership (e.g., profit-sharing compensation for all workers) and developing proactive strategies to identify and address impacts in advance
- Increase wage subsidies (e.g., the Earned Income Tax Credit) and the minimum wage, while creating more economic opportunities by promoting entrepreneurship
- Support local economic development and improve regional competitiveness through sector-based development strategies and investment in digital infrastructure
- Provide key stakeholders with better information on the effects of automation by collecting data on technological advancements, adoption rates, and workforce impacts.

Policy and Programs to Support Both Frontline Workers and Fence-Line Communities

"Automation could be devastating for the local community."

– Roberto Clack, Associate Director, Warehouse Workers for Justice

Increasing automation will create risks for fence-line communities as well as frontline workers. Some of that risk is economic, because increasing automation that reduces the current workforce will have ripple effects across local economies that are tightly intertwined with the freight system. But there are other dangers, including the continued pollution created by the freight system, as well as traffic safety and noise and vibration risks. We recommend the following policies to protect frontline workers as well as the communities in which they work.

Require Automation Impact Reports to better understand and mitigate automation's effects on health and equity.

The National Environmental Policy Act requires federal agencies to examine the environmental effects of proposed actions before those agencies make decisions.[136] California uses the California Environmental Quality Act to achieve similar goals, often through Environmental Impact Reports, for a wide range of projects.[137] Automation projects should have a similar level of scrutiny when subject to public review. Automation Impact Reports (AIRs) would help reveal a wide range of automation-related effects as well as potential mitigations. Although similar to Environmental Impact Reports, AIRs should be broadened beyond air quality, noise, vibrations, and their associated respiratory, cardiovascular, and cancer-related risks. Automation Impact Reports should also address traffic safety and employment and workplace impacts, and include a focus on effects on racial equity across all topic areas. To be effective, AIRs should be conducted by independent parties and include effective worker and community engagement. Examples of when AIRs could be used include a port terminal project or a warehouse development.

Prohibit the use of public funding for any freight automation that may have negative effects on worker and community health.

Public dollars should yield a public benefit, and public funding for freight infrastructure improvements (including direct subsidies and tax incentives) should not accelerate job losses, contribute to poor air quality, or incentivize development that leads to any of the negative effects detailed in this report. As one model example, the federal Climate Smart Ports Act (authored by Congresswoman Barragán) proposes significant investment of public dollars into zero-emission port projects—with a particular focus on air quality improvements—but only with guarantees that the funding won't be used to displace workers.[138]

Accelerate efforts to shift freight transportation to a zero-emission system through incentives, regulations, and permitting decisions.

Automation alone will not lead to any significant improvements in air quality. Electrification, with or without automation, is key to improving air quality. Such changes will also have the added benefit of modest noise reductions. Shifting freight transportation to a zero-emission system requires scaling up government incentive programs to encourage the freight industry to implement zero-emissions technologies. The shift also requires adopting and implementing aggressive regulatory measures at the federal and state levels to mandate and monitor the adoption of clean technologies. Also, where public entities provide approvals for the development of private projects, decision makers should insist on the use of zero-emission equipment.

Implement federal policies to prioritize the safety of freight drivers and other road users.

There is a clear and compelling role the federal government should play to ensure that vehicle-related automation promotes safety and health. Voluntary consensus standards and guidance are useful, but mandates are also critical. Proven safety features, such as automated emergency braking, should be required for new vehicles. Other emerging technologies–from driver supports to high-level automation systems requiring no driver involvement –should all be rigorously and transparently tested for safety in a variety of driving conditions before commercial use. In late 2020, a group of more than 50 public health, medical, consumer, law enforcement, and safety groups and insurance companies released the Autonomous Vehicle Tenets, outlining the federal government's robust role in ensuring autonomous vehicle safety.[139] Although the Tenets are specific to passenger vehicles, the principals provide a roadmap for improving the safety of freight vehicles through oversight, testing, performance standards, and more.

Additional Research Needed

Although many of the health and equity impacts of freight automation are clear, others are not. Specific questions, by category, identified in the development of this report include:

Employment:

- What percentage of displaced freight workers will be able to transition into new positions created by automation?
- Which current positions might translate easily to a more automated industry? Which will be more difficult?
- Is there any emerging evidence indicating 5G's effects on worker health?

Air quality:

- What amount of pollution can be reduced with the widespread use of platooning?
- To what extent will the increased use of platooning result in more trucking operational changes, which, in turn, could counteract any pollution reductions?
- Will the increased use of platooning result in faster-traveling trucks, which risks fuel and pollution reductions?

Traffic safety:

- How will platooning trucks and passenger vehicles interact? Does the chance of collisions increase?
- What are the health and safety issues where humans are still required to monitor and engage with higher levels of truck automation?

- What are the safety implications of trucks self-driving in ever-more complicated roadway conditions?
- How would the reduction in train crew size affect traffic safety in a variety of real-world conditions?

We recommend that additional research be undertaken to answer these questions so that policymakers, industry stakeholders, frontline workers, and fence-line communities can better understand a full range of freight automation's consequences.

Policies and programs to promote healthy automation should build on other freight efforts, unrelated to automation, to promote worker and community health.

It is critical that policies and programs aimed at promoting health and equity with automation build on and augment policies and programs that mitigate the current negative effects of freight transportation on frontline workers and fence-line communities, including those independent of automation.

For example, policymakers' inequitable land use and transportation planning decisions have put freight facilities and thoroughfares near housing, and vice versa, often near and in communities of color. In response, policymakers can better support public health through buffer zones, sound barriers, quiet zones, and other interventions, and can take steps to help people currently in harm's way (e.g., by retrofitting windows and heating, ventilation, and air-conditioning systems for pollution mitigation).

Advocates, stakeholders, and policymakers are increasingly recognizing the need to address pollution from a *cumulative* perspective. Most pollution regulations currently focus solely on the tailpipe or a smokestack, while failing to consider the levels of pollution in which such sources will operate. That's slowly starting to change: for example, the Newark Municipal Council adopted an Environmental Justice and Cumulative Impacts Ordinance to address long-standing health disparities;[140] the Minnesota Pollution Control Agency considers cumulative levels of various air pollution sources before issuing new permits in specific areas of South Minneapolis, because of the history of environmental injustices in the area[141]; and the Environmental Justice for All Act, introduced in 2020 by congressmen Raul Grijalva and Donald McEachin, includes policies on cumulative impacts.[142] ■

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