THE EFFECTS OF WEATHER ON VEHICLE IDLING

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This study, using Vehicle Monitoring Technology (VMT), quantifies the extent to which weather, particularly ambient air temperatures, influence the incidences and duration of engine idling times across a snow resort fleet. With a strong relationship between environmental knowledge and environmental behaviours (Flamm, 2009), it is important that drivers know the impacts of their actions. As a tool, VMT can be used to provide feedback to drivers and reinforce lessons learned from eco-driver training to maximize positive driver behaviour change. The findings from this study present opportunities to improve the sustainability of a snow resort fleet, which can directly contribute information to eco-driver training courses that aim to reduce unnecessary vehicle emissions associated with fuel-inefficient driver behaviour.

During the winter season of 2009-2010, VMT devices were installed in 14 fleet vehicles at Blue Mountain Resorts Limited (BMR) to obtain baseline data on driving behaviour. A detailed summary of the results were provided to department managers. Thereafter, staff expressed that some driving behaviours, namely high levels of idling, are the result of drivers wanting to keep the inside of the vehicles warm during cold winter temperatures. To assess the accuracy of these statements, VMT devices were reinstalled in six[1] fleet vehicles during the 2010 summer

[1] The fleet operates at a smaller capacity during the summer months, with only 6 of the initial 14 vehicles studied during the winter months in operation during the summer.

months (June, July, August) to examine whether there is indeed a relationship between idling and ambient air temperature.

This study seeks to understand the relationship between weather and driver behaviour, associated with operating light and medium duty vehicles within resort fleet during the winter and summer months. It is hypothesized that ambient air temperature (extreme cold in winter and heat in summer) leads to increased instances and duration of vehicle idling. The three core objectives of this research are:

1. Acquire data on driver behaviour across six snow resort fleet vehicles using the variables of time driven, distance driven, time idling, hard decelerations, and hard accelerations.
2. Explore the relationship between temperature and driver behaviour during winter and summer seasons.
3. Identify driving behaviour situations where behaviour changes are needed to improve the fuel efficiency of the fleet.

Study Context

Engine idling can be defined as a situation in which a vehicle is turned on, but is not moving. There are three circumstances under which individuals idle their vehicle: waiting to warm the engine, waiting for something unrelated to traffic (e.g., a passenger), and while in traffic (e.g., at traffic lights, a stop sign) (Carrico et al. 2009). The idling that occurs while in traffic is unavoidable, except in the case of hybrid or electric vehicles. For other circumstances, Natural Resources Canada and the United States Environmental Protection Agency (US EPA) consider idling exceeding 30 seconds as the point at which a vehicle is considered unnecessarily idling (US EPA, 2004; NRCan, 2008).

There is a common misconception that vehicle idling uses less fuel than restarting the vehicle. According to a national survey completed by Natural Resources Canada, respondents claimed to idle because they think it is beneficial to warm a vehicle engine before driving in cold weather (NRCan, 2008). Respondents also indicated that they idle so that there is a comfortable temperature in the vehicle. Respondents to this survey did not believe that idling produces unnecessary pollution, and respondents thought that idling was better for both the engine and the starter (NRCan, 2008). Education campaigns enable drivers to be more aware of their actions and how behaviours impact their fuel consumption and CO_2 emissions.

It is thought that idling reduction campaigns can help foster behavioural changes. McKenzie-Mohr Associates and Lura Consulting (2001); McKenzie-Mohr Associates (2003); and Rutty et al. (2010) have recorded reductions up to 78, 26, and 49%, respectively, after a public education initiative was implemented. These results indicate that public education is an important factor in behaviour change that can lead to reduced idling.

To improve the educational component of driver behaviour, it is important to understand what may influence driver behaviour and subsequent idling times. Weather has been cited as an important factor in vehicles idling (McKenzie-Mohr Associates, 2003, NRCan, 2008), though no study has empirically assessed the degree to which ambient air temperatures affect instances and the duration of idling. This study quantifies the extent to which weather, particularly ambient air temperatures, influences the incidences and duration of engine idling across a snow resort fleet.

Methods

In December 2009, 14 on-board data loggers (CarChip®) were programmed and installed in fleet vehicles at BMR. The CarChip® is a small device (4cm x 5cm x 3cm), and was installed out of sight of the driver by plugging the device into the On-board Diagnostic (OBDII) port found under the dashboard. Once installed the CarChip® reads and stores all the data from the vehicle's on-board computers, continuously logging driving and engine performance. To limit the influence these devices may have on driver behaviour, the staff was notified of the installation but details on which driving variables were being recorded, as well as the purpose of the study, were not made available to drivers.

The CarChips®, were removed every two to three weeks, and the data was downloaded using a USB cable attached to a laptop. The CarChips® were then cleared, reprogrammed and reinstalled into the corresponding vehicle. The CarChips® recorded driver behaviour until

March 31st, 2010 when they were uninstalled. This process was repeated over the summer months with installation occurring in six vehicles beginning June 23rd, 2010, with the final data download on September 20th, 2010.

Vehicle suitability was determined by choosing BMR fleet vehicles compatible with the CarChip® device, and vehicles were selected to provide an approximate overview of BMR's total fleet. To get a complete representation of vehicle function, a minimum of one vehicle was selected from each of the departments of security, grounds and operations, and accounting.

Table 1. Vehicle details

Department Function	Vehicle #	Make	Model	Year	Engine Size (l)
Operations	Vehicle 11	Toyota	Tundra	2007	5.7
Security	Vehicle 12	Dodge	Caravan	2004	3.3
Grounds	Vehicle 18	Ford	Pick-Up	1998	4.6
Security	Vehicle 31	Dodge	Caravan	2000	3
Accounting	Vehicle 32	Toyota	Yaris	2010	1.5
Grounds	Vehicle 70	GMC	Sierra	2004	5.4

The CarChip® continuously reads driving and engine data from the vehicle's on-board computers and stores the data. The recorded variables included the number of daily trips, average and total daily trip times, average and total trip distance, average trip speed, idling time and the total number of accelerations and decelerations per trip. Table 2 presents an overview of the variables, their units, abbreviations, and a description of how the variable was calculated. Seasonal means and totals were generated for each of the variables in Table 2. Data was also aggregated to the vehicle-day level. A 'vehicle-day' is the sum of all driving that occurred in one calendar day by one vehicle. In total, the six vehicles recorded 481 vehicle-days over the course of the winter season. There were 378 vehicle-days recorded by the same six vehicles in the summer. Figures and tables organize results by season.

Idling time consists of any time where the engine is running but the vehicle is not moving; therefore results include both necessary (e.g., waiting at an intersection or stop sign) and unnecessary idling. Idling percentage represents the total amount of idling time divided by the total time with the engine turned on.

Table 2. Driving Behaviours Monitored and Calculated

Variable	Abbreviation	Description
Days Driven	Da_Dv	Number of Days the vehicle is driven
Drive Time (hh:mm)	Dv_Tm	Total time the vehicle is driven
Distance Driven (km)	Tl_Dst	Total distance travelled
Acceleration Count	Accel	Number of times the vehicle performs a speed difference of ≥30km/h in ≤2.8 seconds
Deceleration Count	Decel	Number of times the vehicle performs a speed difference of ≥30km/h in ≤2.4 seconds
Idling Time (hh:mm)	Idl_Tm	Total amount of time the vehicle is idling when the vehicle engine is turned on, but not moving, (speed = 0 km/h)
Percentage of Idling Time (%)	Idl%	Percentage of time vehicle is idling
CO_2 Emissions from Idling (kg)	CO_2_Em	Kilograms of CO_2 emitted when the vehicle is idling[2]
Fuel Consumed from Idling (L)	Fuel_Idl	Litres of fuel consumed while the vehicle is idling[3]
Fuel Cost from Idling ($CAD)	Cost_Idl	Fuel consumed from idling[4]

Data collected using the CarChip® device was coded and examined using Microsoft *Excel* and IBM's *Statistical Package for the Social Sciences (SPSS)*. Various statistical techniques were used to explore the data including descriptive statistics to examine behaviours for multiple variables. Regression analyses were conducted to define the relationship between temperature and vehicle idling. Microsoft *Excel* was also used to plot and graph the aforementioned data.

Winter and summer study periods were separated to distinguish differing periods of activity, and differing weather conditions. BMR is most active in the winter season beginning in mid December, as that is when temperature are cold enough for natural snow or snow making to

[2] 2.289 kg/CO_2/L of gas and 2.663 kg/CO_2/L of diesel (Environment Canada, 2008).
[3] Idling time*fuel flow*60, with fuel flow = engine size* 0.6 / 60 (Environment Canada, 2008).
[4] Fuel consumed from idling*price of fuel (CAD$0.78/L, as per BMR onsite pricing).

occur. As such, vehicle usage changes from winter to summer periods. Though totals of driving behaviour, specifically idling time, cannot be compared directly between seasons, the percentage of time spent idling can be compared. Data was therefore disaggregated by season. In the winter the fleet is driven more, and therefore drivers idle more as well. It is for this reason that percent idling time was chosen as the dependent variable as opposed to total idling time. For the first trip of the day, however, analysis was completed on total idling time as the focus was to estimate the 'warm-up' or 'cool down' period each morning.

Results

It is apparent that the first trip of the day is a special circumstance for some of the vehicles that were studied, with more idling during the first trip than for all other trips that were completed during the day. Due to this phenomenon, data was separated into two categories: first trip of the day, and all other trips of the day. All other trips of the day are aggregated to the vehicle-day level for each vehicle.

Table 3. Seasonal Differences in Idling Behaviour

Vehicle No.	11	12	18	31	32	70
Total Hours Idling in Winter	33.01	78.45	229.29	37.30	73.58	151.92
Total Hours Idling in Summer	6.20	54.78	114.19	50.59	3.92	25.94
Seasonal Difference	**-26.81**	**-23.68**	**-115.11**	**13.29**	**-69.66**	**-125.98**
Total Hours Idling during the First trip of day - winter	5.88	4.94	51.69	0.69	31.12	55.18
Total Hours Idling during the First trip of day - summer	0.97	2.52	11.30	3.78	0.12	2.03
Seasonal Difference	**-4.91**	**-2.42**	**-40.39**	**3.09**	**-30.99**	**-53.15**
Percentage of Idling Time that occurred during first trip of the day - Winter	17.81	6.30	22.54	1.86	42.29	36.32
Percentage of Idling Time that occurred during first trip of the day - Summer	15.66	4.59	9.90	7.48	3.15	7.83
Seasonal Difference	**-2.15**	**-1.70**	**-12.64**	**5.62**	**-39.13**	**-28.49**

Regression analyses indicate that there is a considerable difference in idling behaviour between seasons (winter vs. summer). Though there is some sensitivity to temperature within a season, it is not as evident as the differences between seasons. As would be expected, idling is higher for colder temperatures in the winter, and there is some sensitivity to temperature in the summer, with incidences of idling being higher during hotter temperatures.

When regression analysis was performed for air temperature against idling during one season (winter or summer), the R^2 values were negligible. This was the case for both winter and summer. However, the regression analysis provided R^2 values of statistical significance for the first trip of the day for both seasons against mean temperature. Vehicle 32 had the highest R^2 value for the first trip of the day (R^2= 0.761) and vehicle 70 had the second highest coefficient of determination (R^2= 0.715). Figures 1 and 2 illustrate the relationship between temperature and idling time for vehicles 32 and 70.

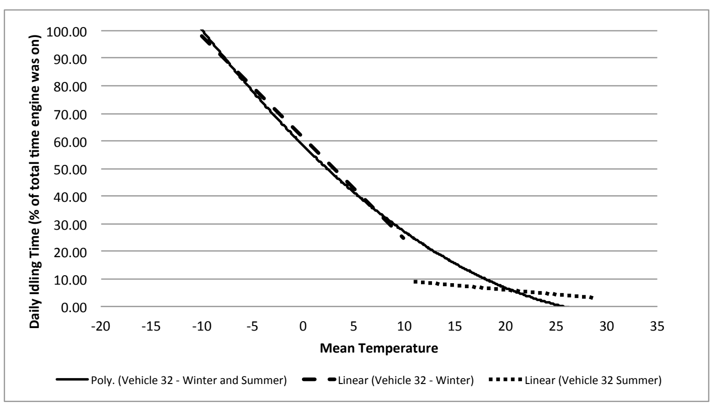

Figure 1. Idling Time (%) vs. Temperature - 1st trip of the day (winter and summer for vehicle 32)

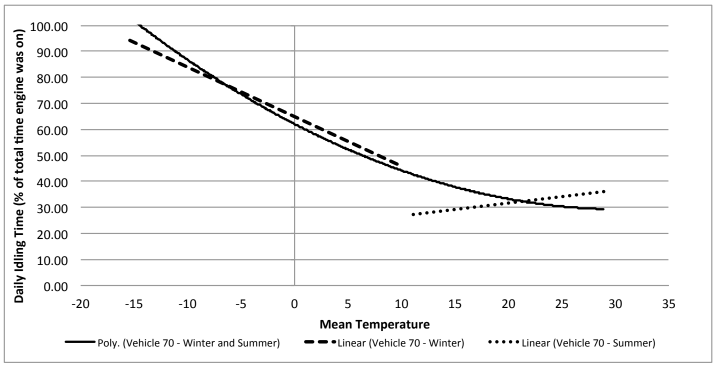

Figure 2. Idling Time (%) vs. Temperature - 1st trip of the day (winter and summer for vehicle 70)

Differences in the strength of relationship can be seen between vehicles. This is a product of vehicle function within the snow resort fleet. Each vehicle has different responsibility, operating hours and duties. For example, security vehicles can operate 24 hours a day and idle to maintain power to their video cameras that are used for surveillance. The accounting vehicle, however, only operates during the day and makes numerous short trips to pick up and deliver mail and supplies. Grounds and operations vehicles are responsible for resort maintenance and have variable schedules. For employees that work outdoors at BMR, vehicles are used in some cases as a place to warm-up during the winter season. For instance, grounds and operations personnel spend the majority of their shifts outdoors, often in inclement weather.

There is a strong relationship between idling and temperature for vehicle 32 and vehicle 70. There is a consistent driver for vehicle 32 and this driver has a very consistent route in both winter and summer. The same can be seen for vehicle 70, which also has the same drivers for both winter and summer. For both of these vehicles, there are very clear seasonal differences in driver behaviour during the first trip of the day when compared to all other trips taken.

Table 4. Relationship of Idling Time (%) vs. Temperature - All Vehicles

Vehicle #	11	12	18	31	32	70
Winter - 1st Trip of Day - Idling Time (%) vs. Mean Temperature						
Constant	26.113	37.614	72.385	21.376	61.912	65.649
Slope	-0.858	-0.664	-0.895	0.262	-3.631	-1.871
p-value	0.077	0.414	0.076	0.809	0.000	0.000
R^2	0.037	0.013	0.033	0.003	0.314	0.212
Winter - Rest of Trips - Idling Time (%) vs. Mean Temperature						
Constant	20.267	40.128	53.928	31.193	14.668	37.100
Slope	-0.286	-0.734	-0.551	-0.292	-0.520	-0.637
p-value	0.333	0.029	0.128	0.614	0.000	0.016
R^2	0.011	0.084	0.025	0.012	0.196	0.057
Summer - 1st Trip of Day - Idling Time (%) vs. Mean Temperature						
Constant	34.840	16.298	42.169	12.499	12.671	23.370
Slope	-0.931	0.418	0.717	1.270	-0.333	0.346
p-value	0.140	0.583	0.300	0.366	0.081	0.728
R^2	0.074	0.006	0.014	0.026	0.035	0.002
Summer - Rest of Trips - Idling Time (%) vs. Mean Temperature						
Constant	20.042	43.364	31.248	34.034	16.003	17.716
Slope	-0.137	-0.553	0.835	0.372	-0.286	0.641
p-value	0.598	0.130	0.015	0.555	0.081	0.118
R^2	0.009	0.044	0.073	0.010	0.035	0.034
Winter and Summer - 1st Trip of Day - Idling Time (%) vs. Mean Temperature						
Slope x	-1.063	0.192	-1.508	0.212	-4.384	-3.079
Slope x p-value	0.153	0.904	0.371	0.867	0.003	0.021
Slope x^2	0.03	-0.076	0.078	0.105	0.105	0.037
Slope x^2 p-value	0.534	0.485	0.495	0.237	0.223	0.646
Constant	17.953	43.131	49.828	16.959	48.519	53.697
R^2	0.325	0.158	0.076	0.497	0.761	0.715

The relationship between idling and temperature during first trip of the day is much weaker for vehicles 11, 12, 18 and 31. These vehicles are driven by a variety of employees and there is no set route or schedule. An increase in morning idling during winter is still seen in these vehicles, though the seasonal difference is not as dramatic as it is for vehicles 32 and 70. Vehicle 31, for example, is a security vehicle that was driven more frequently, and for longer distances during the summer than in the winter. Additionally, vehicle 31 can be in operation for 24 hours in a given day and therefore does not have a warm-up period during the winter. This is the only vehicle to show a summer increase in activity, and as such, demonstrates the possibility of changed vehicle function between seasons.

Figure 3 depicts the relationship between mean air temperature and idling time during all trips in a day except the first trip. Figure 4 depicts the relationship between mean air temperature and idling time during first trip of the day. Figure 5 depicts the relationship between mean air temperature and idling time (minutes) during first trip of the day

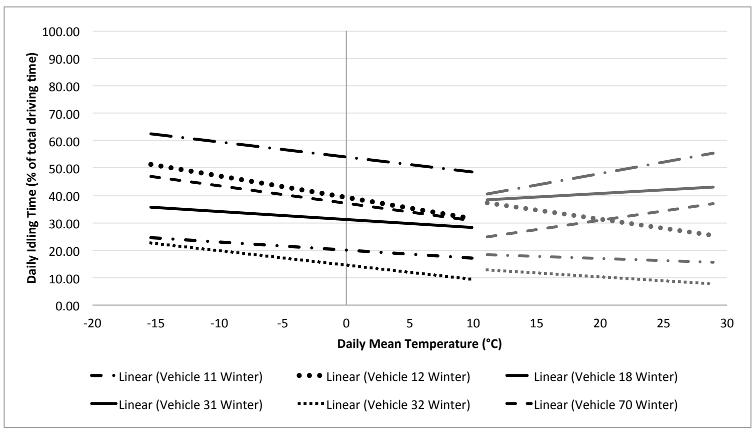

Figure 3. Idling Time (%) vs. Temperature – Rest of the trips of the day (winter and summer)

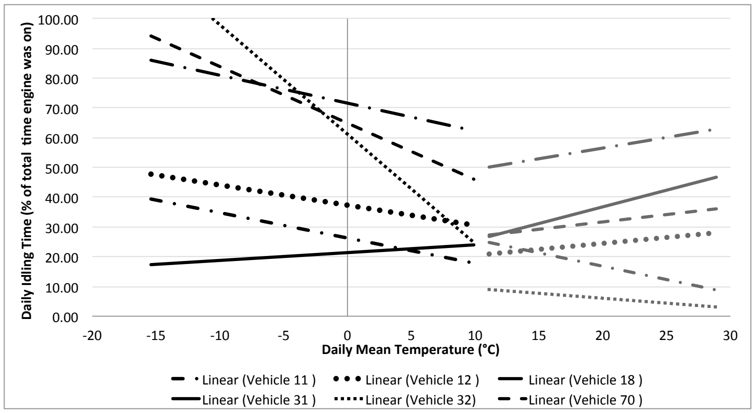

Figure 4. Idling Time (%) vs. Temperature - 1st trip of the day (winter and summer)

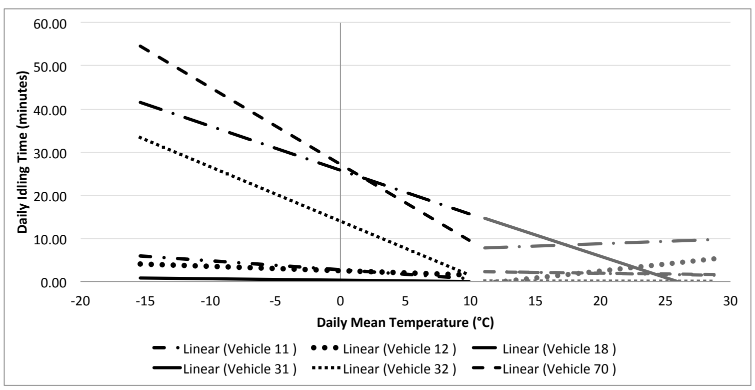

Figure 5. Idling Time (minutes) vs. Temperature - 1st trip of the day (winter and summer)

It is clear that there is a seasonal difference in idling time for the first trip of the day, but is it the same for all the other trips of the day that the vehicles take? Figure 3 compares idling between winter and summer at the vehicle-day level, working with an aggregate of all the trips driven in the day except for the first trip. This graph shows that both summer and winter have very similar distributions in percent idling time, illustrating that there is little seasonal difference in daily idling times between winter and summer seasons.

Table 4. Vehicle-day Summary

Daily Driving Behaviour Summary - Winter							
Vehicle #	**11**	**12**	**18**	**31**	**32**	**70**	**All Vehicles**
Da_Dv	89	60	98	24	106	104	**481**
Dv_Tm	1.55	3.03	3.61	4.45	2.74	2.94	**18.32**
Tl_Dst	64.95	47.43	29.22	79.17	71.53	38.22	**330.52**
Accel	1.06	8.10	0.65	9.13	0.69	6.91	**26.54**
Decel	1.08	10.72	0.98	10.25	2.16	3.08	**28.27**
Idl_Tm	0.37	1.31	2.34	1.55	0.69	1.46	**7.72**
Idl%	23.9	43.1	64.7	34.9	25.3	49.7	**43.8**
CO2_Em	2.90	5.93	9.64	6.40	1.43	10.83	**37.13**
Fuel_Idl	1.27	2.59	4.21	2.80	0.62	4.73	**16.22**
Cost_Idl	$0.99	$2.02	$3.29	$2.18	$0.49	$3.69	**$12.66**
Daily Driving Behaviour Summary - Summer							
Vehicle #	**11**	**12**	**18**	**31**	**32**	**70**	**All Vehicles**
Da_Dv	36	56	81	39	89	77	**378**
Dv_Tm	1.05	3.12	2.69	2.89	0.40	1.08	**11.23**
Tl_Dst	42.56	71.32	33.69	54.46	16.85	24.31	**243.19**
Accel	0.31	0.61	0.17	0.79	0.10	0.79	**2.77**
Decel	0.69	1.61	0.25	4.77	0.75	0.42	**8.49**
Idl_Tm	0.17	0.98	1.41	1.30	0.04	0.34	**4.24**
Idl%	16.6	31.3	52.4	45.0	11.1	31.3	**38.6**
CO2_Em	1.36	4.43	5.81	5.35	0.09	2.50	**19.54**
Fuel_Idl	0.59	1.94	2.54	2.34	0.04	1.09	**8.54**
Cost_Idl	$0.46	$1.51	$1.98	$1.82	$0.03	$0.85	**$6.65**

In the winter season there is a lot of variation between vehicles in terms of driving behaviours. Vehicles were driven a total of 481 days, with the least driven vehicle operating for 24 days totalling 1900km. The most driven vehicle operated 106 days, with a total distance of 7582km. The vehicles idled between 24 and 65% of the time. This leads to an average daily total of more than 16L of fuel consumed and 37kg of CO_2 from idling alone. There is also variation amongst acceleration and deceleration variables. There were 1655 hard accelerations in the winter compared to 160 in the summer. In terms of hard breaking, there were 604 hard decelerations in the winter compared to 256 in the summer.

During the summer there is similar variability in the driving behaviours across vehicles. Vehicles drove a total of 378 days, with the least driven vehicle operating 36 days with a total distance of 1532km. The most driven vehicle was operated for 56 days totalling 3993km. Though half the vehicles were driven for more than 56 days, they did not drive as far. The vehicles idled between 11 and 52% of the time.

There is also variation amongst variables that are of particular relevance for eco-driver training (acceleration, deceleration, idling), though the variation is much smaller. It is among these variables that it becomes clear that opportunities can be pursued to introduce behavioural driving changes that can reduce fuel consumption through eco-driver training. There are opportunities to improve the economic and environmental performance across the fleet by reducing the number of daily hard accelerations (winter=26.5, summer=2.8) and daily hard decelerations (winter=28.3, summer=8.5). For example, hard accelerations and decelerations use 33 to 40% more fuel than if the driver accelerated and decelerated gradually (Ericsson, 2001; Thew, 2007; NRCan, 2009; Saboohi & Farzaneh, 2009).

Idling reduction education is another key area for improvement – specifically during the first trip of the day for winter driving. Over the eight-month duration of the project more than 859 hours were spent idling. It is important to note that idling time includes sedentary time spent at intersections and in traffic. Assuming a generous estimate that 25% of idling time is spent at intersections, which was the lowest recorded winter idling time in this study, 644 hours of unnecessary idling presents a significant avenue for fleet fuel consumption improvement. This is especially important given that only 10% of BMR's vehicles were included in this study.

Limitations

There are two key limitations of the CarChip® as they are applied in this study. The first relates to the capacity of the CarChip® to record and store data. The Carchip® has a storage capacity of 100 hours of driving data at the trip-by-trip level. For some vehicles, the CarChips® reached storage capacity before the download date and therefore some trips are missing from the data set. Additionally, there were times when the CarChip® was removed from the OBDII connector for maintenance reasons and was not re-installed correctly, also affecting data completeness.

The CarChip® can also only store three hours of second-by-second data. CarChips® were downloaded once every three weeks during the winter, and once a month during the summer. This means that though most trips were captured by the CarChip® devices, only 16 hours of second-by-second data was captured for each season for each vehicle. Second-by-second data is important for differentiating between different unnecessary and necessary idling. Given that the CarChip® quantifies idling as any moment in time when the vehicle was in operation, but at zero kilometers per hour, it was not possible to filter out the unnecessary idling. Obtaining second by second data will allow for unnecessary idling to be isolated from all other idling, providing a more accurate unit of analysis.

Conclusions

This study provided a snapshot of driving behaviour for BMR. The data in this study provides a baseline by which BMR can improve upon and compare against once future improvements and eco-driver training sessions have been put in place. There are many ways in which BMR can reduce fleet costs while improving fuel economy and reducing CO_2 emissions.

Identifying the first trip of the day in winter as a key area where unnecessary idling occurs is important for understanding where idling reduction can occur and as such was a key message delivered to staff drivers during their eco-driver training sessions the fall 2010 season. The next steps include installing the CarChips® back into the same vehicles this winter (2010-2011) to assess the effectiveness of the training. The results of this study highlight the opportunities that are available to alter driving behaviour, specifically warm-up times during the first trip of the day. Unnecessary idling is contributing to thousands of kilograms of CO_2 emissions and consuming tens of thousands of dollars in needless fuel consumption. Findings from this project can be used as a key piece of information for other fleet aiming to reduce their CO_2 emissions both within and outside of the tourism industry.

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