ADVANTAGES AND LIMITATIONS OF MAC ADDRESS O-D SURVEY DATA COLLECTION

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ABSTRACT

Reliable data provides the foundation upon which transportation professionals base their work. Without reliable data, they are unable to develop solid conclusions and recommendations for a myriad of projects and applications.

One of the main forms of data that transportation professionals rely upon in long-range planning projects, more specifically Transportation Master Plans, is origin-destination (O-D) survey data. This data typically identifies where people are traveling, why and how often and helps determine what transportation system changes and improvements will be required to accommodate transportation needs in the future.

Oxford County is located in Southwestern Ontario. It covers 2,040 square kilometres (788 square miles) with a 2016 census population of 110,862 persons. The County has five (5) rural municipalities and three (3) urban municipalities and is responsible for the management and maintenance of 614 kilometres of road. In 2016, Oxford County initiated an update to their Transportation Master Plan (TMP). An O-D survey was carried out as part of this update.

Oxford County is progressive from the perspectives of sustainability and investment in new and emerging technologies. Instead of utilizing traditional survey methodologies (direct interview, mail out/mail back) to collect the O-D data, the decision was made to use Media Access Control (MAC) address capture technology to record the survey data since use of this technology is in line with the County's initiatives. The data was collected using Miovision Scout data collection cameras with connected adapters. The adapters captured MAC addresses from Wi-Fi enabled devices within a 30 metre (+/-) radius of each unit. The Scout camera units collect traffic count data concurrent to the MAC address data capture. Use of this technology permitted more data to be collected over a longer period of time at a lower cost. Furthermore, the MAC technology required significantly fewer human resources and allowed data to be collected in a passive manner that did not impact traffic operations or rely on people's willingness to participate in a survey. With fewer human resources needed within the road allowance, there are also safety benefits to using this technology.

INTRODUCTION

One of the main forms of data that transportation professionals rely upon in long-range planning projects, more specifically TMPs, is origin-destination (O-D) survey data. This data typically identifies where people are traveling, why and how often and helps determine what transportation system changes and improvements will be required to accommodate transportation needs in the future.

Paradigm Transportation Solutions Limited recently used Media Access Control (MAC) address capture technology to record the O-D survey data required for the Oxford County TMP update. Use of this technology was in line with the County's initiatives regarding sustainability and investment in new and emerging technologies.

This paper outlines the advantages and limitations of using the MAC address capture technology for O-D survey data collection over a large area with a limited number of survey stations. The paper will also highlight the lessons learned and provide recommendations for future use of the technology including where and when this methodology should be deployed.

BACKGROUND

Oxford County is strategically located on the Transport Canada-identified Ontario-Quebec Continental Gateway. This gateway is a *"vital component of Canada's multimodal transportation system and provides a critical link between all key gateway facilities and also to Canada-U.S. border crossings"*. The County is linked to this gateway via its direct connections to Highway 401 and Highway 403.

Approximately 63%, or 69,550 County residents, live in the three lower-tier urban municipalities of City of Woodstock, Town of Ingersoll and Town of Tillsonburg. The remaining 41,350 people live in the five lower-tier rural municipalities of Township of Zorra, Township of East Zorra-Tavistock, Township of Blandford-Blenheim, Township of South-West Oxford and the Township of Norwich. The population of the County is expected to increase by 11%, to 124,200 people, by 2036 with most growth occurring in the urban areas.

The County has several major employers including Woodstock General Hospital (600 employees) and Toyota (approximately 2,400 employees). Employment is forecast to grow at a modest 16% by 2036. In additional, the County has a large agricultural base with 1,815 active farms and operators (2011 census) and is home to the largest outdoor agricultural trade show in Canada.

Origin-destination (O-D) survey data was required for inclusion of the TMP update being carried out by the County. The survey data was required to provide a broad picture of where people are traveling during the PM peak period. This information was needed to help refine the forecasting model and identify where future transportation improvements may be required.

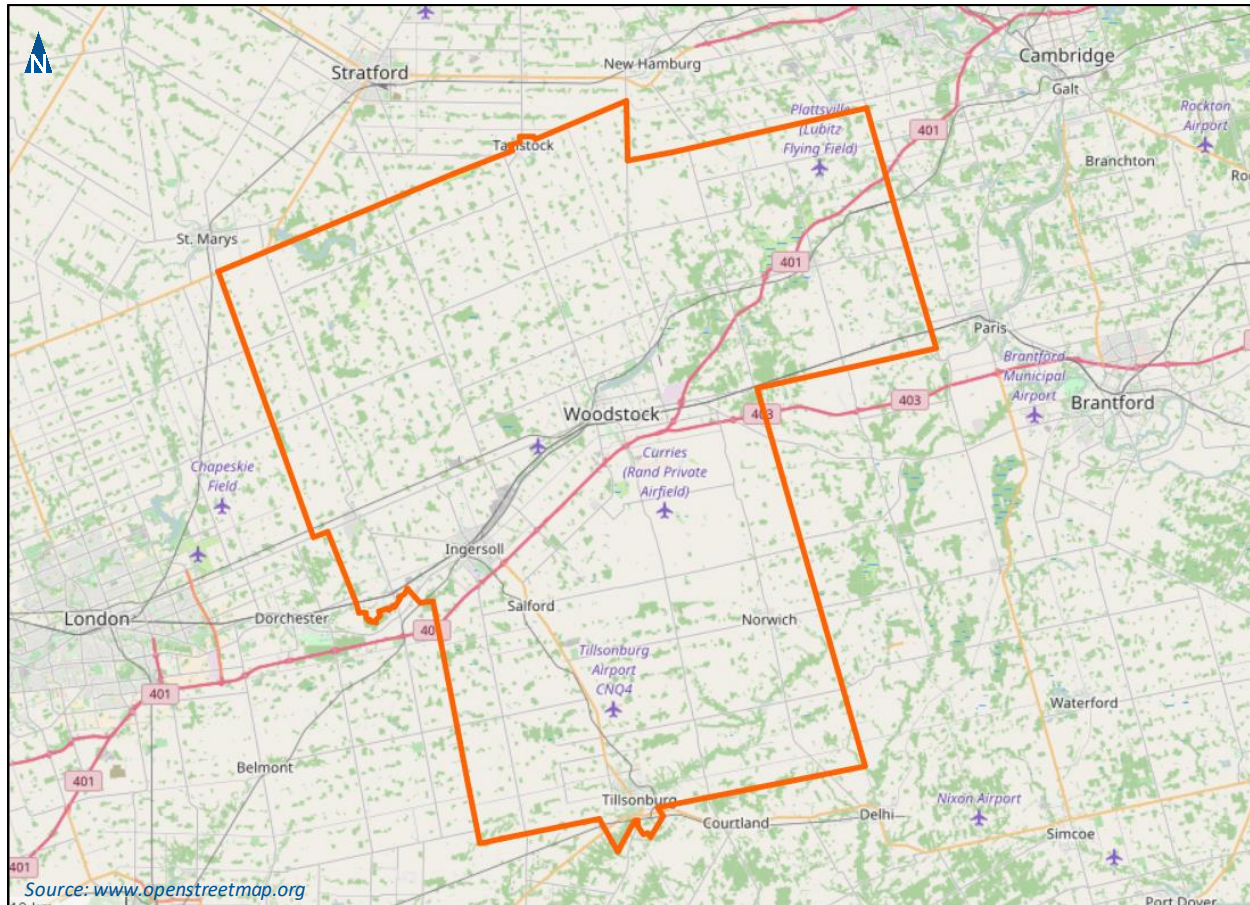**Figure 1** contains a map of Oxford County.

FIGURE 1: OXFORD COUNTY LOCATION

DATA COLLECTION METHODOLOGY

Traditionally O-D survey data is collected manually, either through direct interview surveys or via hand-out/mail back surveys distributed in the field. Both these methodologies can require large staff contingents and lengthy data collection periods to achieve the target sample. As well, the inherent nature of the surveys create traffic delays over and above those normally experienced. This can result in poor survey compliance and a lower overall sample rate.

In Spring 2017, Paradigm Transportation Solutions Limited worked with Miovision Technologies Inc. to develop an O-D survey matrix based on their travel time and delay study. The data is collected using a special "connector adapter" unit attached to the Miovision Scout data collection camera. The adapter captures the MAC addresses of all Bluetooth devices within the unit's range. These addresses are then translated into a proprietary code that is permanent and unique for each device. Each time the device

passes through the range of the data collection unit its code is recorded. At the end of the survey, any static devices are removed from the data set and the O-D survey matrix is generated.

Staff at the County of Oxford have an enthusiasm for new and emerging technologies which provided the opportunity for Paradigm to suggest using MAC address data capture to conduct the O-D survey as a feasible alternative to more traditional data collections methods. The advantages and disadvantages of using this technology were explained to County staff prior to commencing the survey.

The County agreed to use of the MAC address data capture methodology during the PM peak period (3:00 PM to 6:00 PM) at each of the 20 survey stations (**Figure 2**). Data collection was conducted at 10 stations per day over two weekdays: Tuesday, June 13 and Thursday, June 15, 2017 from 8:00 AM to 6:00 PM. Although only three hours of data collection was required, 10 hours were collected due to the cost savings of the technology. The additional hours of data collection provided the opportunity to develop AM and midday peak period trip matrices if needed in the future. The data collection was limited to 10 stations per day due to availability of equipment.

FIGURE 2: DATA COLLECTION LOCATIONS

ADVANTAGES

There are several advantages to using MAC address data capture versus traditional methods including:

▶ **Data collection is not weather dependent** and can be carried out any time of the year during most weather conditions. Traditional surveys are mainly carried out during clear weather conditions with operations often having to be suspended during inclement weather due to safety concerns and potential impacts to traffic. Electronic data collection can occur during clear or inclement conditions. However, as with any data collection, weather monitoring is recommended especially if the data collection is scheduled during winter months.

▶ **Data collection initialization requires much less planning and preparation**. Prior to commencing a traditional survey, many tasks must be completed such as preparation of traffic control plans, hiring and training of staff, contracting police support and securing any required permits. Electronic data collection removes the need for these tasks since formal traffic control plans are not required and when the survey is limited to smaller geographic area, multiple units can be programmed and deployed by a single person in one day. If permits are required to install the units on hydro/telephone poles, these can be obtained during the initial planning stages.

▶ **Data can be collected for longer durations** without staff turnover or significant tear down/setup of survey stations. Data collection is limited to the battery life of the data collection unit. If data collection is required for periods longer than the battery life, multiple units can be deployed at initial setup and programmed to record sequentially.

▶ **Data collection is less expensive than traditional survey methodologies**. Traditional surveys require staff compliments ranging from three to 20+ people per station depending on traffic volume and sample rate. One data collection unit can survey one entire station. The costs to collect the data include the initial purchase of the units, the deployment and retrieval of units, uploading of data for processing and the processing itself. As well, traffic count data is collected by the units concurrent to the survey thereby reducing the need to collect this data separately and for an additional fee. Overall, the cost per hour of MAC address data capture is less than one half of the cost of a traditional survey based on three staff per station. The relative costs to collect MAC address data versus manual data collection decrease as the number of survey staff per station increases.

▶ **Theoretical sample rate is 100%**. If data collection units were deployed on every roadway in and out of the study area, up to 100% of the Bluetooth devices could be captured if they all entered and exited the survey area over the duration of survey. However, as the number of units deployed over a larger area decreases, the rate of data collection decreases as not all vehicles enter and leave the study area.

▶ **Data collection is consistent throughout survey period**. The MAC address data capture methodology and results do not change over the course of data collection. With traditional surveys, the quality and quantity of data collection is unique to each individual interviewer or respondent and this quality can begin to degrade as the survey nears completion. Additionally, since all data is collected electronically, the data can be stored for future viewing and analyses as required.

- **Passive versus active data collection.** The units are typically installed on the side of the road within the right-of-way, do not require any on-road setups and do not interfere with any traffic operations. The units can be deployed and retrieved during non-peak conditions and can remain in the field indefinitely. Since the need to conduct on-road surveys is removed, data is collected in a much safer and more controlled environment, often requiring only an in-field technician for deployment and retrieval. **Figure 3** shows a typical data collection unit deployment.

FIGURE 3: MIOVISION SCOUT DATA COLLECTION UNIT

LIMITATIONS

There are several limitations to using MAC address data capture versus traditional methods including:

- **Data capture is limited to device trips, not person or vehicle trips.** The data collection units record the signature of any Bluetooth enabled device within its range. With today's accessibility to cell phones and the prevalence of connected vehicles, each vehicle could have more than one MAC address associated with it. Therefore, the O-D survey matrix constitutes device trips and not person or vehicles trips. Assumptions regarding the number of devices per vehicle and average auto occupancy need to be developed and applied to the data to derive the number of vehicle trips typically required for modeling purposes.

- **Data is limited to the number of vehicles passing through a survey station**. Additional information such as vehicle classification, direction of travel, trip purpose, trip frequency, vehicle occupancy, extended trip information and any other supporting data currently cannot be collected using this technology. If additional trip information is required, this methodology could be supplemented with traditional in-person surveys at select locations in the study area.

- ► **Data should be collected on the same day.** At present, it is not possible to easily concatenate (link together) the data from multiple survey days to develop a larger, more complex trip matrix. Further enhancements and improvements to the trip matrix report prepared by Miovision is required to permit compilation of multiple matrices into one.

- ► **Cannot control sample rate.** The actual rate of data collection is determined by the number of vehicles recorded at two stations and cannot be monitored or adjusted during the survey. As well, the sample rate diminishes as the geographic survey area increases since trips originating or destined to points within the survey boundary are not included in the matrix. Therefore, the initial data collection periods should be lengthened to ensure an adequate data collection and where possible, the survey area should be as compact as possible.

ANALYSIS

Overall, a total of 32,132 vehicles passed through the survey stations during the 3-hour PM peak period. A total of 12,760 MAC addresses were recorded. When the static addresses (household Wi-Fi, etc.) and the addresses recorded at only one station were removed from the data set, 477 MAC addresses were retained within the PM peak period trip matrices. Since the MAC addresses are related to specific devices, of which there may be multiple in each vehicle, a sample rate was not calculated.

The raw origin-destination matrices per survey day are shown in **Table 1**. These matrices show a total of 164 and 243 device trips respectively passing through the survey stations during the data collection period. Note that these tables show only the device trips captured at two stations. If a device did not pass two stations, is was not included in the matrix.

TABLE 1: RAW TRIP MATRICES

Station - Day 1		1	2	3	4	5	6	7	8	9	10	Total
17	Thames St S & King St W & King St E		0	8	1	1	0	3	0	1	0	14
18	Stover St S & Main St W	0		1	0	0	0	0	0	0	0	1
16	King St W & Whiting St	15	3		3	4	1	2	3	0	0	31
11	Mill Street & Bower Hill Road	3	1	3		1	0	0	2	2	0	12
15	Dundas St & Allen St West	5	0	2	0		0	20	0	0	13	40
20	County Rd 51 & Tillson St & County Rd	0	3	0	0	0		1	8	0	0	12
14	Dundas St & Allen St North	1	0	2	1	19	0		1	0	2	26
19	Highway 19 & Gateway Centre	2	1	2	1	1	3	0		0	0	10
12	37th Line & County Rd 17 & Road 74	1	0	0	0	1	0	0	0		4	6
13	CR 2 & 33rd Line North	0	0	0	1	7	0	2	0	2		12
	Total	27	8	18	7	34	4	28	14	5	19	164

Station - Day 2		1	2	3	4	5	6	7	8	9	10	Total
4	County Rd 29 & County Rd 3		0	0	0	1	1	0	2	0	0	4
5	County Rd 59 & County Rd 33	3		11	5	0	5	2	3	0	2	31
2	Albert St W & County Rd 42	1	0		0	1	3	0	0	0	0	5
1	Woodstock St N & Hope St E	1	0	2		0	2	1	1	0	0	7
9	County Rd 4 & County Rd 2 - East	1	0	1	2		0	36	2	0	1	43
3	County Rd 8 & 16th Line	0	0	4	0	0		0	5	0	0	9
8	County Rd 4 & County Rd 2 - North	0	0	2	0	40	1		18	2	0	63
7	County Rd 4 & County Rd 17 - South	1	0	0	2	7	4	25		13	0	52
6	County Rd 4 & County Rd 17 - West	0	0	0	0	1	0	1	20		0	22
10	County Road 59 & Juliana Dr	1	0	2	0	2	0	1	0	1		7
	Total	8	0	22	9	52	16	66	51	16	3	243

Several steps are required to convert the raw MAC address data (device trips) into vehicle trips:

The initial step in translating the data was to expand the raw data set to represent the total volume of traffic recorded passing each station during the three-hour data collection period. The number of raw data matrix points was divided by the total volume of traffic passing through the survey stations during the data collection period. This resulted in an expansion factor for each day that was applied to the raw data to adjust it up to the total recorded traffic volume for each day. After expansion, the initial device count was 8,661 and 6,945 device trips per day respectively.

TABLE 2: EXPANDED TRIP MATRICES

Station - Day 1		Station										
		1	2	3	4	5	6	7	8	9	10	Total
17	Thames St S & King St W/E		0	422	53	53	0	158	0	53	0	739
18	Stover St S & Main St W	0		53	0	0	0	0	0	0	0	53
16	King St W & Whiting St	792	158		158	211	53	106	158	0	0	1637
11	Mill Street & Bower Hill Rd	158	53	158		53	0	0	106	106	0	634
15	Dundas St & Allen St W	264	0	106	0		0	1056	0	0	687	2112
20	County Rd 51 & County Rd 37	0	158	0	0	0		53	422	0	0	634
14	Dundas St & Allen St N	53	0	106	53	1003	0		53	0	106	1373
19	Highway 19 & Gateway Centre	106	53	106	53	53	158	0		0	0	528
12	37th Line & County Rd 17 & Road 74	53	0	0	0	53	0	0	0		211	317
13	County Rd 2 & 33rd Line N	0	0	0	53	370	0	106	0	106		634
	Total	1426	422	951	370	1796	211	1479	739	264	1003	8661

Station - Day 2		Station										
		1	2	3	4	5	6	7	8	9	10	Total
4	County Rd 29 & County Rd 3		0	0	0	29	29	0	57	0	0	114
5	County Rd 59 & County Rd 33	86		314	143	0	143	57	86	0	57	886
2	Albert St W & County Rd 42	29	0		0	29	86	0	0	0	0	143
1	Woodstock St N & Hope St E	29	0	57		0	57	29	29	0	0	200
9	County Rd 4 & County Rd 2 - East	29	0	29	57		0	1029	57	0	29	1229
3	County Rd 8 & 16th Line	0	0	114	0	0		0	143	0	0	257
8	County Rd 4 & County Rd 2 - North	0	0	57	0	1143	29		514	57	0	1801
7	County Rd 4 & County Rd 17 - South	29	0	0	57	200	114	715		372	0	1486
6	County Rd 4 & County Rd 17 - West	0	0	0	0	29	0	29	572		0	629
10	County Road 59 & Juliana Dr	29	0	57	0	57	0	29	0	29		200
	Total	229	0	629	257	1486	457	1886	1458	457	86	6945

The next step in the process was determination of an auto occupancy factor. The Transportation Tomorrow Survey (TTS) survey would typically be used to determine auto occupancy rates within Southern Ontario. However, Oxford County is not included in the TTS database since the County is not within the Toronto commuter shed. Therefore, assumptions regarding auto occupancy and average number of devices per vehicle were required to translate the data into vehicle trips.

The neighbouring census divisions (CD) of Brant County (CD 124) and the City of Brantford (CD 147) were utilized to determine auto occupancy. The City of Brantford is located within Brant County which is a mainly rural County comprising 1,093 square kilometres with a 2016 Census population of 134,800 persons. In addition to population,

Brant County has other similarities to Oxford County including multiple direct connections to the provincial highway network, employment lands located adjacent to this network and few urban centres within the County; therefore, auto occupancy was considered to be indicative of Oxford County. The resulting TTS auto occupancy rate was 1.32 persons per vehicle. This factor was applied to the expanded matrices, resulting in a total of 6,542 and 5,246 device trips per day respectively.

TABLE 3: AUTO OCCUPANCY ADJUSTED TRIP MATRICES

Station - Day 1	Station										
	1	2	3	4	5	6	7	8	9	10	Total
17 Thames St S & King St W/E		0	319	40	40	0	120	0	40	0	558
18 Stover St S & Main St W	0		40	0	0	0	0	0	0	0	40
16 King St W & Whiting St	598	120		120	160	40	80	120	0	0	1237
11 Mill Street & Bower Hill Rd	120	40	120		40	0	0	80	80	0	479
15 Dundas St & Allen St W	199	0	80	0		0	798	0	0	519	1596
20 County Rd 51 & County Rd 37	0	120	0	0	0		40	319	0	0	479
14 Dundas St & Allen St N	40	0	80	40	758	0		40	0	80	1037
19 Highway 19 & Gateway Centre	80	40	80	40	40	120	0		0	0	399
12 37th Line & County Rd 17 & Road 74	40	0	0	0	40	0	0	0		160	239
13 County Rd 2 & 33rd Line N	0	0	0	40	279	0	80	0	80		479
Total	1077	319	718	279	1356	160	1117	558	199	758	6542

Station - Day 2	Station										
	1	2	3	4	5	6	7	8	9	10	Total
4 County Rd 29 & County Rd 3		0	0	0	22	22	0	43	0	0	86
5 County Rd 59 & County Rd 33	65		237	108	0	108	43	65	0	43	669
2 Albert St W & County Rd 42	22	0		0	22	65	0	0	0	0	108
1 Woodstock St N & Hope St E	22	0	43		0	43	22	22	0	0	151
9 County Rd 4 & County Rd 2 - East	22	0	22	43		0	777	43	0	22	928
3 County Rd 8 & 16th Line	0	0	86	0	0		0	108	0	0	194
8 County Rd 4 & County Rd 2 - North	0	0	43	0	864	22		389	43	0	1360
7 County Rd 4 & County Rd 17 - South	22	0	0	43	151	86	540		281	0	1123
6 County Rd 4 & County Rd 17 - West	0	0	0	0	22	0	22	432		0	475
10 County Road 59 & Juliana Dr	22	0	43	0	43	0	22	0	22		151
Total	173	0	475	194	1123	345	1425	1101	345	65	5246

The 2017 Canadian Radio-television and Telecommunications Commission Communications Monitoring report was reviewed to determine the rate of cell phone ownership within Canada. According the report, 87.5% of Canadians, or about 31 million Canadians, own a cell phone. When this rate of cell phone ownership was applied to the auto occupancy adjusted matrices, it resulted in a total device trip count of 5,724 and 4,590 trips respectively. Since no further adjustments could be made to the data, the matrices were considered to represent the total vehicle trips passing through the stations during the three-hour data capture period.

TABLE 4: FINAL ADJUSTED TRIP MATRICES

Station - Day 1	Station										
	1	2	3	4	5	6	7	8	9	10	Total
17 Thames St S & King St W/E		0	279	35	35	0	105	0	35	0	489
18 Stover St S & Main St W	0		35	0	0	0	0	0	0	0	35
16 King St W & Whiting St	524	105		105	140	35	70	105	0	0	1082
11 Mill Street & Bower Hill Rd	105	35	105		35	0	0	70	70	0	419
15 Dundas St & Allen St W	175	0	70	0		0	698	0	0	454	1396
20 County Rd 51 & County Rd 37	0	105	0	0	0		35	279	0	0	419
14 Dundas St & Allen St N	35	0	70	35	663	0		35	0	70	907
19 Highway 19 & Gateway Centre	70	35	70	35	35	105	0		0	0	349
12 37th Line & County Rd 17 & Road 74	35	0	0	0	35	0	0	0		140	209
13 County Rd 2 & 33rd Line N	0	0	0	35	244	0	70	0	70		419
Total	942	279	628	244	1187	140	977	489	175	663	5724

Station - Day 2	Station										
	1	2	3	4	5	6	7	8	9	10	Total
4 County Rd 29 & County Rd 3		0	0	0	19	19	0	38	0	0	76
5 County Rd 59 & County Rd 33	57		208	94	0	94	38	57	0	38	586
2 Albert St W & County Rd 42	19	0		0	19	57	0	0	0	0	94
1 Woodstock St N & Hope St E	19	0	38		0	38	19	19	0	0	132
9 County Rd 4 & County Rd 2 - East	19	0	19	38		0	680	38	0	19	812
3 County Rd 8 & 16th Line	0	0	76	0	0		0	94	0	0	170
8 County Rd 4 & County Rd 2 - North	0	0	38	0	756	19		340	38	0	1190
7 County Rd 4 & County Rd 17 - South	19	0	0	38	132	76	472		246	0	982
6 County Rd 4 & County Rd 17 - West	0	0	0	0	19	0	19	378		0	416
10 County Road 59 & Juliana Dr	19	0	38	0	38	0	19	0	19		132
Total	151	0	416	170	982	302	1247	963	302	57	4590

CONCLUSION

Origin-destination survey data is a vital tool for transportation professionals as it provides real-time information about typical trip making. As technology advances, the need to collect O-D data using traditional methods such as direct interview or mail out/mail back surveys will diminish.

The use of MAC address data capture is recommended for a variety of applications including:

- Projects in smaller geographic survey areas;
- Locations where traditional survey methods are unsafe or too costly;
- Where long-duration data collection is required; and
- When the technology can also be used in conjunction with or as a supplement to other O-D survey methods.

The use of MAC address data capture is currently not recommended when:

- Supplemental trip information is needed (frequency, purpose, etc.);
- Only passenger vehicle trip information is required;
- A target sample rate is required;

- Peak hour (versus peak period) data is required; and
- Data regarding auto occupancy and number of Bluetooth devices per vehicle is not available to translate device trips into auto trips.

Overall, this technology not only has the potential to provide origin-destination data, it has the potential, in time, to be translated for additional uses such as trip distribution and routing. With guidance from the transportation community, the developers can continue to improve and expand this technology to better meet transportation data collection requirements.

REFERENCES

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