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ABSTRACT

Rapid advances in digital technologies have allowed robots to become more autonomous and efficacious than ever before. Future developments in robotics hold the potential to transform human robot interactions. We can expect to see robots performing a variety of functions in public spaces. Possibilities exist for robots to greatly improve the quality of our lives and to contribute positively to the safety, creative potential, and atmosphere of public spaces. But as this trend develops, the risk emerges of robots transforming public spaces and social interactions in undesirable ways. By reviewing previous public policy approaches to harnessing and regulating disruptive technology, we consider how public policy could simultaneously enhance opportunities created by the presence of robots in public spaces and reduce the risks of undesirable outcomes. We summarize key insights into a policy design checklist to guide policies on robots in public spaces. These insights cover (1) safety, (2) privacy and ethics, (3) productivity, (4) esthetics, (5) co-creation, (6) equitable access, and (7) systemic innovation.

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Over a century of science fiction writing has given us images of robots, some positive, some negative. Comics, movies, videos and computer games have made those images more vivid. Asked to describe or draw a robot, many people could immediately respond with scenarios inspired by these fictional portrayals (Horstmann and Krämer 2019). Meanwhile, rapid advances in artificial intelligence and automation technology have seen actual robots appearing and performing specific functions in public spaces. Today, they can be spotted in supermarkets, malls, airports, hospitals, parks, and on streets and sidewalks. Their activities include cleaning, delivering food or parcels, or providing security or public information. Yet, for now, little is known about how robots shape our experience of public space as they interact with people and move through these environments. Moreover, little effort has gone into the development of public policy anticipating the ways that citizens will increasingly come to interact with robots. In this paper, we consider how public policy could simultaneously enhance

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opportunities created by the presence of robots in public spaces and reduce the risks of undesirable outcomes. We summarize key insights into a policy design checklist to guide refinement of policy concerning robots in public spaces. These insights cover safety, privacy and ethics, productivity, esthetics, co-creation, equity of access, and systemic innovation.

In the years ahead, robots will become more visible and commonplace, as robotics and allied technologies continue to advance, and as industries devise more applications for them. Consider two examples. First, delivery robots are becoming more common. Starship Technologies, headquartered in San Francisco, has created delivery robots used primarily to take fast food orders from restaurants to customers, meeting them by their homes or offices or wherever they intend to eat. The electric-powered robots resemble small storage lockers on wheels. They ride on sidewalks at the same speed as adults typically walk. Starship Technologies has targeted university campuses as places where most of these robots have been deployed to date. As of February 2021, Starships were operating in the United States, the United Kingdom, Finland and Estonia, and more than one million meal deliveries had occurred. Nuro, based in Mountain View, California has developed the R-2, another delivery robot. Unlike the Starship, the Nuro R-2 travels as a self-driving electric vehicle on roads at the speed of regular traffic. It too can deliver meals, but its capabilities extend to transporting anything from groceries to dry cleaning. Nuro seeks to have household errands become a thing of the past.

Second, robots are being used for surveillance and security purposes. These uses have grown during the COVID-19 global pandemic. Spot is a robot that runs on four legs and has the appearance of a dog. Designed to operate in unstructured environments inaccessible to other robots, Spot has been made commercially by Boston Dynamics since 2019. During 2020, the Singapore government deployed Spot in parks across the city to ensure that walkers, runners, and other park visitors were practicing social distancing. Using remote navigation and equipped with a camera and prerecorded message, Spot "barks" a warning whenever it comes across someone who is not complying with safe distancing rules. The Singapore government has also deployed a fleet of drones to observe parks from above and measure how many visitors are at each location. The data are then aggregated to a website that locals can use to determine in real time which parks currently have the lowest number of visitors. In another surveillance and security application, robots developed by Cobalt Robotics in San Mateo, California have been used to replace humans in security activities during COVID-19. The Cobalt robots conduct temperature screening, identify that people are wearing masks, and monitor for social distancing. In Melbourne, Australia, these robots have been deployed in COVID-19 quarantine hotels to check that guests are not opening their doors or leaving their rooms. If the robots detect any breaches or anomalies, they send an alert to authorized officers, including police, who can enforce the rules.

Well-designed, anticipatory public policy can do much to ensure that society reaps the greatest benefits from new technology while reducing possible harms (Cairney and St Denny 2020; Görür et al. 2018). Such policymaking can prove critical in shaping the trajectory of technology adoption (Aydin 2019; Boucher 2016). Looking ahead, while many opportunities will emerge for helpful human–robot interactions, productivity enhancements, and creative problem solving, risks also exist. If robots "in the wild" are not carefully managed, unfortunate events could occur (Selma, Michalowski, and Simmons 2006). In turn, these could have the broader spillover effect of undermining public trust in their use. Poor public management of robots could serve to undermine their broader utilization and, hence, limit how robots could positively contribute to the quality of our lives (Belanche et al. 2014; Hubbard, 2014; Li, Hess, and Valacich 2008).

Before turning to our discussion of robots in public spaces, it is useful to briefly review the definition of robots and human–robot interactions. Doing so assists in explaining why the presence of robots in public spaces is a significant development, one that deserves more attention by public policy researchers and practitioners. At the most basic level, robots are machines that exhibit intelligence and autonomy. They can be left alone to complete specified tasks or a program of activities. Contemporary advances in artificial intelligence and robotics are leading to the creation of robots that are increasingly exhibiting higher levels of intelligence and autonomy than their predecessors. High functioning robots can learn and adapt to their environments. The multidisciplinary field of Human–Robot Interaction (HRI) is driving the development of robots that engage in complicated interpretative tasks, including understanding speech, recognizing facial features, and inferring the emotional state of humans they are interacting with (Beer, Fisk, and Rogers 2014; Young et al. 2011). Contributors to this field seek to combine the skills of both humans and robots to improve performance in a wide variety of tasks. These fall into the category of Human–Robot Collaboration, where efforts are underway to advance knowledge of what interactions and collaborations are feasible and how they can be refined to generate even more complex engagements (Gervasi, Mastrogiacomo, and Franceschini 2020).

1. Robots in public spaces

The increasing sophistication of robots and their capabilities to engage in a socially intelligent manner with humans hold significant implications for public spaces and how we use them. Del Casino et al. (2020) argue that robots are "increasingly becoming woven into, and thus helping to create, our complex, continuously evolving, and contingent socio-spatial realities" (p.611). As these changes occur, they will impact on how we use public spaces. The introduction of robots in public spaces and the likely expansion of their activities and numbers will have implications for public safety and for human productive capabilities within those spaces. In addition, the presence of robots will change the look and feel of those spaces, the complex set of conditions that establish the "atmospheres" within them (Edensor and Sumartojo 2015; Sumartojo, Edensor, and Pink 2019), and by extension how people make sense of and value those shared spaces.

Public spaces can be thought of as anywhere that groups of people who may or may not know each other can freely assemble, move about, and interact. Understood in this way, many legally private spaces can be seen as functionally public. We might call them quasi-public. Shopping malls, airports, pubs and restaurants are typically privately-owned, yet people can exercise a high degree of discretion concerning who they meet with and what they do within those spaces. In contrast, most outdoor public spaces like streets and parks are publicly owned and subject to governance by councils or other legislative bodies. However, there are also gardens, parks, and some beach areas that are quasi-public in nature. As applications for robots grow and people accord increasing value to their contributions to everyday life, all who govern public and quasi-public spaces will need to give more consideration to how laws and regulations can appropriately guide the activities of robots. Questions of public safety will be paramount. Yet how robots alter the atmosphere of public spaces must also be carefully considered. Governors cannot fully control atmospheres, but in allowing robots into public spaces they can specify the allowable features and functions of those robots, how many will be allowed to operate in the space, and the hours of operation. This is similar to how urban planning regulations, for example, co-constitute the atmospheres of public spaces by determining standards for traffic, lighting, construction materials or footpath widths. Laws and regulations of this kind related to robots could serve to support efforts to ensure public safety. Beyond this, they could have implications – both positive and negative – for advancing productivity.

Among scholars of governance, public management, and public policy, explorations of the growing capabilities of robots and their social implications have received limited attention to date. Dickinson et al. (2018) explored the use of robots in the delivery of care services. They noted that considerable training would be vital, both for staff working in care services and for patients who could receive some services via the work of robots. These researchers recognized that limitations in how people perceive and work with robots could limit the effectiveness of the technology. They also noted the importance of establishing appropriate regulatory regimes, noting that actions on the part of governments could both support and inhibit the greater use of robots in the delivery of care services. Similar points have been made by Si Ying and Taeihagh (2020) in their study of the adoption of robots in long-term care in Singapore. Many of the issues raised concerning robots and care services could be generalized as we think about the introduction of robots into public spaces more broadly.

2. Key public policy issues

Robots have the potential to contribute greatly to the quality of human life, as we have seen during the COVID-19 pandemic, as robots have been increasingly used for delivery and cleaning services, as well as telehealth and other health-care specific applications. Their growing prevalence in public spaces could propel many changes. While some people might welcome those changes, others might find them deeply confronting. When people experience changes in their environments and desire to collectively negotiate effective ways to manage such change, they turn to their governments for guidance and support. Policy researchers and practitioners can add much to the ensuing discussions and aid in the identification of positive ways forward. That advice can be useful for indicating both policy actions that could be helpful and those that could be unhelpful. Here, we review previous public policy approaches to harnessing and regulating disruptive technology. We focus the review around three matters: trust, planning, and socio-technical transitions. These matters take us from the micro-level, where the focus is on interactions between individuals and robots, through to the macro-level, where the focus is on how to capture value for society as a whole from the greater presence of robots in public spaces. Throughout, we note how public policy could simultaneously enhance opportunities created by the presence of robots in public spaces and reduce the risks of undesirable outcomes.

2.1. Trust

A prerequisite for human acceptance and use of new technology is that the technology is viewed by people as trustworthy (Hancock et al. 2011). Transparency concerning the nature of the technology and its capabilities and limitations is essential to allowing trust to develop (Wortham and Theodorou 2017). In the case of robots, the key constituents of trust are perception of safety, perception of competence, and perception of integrity in the use of information. These constituents parallel those people apply when working with professional service providers. For example, when choosing a medical specialist to perform a procedure or treat an illness, individuals will seek someone who they feel safe with, who they judge to be highly capable to address the presenting condition, and who will maintain patient-doctor confidentiality. These key constituents of trust present a high bar for the acceptance of robots in the public space. People must trust that the presence of robots will not cause them any physical harm. This suggests the need for robots and those responsible for their operation to pass threshold tests of safety (Kulić and Croft 2007; Lindblom and Wei 2018). This is equivalent to the typical government regulation of cars and their drivers. Cars are usually required to be regularly tested for their roadworthiness. Those who drive cars that lack a current certificate of safety can face fines. And drivers, too, must hold licenses, which are subject to regular renewal rules. Renewal can often require the passing of tests. These may focus on knowledge of road rules or practical operating skills. More recently, the operation of drones has been subjected to similar kinds of rule-making (Boucher 2016). For robots to be trusted in public spaces, it is likely that new regulations will need to be developed relating to the safety of the robots themselves and the competency of those seeking to release them in public spaces. Publication of ISO 13482, a safety standard for personal care robots, has led the way here. Until it was promulgated, only general safety standards for machines were available and the lack of a specialized safety standard with detailed requirements resulted in uncertainty and a relatively high residual risk for manufacturers (Jacobs and Singh Virk 2014). A complicating factor here is that as robots become more autonomous, the relationships between the operator and the robot becomes more indirect. This raises challenges for those making public policy around the operation of robots in public spaces (Hubbard 2014; Hancock 2019).

Beyond being judged as safe, robots in public spaces must also be judged as competent (Jensen et al. 2018; Park, Jenkins, and Jiang 2008). Even if they are deemed safe, public trust in robots will rapidly erode if the robots do not perform their specified tasks at expected levels of quality (Dzindolet et al. 2003). For example, people will not trust robots designed to deliver meals if they find a robot has delivered a different meal than was ordered, or if the meal arrives cold, incomplete or not at all. But reputation also matters. Even if people have not had a bad experience with a robot, they will soon judge them untrustworthy if they hear stories of other people who have had unfortunate robot experiences. The competency of robots will be dependent on both the capabilities they have, the effectiveness of robot operators in programming them and their abilities to cope with the unpredictable nature of public space. Given this, the governors of specific public spaces might choose to test task competency before allowing robots to operate there. Operating licenses could be restrictive, so that robots would be licensed to perform certain tasks but not others.

To perform effectively, robots frequently access information from datasets. For example, how they get from place to place can be dependent, in part, on their ability to engage with global positioning systems, just as smart phones give directions to humans. The ability of robots to continuously collect information through cameras, microphones, and other sensors means that they are both dependent on datasets and actively contributing to the continuous expansion of those datasets. Through such capability, robots can potentially acquire and maintain expert ability to recognize people and remember key details about them. This raises major privacy concerns (Xu et al. 2014). When a robot is making a delivery, there are multiple other ways that it could be acquiring information about the humans around it – and not just those that it interacts with directly. To the extent that robots are viewed as agents of "big brother," trust in them will erode. Major public policy issues arise concerning how much information robots collect and share with remote databases. Without being addressed, these concerns could severely limit the acceptance of robots in public spaces.

2.2. Planning

Public policies are often devised to address challenges arising from human behavior in public spaces. It has long been recognized that problems arise when spaces are shared and demarcation of property rights is deemed expensive (Olson 1965). The tragedy of the commons arises when shared spaces become congested or overused (Hardin 1968). These considerations are relevant to the use of robots in public spaces. At a minimum, there is the possibility that the presence and actions of robots in public spaces will prove inconvenient or unpleasant to people. That situation is equivalent to the creation of a negative externality, where consensual transactions between specific parties have spillover effects that are not accounted for in the original transaction. Air pollution and industrial noise are common examples of negative externalities. Societies deal with them through planning procedures and the creation of rules and regulations about actions that can be taken in specific spaces. Often, externalities become most apparent with population increases. Actions taken when few others are around might be deemed acceptable in those circumstances. The same actions, when many people are engaging in them, serve to create negative externalities and calls are made for government regulation. All of this suggests that planning is vital to ensure that robots in public spaces contribute to the quality of life of as many people as possible in those spaces and that negative consequences for people in those same spaces are minimized. Most importantly, it is clear that the rules to be established will differ depending on the nature of the public space, what types of robots are in such spaces, how many there are, and what kinds of things they are doing (like security patrols or surface disinfection, which are both about public safety but look and feel very different). In the public management literature, a fair amount has been written about the creation of public value (Moore 1995, 2013). Here, governors (who establish the authorizing environment) assess proposals for procedural changes and also make decisions about whether public resources should be devoted to support specific proposals. That perspective could usefully inform future explorations of how to effectively govern the use of robots in public spaces.

2.3. Socio-technological transitions

Over the past two decades, a literature has emerged to explore the processes through which norms and practices associated with new technologies introduced in experimental or "niche" settings (Rip and René 1998) become adopted more widely (Berkhout, Adrian, and Andy 2004). These processes have come to be referred to as "socio-technological transitions." Much of the contemporary literature is concerned with transitions associated with promoting more sustainable development and mitigating against climate change (Geels and Kemp 2007). However, the concept of "socio-technical transition" is well-suited to considering how the growing prevalence of robots in public spaces might lead to broad acceptance and application of robots throughout society. Beyond the trust and planning issues already discussed, robots in the public space open other issues. There is the issue of value capture. If the introduction of robots in public spaces leads to many positive contributions to the quality of human life, then there would be value for society in as many people as possible being able to enjoy those benefits. Relatedly, there is the issue of unfair distribution of benefits. For example, with the growing use of food delivery robots, a concern is raised that people who can afford to use the service benefit substantially, while those who cannot afford the service both fail to benefit from it and also have their ability to use public space degraded. That is because the food delivery robots take up significant sidewalk space and make walking on sidewalks less attractive. As we know from literature on the digital divide, both lack of access to technology and lack of skills in using technology contribute to major differences across society in who benefits from advances in information technology (Van Deursen and Van Dijk 2011). Moreover, the specific tasks that robots perform may be valued very differently for different members of the public. An example here is the brief deployment in 2017 of a robot in San Francisco to monitor spaces where homeless people were living. The robot ended up wrapped in a tarp and smeared in barbeque sauce, which effectively ended its patrols (Holley 2017).

Table 1 summarizes the key issues that we have introduced here concerning robots in public spaces. Potentially, a role exists for governments in supporting the deployment of robots being used in the public space. That role can be executed in a number of ways, ranging from ensuring that everyone knows of the benefits of robots to subsidization of the introduction of robots in specific public spaces. Room also exists for the development of various "policy mixes" to drive innovation processes (Kern, Rogge, and Howlett 2019). The greater use of robots in public spaces also opens possibilities for innovations in how people and robots interact. While a growing literature has explored the relationship between provision of government services and the agency of service

Table 1. Robots in public spaces – key issues.

Issue	Explanation
1 Safety	Robots can create safety risks to the public due to both physical design features and how operators design and control their functionality.
2 Privacy and Ethics	Robots can raise privacy concerns because they collect large amounts of unique information during their interactions with people and the environment and can contribute that information to existing datasets for potentially many subsequent, unrelated uses.
3 Productivity	Robots might enhance productivity in specific activities but hinder or obstruct other activities.
4 Esthetics	Robots might detract from the esthetics of a public space, making that space less convenient for citizens, more crowded, and unattractive.
5 Co-Creation	Robot designers could develop robots without considering whether or not their presence and actions are broadly acceptable to the communities where they will be deployed.
6 Equitable Access	Greater use of robots in public spaces could produce benefits only enjoyed by affluent individuals and communities while imposing unwelcome challenges for poorer ones.
7 System Innovation	If the operations of robots in public spaces are poorly handled, their potential to enhance the quality of human life could be limited.

clients (Alford 2014), much scope remains for exploring how people work with robots and discovering the benefits that can flow from those interactions.

3. A policy design checklist

Having reviewed key issues raised by the growing presence of robots in public spaces, we here collate emerging insights into a policy checklist. The checklist contains key questions relating to seven topics: (1) ensuring safety, (2) addressing privacy and ethical concerns, (3) advancing productivity, (4) attending to esthetics, (5) encouraging co-creation, (6) promoting equitable access, and (7) facilitating systemic innovation. The checklist and key questions have been uniquely developed for this discussion. However, the matters covered map onto classic goals of public policy analysis which include defending people and property, promoting human flourishing, promoting efficiency, and promoting social equity (Mintrom 2019). Ethical concerns have also long been a primary concern in policy analysis (Mintrom 2012). Questions of esthetics have been less commonly discussed by policy scholars, although they have certainly been apparent in discussions of urban design (Jacobs 1961; Kunstler 1994; Sumartojo, Edensor, and Pink 2019). Questions of co-design and co-creation have received more attention by public policy and public management researchers in recent years (Alford 2014, Mintrom and Luetjens 2016; Osborne, Radnor, and Strokosch 2016). While the questions in the checklist are nonexhaustive, they reflect established discussions among policy researchers and practitioners concerning matters to address in policy design.

Table 2 summarizes the policy design checklist. The following discussion elaborates on how the seven questions in the Checklist might be addressed. For each question in the checklist, we briefly review why it matters, what the ideal outcome would be, and starting points for policy design. Consideration is also given to points of connection across these topics. Given the foregoing review, we are confident that efforts by policymakers to systematically answer the questions on this checklist will contribute strongly to the development of effective policy governing robots in public spaces.

Question 1: How Can We Ensure Safety? The operation of robots in public spaces raises safety concerns that must be addressed from the outset. Safety matters relating to

Table 2. Robots in public spaces – a policy design checklist.

Checklist Questions	Proposed Policy Responses	Explanation
1 How Can We Ensure Safety?	Regulation, Monitoring, and Enforcement	Regulation and monitoring could reduce safety risks to the public through prescribing specific features of robots and requiring operators hold licenses.
2 How Can We Address Privacy and Ethics Concerns?	*Regulation, Monitoring, and Enforcement*	Privacy and ethics concerns could be addressed through specification of appropriate uses of what can be done with the information robots collect and monitoring to reduce the risk that privacy breaches go undetected.
3 How Can We Advance Productivity?	*Regulations and Provision of Incentives*	Regulations could ensure that robots only operate in public when they are deemed to enhance productivity. Incentives could be provided to encourage robot designers to ensure robots enhance productivity and do not hinder other activities.
4 How Should We Attend to Esthetics?	*Monitoring and Co-Design*	Monitoring could ensure robots contribute to the esthetics of public spaces. Mechanisms for co-design could increase the likelihood that ideas and concerns of citizens are incorporated into the calibration of robots for specific public spaces.
5 How Can We Encourage Co-creation?	*Provision of Incentives*	Incentives could be provided, including prizes, to encourage robot designers to work with citizens in developing robots for use in public spaces.
6 How can we promote equitable access?	*Monitoring and Subsidies*	Deployment of robots could be monitored to assess who benefits most from their use in public spaces. Provision of subsidies could increase the likelihood that the benefits of robots would be enjoyed by all members of society.
7 How Can We Facilitate Systemic Innovation?	*Monitoring and Funding*	Government monitoring could include environment scans to assess how new and promising developments could be broadly introduced. Funds could be used to support system innovation, in the same way that funds have frequently been allocated to aspects of Research and Development.

a single robot increase as multiple robots enter a public space. The first concern must be with human safety, to ensure that people are not placed at risk of injury due to the operation of robots around them. Additional concerns relate to the safety of other objects and property. Further, the safety of robots themselves also matters. To the extent that robots are at risk of damage through accidents, the efficiency gains promised by their introduction could quickly erode. The ideal outcome is for robots to be functioning in public spaces in ways that do not pose risks to the people and things around them. When people perceive robots as safe, they are more likely to trust them and, hence, come to treat them as "normal" parts of the environment. The creation of rules for the safe operation of robots will be crucial for ensuring safety, just as the many rules concerning the operation of automobiles have been essential to them becoming part of everyday life in many places. Policy design for the safe operation of robots could be usefully informed by review of the regulations that have facilitated introduction and increasing use of other mobile technologies, such as automobiles, motorbikes, scooters, and drones. Consideration must also be given to management of congestion. While this is unlikely to be an immediate concern, the increasing presence of robots in public spaces could lead to congestion, which could be managed through clear demarcation of operating spaces, equivalent to the introduction of highways dedicated to specific vehicles and the creation of bicycle lanes.

Question 2: How Can We Address Privacy and Ethical Concerns? Public space is complex and inherently political because of the various power structures and inequalities implicit and reflected in it. Any new technologies enter into an already contested realm and provoke new forms of discussion and debate. Like all other technologies, robots have biases in their design and implementation. It is not hard to imagine robots being coupled with facial recognition software that is racially discriminatory, for example. Already, robots have tangled with homeless people who should also have rights within public spaces. Here we connect to bigger literatures on urban public space on the one hand and ethical and responsible approaches to the development and application of technologies on the other. Recently, concerns have been raised about the use of drones and robots to conduct security patrols (Aydin 2019; Boucher 2016). An "ethics first" and people-focused approach involves taking technological possibilities to be just that – possibilities (Pink 2020; Pink and Lanzeni 2018). Anthropological research shows that people do not use technologies as engineers and designers imagined they should. There will always be unintended consequences. The challenge is to ensure that, as far as possible, those consequences are positive. Our lives are not governed by technologies created for us, but by how the possibilities they offer fit with our everyday needs and priorities. To work effectively and ethically in public spaces, the affordances of robots and their applications must remain flexible. Public policies must create opportunities for people in specific localities to engage, learn and create their shared sense of meaning regarding the activities of robots in public spaces.

Question 3: How Can We Advance Productivity? While the novelty of robots might lead some to view them as large toys primarily of entertainment value, their introduction is motivated by the drive for efficiency. Among the attractive features of robots, high on the list are their ability to work without getting bored or tired, and their ability to perform tasks that might be dangerous or injurious to human workers (see Maeda 2019). Robots have potential to perform many tasks previously performed by humans. As well as reducing risks to human workers associated with specific tasks, robots can often perform those tasks more effectively than humans. Their extensive use in factories confirms this. Consequently, increased use of robots in public spaces represents a major opportunity for advancing productivity. The extent to which robots advance productivity will be influenced by the safety considerations already noted and, relatedly, by how receptive people are to having robots operating around them. Two contrasting scenarios emerge. In one, robots could operate in public spaces when humans are not present. This would avoid various human–robot interactions and would avoid problems arising from human fears or dislikes for robots. But many opportunities to advance productivity would be lost. A more attractive scenario would involve robots sharing public spaces with humans, both going about their activities in ways that combine independent routines with explicit human interactions. The ideal outcome would be human–robot interactions that are encouraged to advance productivity gains. Such gains will arise from continuous exploration of how robots can enhance the quality of human experiences in public spaces.

Policy design needs to ensure regulation of robots in public spaces for safety reasons and also to protect valued human rights, such as privacy and freedom of association. At the same time, policy designers should avoid making regulations that "lock in" current technology, and that unnecessarily inhibit opportunities for robots to advance productivity. Evidence from the literature on environmental regulation suggests long-term productivity growth is most likely to occur when regulations stipulate valued outcomes and encourage measurement of progress toward those outcomes rather than when regulations focus on the specifications of the technology intended to meet those outcomes (Bardach and Kagan 1982; Schultze 2010). The stipulation of valued outcomes creates incentives for on-going improvements in the design and deployment of robots in public spaces.

Question 4: How Should We Attend to Esthetics? Like any change in the structures and details of public spaces, the introduction of new technology into public spaces can potentially enhance or erode the overall quality of our experiences within them. Often with the management of public spaces, controversy arises when changes are made. Some people like them. Others loathe them (Kunstler 1994). We can expect controversy of this sort will accompany the increasing deployment of robots in public spaces. Related to the productivity discussion above, some might be in favor of the deployment of cleaning robots, for their potential to improve the cleanliness and appearance of public spaces. On the other hand, others might be opposed to such a change because they fear the resulting increased surveillance and potentially the loss of human jobs. While esthetics will be part of the debate, it is not the only reason for the resistance to change. However, much needless controversy can be avoided through the creation of processes where issues of esthetics are openly debated among those who govern public spaces. Who gets to contribute to those debates will depend crucially on ownership of the spaces being discussed.

Many public spaces are legally private spaces, in the sense that the properties in which the public assemble or move about are privately owned and managed. Shopping malls, airports, pubs and restaurants are common examples. But most outdoor public spaces like streets and parks are publicly owned and subject to governance by councils or other legislative bodies. All who govern public spaces need to consider how the presence of robots will alter the "atmospheres" of those spaces. Governors cannot fully control atmospheres, but in allowing robots into public spaces they can specify the allowable features and functions of those robots, how many will be allowed to operate in the space, and the hours of operation. Regulations of this kind could serve to support efforts to ensure safety. They could also have implications for advancing productivity and supporting social justice. A key design concern should be to balance esthetics of robots in a public space with the preservation or development of a specific atmosphere. Recognition must be given to the possibility that strict regulation around esthetics could have implications for advancing productivity. But there need not be a tradeoff here. Indeed, the possibility arises for esthetic considerations to promote improvements in overall robot design or to make them specific to the environments in which they are deployed. For example, people are much more likely to be tolerant of robots and open to engaging with them if they are considered to be a positive public presence and contribute to the enjoyment and safety of shared public spaces.

Question 5: How Can We Encourage Co-creation? Many products and services in society are co-produced. People play crucial roles in determining the quality of the experiences they have with particular products and services. For example, personal fitness is co-produced. The quality of a set of fitness equipment will make little difference if a person does not make time to use it. Likewise, the services of a personal trainer will contribute to a person's fitness only if that person shows up for training sessions and engages in appropriate follow-up activities. Co-creation happens when the consumer plays a central role in designing the experience. With respect to personal fitness, co-creation occurs when a personal trainer and a customer discuss and decide the features of the exercise session they will conduct together. Digital technologies, including robots, introduce new opportunities for co-creation between people and service providers. Continuing our fitness example, robots have been deployed to assist people with their rehabilitation from accidents. They are able to monitor how an individual is responding to a specific activity and then make appropriate adjustments, such as raising or lowering the level of effort required to complete the activity.

With the increasing deployment of robots in public spaces, there is much to be gained from robotics engineers continually assessing, devising, and exploring human-robot interactions in the specific spatial contexts of their use with the purpose of encouraging new opportunities for co-creation. At heart, this requires people to become sufficiently comfortable interacting with robots that they identify helpful variations on the actions that robots can perform, or even propose completely new actions. The astounding development of so many creative applications for smart phones offers clues of the massive opportunities in store as robots become more common in public spaces. For policy designers, the challenge is to ensure that robots are suitably regulated so that people value their interactions with them sufficiently to suggest ways to enhance future interactions. Beyond setting broader parameters, policy designers could contribute to the otherwise organic process by which co-creation will evolve. For example, policy designers should look for ways to encourage co-creation with individuals and groups that could otherwise be marginalized in public spaces, but who have a stake in its safety and amenability. Supporting such processes could contribute to better outcomes for all people interacting with robots in public spaces. A related point is that co-creation must account for the particular settings in which people will engage with or encounter robots. An outcome that suits one community or public space may not be appropriate for another, and genuine co-creation processes must speak to the specific conditions and concerns of individuals and groups involved. This suggests that applications of robots that work effectively for specific locations, spaces, populations, languages, needs, and so on, are more ethical and necessary, which means that policy should be flexible enough to allow localized discussions of how robots will be deployed and the affordances they display. This possibility of localization is consistent with the "unfinished" nature of robot applications like the popular Pepper, a robot that is intended to be completed by users through novel programming. The scope for genuine co-creation is broad, but it will need to be carefully managed.

Question 6: How can we promote equitable access? Given the resources needed to effectively introduce and maintain robots in public spaces, it is reasonable to anticipate that innovations along these lines will happen first in more prosperous locations. The concern here is that the social benefits to be derived from robots in public spaces will be realized mainly by affluent individuals and groups, along with a few others who gain access to their semi-exclusive realms. A classic function of public policy is to address inequalities in society. In this regard, policy design efforts regarding robots in public spaces have much to offer. Policy designers could monitor cutting edge developments in these emerging uses of robots and explore ways that the introduction of robots performing similar roles in disadvantaged communities could be funded or subsidized. Just as governments at many jurisdictional levels have long had agencies devoted to policymaking on transportation issues, there could be merit in governments establishing a unit or division specifically devoted to public robotics that treats it as similarly entangled with many other policy areas.

Question 7: How Can We Facilitate Systemic Innovation? There is a risk that the benefits of introducing robots in the public space will not be fully realized, as businesses, governments, and citizens become satisfied with limited gains. Governments can promote systemic innovation. Much scope exists for monitoring, learning, and the sharing of "best practice" knowledge. As with the encouragement of co-creation, it is reasonable to expect that improvements in practice over time will be driven mainly by the actions of business people and various players in the robotics industry, although these actors must account for public concerns. Here, the facilitative role of government is vital and should be encouraged. It can do much to ensure a range of voices will be heard and new insights will emerge through discussions among people and groups who might not otherwise take the time to listen to and learn from each other.

4. Conclusion

Rapid advances in digital technologies have allowed robots to become more autonomous and efficacious than ever before. We can expect to see robots performing an increasing variety of functions in public spaces, with future developments in robotics holding the potential to transform human robot interactions, and to shape how people engage with each other and with technology more generally. Possibilities exist for robots to greatly improve the quality of our lives and to contribute positively to the safety, creative potential, and inclusive atmospheres of public spaces. But as this trend develops, the risk emerges of robots transforming public spaces and social interactions in undesirable ways. There are vital roles here for government, although discussion of the public policy implications of advances in robotics has so far been limited. We seek to encourage considerably more exploration by policy scholars and policy practitioners of how policy design can promote good outcomes with respect to the increasing presence of robots in our lives.

In this paper, we have reviewed previous public policy approaches to harnessing and regulating disruptive technology. In so doing, we considered how public policy might simultaneously enhance opportunities created by the presence of robots in public spaces and reduce the risks of undesirable outcomes. We then presented a policy design checklist to guide policies on robots in public spaces, covering safety, privacy and ethics, productivity, esthetics, co-creation, equitable access, and systemic innovation. Looking to the future, many possibilities exist for broad, societal benefits to occur from the growing prevalence of robots in public spaces. It is incumbent on the governors of public and quasi-public spaces to devise regulatory regimes that are flexible and fit for purpose, while not inhibiting innovations that are necessary to match the pace of continuous advances in human robot interactions. The policy design checklist presented here is intended to aid the development of policy approaches that promote ethical outcomes and value capture for as many people as possible.

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