The Future of Traffic Monitoring – A New Perspective Using Drones

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Abstract

Unmanned Aerial Vehicles (UAVs) have been successfully used as an alternative to traditional traffic monitoring practice given their low cost and improved mobility. A UAV was used to investigate how quickly drivers adapted to the introduction of the first two-lane roundabout in New Brunswick. The footage provided by the UAV was manually analyzed to interpret changes in driving errors as they became more familiar with the new facility. The video also allowed for real-world estimates of driver gap acceptance for use in capacity analyses. The captured data has led to recommended design changes that should lead to a safer facility going forward. Transport Canada is the governing body for UAV regulation in Canada and the application process undertaken for the research done at the roundabout is discussed. Operational practices for the best use of UAVs for traffic monitoring are also recommended, which include surveys that traditionally require significant person-power.

Résumé

Des drones (véhicules aériens sans pilote, UAV) ont été utilisés avec succès comme alternative à la pratique courante de surveillance du trafic, compte tenu de leur faible coût et de leur mobilité améliorée. Dans la présente étude, un drone (UAV) a été utilisé pour enquêter sur la rapidité avec laquelle les conducteurs se sont adaptés à l'introduction du premier rond-point à deux voies au Nouveau-Brunswick. Les images fournies par le drone ont été analysées manuellement en vue de déceler les erreurs de conduite au moment où les conducteurs se familiarisaient davantage avec la nouvelle installation. L'enregistrement-vidéo a également permis d'estimer en temps réel les écarts acceptables entre véhicules; de telles données pourraient être utilisées par la suite dans les analyses de capacité. L'information obtenue a permis de faire des recommandations judicieuses dans la conception pouvant conduire à une installation plus sécuritaire à l'avenir. Transports Canada étant l'institution responsable de la réglementation des drones (UAV) à travers le pays, le processus de demande de permis de leur utilisation pour la recherche effectuée au rond-point est discuté. Les pratiques opérationnelles pour la meilleure utilisation des véhicules aériens sans pilote (UAV) pour la surveillance de la circulation routière sont également recommandées, y compris des enquêtes qui nécessitent traditionnellement une main d'œuvre importante.

INTRODUCTION

Technological advancements have challenged traditional methods of transportation engineering. Traffic monitoring has traditionally required significant on the ground person-power that is resource intensive. Unmanned Aerial Vehicles (UAVs) have recently become prominent in the commercial market and are equipped with a video camera, geo-positioning sensors, and communications hardware which can relay data to the ground. The efficiency of traditional data collection methods can be improved through the use of UAVs for traffic monitoring.

A UAV was used to investigate driver behaviour at a new two-lane roundabout in New Brunswick from September 2015 – 2016. Data was collected at 1-month intervals and analyzed manually to interpret driver errors and how they improved over time. An operational analysis which included the development of critical and follow-up headway values used by traditional capacity analyses was also undertaken using the UAV video footage.

BACKGROUND

Traffic using roadway networks can be difficult to monitor on the ground as it requires fixed infrastructure and is often labour intensive [1]. Technological advancements have challenged traditional means of gathering transportation data in favor of more efficient alternatives. The use of UAVs, commonly known as drones, for traffic monitoring is a valuable tool to improve efficiency in data collection. Their use may be preferred for certain applications over inductive loop detectors, radar, and ultra-sound technologies because of low cost and improved mobility [2]. UAVs, equipped with a video camera, geo-positioning sensors, and communications hardware to relay the data to the ground, are available on the commercial market. UAVs are able to cover a wide span of area efficiently with minimal set up time. Many current models are equipped with cellular compatible technology, which allows a cell phone to serve as the control station, feeding live video footage from the drone to the cellular device in real time.

Research has been completed on UAVs at the Ohio State University, where a UAV complete with two cameras flew at an altitude of 150m for two hours, while transmitting video [1]. Ohio State investigated five applications for the UAV in terms of traffic monitoring: measuring level of service, estimating average annual daily travel, examining intersection operation, measuring original destination, and measuring parking lot utilization [1]. Ohio State's findings in intersection operations included analyzing video segments to determine queues, arrival rates, and turning movements [1]. Ohio State developed a simplistic computer program based on the queuing data to determine the capacity of the intersection [1].

Real time data allows for the mitigation and redirection of traffic should an emergency such as a collision, natural disaster, or humanitarian crisis occur [3]. Real-time data collection is difficult for a UAV due to the complexity of aerial images [2] and the subsequent reliance on post-data collection analysis. The University of California at Berkeley has developed an algorithm for real-time road detection using a UAV by processing a single image of the target road. The detection process assumes that roads are regions which can be approximated by line segments. The algorithm has been tested on ten thousand images which have been successful, and detection of multiple roads such as intersecting roads was possible in more than 50% of the images [3].

Kanistras *et al*. have proposed a similar project where a UAV will collect real-time data to monitor traffic, evaluate and assess traffic patterns, and provide video counts. The vision system

has on-board and on the ground processing capabilities which contain algorithms allowing for automatic adjustments to be made to the system.

A CASE STUDY

The first two-lane roundabout in New Brunswick opened in Fredericton on September 2015. The roundabout development raised significant safety concerns given the unfamiliarity that local drivers had with using two-lane roundabouts. The project provided a unique opportunity to study driver behaviour and how it changed over time as drivers became more familiar with its operation. Video footage was collected at approximately 1-month intervals for a year through the use of an unmanned aerial vehicle (UAV) to extract driver error information.

Operational analyses were completed using the footage which indicated that the default critical and follow-up headway values used by HCS 2010 underestimate driver behaviour relative to gap-acceptance. New critical and follow-up headway values were developed based on video analysis to better reflect local driver characteristics.

1. Methodology

Data collection for the Route 8/Smythe Street roundabout began in September 2015 and continued to September 2016, resulting in the accumulation of a full year of data. An unmanned aerial vehicle model DJI Phantom 3 Professional (Figure 1) was flown for a one-hour period monthly.

Figure 1 - DJI Phantom 3 Professional
[www.bhphotovideo.com]

The image provides a perfectly centered aerial image (rather than orthogonal) which provides the ability to monitor vehicle off-tracking throughout the roundabout. A typical frame capture is shown in Figure 2.

Figure 2 - Aerial view of roundabout captured by drone from 150m

The rectangular-shaped frame of the footage was selected intentionally to allow a greater view of the Route 8 approaches. This allows for queuing to be shown for the purpose of capacity investigations, as well as speed investigations as vehicles transition from a rural two-lane divided highway into an urban two-lane roundabout.

Data were collected once a month by the drone for a duration of approximately one hour at non-peak hours throughout the year to normalize for potentially aggressive driving during peak periods. The drone battery life was the limiting factor as each battery held approximately 15 minutes of charge, requiring four batteries to collect an hour of data.

Traffic counts on a given day were used as input to the HCS2010 capacity software, which indicated v/c ratios which exceeded one. Given that continuous queuing was not observed, calibration for critical and follow-up headway values were required.

An hour of footage recorded for the capacity analysis was used to determine the critical and follow-up headways. The east and westbound lanes were not at or near capacity (constant queuing); however, the north and southbound approach lanes were found to be at capacity. Both the right and left lane for the north and southbound lanes were analyzed separately. Accepted and rejected headways were recorded for all vehicles in the northbound and southbound approaches, as these approaches were observed to be operating at or near capacity. Figure 3 depicts the areas where time stamps were collected, using the northbound approach as illustration. For each approach lane analyzed, the time at which a vehicle came to a stop and entered the roundabout at line 2, shown in Figure 3, was recorded. The time when circulating vehicles in either the inside or outside lane crossed line 1 was also recorded. Using these three

recordings, the accepted and rejected gaps by each entering driver was recorded. The follow-up headway was also recorded when two consecutive vehicles entered at line 2 using the same gap in circulating traffic, provided there were queuing conditions.
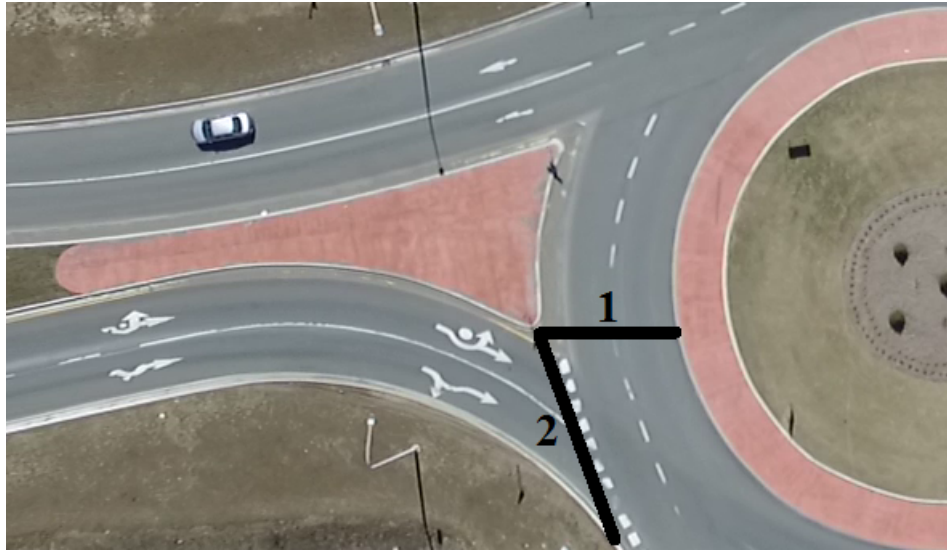

Figure 3 - Follow-up headway data collection

2. Results

The error observation period was intended to be undertaken from September 2015 to September 2016, resulting in a full year of data; however, construction began on a major uptown connection in the south side of Fredericton in June 2016. The construction influenced drivers to redirect their route to the Smythe Street roundabout, who otherwise may have avoided the roundabout. The disturbance caused by the construction altered the "normal" environment in which driver behaviour was being observed; therefore, vehicle errors were not observed during the construction period which ended in early September 2016. Error observations were therefore made from September 2015 to September 2016, bar June, July, and August.

Errors peaked at the onset, during the first month of opening, which was to be expected as drivers were the most unfamiliar. All driver error types have declined since the roundabout's opening. Figure 3 indicates total driver error reduction throughout the observation period. The total number of errors fell approximately 74% during the 52 week observation period since the roundabout first opened.
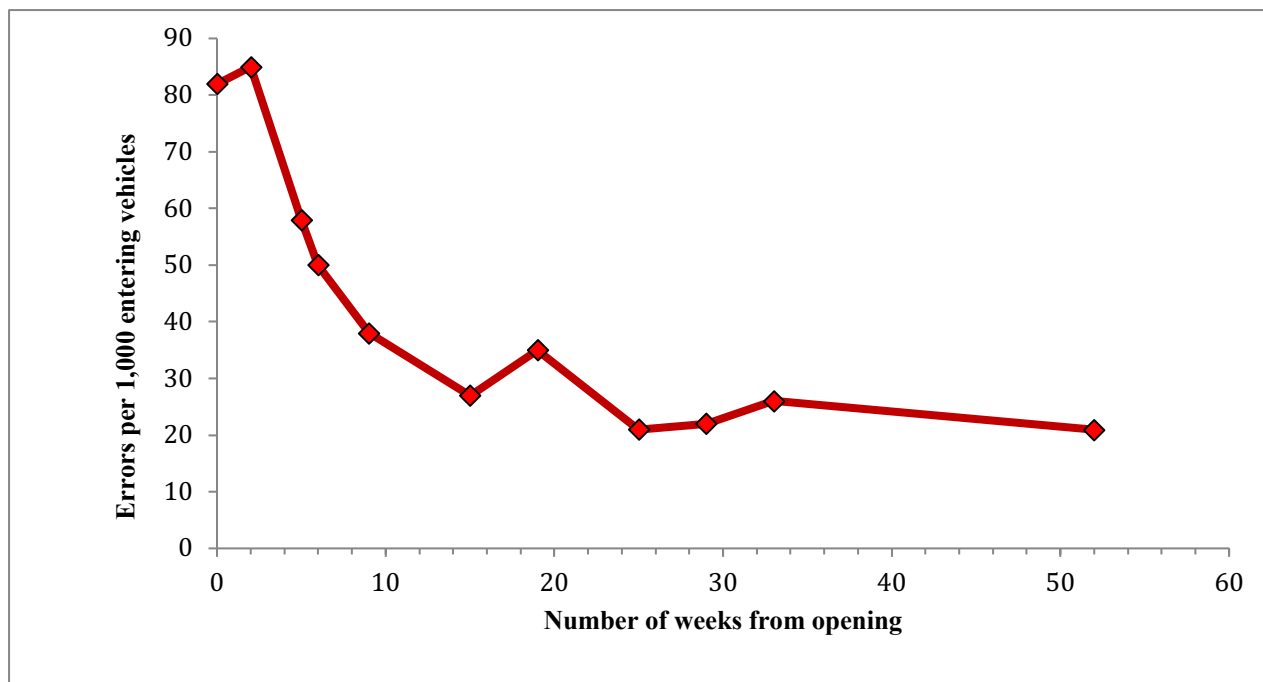
Figure 4 -Total driver errors

The percent reduction of each error and the percent total of each error for the entirety of the research are presented in Table 1.

	% Reduction (September 2015 – 2016)	% of Total Errors (September/16)
Changing lanes within roundabout	81	60
Not yielding to traffic already in roundabout	59	16
Improper lane usage	15	16
Stopping within roundabout	39	5
Not giving ROW to trucks	0	3
Left-turn (wrong way)	100	0
Total Error	**74**	**100**

Table 1 - Percent Error Reduction and Percent of Total Errors

UNMANNED AERIAL VEHICLE APPROVAL

Transport Canada is the governing body in Canada that is responsible for the regulation of UAVs in Canadian Airspace. An application was required as it was not possible for this project to "stay at least 30 metres away from people, animals, buildings, structures, and vehicles not involved in the operation", which is required for an unmanned aerial vehicle of 2kg or less.

Transport Canada states that there are two main types of applications, a Compliant Operation Application and a Restricted Operator Application, which has three sub methodologies: Complex Application, Simplified Application, and a Model Aeronautics Association of Canada/Academy of Model Aeronautics Application (MAAC/AMA). For the application of this project a Restricted Operator – Simplified Application was appropriate after discussion with the Atlantic Regional Civil Aviation Inspector.

A Restricted Operator Application is described by Transport Canada (2014) as:
"Restricted Operator Application: These certificate applicants are either unable or unwilling to meet the criteria to become a Compliant Operator or compliance with these criteria is not required based on the scope and complexity of the operation. Again, these operators will be granted fewer privileges than those extended to Compliant Operators."

A Simplified Application is described by Transport Canada (2014) as:
"Simplified Application: Applies to small UAVs, operated within Visual Line of Sight (VLOS) where the scope of operation is limited. See specific eligibility requirements and the SFOC application process in Section 11 of this Staff Instruction (SI)."

The Restricted Operator – Simplified Application format required information describing:
1. Applicant Main Contact
2. Operation Manager Main Contact
3. Operation Manager Flight Contact
4. Operation Type and Purpose
5. Operation Dates
6. UAV Specifications
7. Security Plan
8. Emergency Plan
9. Ground Supervisor Contact
10. Flight Plan
11. Pilot Qualifications
12. Inspections and Operations

The 14-page application was filed on May 11, 2015, with approval granted from Transport Canada on June 12, 2015. A renewal was filed in January 2016 for the blanket coverage of the remainder of the project (until September 2016), which was also approved.

In May 2015 Transport Canada published a Notice of Proposed Amendment [4] in which they addressed proposed changes to UAV regulation such as:

- New flight rules
- Aircraft marking and registration requirements
- Knowledge testing
- Minimum age limits
- Pilot permits for UAV pilots

These proposed regulations have yet to come into effect; however, they may alter the application process for traffic monitoring as it is described for this project.

OPERATIONAL RECOMMENDATIONS

1. Overview

Although the infancy of the traffic monitoring using drones lends to a still evolving best practice, to date, there are recommendations in place for maximized benefit when using an unmanned aerial vehicle. However, these recommendations are likely to evolve as more comprehensive studies are done on the unmanned aerial vehicle usage.

2. Future Studies

An unmanned aerial vehicle is best suited for traffic/transportation surveys which traditionally require significant labour or surveys where more comprehensive data is required. The low cost and lack of required infrastructure of UAVs make them a cost effective alternative. These include, but are not limited to:

1. Intersection Studies - Delay experienced by drivers at an intersection is well suited to the video footage collected by a UAV; additionally, right-of-way compliance among vehicles and pedestrians can be observed using UAV footage.

2. Safety Estimation – The research area of vehicle trajectory monitoring as a proxy for an intersection's safety performance is quickly evolving as a potential objective metric. Most of the current work has used software that synthesizes video imagery normally captured from a fixed point to the side of the intersection. The ability of a UAV to capture aerial imagery will provide much better information to allow the software to estimate "time to impact" measurements of near-misses. In effect, this will allow a better measurement of the safety performance or potential of an intersection without having to wait for years of collision data to accumulate.

2. Origin Destination Studies – The tracking of turning movements at complicated intersections (particularly roundabouts) are well suited to UAV data collection, which would otherwise require significant person-power to accomplish. Traffic flow patterns at other more localized sites which are difficult to observe on the ground, such as interchanges, can be easily monitored by employing UAVs.

3. Parking Studies - Parking studies that capture occupancy, duration, and accumulation characteristics traditionally require significant numbers of people to cover a relatively small urban environment. The use of a UAV would be well suited to this use as it would eliminate the need for people.

4. Spot Speed Studies - UAV footage allows for vehicle speeds to be remotely observed in real time by measuring the time for a vehicle to move between two points of known distance. Given the discrete nature of a UAV, it is probable that it could be of assistance to law enforcement.

CONCLUSIONS

The use of UAVs for traffic monitoring is largely still in its infancy. UAVs may be a more cost effective alternative to traditional methods, as they can gather detailed data over large areas while requires less person-power. Notable research on the use of UAVs for traffic monitoring was completed by Ohio State University, where give applications were investigated including: measuring level of service, estimating average annual daily travel, examining intersection operation, measuring origin destination, and measuring parking lot utilization [1].

UAV technology was successfully used to investigate driver behaviour at a complex intersection (roundabout) in New Brunswick. Data involving distinct driving errors was retrieved from the footage and evaluated to determine how the facility was functioning from a road safety perspective. A capacity analysis was also undertaken using the UAV footage and assisted in developing new critical and follow-up headway values for HCS 2010 software.

Transport Canada is the governing body for UAV regulation in Canada. For professional traffic monitoring a licence will be required and a Regional Civil Aviation Inspector can assist in the application process. An update to the regulations has been put forward and will likely alter the current licencing qualifications that are required for the use of UAVs in the coming year. Operational recommendations for the use of UAVs were highlighted and included: intersection studies, safety estimation, origin destination studies, parking studies, and spot speed studies.

In conclusion, the use of UAVs for traffic monitoring have provided promising results, while still in its early stages of gaining prominence over traditional methods. The future implementation of UAVs for traffic monitoring will allow for more comprehensive studies to be completed, bettering the recommendations for the best practice of UAVs in transportation engineering.

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