Robots Among Us: An Analysis of Community Perspectives and Reactions toward Sidewalk Delivery Robots in the City of San José

Project 2203
May 2022

Serena Alexander, PhD

Introduction

Sidewalk delivery robots, once only a sci-fi reality, are getting more attention these days because of their potential to revolutionize ground-based delivery and serve as a "last-mile" solution that takes the human out of the loop. The robots simply navigate to your address while using cameras to avoid accidents and locking features to prevent theft. These robots claim that they can make it easier to do contact-free deliveries, empowering restaurants and consumers to save money, and even reduce greenhouse gas (GHG) emissions, traffic congestion, and parking problem on the streets. Could these robots even improve quality of life by safe and cost-effective delivery of food, medicine, and other small packages to individuals with no access to cars?

The revolutionary promise of sidewalk delivery robots comes with several loose ends. Most importantly, these robots will only achieve significant economic, environmental, and social benefits through scale. This means many robots rolling over the sidewalks of our cities. Even if the robots move smoothly across the sidewalks without bumping into people, the question is: are we ready to share the sidewalk with these delivery robots?

Through observations, intercept surveys and interviews with community members and stakeholders, this perspective offers an insight into how the community feels about this technology, as well as how the delivery robots interact with pedestrians on our sidewalks.

Methodology

A group of graduate urban and regional planning students at San José State University, with logistical support from the City of San José and a sidewalk delivery robot company named Kiwibot, collected the data for this project during Fall 2021 semester. The students collected different types of data through:

1) Observations

Using an observation protocol provided by the City of San José, the students observed a robot as it travelled on the sidewalk for at least two blocks at a time. Observations took place during the day on October 6th, 8th, 13th, 27th, and 29th in Downtown San José, and on the 20th and 21st in the West Valley Mall (located on Stevens Creek Boulevard in Santa Clara, CA). Each student conducted observations for a minimum of three hours, split into half or one-hour segments in different days. The students conducted a total of twelve hours of observations (nine hours in Downtown San José and three hours in Westfield Valley Fair Mall), noting how the delivery robots operated on the

sidewalk as they shared the space with pedestrians, street fixtures, trees, and other obstacles. To ensure that their presence did not impact human interactions with the robot, the students walked in a distance from the robot. The students recorded if and the number of times the robot moved around people; close calls or incidents with people, animals, or other objects; as well as people's reactions to the robot, such as taking pictures, attempting to move it, or purposefully blocking it. All observations were tallied and analyzed using a single spreadsheet.

2) Intercept surveys

Using a survey protocol provided by the City of San José, the students conducted intercept surveys with pedestrians who shared the sidewalk with robots. Intercept surveys were collected on October 6th, 8th, 21st and 28th in Downtown San José (Santa Clara St. and North 2nd/Paseo de San Antonio near San José State University), and at the Westfield Valley Fair Mall. The students asked questions about people's initial reaction to seeing a delivery robot moving on the sidewalk, their perception of safety around a robot, and their interest in receiving a meal and/or package delivery from a robot. In total, the students surveyed 82 individuals. All responses were organized into a single spreadsheet for analysis.

3) Interviews with community members and stakeholder organizations

Using interview guides provided by the City of San José, several groups of students conducted interviews with community members and representatives from community or pedestrian advocacy organizations. To ensure a representative sample, the students interviewed individuals and organizations representing various demographic groups and people or communities with different abilities and resources. All community members interviewed were residents of the City of San José. Participants from community organizations located around the city were recruited based on the potential impact of delivery robots on the communities they served, and/or their expertise on robot delivery technology. The interviews were conducted during the months of September, October, and November in 2021. In total, the students interviewed 26 community members and 13 representatives from community organizations via Zoom. Each interview lasted approximately 30 minutes, and all interviewees signed a consent form provided by the city to participate in the study. During the interviews, the students asked questions about the respondents' familiarity with sidewalk delivery robots, their initial feelings and concerns about the technology, opportunities or advantages associated with robot delivery, and strategies to address the drawbacks by technological advancements or policy interventions. All interviews were recorded, transcribed, and analyzed thematically.

Findings

1) Observations

1a) People are generally confused and curious about robot movements and tend to move around the robots or change directions to avoid collision

In both locations, the robots stopped often and started seemingly at random, confusing people and prompting them to walk around them or change direction to avoid collision. When the robots stopped,

people would also stop and either look at the robots' front (which displays facial expressions such as smiles or frowns) for a second and tentatively move around it or change direction completely. It was far less common for the robots to move around people. When the robots moved around people standing or sitting, people often watched them go by curiously. Figure 1 shows the general patterns of robot and human movements in a shared space reported by the total number of times they occurred during one hour of observation. It is important to note that most people are not yet used to sharing space with delivery robots and do not know how to communicate with them. The traditional non-verbal cues such as body language and eye contact used to communicate with other pedestrians or cyclists are useless for robots, and people are thus unsure how the robots will move next.

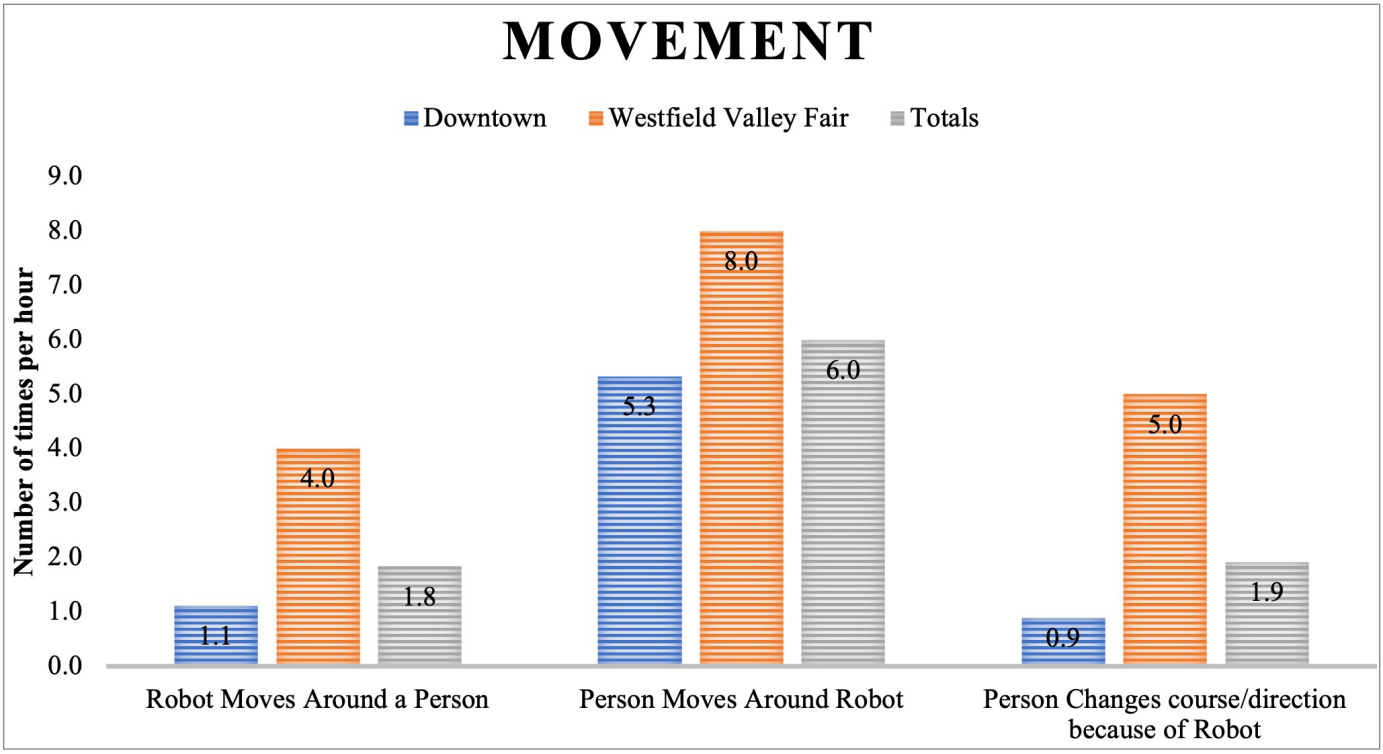

Figure 1. Patterns of Robot and Human Movements in a Shared Space

1b) The settings in which the robot operates matter, but the general patterns of human interactions with the robots do not necessarily change because of differences in the settings

Observing the movement of delivery robots in two different settings, one (in Downtown San José) with generally wider sidewalks and one (at Westfield) in a more crowded and relatively compact shopping mall, allows a better understanding of how human interactions with the robots might change if robots start to compete for space on the crowded sidewalks. Downtown San José has wide, well-maintained sidewalks that were not crowded during observations. Also, student researchers noted that the typical pedestrian in Downtown San José was an adult. It should also be mentioned that the robots had memorized routes when operating in Downtown San José. On the other hand, Westfield Valley Fair mall represented a completely different setting. The students described a more compact, relatively crowded space occupied by different types of people including families with small children. Unlike Downtown San José (where Kiwibot set a fixed route for deliveries to simplify the process), robots followed an undetermined path to perform deliveries around the mall.

Due to these different settings, it is not surprising that almost 40% of all tallied observations were in the Westview Valley Fair Mall, despite only 30% of total observation hours spent in this location. This simply means that more people encountered the delivery robots in a different setting.

Nevertheless, the general patterns of human interactions with the robots did not change because of the different settings. For example, in both settings the most common reaction to a delivery robot was taking pictures. People who were taking pictures were often smiling and greeting or admiring the robot. The second most common reaction in both settings was messing with the robot unintentionally or deliberately. These instances involved unintentional blocking when taking pictures or taking a closer look, deliberately stepping in front of the robot out of curiosity, and in rare cases, continually stepping in front of it, or following it for a while. Lastly, people did not throw items at the robots or otherwise vandalize the robots regardless of how crowded or empty the space was. Figure 2 shows how people reacted to robots in Downtown San José and the Westview Valley Fair Mall.

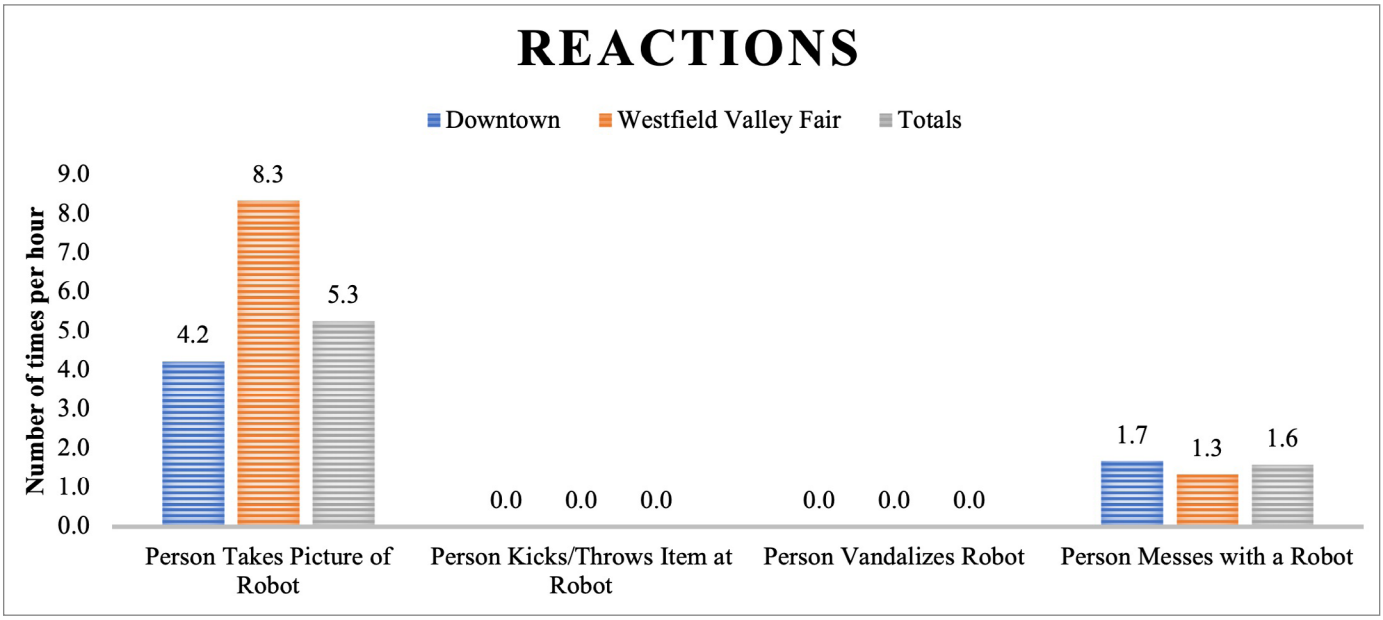

Figure 2. Reactions to Delivery Robots

1c) Despite some close calls, robots did not hit people or objects

Close calls with a person made up 43% of total observations related to close calls and incidents, while close calls with animals such as dogs made up 14%. Some of the most concerning incidents involved cars and cyclists who moved fast and did not see the small robot on the ground. Despite their flagpoles, the fact that Kiwibots only measure 20.5 x 16 x 20 inches in size makes them vulnerable to being run over. Additionally, similar to pedestrians, drivers and cyclists are unable to rely on non-verbal communication with the robots, making them uncertain if they should keep moving after the robots stops. Despite these close calls, the robots never ran into people or objects during observations.

1d) Bystanders are empathetic towards robots that tip over or get stuck

In all incidents where the robot tipped over or otherwise got stuck, bystanders put them right side up and set them on their way. During nine hours of observations, the robots got stuck nine times, and tipped over three times. These behaviors suggest that people treat robots almost like a pet, a child or otherwise a vulnerable object that needs to be protected as opposed to an advanced device capable of problem-solving. However, empathy for the robots can potentially put people in dangerous situations. For example, when one of the robots got stuck in wires at an active construction site, the construction workers went out of their way to rescue the robot without reservations. Although the construction worker (who was most likely familiar with the site and its safety protocols) was able to remove the robot safely, it is possible that community members will sacrifice their own safety to protect the robots that get stuck in dangerous places, such as construction sites or light rail tracks.

Figure 3 shows close calls and incidents.

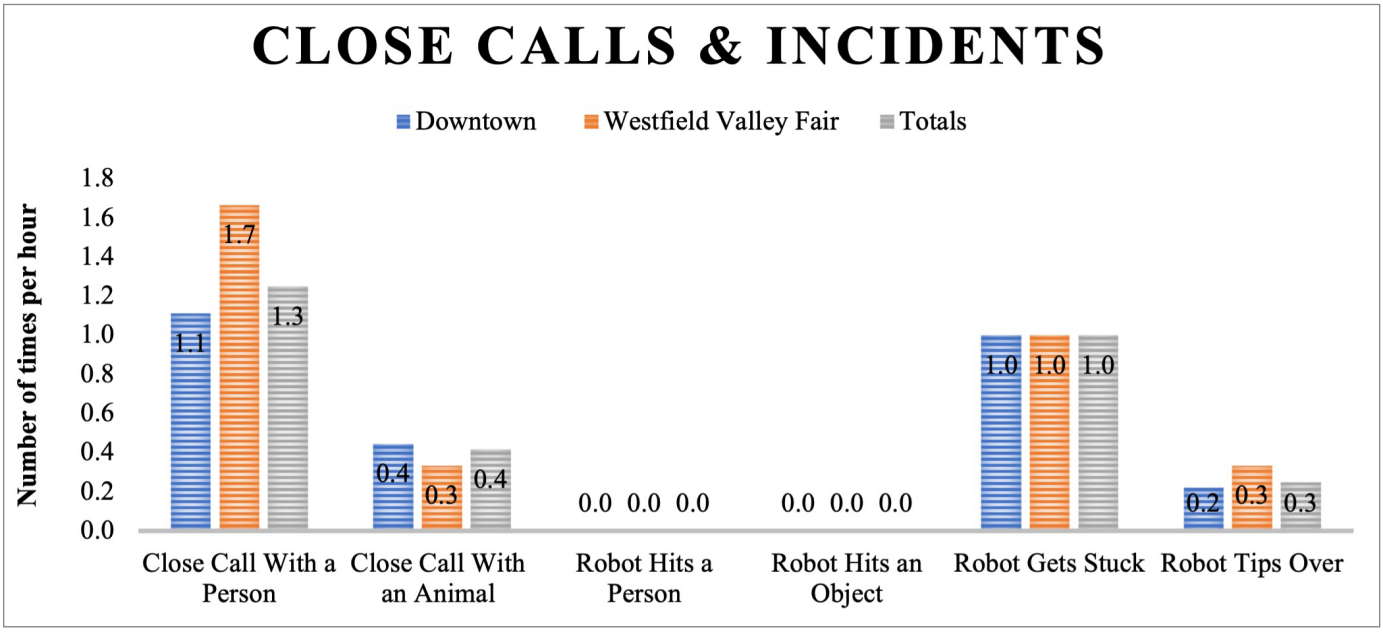

Figure 3. Close Calls and Incidents

2) Intercept Surveys

2a) People are generally enthusiastic and curious about delivery robots and feel safe around them

Results from intercept surveys indicate that people are generally curious and excited about the prospect of robots delivering food, medicine, and small packages, and feel safe around robots. More than 90% of all respondents had a positive reaction when asked about delivery robots, and more than 80% of respondents felt very safe or safe around them. Figure 4 shows how safe people felt around delivery robots. Although many people had not yet seen a delivery robot in person, they overwhelmingly expressed an interest in learning more about this technology and utilizing it in the future. The most common reaction to seeing a Kiwibot was that of surprise and or curiosity. Community members often used positive or neutral adjectives such as “cute”, “cool”, “marvelous”, “modern”, and “futuristic” to describe how they felt about delivery robots.

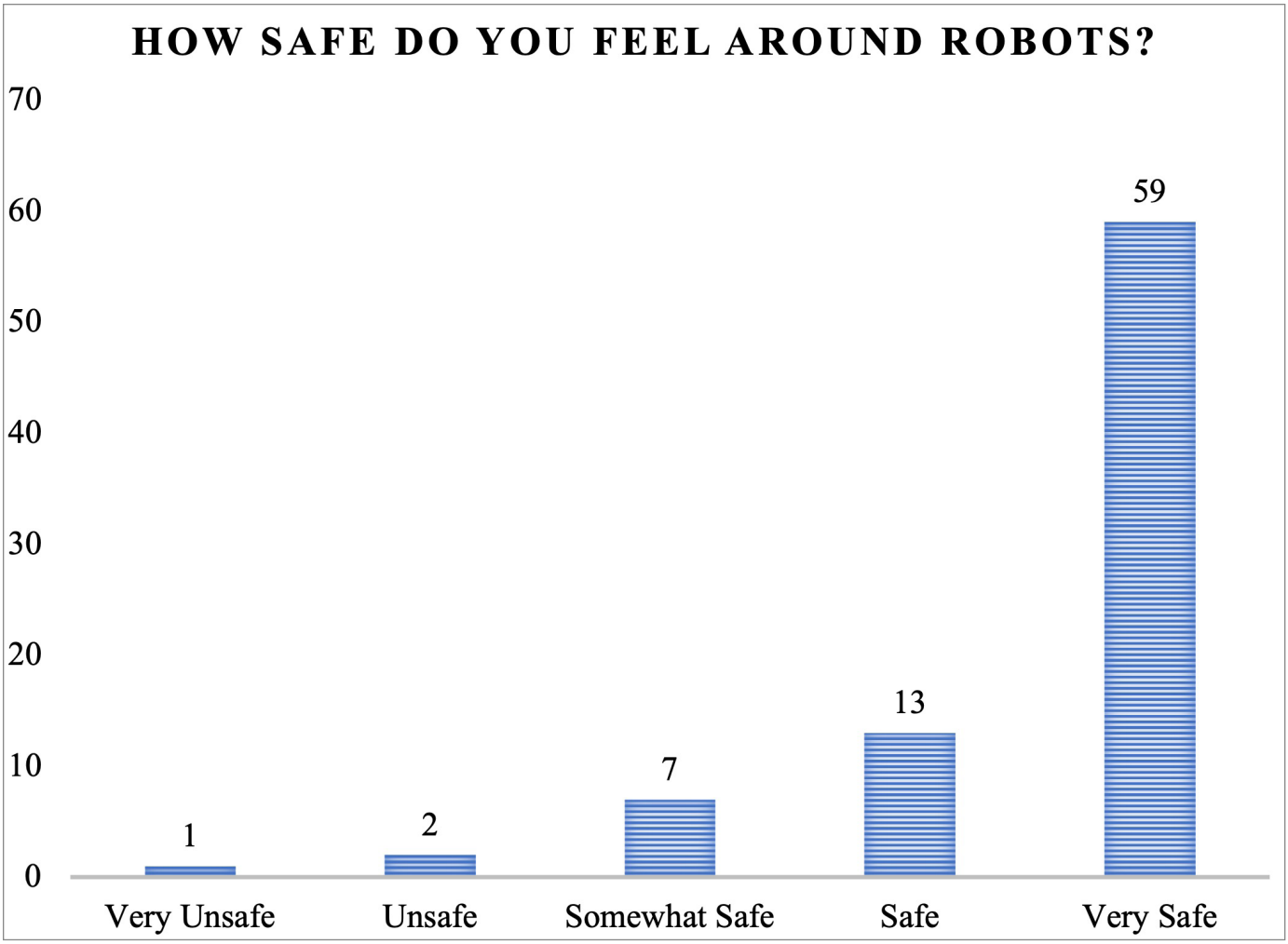

Figure 4. Perception of Safety around Delivery Robots

2b) People have broad awareness of the limitations and potentials of delivery robots

Although more than 70% of the respondents reported that they would consider using robot delivery services, many were aware of the limitations or challenges of this technology despite its potentials. Common concerns included slow service, limited service-range, and the potential of being tampered with. People were also broadly aware that robot delivery could become more efficient and convenient as the technology progresses. Lastly, some respondents acknowledged that robots offer truly contactless delivery services, and these services are particularly useful for safely delivering food and medicine to people with limited access to transportation options, such as the elderly, disabled individuals, and those residing in disadvantaged communities.

3) Interviews with community members and stakeholder organizations

3a) Interviewees deemed the deployment of delivery robots inevitable despite the limitations of current technology and uncertainties involved with their widespread use.

Both community members and representatives of stakeholder organizations were broadly aware of the current challenges of delivery robots, but interviewees considered the deployment of delivery robots inevitable. Interviewees, like survey respondents, were generally enthusiastic about the technology and discussed various scenarios for how and when delivery robots will be available on a widespread scale. Some interviewees described delivery robots as a more efficient alternative to cargo bikes; others considered delivery robots as a viable option for fast and efficient contactless delivery of food, medicine, and other small packages. Several interviewees mentioned that food delivery and online shopping exploded in popularity during the COVID-19 pandemic, further justifying the need for delivery robots. Nevertheless, many interviewees were generally aware of current limitations of the technology and various uncertainties about its potentials and environmental co-benefits. For example, in a scenario where delivery robots predominantly replace cargo bikes, this new technology will not result in significant Vehicle Miles Traveled (VMT) or greenhouse gas (GHG) emissions reduction. Similarly, if widespread use of delivery robots turns out to be unrealistic in many parts of the city, VMT and emissions reductions can be negligible. For example, one interviewee acknowledged that not all parts of the city have sidewalks that would be appropriate for delivery robots, and while the technology of delivery robots is advancing quickly, infrastructure development to support this technology can be rather slow.

3b) Delivery robots are considered safer than autonomous passenger vehicles, but interviewees were still concerned about safety from and the safety of the robots.

When it came to safety, interviewees expressed different attitudes and views. Many interviewees focused more on the safety of the robots, while others discussed safety from the robots on sidewalks, streets, and other public spaces. Although the delivery robots have several safety features to prevent accidents, theft, and vandalism–such as cameras, sirens, and location tracking features–people still worried about the safety of the robots. One interviewee compared the delivery robots to electric scooters that were thrown into San Francisco Bay– “destroying the scooters, polluting the environment, and harboring bad feelings toward e-scooter companies or the technology”.

Interviewees were generally less worried about safety from delivery robots, at least when compared to autonomous passenger vehicles or even micro-mobility options such as e-scooters. The small size and the low speed of delivery robots, as well as the advanced sensors robots used to navigate around people, were the most cited reasons interviewees discussed to explain why delivery robots are generally safer. None of the interviewees mentioned witnessing or hearing about the delivery robots bumping into people, animals, or objects or even blocking the sidewalks. Interviewees representing organizations that used delivery robots regularly were generally impressed by the robots’ ability to navigate around pedestrians and avoid potential conflicts. One such individual shared an incident where the robot avoided conflict by quickly going around a person who began yelling at it, “almost like how a human would navigate such a situation”. The main concern raised by the interviewees was robots potentially blocking parts of the sidewalk or a crosswalk that are necessary for individuals with physical disabilities to safely navigate city streets. “For me, the only [safety] concern about delivery robots really is just making sure that there’s no access issues for

disabled people that need to have clear ingress and egress [to] be able to navigate city streets," one interviewee explained.

3c) Some people have privacy and data protection concerns about delivery robots and are generally skeptical of the cameras on the robots.

Interviewees raised several privacy and data protection concerns. Most interviewees were concerned about personal data (e.g., address, pictures or video recordings, and biographical data) collected, stored, or processed by delivery robots, and thought that the city government should establish clear protocol and guidelines. The most common concern was the cameras on the delivery robots that might take pictures, video, or audio recordings. "[I have] privacy concerns since we live in an age where we are being constantly monitored online and now in the public sphere as well… I understand that the camera is very necessary to the operation of these [robots] because now they're remotely operated...but yes, it's very scary to think about who has access to that [data] or whether the video will be stored somewhere," explained one interviewee. Due to the requirements set by the City of San José, the robots were not allowed to record anything during the pilot project, but the concerned interviewees were likely unaware of these requirements. Several interviewees also mentioned existing restrictions and data protection regulations for personal data collected by robots or robot delivery companies through the delivery process. Since the delivery robots can be potentially stolen or tampered with, if any data is stored on the robot at all, it is at risk of misuse. A few interviewees also mentioned the risks that a potential insecure connection to the internet might cause. If delivery robots use Bluetooth or Wi-Fi to establish an insecure internet connection, there is a risk of sensitive information breach.

3d) Ranging from sidewalk-equity, access, and jobs, delivery robots raise equity questions.

Despite the prospective environmental, social, and economic benefits offered by delivery robots, there was a consensus among interviewees that discussions around equity dimensions of robot technology are critical for community wellbeing.

One common theme was sidewalk equity, which has two important dimensions: 1) whether all parts of the city offer sidewalks appropriate for robot delivery regardless of the community's socioeconomic straits; and 2) whether delivery robots can potentially limit access to and use of sidewalks for others. Interviewees mentioned that harder-to-maneuver or less well-maintained sidewalks in parts of the city can make robot delivery very difficult if not impossible. Because these sidewalks are likely disproportionally located in disadvantaged communities, these communities might not get access to robot delivery services at all. "If robots only deliver in areas with nice and wide sidewalks, the ones who likely need these services the most but happen to live in neighborhoods with no such infrastructure will not see any benefits from this technology," mentioned one interviewee. While some interviewees focused mostly on the distributional impacts of robot delivery services, others questioned the fairness of how sidewalks are shared with robots and micro-mobility devices. "I do notice that [e-scooters] are given so much more priority on the street than people who have no option but to exist and live on the street," one interviewee explained when voicing their concern about robots being potentially prioritized over people.

Another major theme related to equity was jobs. Interviewees discussed both negative and positive ways robot delivery could impact jobs. On the one hand, interviewees were concerned that delivery

service jobs (like many other service industry jobs) could eventually be phased out by artificial intelligence and automation. However, some interviewees mentioned that if delivery robots cut costs for local restaurants and other small businesses, this could result in more jobs created in the local economy both directly (i.e. businesses hiring people) and indirectly (the ripple effect of higher incomes for business owners and staff). "On the job opportunity side, if [robot delivery] can help support [local] businesses [by adding] to their customer base, [this] will keep those people working and hiring, right? So, it feels like the chain of events can be helpful," one interviewee mentioned. Overall, interviewees were not against the technology because it results in short-term disruption of employment–provided that the government supports the ones negatively impacted by these disruptions: "I'm of the mindset that progress does displace certain jobs. And in the short term, some groups that rely on those kind of jobs [are going to be impacted]. Cities can provide [job training] programs to help offset that somehow."

3e) Direct and indirect as well as positive and negative environmental impacts of delivery robots should be assessed.

Interviewees discussed various scenarios to gauge the direct and indirect, and positive and negative environmental impacts of delivery robots. Although most interviewees were enthusiastic about the emissions reduction potential of delivery robots, many were aware of potential negative environmental impacts or scenarios under which such emissions reduction would be unrealistic. For example, if robots predominately replace cargo bikes or small electric vehicles used for delivery, robot delivery will not result in significant emissions reduction. Some interviewees were also aware that the convenience and lower cost of robot delivery might promote wasteful behavior among consumers since many restaurants still use plastic packaging or excessive packaging. Other interviewees expressed a concern about the life cycle environmental impacts of delivery robots. "If these robots are more likely to be vandalized as opposed to other delivery vehicles, the life cycle environmental impacts of replacing them should be seriously considered," one interviewee explained.

3f) "It's not just delivery"–the robots can be used in other innovative ways to improve safety and walkability.

Some interviewees offered several interesting perspectives on how the robots can be repurposed to serve other community needs. Four themes emerged from interview data demonstrating innovative ideas about other ways the robots can be used. First, robots can play the role of "safety ambassadors" patrolling "high-impact areas" at night. For example, robots can autonomously patrol areas around SJSU at night or escort people who might feel unsafe walking in Downtown San José at night. Second, the robots can assist in crime and sidewalk condition reporting because of their video and location recording capabilities. Third, robots can offer self-guided tours to help tourists and locals navigate destinations around the city: "The users listen to a self-guided audio tour on their phones, and the robots navigate the way so that users don't get lost," explained an interviewee. Lastly, the robots can play the role of servers to deliver drinks and food at social events. The robots can help lower the cost of such events, "minimize the risk of COVID-19 exposure", and "serve as a conversation starter among attendees", one interviewee explained.

Conclusions and Policy Considerations

Community members have greeted sidewalk delivery robots with a mixture of curiosity and wariness. In an era where people expect a fast contactless delivery for food, medicine and other items, people see a potential role for these intelligent devices. These robots roll on the same public spaces as humans–such as sidewalks, crosswalks, and bike lanes–carefully avoiding collisions while interacting with humans by changing their face features. For example, the robots can display a smiley face while performing their delivery duties, or an angry face if people block their way. People are equally eager to interact with the robots but are often unsure about the capabilities and risks of these small four-wheeled devices. Although most people feel safe around delivery robots, people also worried about the safety of the robot or potential security issues with the data it collects.

People know that delivery robots are coming but are concerned that policy and required infrastructure might lag. The rules on where and how these intelligent devices should operate to generate the greatest environmental, economic, and social equity benefits are still being developed. Some key considerations to guide policy development and planning include:

1) Potential environmental impacts: Findings from this study indicate that community members and stakeholders are generally aware of both positive and negative potential environmental impacts associated with delivery robots. Planners and policymakers should examine the potential environmental impacts of delivery robots holistically to maximize positive impacts and minimize negative consequences. For example, deployment of delivery robots has been introduced as a promising zero-emission last-mile solution. However, the GHG emissions reduction potential of delivery robots as a last-mile delivery solution will only be achieved through scale. This scaling requires appropriate and well-maintained sidewalks and crosswalks across the city to ensure the robots can navigate throughout all neighborhoods smoothly without blocking access for others, including individuals with disabilities. Another example of environmental impact is promoting or requiring eco-friendly packaging for robot delivery to reduce the adverse impact of plastic waste on the environment.

2) Community needs: Results from this study indicate that delivery robots can be used in other creative ways to meet a wide range of community needs. In addition to delivering food, medicine and other small packages, robots can serve as safety ambassadors and tour guides, report sidewalk hazards, and serve food and drinks at community events. Also, the city can develop programs in collaboration with community organizations to deliver food and necessities to communities in need, such as people with limited mobility or people without access to healthy food options.

3) Local economic impacts: Interviewees had mixed responses on the potential economic impacts of delivery robots. Sidewalk delivery robots can potentially lessen dependance on costly delivery apps for local restaurants and small businesses. Common delivery apps such as Grubhub, Doordash, and UberEats often charge restaurants expensive commission fees. Delivery robots can help reduce these costs for local restaurants and help them maintain their online customer base. As such, these robots can be viewed as a local economic development opportunity. However, interviewees were also concerned that delivery jobs will be replaced by robots, and the government should invest in workforce development and job training programs to help individuals who lose their jobs.

4) Safety and privacy: Although the limited data collected in this study suggests that delivery robots are generally safe, several safety and privacy questions remain. The current generation of delivery robots are small and slow and require operators to monitor them. Thus, the main safety concern appears to be the safety of the robots–since drivers and cyclists might not see them, or people might vandalize them. Heavier, faster, or fully autonomous delivery robots can raise different kinds of safety and security concerns. Since it would be very difficult to gauge the safety of the delivery robots without sufficient data, local or state governments should require robot companies to share accident and other safety data.

Robot delivery technology to improve safety and protect privacy is advancing, but local governments have an important role to play. For example, local governments can examine data collecting and storing capabilities of delivery robots, and craft appropriate policies to ensure user privacy and personal information protection. Similarly, local governments can develop a list of safety features that delivery robots should include to operate within the city. For example, student researchers noted that a taller flagpole or a bigger flag could help the robots be more visible on the streets, and thus less likely to be run over by vehicles. Pilot testing delivery robots can help local governments identify and regulate a range of potential safety and privacy shortcomings. Engaging the community to identify and address the safety and privacy concerns associated with delivery robots is also a critical step.

5) Equity: Deployment of sidewalk delivery robots raises several equity questions that should be placed at the center of local policymaking and planning. Technological advancements can improve effectiveness, efficiency and even safety of delivery robots over time, but it is up to the local community to ensure equity. If robots can be used to effectively deliver food, medicine and other necessities to community members, the city can improve equitable access for all. For example, local governments can ensure that sidewalks are wide enough and in generally good condition to support both pedestrian and robot traffic across the entire city. Local governments can also require robot delivery apps to follow accessibility guidelines. If the potential negative impacts of delivery robots are likely to disproportionately harm certain populations, such as individuals with disabilities or delivery workers, measures should be taken to prevent or minimize these impacts.

It is likely that humans will eventually learn how to effectively and safety use robots for community wellbeing. Until then, we should wonder what risks and benefits these robots offer, and how we can maximize the benefits while minimizing the risks. This phase not only includes technological advancements, but also development of innovative policy and planning solutions as well as meaningful community engagement.

Acknowledgement

The author thanks the following people for their important contributions to this project:

- Graduate Master in Urban Planning (MUP) students at SJSU
- Sarah Abroff from the City of San José
- Amanda Howell from the University of Oregon
- MTI staff

About the Author
Dr. Serena Alexander is an Associate Professor of Urban and Regional Planning and Director of Urban Online at San José State University. Her research focuses on developing cutting-edge strategies to address climate change and climate justice.

This report can be accessed at
transweb.sjsu.edu/research/2203

MTI is a University Transportation Center sponsored by the U.S. Department of Transportation's Office of the Assistant Secretary for Research and Technology and by Caltrans. The Institute is located within San José State University's Lucas Graduate School of Business.