Vehicle Monitoring Technology: Quantifying Driver Behaviour and Fuel Consumption Among Ski Resort Fleet

Research Team:

Michelle Rutty[1], Lindsay Matthews[1], and Tania Del Matto[2]
[1] University of Waterloo, Canada
[2] My Sustainable Canada

December 2010

ONTARIO SNOW RESORTS ASSOCIATION

My Sustainable Canada
Make the connection between your purchase and our planet

For inquires into this study, please contact:

My Sustainable Canada
743 Avondale Avenue
Kitchener, ON N2M 2W6
519.886.3699 / info@mysuscan.org
www.MySustainableCanada.org

The authors of this report would like to greatly acknowledge the study participants for their contributions in time and resources:

Bruce Haynes, Ontario Snow Resorts Association
Lindsay Ayers, Blue Mountain Resorts Limited
Martin Kimble and Dennis Nesbitt, Horseshoe Resort
Gene Matthews and Fred Finn, Glen Eden Ski and Snowboard Centre
Dr. Jean Andrey, University of Waterloo

We also would like to acknowledge the funding received, without which this study would not have been possible:

Natural Resources Canada
MITACs Accelerate
YMCA Eco Internship Program

Disclaimer

The findings of this study are a result of the research conducted and do not reflect the specific opinions of the study participants or the funders of this study.

Table of Contents

Introduction....4
Research Goals....4
Context 5
Method....5
Results 7
Limitations....10
Applicability: Ontario Snow Resorts Association 10
Moving Forward 11
Acknowledgements 11

Introduction

Winter tourism has been consistently identified as highly vulnerable to climate change. Projected decreases in natural snow availability due to warmer temperatures may lead to a range of impacts on this multi-billion dollar sector in Canada, including decreased season length, increased operating costs for snowmaking, as well as reduced visitation, and associated revenue and job losses. Global mean concentrations of the greenhouse gas carbon dioxide (CO_2), which results primarily from the burning of fossil fuels, is one of the largest contributors (75%) to current radiative forcing (a concept used for quantitative comparisons of the strength of human agents in causing climate change) (Forster et al. 2007). The passion many Canadians have for skiing and snowboarding and the climate conditions needed to enjoy this mass tourism product, presents an innovative avenue to raise awareness of this vulnerability and foster sustainable behavioural changes that can reduce CO_2 emissions and climate altering impacts.

Recognizing the dependence of winter sports on the natural ecosystem and the potential impacts of climate change within it, interest among members of the Ontario Snow Resort Association (OSRA) to reduce engine idling practices at ski resorts has been raised. During the 2008-2009 ski season, the Engine Idling Reduction Program was launched, reaching over 126,000 visiting drivers and guests, resulting in CO_2 emissions reductions at Ontario resorts between 6 and 49%. This past year (2009-2010 ski season) the focus on emissions reductions was turned inward, with members seeking opportunities to reduce unnecessary idling within their own fleet of on-resort vehicles. As a result, this research project was developed.

By demonstrating the usefulness of in-vehicle engine monitoring technology, this project will emphasize the potential to successfully reduce CO_2 emissions that are generated by the operation of a ski resort fleet in Ontario, Canada. Baseline data was acquired on driving behaviour and engine idling to assess opportunities to achieve increased fuel efficiency and emissions reductions through the adoption of eco-driver training. Best practices from this project will be used as a model for additional ski resort operations, with the aim of improving the industry's environmental performance throughout Canada. This is the first known study to quantify the relationship between the economic and environmental impacts of driver behaviour within a tourism setting, and represents a novel means for ski resort operations to enhance their environmental and economic sustainability through a measurable reduction in harmful vehicle emissions.

Research Goals

1. Acquire baseline data on the following driver behaviour parameters: trip duration, frequency and distance; hard acceleration and deceleration events; speed; idling time; fuel consumption; and CO_2 emissions
2. Monitor and quantify driver behaviour in fleet vehicles that perform a range of duties across a ski resort. Departments examined included: passenger shuttles, security, grounds and maintenance, food and beverage, and mail delivery.
3. Based on the results of the aforementioned points, assess opportunities (by driver and department) to reduce climate altering CO_2 emissions that result from the operation of a ski resort fleet.
4. Identify best practices associated with the use of on-board vehicle monitoring devices.

Context

Road transport forms an important component of greenhouse gas emissions in Canada, with vehicle use, fuel consumption and its associated CO_2 emissions projected to increase well into the future (Beusen et al. 2009, International Energy Agency 2005, Saboohi & Farzaneh 2009). Reducing fuel consumption by educating drivers on how to change their driving behaviour has great potential to be a cost-efficient approach to reducing energy use, improving the quality of the local environment and lowering fuel costs. Ecological, economical and safe driving (eco-driving) is a relatively new concept which was first developed and integrated into driver training courses by the German Federation of Driving Instructor Associations in the mid-1990s (Dandrea 1996). There are three key facets that govern eco-driving. (1) Smooth and gradual acceleration and deceleration. Driving based on sudden acceleration/deceleration uses approximately 33-40% more fuel (Ericsson 2001, NRCan 2009a, Saboohi & Farzaneh 2009, Thew 2007). (2) Maintaining a steady speed by anticipating traffic flow while adhering to the posted speed limits. While each vehicle reaches its optimal fuel economy at different speeds, fuel efficiency decreases 10-23% at speeds above 90 kilometers per hour (60 miles per hour) (NRCan 2009a, West et al. 1999). (3) Avoid idling by turning off the engine when not in use. Idling is the most inefficient use of fuel at zero kilometers per liter of gas. More than 10 seconds of idling consumes more fuel than would have been used if the engine was turned off and restarted (NRCan 2009b).

Although there are very limited studies that have evaluated eco-trained drivers, the results are promising. A literature review for the European Conference of Ministers of Transport by the International Energy Agency (2005) found an average estimated reduction of fuel consumption of 5% for OECD (Organization for Economic Cooperation and Development) regions. Since then, additional studies have recorded 2% decrease in fuel consumption 12 months after corporate bus drivers were trained (Wahlberg 2007). Zarkadoula et al. (2007) noted a decrease of 18% for two bus drivers and an average decrease of 10% for all bus drivers during a post-training monitoring period of two months. Beusen et al. (2009) stated average fuel consumption four months after the course fell 5%, with most drivers showing an immediate improvement in fuel consumption. This is also the only known study that details the influence of eco-driver training on idling, which realized an average decrease of 1.5%.

Fostering behaviour change is central to achieving sustainability (Schmuck & Vlek 2003, Butler 1999, Bramwell et al. 1996) and individuals and businesses must be encouraged to engage in an array of activities, such as altering transportation habits. In order to quantify the potential benefits of eco-driver training towards improving resort sustainability, baseline data was acquired prior to the behavioural intervention. As part of a three step process (pre-eco-driver training; eco-driver training; post-eco-driver training), this paper highlights the results of the first phase. This project pioneers the use of vehicle monitoring technology within a tourism context to assess opportunities to harness eco-driver training to improve fuel efficiency and emissions reductions associated with the operation of a fleet of vehicles at a ski resort. This model holds promise for extension into other ski resorts in Canada, as well as other nations and types of tourism destinations.

Method

Blue Mountain Resorts Limited (BMR), Glen Eden Ski and Snowboarding Centre (GE) and Horseshoe Resort (HS) were chosen as the sites to launch this research. The first phase of the project began in December 2009 with the programming and installation of on-board data loggers (CarChip®) into 22 light and medium class fleet vehicles (BMR 14; GE 3; HS 5). The relatively small device (4cm x 5cm x 3cm) was installed out of sight of the driver by plugging the device into the On-board Diagnostic (OBD) port found under the dashboard. The research team documented the vehicle year, manufacturer and model, engine size and fuel type for each vehicle. Unfortunately not all of the vehicle details were available from management staff at GE and HS. In those cases where information is missing and an estimation was made (e.g., engine size) a note has been indicated in the individual vehicle summary of analysis (see appendix).

Table 1. Vehicle Details

Resort Vehicle #	Year	CarChip® #	Fuel Type	Vehicle Manufacturer & Model	Engine Size	Department
01	1999	10013	Diesel	Ford E450 Bus	7.3	Shuttles
10	2008	10016	Unleaded	Honda Fit	1.5	IT
11	2007	10001	Unleaded	Toyota Tundra	4.7	Operations
18	1998	10009	Unleaded	Ford 250 4x4	4.6	Grounds
26	2005	10012	Diesel	Ford Senator 24-passenger	6	Shuttles
31	2000	10015	Unleaded	Dodge Caravan	3	Security
32	2010	10003	Unleaded	Toyota Yaris	1.5	Accounting
36	1997	10010	Unleaded	GMC Pick-up	5	Grounds
39	1999	10005	Unleaded	Chevrolet Venture Van	3.4	IT
60	2002	10002	Unleaded	Ford F150	5.4	Operations
63	2002	10014	Unleaded	GMC Safari Van	4.3	Security
66	2000	10006	Unleaded	Chevrolet Van	5.7	Grounds
70	2004	10007	Unleaded	GMC Sierra	5.4	Grounds
89	1995	10011	Diesel	Ford CTV Bus	7.5	Shuttles
32	N/A	20006	Unleaded	Ford 450 dump truck	4.7	Grounds
97	N/A	10001	Unleaded	Chevrolet Truck	4.7	Grounds
99	N/A	20002	Unleaded	Dodge Ram 2500	4.7	Grounds
310	2009	20007	Diesel	GMC 2500	6.6	Delivery
315	2008	20001	Unleaded	GMC Sierra	6	Multi-use
336	2009	20003	Unleaded	GMC Sierra	6	Multi-use
337	2010	20002	Unleaded	GMC Sierra	6	Security
340	2010	20008	Unleaded	GMC Terrain	2.4	Personal

Once installed, the CarChip®, while not interfering with the engine management system, continuously reads the driving and engine performance data from the vehicle's on-board computers and stores the data on an internal memory card. Selected parameters were recorded based on their perceived relevance for future eco-driver training, focusing on environmental performance and fuel consumption. These included the number of daily trips, average and total daily trip times, average and total trip distance, average trip speed, top trip speed, trip time over 110 kilometers per hour, idling time and the total number of accelerations and decelerations per trip. Table 2 presents an overview of the parameters, their units, corresponding abbreviations, and a description including how the parameter was calculated.

The CarChips® were removed from each vehicle bi-weekly and the data was downloaded using a universal serial bus (USB) cable. The CarChip® memories were then cleared, reprogrammed and reinstalled into the corresponding vehicle to continue data logging. Data was recorded for the duration of the season, with the devices removed in April 2010. DriveRight Fleet Management Software Package was used in conjunction with Microsoft Excel, to view, analyze and calculate the data at varying degrees of detail.

Table 2. Variables Monitored and Calculated

Parameter	Denotation	Description
Drive Time (hh:mm)	Dv_Tm	Total time the vehicle is driven
Distance Driven (km)	Tl_Dst	Total distance travelled
Average Trip Distance (km)	Av_Dst	Average distanced travelled
Time over 110km/h (hh:mm)	Tm_Ov	Time travelled with speeds over 110km/hr
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	Idl	When the vehicle engine is turned on, but not moving (speed = 0 km/h)
Idling Time (hh:mm)	Idl_Tm	Total amount of time the vehicle is idling
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[1]
Fuel Consumed from Idling (L)	Fuel_Idl	Litres of fuel consumed while the vehicle is idling[2]
Fuel Cost from Idling ($CAD)	Cost_Idl	Cost of fuel consumed from idling[3]

Results

Each resort was provided with detailed summaries that outlined the results of each vehicle that participated in the study (see appendix). Analysis included trip summaries (e.g., frequency and duration), driving summaries (e.g., duration, distance, speed, accelerations/deceleration counts), summary of the vehicle's fuel consumption and environmental performance (e.g., idling time, CO_2 emissions, fuel consumption, fuel costs from idling), and the comparative standing of the each vehicle in relation to the other fleet vehicles at the resort. A detailed summary of daily trip information, in addition to a list of recommended behavioural changes to improve environmental and safety performance were also provided. An overview of the daily averages and totals for both individual vehicles and the summation of results by resort fleet are provided in

[1] 2.289 kg/CO_2/L of gas and 2.663 kg/CO_2/L of diesel (Environment Canada, 2008).
[2] Idling time*fuel flow*60, with fuel flow = engine size* 0.6 / 60 (Environment Canada, 2008).
[3] Fuel consumed from idling*price of fuel (CAD$0.78/L, as per BMR onsite pricing).

Table 3.

Across the recorded parameters it is evident that the range of variation among the vehicles is quite large, particularly with regard to those associated with trip and driving summaries. Within these parameters, total drive time per day varies between 17 minutes to over 11 hours, with total distance varying between 9 and over 240 kilometers per day and average trip distance between 1 and 27 kilometers. Much of this variation is due to the function that each fleet vehicle performs at the resort. Moreover, speeds vary substantially across the sample of vehicles because some vehicles are required to stay on resort (maximum posted speed limits of 40km/h and 60km/h) compared to others that leave the resort and drive on highways (maximum posted speed limit of 80km/h and 100km/h).

However, variation amongst parameters that are of particular relevance for eco-driver training (speed, acceleration, deceleration, idling) are much smaller. It is among these parameters that it becomes increasingly clear that opportunities can be sought to introduce behavioural driving changes that can reduce fuel consumption and limit harmful idling emissions. For example, of those vehicles that were driven off-resort and thereby driven at speeds equal to or greater than 110km per hour (vehicles 10, 11, 32 and 60 at BMR; 32 and 97 at GE; all at HS), decreases fuel efficiency up to 23% (NRCan 2009a, West et al. 1999). Further opportunities to improve the economic and environmental performance across the sample of fleet vehicles include reducing the number of daily hard accelerations (52.5) and hard decelerations (75.8), which uses approximately 33-40% more fuel than if the driver accelerated and decelerated gradually (Ericsson 2001, NRCan 2009a, Saboohi & Farzaneh 2009, Thew 2007). Idling is another driving behaviour that can be addressed, as when the vehicles engines were turned on, they idled for more than 34% of the time at BMR, 43% at GE and 27% at HS. This leads to an average daily total of more than 172kg of CO_2, and consumes over 70L of fuel across the fleet studied among the 3 ski resorts. For four of the vehicles at BMR, the first trip of the day was responsible for 23 to 42% of total idling time and thereby a significant amount of emissions and unnecessary fuel consumption. This presents an interesting avenue through which to target idling reduction, debunking the common myth that idling is an effective way to warm up your vehicle as studies from Environment Canada (2008) reveal the best way is in fact to drive it.

The average operating season for a ski resort in Ontario is 100 days between the months of December and March, depending on weather. Based on the average daily totals, this equates to over 17 000 kg of CO_2 emissions, and more than 7000L of fuel or nearly $5,400 per season from idling, in addition to the extra emissions and fuel consumed from speeding and hard acceleration/decelerations. If these numbers were to be extrapolated beyond just those vehicles sampled in this study to the entire fleet at just these three resorts, thousands of kilograms of emissions would be released, with tens of thousands of dollars wasted. For example, the BMR ski resort fleet (55 vehicles), assuming average daily totals remained the same across the operating season, idling would emit in excess of 42 000 kg of CO_2, which is the equivalent of more than 16,000L of fuel priced at nearly $13,000 (or approximately 24% of BMR total fuel consumption). Looking at these results, the opportunities available to improve the environmental and economic performance of ski resort fleets become increasingly apparent.

Table 3. Daily Average and Daily Totals by Parameter and Resort

Vehicle	Dv_Tm	Tl_Dst	Av_Dst	Tm_Ov	Accel	Decel	Idl_Tm	Idl%	CO_2_Em	Fuel_Idl	Cost_Idl
Blue Mountain Resorts Limited											
01	9:47	199	25	0	0.7	7.2	2:41	28	31.4	11.8	9.18
10	0:31	21	4	1:27	1	0.6	0:05	17	0.2	0.1	0.06
11	1:29	62	7	0:40	1	1	0:21	24	2.3	1	0.78
18	2:46	39	2	0	3	2.6	1:21	49	2.6	3.8	2.93
26	11:37	248	27	0	0.6	4.6	2:54	25	15.3	5.7	4.47
31	4:27	79	3	0	9.1	10.3	1:33	35	6.4	2.8	2.18
32	2:45	72	2	0:02	0.7	2.2	0:41	25	1.4	0.6	0.49
36	3:31	29	2	0	0.6	1	2:18	65	15.8	6.9	5.37
39	0:17	9	2	0	2	0.6	0:04	23	0.3	0.1	0.11
60	1:18	61	8	0:38	2.5	1.4	0:14	19	1.8	0.8	0.62
63	2:41	38	3	0	9.5	11.7	1:13	45	7.2	3.1	2.44
66	1:09	26	2	0	6.9	4.3	0:20	29	2.6	1.2	0.9
70	2:56	38	2	0	6.9	3.1	1:27	50	10.8	4.7	3.69
89	6:14	102	19	0	0.2	8.4	2:38	42	31.7	11.9	9.27
Daily Average	3:40	73	8	0:15	3.2	4.2	1:16	34	9.7	3.9	3.03
Daily Total	51:30	1022	-	2:07	44.8	58.9	17:89	-	135.7	54.5	41.48
Glen Eden Ski and Snowboard Club											
32	1:31	19	3	0:09	1.6	3.1	0:44	48	6.9	3.0	2.35
97	1:27	38	1	0:50	1.2	1.8	0:30	34	2.4	1.1	0.82
99	2:03	21	1	0:00	1.7	3.2	0:58	47	7.6	3.3	2.59
Daily Average	1:54	26	2	0:20	1.5	2.7	0:44	43	5.6	2.5	1.92
Daily Total	4:61	78	-	0:59	4.5	8.1	1:32	-	16.9	7.4	5.76
Horseshoe Resort											
310	2:46	114	7	1:41	0.8	1.6	0:56	34	8.5	3.7	2.91
315	0:39	16	1	0:17	0.4	0.4	0:14	37	1.6	0.7	0.54
336	2:20	125	9	3:02	0.8	1.7	0:25	18	2.8	1.2	0.94
337	2:33	68	2	0:42	0.7	2.2	0:50	33	5.5	2.4	1.89
340	2:16	135	12	2:08	0.5	2.9	0:18	14	1.0	0.4	0.35
Daily Average	1:91	92	6	1:42	0.6	1.8	0:33	27	3.9	1.7	1.30
Daily Total	9:54	458	-	7:10	3.2	8.8	1:63	-	19.4	8.4	6.60
Summation of results across all three resorts											
Daily Average[4]	2:28	64	5	1:77	1.8	2.9	0:64	35	6.4	2.7	2.08
Daily Total[5]	65:45	1558	-	9:76	52.5	75.8	20:84	-	172	70.3	53.84

[4] Daily average of each resort/3

[5] The sum of all three resorts' daily total

Limitations

There are two key limitations of the CarChip® as they are applied in this study. The first relates to idling. There are three circumstances in which individuals may idle their vehicle, including to warm the engine, waiting for something unrelated to traffic (e.g., a passenger), and while commuting (e.g., at a stop sign, traffic lights, railway crossing) (Carrico et al. 2009). This latter idling circumstance is difficult to avoid for functional and safety purposes and can therefore be deemed necessary idling and should not be included in the daily average and total idling time. Unfortunately the CarChip® quantified idling at every point when a vehicle was at zero kilometers per hour. In recognition of this limitation, phase three of this study (post-eco-driver training data collection) will collect second by second data and calculate those circumstances when the vehicle is idling for 60[6] seconds or less as necessary idling, thereby removing these circumstances from the daily averages and totals.

The second limitation is the inability to calculate specific fuel consumption and CO_2 emissions for the parameters of speed, hard acceleration and hard deceleration. The CarChips® are not programmed to measure the exact degree of speeding, but rather to identify the duration of speeds over 110 kilometers per hour. Without such data, the precise decrease in fuel efficiency cannot be arrived at. This is similar for the acceleration and deceleration parameters, to which the CarChip® is unable to capture precise data on the speed and time difference at which the incident occurred. Although this data would be helpful, value remains in identifying the frequency of their occurrence as behavioural changes can target the reduction of these events.

Applicability: Ontario Snow Resorts Association

This report was compiled for the Ontario Snow Resorts Association (OSRA), which is the voice for the Ontario snow resort industry. With over 63 alpine and nordic snow resort members, this practical information on best practices for snow resort owners and operators can have a positive and wide reaching influence on the environmental sustainability of the industry in Ontario. This project provided tangible results to OSRA that can be used to inform its members on how driver behavior can significantly influence both the environmental and economic performance of each resort.

Key benefits included:

- Providing the first insight into the quantity of both fuel consumed and greenhouse gases emitted as a result of idling vehicles within a ski resort fleet.
- Identification of potential fuel savings and emissions reductions that can be achieved through the adoption of eco-driver training.
- Access to a report with comprehensive and individualized results (by driver and department) that can inform the effective use of vehicle monitoring technology as a means to improve operational efficiency, safety and environmental performance.

[6] Idling for 60 seconds or greater has been identified by NRCan as unnecessary idling (NRCan 2008).

Moving Forward

The results of this study highlight the opportunities that are available to alter driving behaviour that is leading to thousands of kilograms of CO_2 emissions and consuming tens of thousands of dollars in unnecessary fuel consumption. Eco-driver training courses, based on the assessments and opportunities identified through this project, are being delivered to fleet drivers throughout autumn (November-December 2010). Results from this project are being incorporated into the courses, tailoring the curriculum to focus on those parameters where the drivers were the most inefficient. In order to assess the effectiveness of this training on driver behaviour, the next data collection phase will aim to install the CarChips® back into the same vehicles in preparation for the upcoming ski season (winter 2010-2011). Once the data is downloaded and analyzed, it is hoped that the eco-driver training will reveal an improvement in the environmental and economic performance.

Immediate plans also include communicating the results within the ski industry through the OSRA annual general meeting and fall education week, to the academic community, as well as to decision makers from government and NGOs through journals and conferences in the fields of Geography, Tourism-Leisure Studies, Transportation, and Climate Change Vulnerability.

Acknowledgements

We wish to thank the participating resorts for making staff time available for the conducting of data collection and meetings at Blue Mountain Resorts Limited, Glen Eden Ski and Snowboard Centre and Horseshoe Resort. Sincerest gratitude is extended to Dr. Jean Andrey for her in-kind support and feedback that was provided throughout this research project. Financial support by the MITACs Accelerate Program, Natural Resources Canada and the Ontario Snow Resorts Association is also gratefully acknowledged.