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Are drivers ready for traffic enforcement drones?

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ABSTRACT

Traffic enforcement drones reduce high-risk driving behavior which often leads to traffic crashes. However, the introduction of drones may face a public acceptance challenge which may severely hinder their potential impact. In this paper, we report and discuss the results of a drivers' survey, administered both in the US and Israel, regarding the benefits, concerns and policy considerations for the deployment of traffic enforcement drones. The results show that drivers perceive traffic enforcement drones as significantly more efficient and deterring compared to current aerial traffic enforcement resources (i.e., police helicopters) and comparable in quality to speed cameras. Privacy and safety are the main concerns expressed with regards to such technology, yet these concerns have been shown to be significantly relieved if traffic enforcement drones are restricted to interurban spaces. Interestingly, only a few Israeli participants object to the introduction of traffic enforcement drones to the traffic police's arsenal compared to about half of American participants. These results combine to suggest several practical guidelines for decision-makers which can facilitate the deployment of this potentially life-saving technology in the field.

1. Introduction

An imperative component in mitigating traffic crashes and dangerous driving behavior is efficient traffic enforcement, which is based on giving drivers the feeling that they are likely to be caught and sanctioned when breaking the law (Elvik et al., 2009; World Health Organization, 2016). Recently, in order to increase the traffic police's omnipresence and reduce costs, worldwide preliminary testing has been done on the use of *traffic enforcement drones* (e.g., in Canada (Smith, 2017), India (Malhotra, 2016), Russia (NTV, 2017) and China (News, 2016), to name a few of the countries involved). The major advantage of drones compared to traditional traffic enforcement resources (e.g., police cruisers and speed cameras) is their ability to provide both a "bird's eye view" of drivers as well as their flexible mobility, which is not bound to road network structure and traffic congestion. It is not that the use of drones expands the traffic police's capabilities per se - after all, police helicopters have been used for decades. However, due to their low cost and relatively simple operation, drones can provide an economical alternative to the existing aerial resources which can lead to their increased deployment and impact in practice.

Beyond the technological and legislative challenges associated with deploying drones for traffic enforcement, the use of traffic enforcement drones may face a *public-acceptance challenge*. For example, the Los Angeles Police Department (LAPD) has only recently begun to use drones (and only under a highly restrictive policy) due to wide opposition from citizens who felt the department would use the drones to track and observe unsuspecting citizens around the city (Mather, 2017). "Ultimately, winning over the public may be a greater challenge than tackling the technological or regulatory ones", claims the United States postal service inspector general in The US Postal (2017).

In this paper, we report on a drivers' opinion survey regarding the use of traffic enforcement drones, administered in the US and Israel at the beginning of 2018.[1] The paper seeks to address three major questions:

1. How are drones perceived by drivers compared to traditional traffic enforcement resources (e.g., speed cameras) and would their introduction change the traffic police's image?
2. What are the major public concerns regarding the introduction of traffic enforcement drones and how might they differ from a case where private individuals operate drones?
3. What types of traffic violations, if any, would the public want to see enforced by drones?

This paper is organized as follows: Section 2 provides background on the adoption of drone technology and the importance of public views in traffic safety literature. Section 3 describes the procedure used for collecting and analyzing public views on traffic enforcement drones and

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[1] The survey was approved by the corresponding IRB.

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the results. Section 4 provides a discussion of the results and summarizes the implications of the findings.

2. Background

2.1. Adoption of drone technology: a (brief) overview

Drone technology is mainly used in three major sectors:

First, *military use*: Today, drones have become a vital tool in the military arsenal of many countries (e.g., the US, UK and Canada) and have gained massive media attention due to their efficiency as well as their controversy in warfare (Kilcullen and Exum, 2009).

Second, *civilian use*: The potential civilian cases for the use of drone technology are only bounded by the industry's imagination and governmental legislation. For example, various postal services worldwide (e.g., in the US, Germany, Australia, Switzerland, Singapore and the Ukraine) have started experimenting or preparing for drone-enhanced delivery systems (The US Postal, 2017). Commercial companies have also begun to realize the economic potential of drone-based deliveries. For example, Amazon, which is perhaps the leading company in the field, has already begun field testing in the UK, Canada and the Netherlands with their *Amazon Prime Air* service (D'Andrea, 2014). Recently, the United Parcel Service (UPS) performed a preliminary field test in which a delivery man would park the truck in a neighborhood, load a package onto a drone and then continue on his way to make another delivery at a different address (McFarland, 2017). The drone would find its way back to the truck and pick up another package. Domino's Pizza in both New Zealand and Israel has also recently performed preliminary deliveries to customers by air (Pizza, 2016; Ynet, 2018). Along with drone-based delivery, drones in the civilian sector are also penetrating the fields of construction, agriculture and forestry, search and rescue, firefighting, disaster relief, wildlife management, journalism, pesticide application, and many ever-growing new examples (new drone applications are updated on a daily basis at https://unmanned-aerial.com/).

Last, and most relevant for this study, *law enforcement use*: The use of drones for mitigating various types of crimes and security challenges such as illegal poaching (e.g., (Park et al., 2015; Xu et al., 2018)) has been investigated in the literature. Drones, unlike traditional security and law enforcement resources, are generally inexpensive and malleable, allowing for the adjustment of security practices and policies given unexpected changes in the environment. For example, unlike traditional police cruisers, police drones are not bounded to a road network structure and thus can avoid traffic congestion, hover above crime scenes, etc. As a result, police forces worldwide have been deploying and adopting drone technology for various tactical and surveillance tasks such as hostage situations, manhunts, crime scene investigation, etc. (McBride, 2009, Chapter D). New York (New York State, 2018) and Texas (Texas, 2018) are some of the most recent examples of law enforcement adoption of drone technology. Drones have also been deployed in preliminary field trials for traffic enforcement in different places around the world. However, due to the preliminary nature of these trials, traffic police forces usually deploy a single drone which is remotely controlled by a human operator, and, once a violation is noticed by the operator, a police cruiser is sent to intercept the offender. With the advancements of autonomous and semi-autonomous drone navigation, image and video recognition, reduced costs of drone technology and the recent development of computational frameworks for traffic enforcement drones (see Rosenfeld et al., 2018), further drone proliferation seems inevitable (Boyle et al., 2018).

In spite of their potential benefits for the discussed sectors, several challenges currently delay the wider adoption of drone technology. These challenges include economic challenges (e.g., purchasing and maintaining a fleet of high-quality drones as well as recruiting/training the appropriate manpower to handle the drones), technological challenges (i.e., developing and validating drone capabilities), legislative challenges (e.g., who is allowed to deploy drones and where) and *public-acceptance challenges* (e.g., would the public oppose the proposed drone use). While significant headway is being made in many of the above challenges (e.g., drone prices are consistently dropping, new drone technology and algorithms are being designed in academia and deployed in the industry, regulations are being created regarding drone use by different countries, etc.), in this article, we focus on the challenge of public acceptance in the domain of traffic enforcement, which has received very little attention to date in road safety literature.

2.2. Public opinion

Surveys are widely acknowledged as a valuable methodology in traffic safety literature. Recently, Schechtman et al. (2016) presented a drivers' survey regarding the effects of speed cameras in Israel and identified the major reasons for speeding. Additional studies such as Yannis et al. (2013) and Murray et al. (2010) have employed a similar survey-based methodology to identify and investigate drivers' opinions and behavior in light of different traffic laws and enforcement policies.

To facilitate a better understanding of public views and concerns regarding drone technology, surveys have been administered around the world (a few recent examples include the US (The US Postal, 2016), Denmark (Bajde et al., 2017), Germany (Lidynia et al., 2017) and Switzerland (Klauser and Pedrozo, 2017)). These surveys have mainly focused on *commercial and civilian use* of drones. From a law enforcement perspective, recent US-based studies (Letterman et al., 2013; Herron et al., 2014; Saint Leo, 2016) have estimated that 60–70% of Americans support the use of drone technology for fighting crime. However, these studies have importantly noted that not all law enforcement operations are regarded in the same way by the public. For example, hostage situations and traffic enforcement could very well be regarded differently. To the best of our knowledge, this is the first study to investigate public opinion on drone use in traffic enforcement.

In the above discussed studies, the most widely stated concerns regarding drone use are *privacy* and *safety*, regardless of the examined sector. Specifically, drone use by different organizations (e.g., postal services, package delivery companies, police, etc.) seems to raise significant concerns regarding the potential infringement of one's privacy through unauthorized aerial footage of their homes and property, and even the illegal tracing of one's movements. An additional concern often reported is the risk of injuries or severe property damage due to malfunctions, interference of drones with airplanes and even potential terrorist use. These concerns, among others, are also investigated in this study.

3. Method

3.1. Design

The survey, available in its English format in Appendix A, was administered to two participant groups: The first group consists of 115 US participants, recruited via the popular crowd-sourcing platform Amazon Mechanical Turk (AMT)[2] (Mason and Suri, 2012), denoted the *US-Group*. The second group consists of 125 Israeli citizens, recruited by approaching people in public places (e.g., the mall, gas stations) and publishing advertisements on online platforms (e.g., Facebook groups about public transportation), denoted the *IL-Group*. All of the participants have a valid driver's license and were presented with the same survey, professionally translated by a paid expert.

To ensure the quality of the analyzed data, we first filtered out all partial responses (i.e., those who did not complete the entire survey) and those who completed the survey unrealistically quickly (in less than 3 minutes). Following this process, we were left with 100 participants from 39 states in the US-Group, ranging in age from 18 to 71

[2] https://www.mturk.com/.

(mean = 35, s.d. = 9.9), with 43 females and 57 males, and 100 participants in the IL-Group, ranging in age from 18 to 58 (mean = 31, s.d. = 8.4), with 40 females and 60 males. The following analysis refers to these participants alone.

Participants from the US-Group were paid $1 for their participation while participants from the IL-Group did not receive any compensation. The survey was administered during January 2018 and the first two weeks of February 2018 for both groups.

For the following analysis of the obtained results we used four statistical measures: First, comparisons between the IL-Group and the US-Group were performed using the Mann–Whitney *U*-test (Nachar et al., 2008), suitable for comparing unpaired ordinal data (as is the case for most of the survey questions). In the case of a numerical question, the comparison was performed using a standard independent samples *t*-test. Second, within-subject comparisons (i.e., comparing participants' answers across different questions) were performed using the Wilcoxon signed rank test (Woolson, 2008), suitable for comparing repeated-measurements over ordinal scales. Third, when performing a within-subject comparison across more than two measures, the Friedman test (Friedman, 1937) was first performed, followed by pairwise comparisons using the Wilcoxon Signed-Rank test with the Bonferroni correction (denoted WSRtwB) (Napierala, 2012). Correlations between ordinal variables were reported using the common Spearman's Rank Correlation (denoted ρ) (Zar, 1998).

3.2. Results

3.2.1. Effectiveness and deterrence

We asked each participant to rate each of the seven most popular traffic enforcement resources (speed cameras, traffic light cameras, police cruisers, police motorcycles, officers at the side of the road, police helicopters and drones) with respect to its effectiveness in mitigating traffic crashes (i.e., effectiveness) and its ability to reduce traffic violations (i.e., deterrence) on a 3-point Likert scale (below average, average, above average). An initial examination of the results using the Friedman test indicates that the examined traffic enforcement resources are significantly different on both the effectiveness and deterrence criteria ($p < 0.05$). A more detailed analysis reveals that police helicopters are rated as the *least effective and deterring resource* of the seven examined resources (approximately 80% of participants rate police helicopters as average or below on both criteria). Statistically, participants are significantly more likely to rate police helicopters lower than all other examined enforcement resources, for both the US and IL groups, under both the effectiveness and deterrence criteria using WSRtwB ($p < 0.05/21$). As for the use of drones, the IL-Group and US-Group differ significantly: The IL-Group perceives drones as more effective and deterring compared to speed cameras (which suffer from a bad image in Israel – see Schechtman et al. (2016) for a discussion) and as effective and deterring as traffic light cameras using WSRtwB, $p < 0.05/21$. On the other hand, the US-Group perceives drones as less effective and deterring compared to both speed cameras and traffic light cameras (which in turn do not differ significantly) using WSRtwB, $p < 0.05/21$. Interestingly, for both groups, it is clear that the "traditional" enforcement resources are rated higher in terms of efficiency and deterrence – namely police cruisers, police motorcycles and officers at the side of the road are rated by 88–94% of US participants and by 93–95% of IL participants as deterring on an average level or above, and by 80–88% of the US participants and by 70–79% for the IL participants as effective on an average level or above. Fig. 1 illustrates the participants' answers.

Generally, participants in both groups consider all enforcement means as more deterring than effective in mitigating traffic crashes using multiple Wilcoxon signed-rank tests ($p < 0.05$). Considering the multitude of factors which influence traffic safety which cannot be affected by efficient traffic police enforcement (weather, infrastructure, etc.), the difference is not surprising.

3.2.2. Traffic police image

At the beginning of the survey, we asked participants to rate their overall impression of their traffic police. Interestingly, we find that the Israeli Traffic Police seems to suffer from a significantly poorer image compared to the US traffic police, with only 20% of participants from the IL-Group reporting that their overall impression of the Israeli traffic police is either positive or very positive compared to 43% of the US-Group participants using the U-test, $p < 0.05$. This image was not found to be strongly correlated for either group with the self-reported number of traffic citations or number of parking citations one received in the past (approximately a Spearman's Rank Correlation of $\rho = 0.11$ for both groups and conditions). Despite the results above, most participants report that they either agree or very much agree that the traffic police is important for reducing the number of traffic crashes (80% of the IL-Group, 71% of the US-Group), for maintaining public order on the roads (84% of the IL-Group, 75% of the US-Group) and that one of the major reasons for them to avoid traffic violations is the possibility of getting a traffic citation (50% of the IL-Group, 72% of the US-Group). None of the above differences was found to be statistically significant using the U-test (for comparing the populations) and Wilcoxon signed-rank test (for comparing the first two questions).

The introduction of traffic enforcement drones was found to considerably improve drivers' impressions of the traffic police for both groups. For the IL-Group, 43% of participants reported that the introduction of drones would have a positive or very positive impact on their attitude towards the traffic police. Similarly, 53% of the US-Group reported the same.

3.2.3. Concerns

Participants were asked to rank six of the most widely stated concerns regarding drones (based on surveys discussed in Section 2): (1) Hazard to airplanes; (2) Privacy; (3) Bodily harm or property damage due to a technical malfunction; (4) Bodily harm or property damage due to human error; (5) Potential use by terrorist organizations; and (6) Eyesore and annoyance. Participants were asked to provide such ranking in three different contexts: First, while considering drones that are operated by private individuals in public spaces. Then, while considering drones that are operated by the traffic police in *urban* spaces. Lastly, while considering drones that are operated by the traffic police in *interurban* spaces.

First, we notice that Concern 1 (Hazard to airplanes) is the most widely stated *least* bothering concern for both groups across the three contexts using the Friedman test followed by WSRtwB ($p < 0.05/15$), only contested by Concern 6 (Eyesore and annoyance) which is also ranked very low (for which the difference from Concern 1 was not found to be significant for the US-group). Concern 1 scored an average rank of 4.4–4.6 for the IL-Group and 4–4.3 for the US-Group, in all three of the examined contexts (with no significant difference between them). As for Concern 6, it was ranked 3.8–4.6 for the IL-Group and 4–4.9 for the US-Group. Interestingly, while no clear trend was found for Concern 1, participants consider drones more annoying if they are used by the police in *urban* areas using the Friedman test followed by WSRtwB, $p < 0.05/3$. Specifically, for the IL-Group, Concern 6 scores an average rank of 4.6 in the context of use by private individuals while scoring 4.3 for traffic police interurban use and 3.8 for traffic police urban use. A similar statistically significant trend was observed for the US-Group. For both groups, the most widely stated *most* bothering concern is *privacy* (Concern 2) with an average rank of 2.3–2.8 for both groups and all contexts (using the Friedman test followed by WSRtwB, $p < 0.05/15$). While no significant difference could be detected between the ranking of Concern 2 under police use and private use using the Friedman test followed by WSRtwB, a significant difference was found when comparing the traffic police urban use and traffic police interurban use, $p < 0.05/3$. Specifically, for both groups, the privacy concern seems to be significantly mitigated by interurban use, with the average rank of 2.3 in the urban case compared to an average rank of

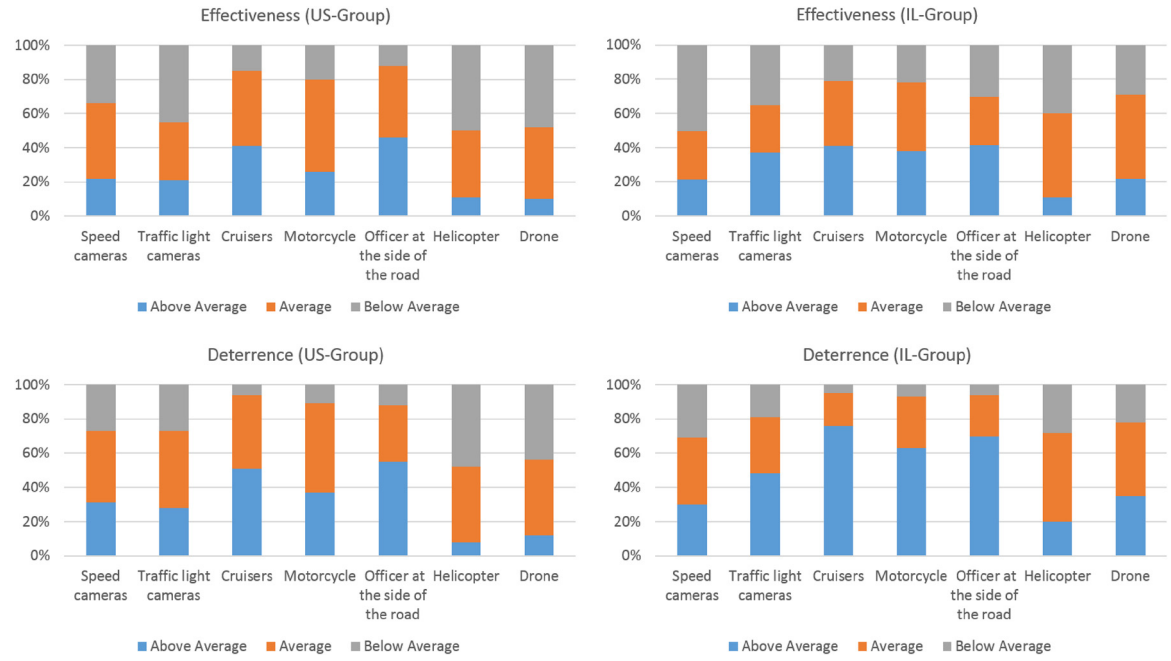

Fig. 1. Driver estimated effectiveness and deterrence of seven popular traffic enforcement resources.

2.5–2.8 in the interurban case. Concern 2 is followed in rank by the *safety concerns* – Concern 4 (Bodily harm or property damage due to human error) and Concern 3 (Bodily harm or property damage due to a technical malfunction), without a statistically significant difference between the two using WSRtwB. Interestingly, Concern 4 is ranked in almost the same way for both groups under all tested contexts, with an average rank of between 2.8 and 2.9. However, Concern 3 reveals statistically significant differences between the private individual's use and traffic police use using the Friedman test followed by WSRtwB, $p < 0.05/3$. Specifically, for private individual use, Concern 3 achieves an average rank of 3.2 (IL-Group) and 3.4 (US-Group), while for traffic police urban use it averages 2.7–3 (IL-Group) and 2.9–3 (US-Group). Furthermore, using the same analysis, we find that the traffic police urban use provokes higher rankings compared to traffic police interurban use for both groups, $p < 0.05/3$. In other words, participants are concerned with bodily harm or property damage due to human error or technical malfunctions without a statistically significant difference between the two, however while the former is consistent with the concerns of private individual use, the latter is significantly intensified in light of urban traffic police use, possibly suggesting that participants distinguish traffic enforcement drones as being more dangerous than private drones. The analysis is completed with Concern 5 (Potential use by terrorist organizations). Considering private individual use, Concern 5 is ranked significantly higher for the IL-Group as compared to the US-Group using the U-test (2.9 vs. 3.7, $p < 0.05$), which can be explained by recent drone-related homeland security issues in Israel (CNN, 2018). Nevertheless, using the Friedman test with WSRtwB, we find that for both countries, Concern 5 is significantly mitigated for traffic police use with an IL-Group average ranking of 3.9–4.2 and a US-Group average ranking of 4.3–4.5 ($p < 0.05/3$). Note however that there is no significant difference between urban and interurban uses for the two groups.

Fig. 2a and 2b summarizes the results above.

3.3. Traffic violations

Participants were asked to state all traffic violations they would want to see enforced by drones, if any. The most widely stated violations that participants would want to see enforced by drones are "*Identifying stolen vehicles or unauthorized vehicles*" (80% – IL, 73% – US) followed by "*Aggressive/irresponsible driving*" (75% – IL, 69% – US). Interestingly, the two groups do not seem to agree on the remaining examined offenses "Speeding" (33% – IL-Group, 47% – US-Group), "Illegal passing" (72% – IL-Group, 27% – US-Group), "Littering" (46% IL-Group, 16% US-Group), "Illegal/dangerous parking" (50% IL-Group, 23% US-Group), "Red light running" (66% IL-Group, 47% US-Group) and "Right of way/stop signs" (42% IL-Group, 15% US-Group). See Fig. 3 for an illustration.

The results show greater levels of approval reported by the IL-Group for the use of drones to enforce different violations compared to the US-Group using an independent samples *t*-test (4.6 vs. 2.2 stated violations, $p < 0.05$). This result is also consistent with the results discussed next as to the public acceptance/rejection of traffic enforcement drones.

3.3.1. Deployment of traffic enforcement drones

To better understand participants' overall attitude towards drone use, by either private individuals or the traffic police, we asked participants the following three questions at different points in the survey: First, "Rate the following statement: I think private individual drones should be banned", then "Are you pro or against the traffic police operating drones in *urban* spaces?" and "Are you pro or against the traffic police operating drones in *interurban* spaces?".

The results show that the IL-Group does not hold negative views on drones, with only 18% supporting a ban on private drones, 25% objecting to the use of traffic enforcement drones in *urban* spaces and 18% objecting to the use of traffic enforcement drones in *interurban* spaces. Similarly, Israeli participants are significantly more likely to support the use of traffic enforcement drones in *interurban spaces* compared to their use in *urban spaces* using a Wilcoxon signed-rank test, $p < 0.05$. On the other hand, the US-Group holds more skeptical views compared to the IL-Group, with 31% supporting the ban on private drones, 46% objecting to the use of traffic enforcement drones in urban spaces and 45% objecting to the use of traffic enforcement drones in interurban spaces (unlike the IL-Group, with no significant difference between the two police use cases). See Fig. 4 for an illustration of participants' attitude towards the deployment of traffic enforcement drones in interurban spaces.

Despite the apparent differences in their views, both groups seem to

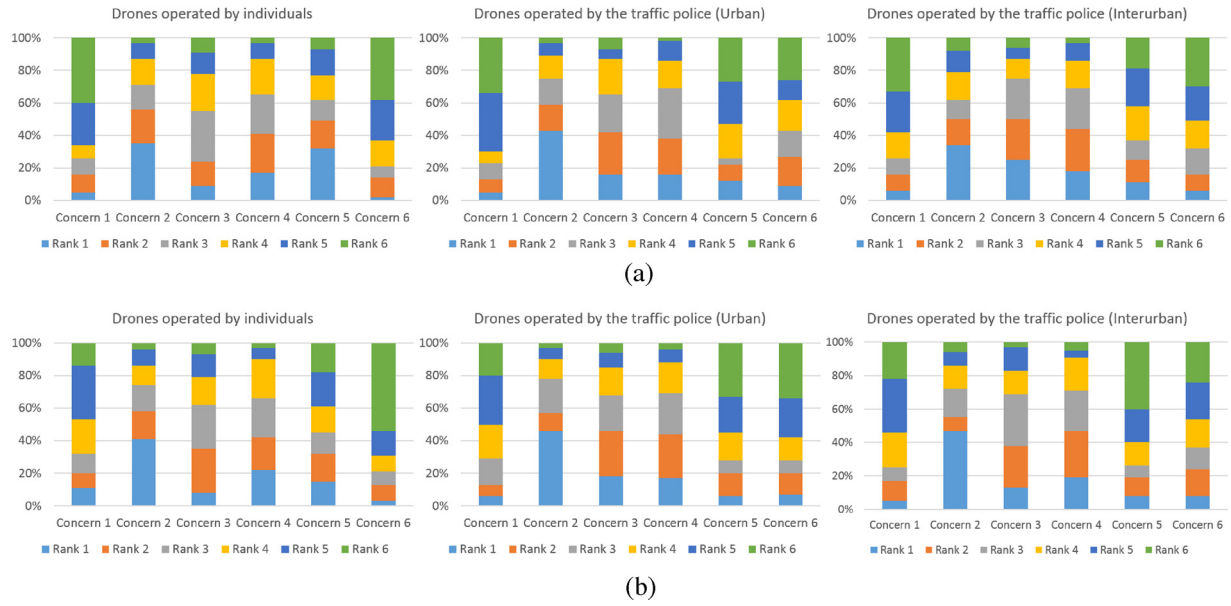

Fig. 2. The **IL-Group** reported ranked concerns across the three examined drone use cases. The **US-Group** reported ranked concerns across the three examined drone use cases.

agree that traffic enforcement drones are expected to be operational in the near future with 65–66% of participants expecting to see traffic enforcement drones in the sky within the next 5 years (only 12–13% believe that traffic enforcement drones will never be realized).

4. Discussion and conclusions

Before we turn to discuss the obtained results, it is worthwhile to discuss their strengths and possible limitations. As for their strengths, it is important to note that the results compare drivers' beliefs and perceptions relating to traffic enforcement drones, not only across different jurisdictions (i.e., urban and interurban), but also compared to other traffic law enforcement resources. Furthermore, the results depict the opinions of two driver samples drawn from the US and Israel, providing insights into how beliefs and perceptions toward traffic enforcement drones may be influenced by broader social and cultural factors. However, it is important to note that the two participant groups were recruited using a different recruitment protocol which may influence the observed differences between the American and Israeli groups. Specifically, American participants were recruited via the crowd-sourcing AMT platform which, despite being an established and popular survey platform among social scientists, suffers from a few inherent limitations which may hinder the generalization of the results (Paolacci and Chandler, 2014) (e.g., only people with Internet access may be recruited). Israeli participants, on the other hand, were not recruited from AMT since Israelis cannot register to AMT. Also, note that since the deployment of traffic enforcement drones is still very scarce, some of the survey questions are of an hypothetical nature.

Now, let us discuss the obtained results by revisiting the three main questions which we set out to investigate in this article.

First, the results show that traffic enforcement drones are perceived as more effective and deterring compared to the expensive aerial resources currently applied by traffic police (i.e., police helicopters). Israeli participants further perceive traffic enforcement drones as more effective and deterring than automated speed cameras and comparably effective and deterring compared to traffic light cameras. American participants, on the other hand, are a little more skeptical as to the traffic enforcement drones' capabilities, rating them lower than speed cameras and traffic light cameras. Nonetheless, for both groups, all examined traffic enforcement resources are superseded by the traditional human-based enforcement resources such as police cruisers and motorcycles. These results are further supported by a recent simulated

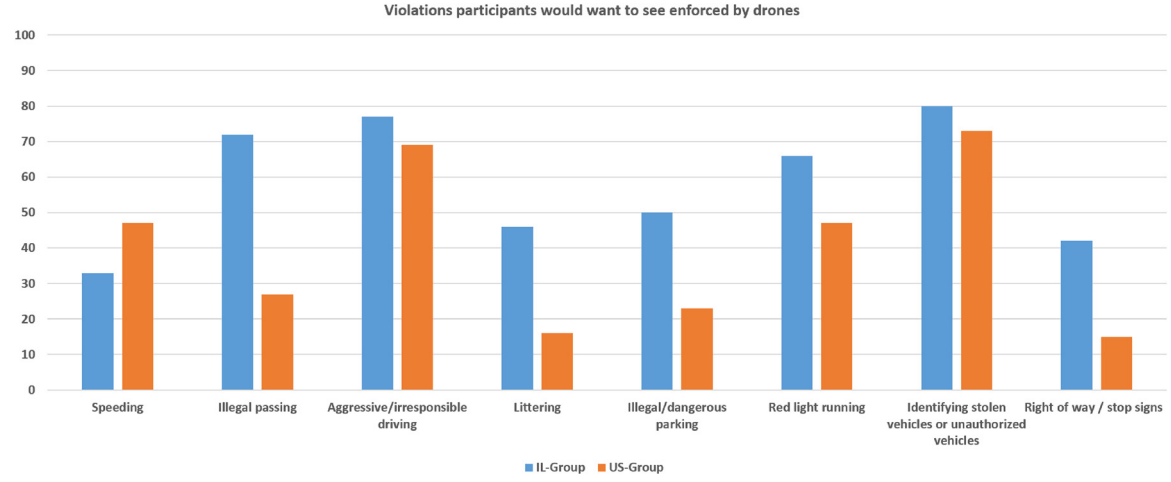

Fig. 3. Approval rates of different offenses which could potentially be enforced by traffic enforcement drones.

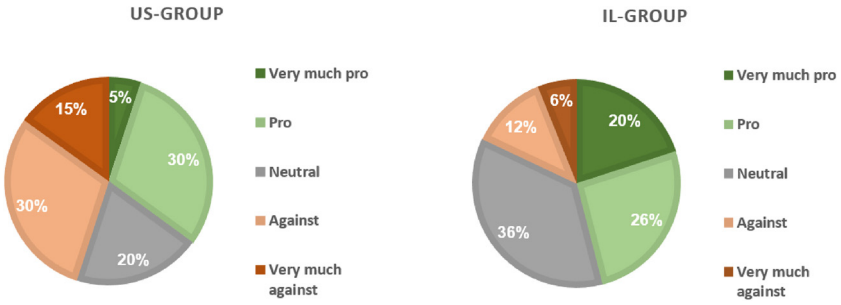

Fig. 4. Participants' attitude towards the deployment of traffic enforcement drones in interurban spaces.

driving experiment (Rosenfeld et al., 2018), where the effect of traffic enforcement drones on driving speed was tested and compared with that of police cruisers. The study found that drivers reduce their speed considerably when encountered with police enforcement, yet the intensity of their reaction is significantly greater for police cruisers compared to traffic enforcement drones (an average slow-down of 13 km/h vs. 8.5 km/h on a two-lane interurban road with a speed limit of 80 km/h). It is our assessment that traffic enforcement drones are considered by the public not as an alternative to human-based traffic enforcement resources but as a possibly improved automated tool that could have a significant impact in mitigating traffic crashes and deterring risky driving behavior. The results further show that the introduction of drones may have a significant positive impact on drivers' impressions of the traffic police, which generally suffers from a negative image. These results are also consistent with the United States Postal Service's estimation (The US Postal, 2016) that the adoption of drone technology will improve the service image.

Second, consistent with previous studies, *privacy* seems to remain the most troubling concern regarding drone use in general. Contrary to what the author initially expected in terms of privacy concerns, the use of drones by the traffic police, in either urban or interurban spaces, *is not found to provoke statistically significantly different reactions compared to the use of drones by private individuals*. *Safety concerns* closely follow the privacy concern in the ranking of drivers' concerns for all examined use contexts. Many researchers claim that safety concerns are not unique to drones or to a specific use context, and in fact these are similar to the safety concerns expressed for other new technologies such as autonomous cars (Clarke, 2014). Nonetheless, safety concerns seem to provoke different reactions from the public depending on their use context. Specifically, participants from both groups seem to be significantly more bothered by traffic police drones compared to private individual drones in terms of safety. This phenomenon can be partially attributed to the destructive military drone use displayed in popular media and the news (e.g., Whitlock, 2014). However, it is important to note that traffic enforcement drones differ considerably in size and weight from most military drones and resemble private individual drones. We speculate that given the relatively small size of the traffic enforcement drones being tested around the world (about 1 m long and wide), this concern will become more comparable with that of private individual drones in the future. Interestingly, for both the privacy and safety concerns, the use of drones by the traffic police in *interurban spaces* is considered less troubling than the use of drones by traffic police in urban spaces. These results combine to suggest that, from a public perspective, the introduction of drones imposes similar concerns to those imposed by drone use by private individuals, however the introduction of drone technology in *interurban space*, where privacy and safety are generally less troubling, is likely to receive a more positive public attitude. In fact, Israeli participants have expressed significantly more positive views on traffic enforcement drones in interurban spaces compared to the use in urban spaces. American participants, on the other hand, reported only a slightly more positive attitude towards interurban use which does not differ significantly from urban use of traffic enforcement drones. Generally, American participants seem to express a negative attitude towards the use of traffic enforcement drones, with almost half of the participants reporting a negative or very negative attitude towards the notion.

Lastly, participants from both groups seem to widely agree that if traffic enforcement drones were to be deployed, they should identify stolen/unauthorized vehicles and aggressive/irresponsible driving, both receiving a 70–80% approval rate among participants in both groups. However, Israeli and American participants differ in their opinion towards other traffic offenses; most notable is "Illegal passing", the enforcement for which is widely supported by Israeli participants (72%) compared to only 27% support from American participants. Generally, Israeli participants have noted significantly more violations that they want to see enforced by drones compared to Americans. This result is not very surprising considering the relatively negative attitude American participants express towards the very notion of traffic enforcement drones, as discussed above.

The results of this study suggest that traffic police forces should perform several precautionary measures in order to allow for a more smooth integration of drone technology from a public acceptance perspective. We list a few possible courses of action which, in our opinion, can ease public acceptance of traffic enforcement drones:

1. The deployment of traffic enforcement drones should start in *interurban spaces*, where privacy and safety are perceived by the public to be less troubling as compared to urban spaces.
2. An official *privacy preserving policy* (e.g., limiting the storage of drone footage to a very restricted time, blurring pedestrians' faces, allowing officers to access only violation footage, etc.) could mitigate some of the privacy concerns which seem to be most troubling for the public. In addition, successful *field trials of the system which could be shared with the public* via public campaigns could mitigate some of the safety concerns.
3. Enforcing *widely approved offenses* could bring about higher public approval which in turn could facilitate the transition into additional violations.

Recall that this study focused only on the public acceptance challenges associated with the adoption of traffic enforcement drones. It is well known that low *organizational acceptance* can also pose a significant barrier towards the adoption of technological solutions, especially in security domains (Tambe, 2011). Therefore, in future work, we intend to explore this potential barrier by examining both *police officials* and *Police officers'* beliefs and perceptions relating to the deployment of traffic enforcement drones.

Since the evaluation of traffic enforcement drones in the real world is still scarce, our understanding of the challenges and opportunities of this technology is still limited. Therefore, we further plan to investigate the use of drones for enforcing traffic laws *within the university's compound*. Note that while we cannot actively enforce traffic laws on the roads (only the traffic police can), we did establish preliminary cooperation with the university's security department in order for them to

issue warnings to offending drivers. This will allow us to investigate the potential effect of traffic enforcement drones in real world settings.

We hope that the presented study will encourage additional researchers, practitioners and legislators to work on lowering the barriers towards the adoption of traffic enforcement drones, which could in turn make the roads safer and save lives.

Appendix A. Questionnaire

Part 1 – Demographics

1. Age [numerical answer only]
2. For how many years have you had a driver's license? [numerical answer only]
3. Gender [M/F]
4. Country:
5. State (if applicable):
6. Education: [High-school, Non-academic diploma, Bachelor's degree, Graduate school]
7. What is your impression of new technologies?
   - I'm very much interested and adopt them often
   - I like new technologies
   - I'm not interested in new technologies
   - I'm bothered by new technologies
   - I try to avoid new technologies

Part 2: Traffic police

1. How positive or negative is your overall impression of the traffic police? [Scale: Very positive, Somewhat positive, Neither positive nor negative, Somewhat negative, Very negative]
2. How many traffic citations have you received in the last 5 years? [Zero, 1–2, 3–5, more than 5]
3. How many parking tickets have you received in the last 5 years? [Zero, 1–2, 3–5, more than 5]
4. Has your driver's license ever been revoked? [Yes/No]
5. Rate the following statements: [Scale: Very much agree, Agree, Neutral, Disagree, Very much Disagree]
   - Traffic Police is important for reducing the number of traffic crashes.
   - Traffic Police is important in maintaining public order on the roads.
   - One of the major reasons for me to avoid traffic violations (those which do not directly risk lives, such as passing on the right) is the possibility of getting a traffic citation

Part 3: Civilian drones

1. Rate the following statements: [Scale: Very much agree, Agree, Neutral, Disagree, Very much Disagree]
   - I'm aware of drone technology
   - I'm concerned with the use of drones in public spaces
   - I think that drones belonging to private individuals should be banned
2. Rank the following concerns from the most bothersome (#1) to the least (#6) when considering private individuals operating drones in public spaces: [Random order]
   - Hazard to airplanes
   - Privacy
   - Bodily harm or property damage due to a technical malfunction
   - Bodily harm or property damage due to human error
   - Potential use by terrorist organizations
   - Eyesore and annoyance

Part 4: Drones for traffic enforcement

1. For the following traffic enforcement resources, state your perceived level of effectiveness in reducing traffic crashes (Low, Average, High) and the level of deterrence in reducing traffic violations (Low, Average, High): [Random order]
   - Speed cameras
   - Traffic light cameras
   - Police cruiser
   - Police motorcycle
   - Officer at the side of the road
   - Police helicopter
   - Drone
2. Rank the following concerns from the most bothersome (#1) to the least (#6) when considering the traffic police operating drones in **urban** spaces:
   - Hazard to airplanes
   - Privacy
   - Bodily harm or property damage due to a technical malfunction
   - Bodily harm or property damage due to human error
   - Potential use by terrorist organizations
   - Eyesore and annoyance
3. Are you pro or against the traffic police operating drones in **urban** spaces? [Scale: I'm very much pro, I'm pro, Neutral/I don't know, I'm against, I'm very much against].
4. Rank the following concerns from the most bothersome (#1) to the least (#6) when considering the traffic police operating drones in **interurban** spaces:
   - Hazard to airplanes
   - Privacy
   - Bodily harm or property damage due to a technical malfunction
   - Bodily harm or property damage due to human error
   - Potential use by terrorist organizations
   - Eyesore and annoyance
5. Are you pro or against the traffic police operating drones in **interurban** spaces? [Scale: I'm very much pro, I'm pro, Neutral/I don't know, I'm against, I'm very much against].
6. What types of traffic violations would I want to see enforced by drones? You can mark more or less than one option [Random order].
   - Speeding
   - Illegal passing
   - Aggressive/irresponsible driving
   - Littering
   - Illegal/dangerous parking
   - Red light running
   - Identifying stolen vehicles or unauthorized vehicles
   - Right of way / stop signs
7. When do you expect to see drones in traffic enforcement?
   - Within the next 2 years
   - Between 3 and 5 years
   - Between 5 and 10 years
   - More than 10 years or Never
8. Would the use of drones for traffic enforcement change your impression of the traffic police? [very positively, positively, no, negatively, very negatively]

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