Reduction in Vehicle Idling Emissions Using RFID Parking Permits

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This project analyzed emissions savings as a result of converting UW-Madison parking ramp permits from magnetic stripe (Magstripe) cards to RFID-enabled hanging permits. Radio Frequency Identification permits (RFID) allow drivers to remain in their vehicles without coming to a complete stop while entering a parking ramp or garage, whereas Magstripe cards require a driver to stop and reach out their window to swipe the card for access. The reduced entry and exit time from this conversion to RFID equates to shorter vehicle queues, lower idling time and, ultimately, lower fuel consumption and vehicle emissions.

RFID Background

RFID tags contain electronically stored data that can be read wirelessly by scanners. For the purposes of RFID implanted into parking permits, this stored data contains an access number for a designated parking garage or ramp. When a vehicle has this tag displayed near the entrance or exit of the parking structure, an RFID antenna scans the tag and sends the information to a database for verification. Once verification is accepted, the gate is opened and the vehicle can pass through. A typical setup can be seen in Figure 1.

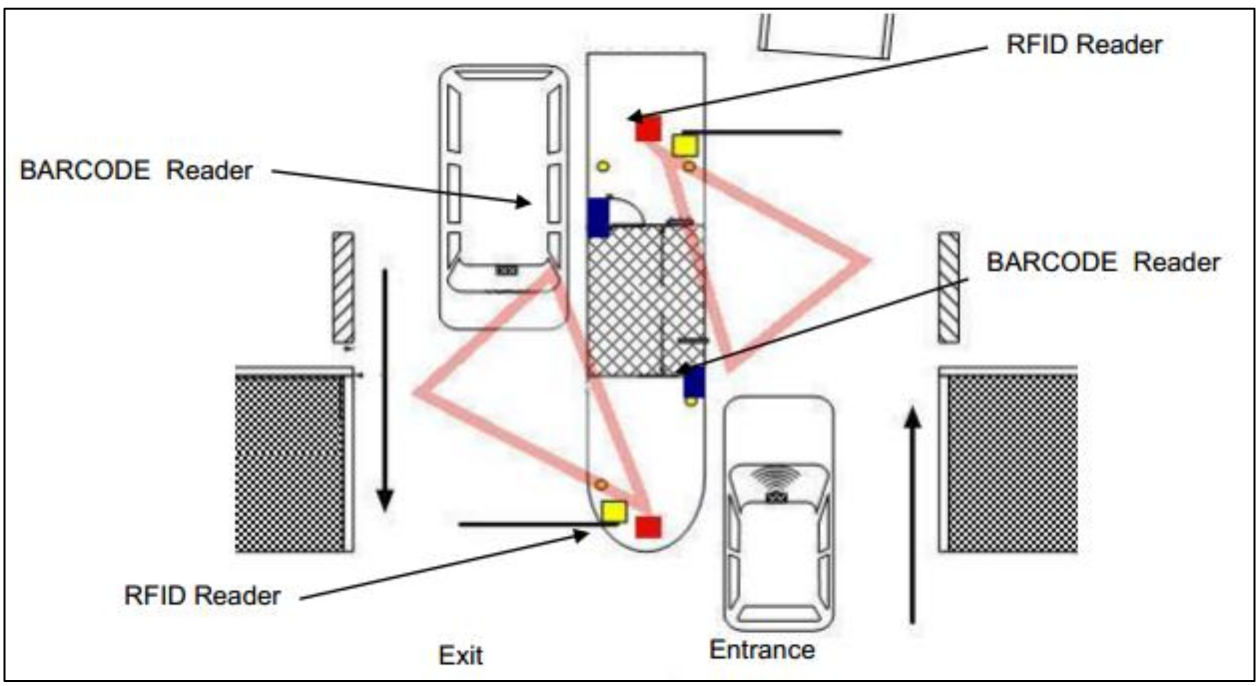

Figure 1. Automated Parking Ramp Access Setup

RFID tags increase convenience for permit holders while controlling cost. RFID systems are more flexible in their installation and require less maintenance compared to magnetic strip systems. The increased complexity of an RFID tag causes a slight increase in per-permit cost, but also decreases the possibility of fraud. This higher per-permit cost is expected to decrease as the technology is further developed and produced.

Tools and Methods

To complete this analysis, various tools and personnel were utilized. Table 1 displays idling emissions statistics from the U.S EPA that were used to determine the amount of carbon monoxide (CO), carbon dioxide, volatile organic compounds (VOCs), nitrogen oxides (NOx), total hydrocarbons (THC), and particulate matter (both $PM_{2.5}$ and PM_{10}) emitted during a vehicle's entrance and exit from parking ramps.

Table 1. Average Idle Emission Rates by Pollutant and Vehicle Type

Pollutant	Units	LDGV	LDGT	HDGV	LDDV	LDDT	HDDV	MC
VOC	g/hr g/min	2.683 0.045	4.043 0.067	6.495 0.108	1.373 0.023	2.720 0.045	3.455 0.058	19.153 0.319
THC	g/hr g/min	3.163 0.053	4.838 0.081	7.260 0.121	1.353 0.023	2.680 0.045	3.503 0.058	21.115 0.352
CO	g/hr g/min	71.225 1.187	72.725 1.212	151.900 2.532	7.018 0.117	5.853 0.098	25.628 0.427	301.075 5.018
NOx	g/hr g/min	3.515 0.059	4.065 0.068	5.330 0.089	2.690 0.045	3.705 0.062	33.763 0.563	1.625 0.027
$PM_{2.5}$	g/hr g/min	N/A[1] N/A[1]	N/A[1] N/A[1]	N/A[1] N/A[1]	N/A[1] N/A[1]	N/A[1] N/A[1]	1.100 0.018	N/A[1] N/A[1]
PM_{10}	g/hr g/min	N/A[1] N/A[1]	N/A[1] N/A[1]	N/A[1] N/A[1]	N/A[1] N/A[1]	N/A[1] N/A[1]	1.196 0.020	N/A[1] N/A[1]

The emission rates of CO, CO_2, VOC, and NOx were then used to determine the total amount of emissions per entrance or exit period, which will be hereafter referred to as a service interval. The vehicle type analyzed for this project was Light Duty Gasoline-fueled Vehicles (LDGV). Other vehicles presented in the table, but were not used in this report include:

- Light Duty Gasoline-fueled Trucks (LDGT)
- Heavy Duty Gasoline-fueled Vehicles (HDGV)
- Light Duty Diesel Vehicles (LDDV)
- Light Duty Diesel Trucks (LDDT)
- Heavy Duty Diesel Vehicles (HDDV)

- Motorcycles (MC)

The University's Transportation Services was able to provide data for entry and exit logs of vehicles in Lot 17 on campus. These data logs were compared to video footage at the lot used to compare service intervals for both Magstripe and RFID users. The observed service intervals for both types of permits allowed a threshold interarrival time to be determined for use in a queue analysis. A queue analysis involves creating a model to predict queue lengths and waiting times. Such an analysis was necessary due to the vastly different waiting times a lot user could experience based on their arrival time. Figures 2 and 3 demonstrate the peak service hours for the entrances and exits of Lot 17 respectively.

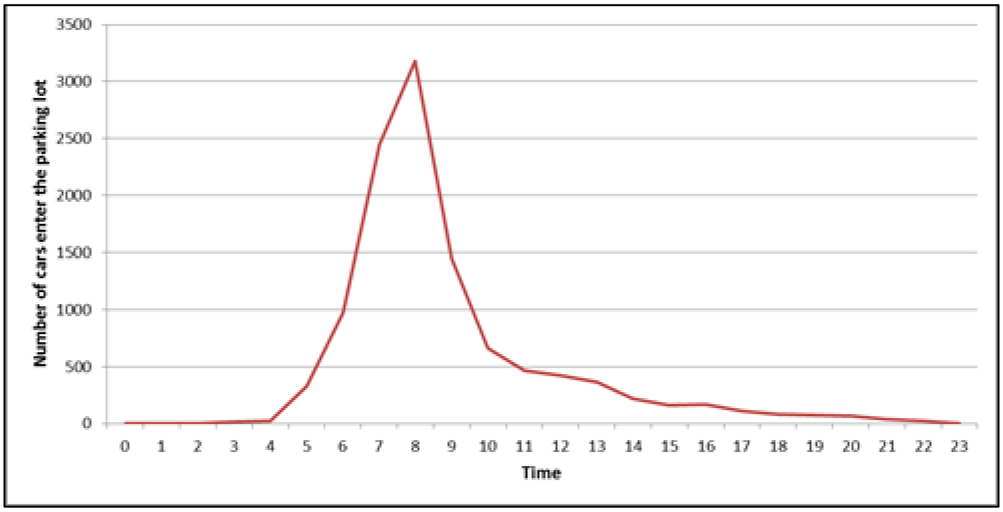

Figure 2. 24 Hour Distribution of Vehicles Entering Lot 17 Entrance 9 (Aug. 2012-April 2013 Average)

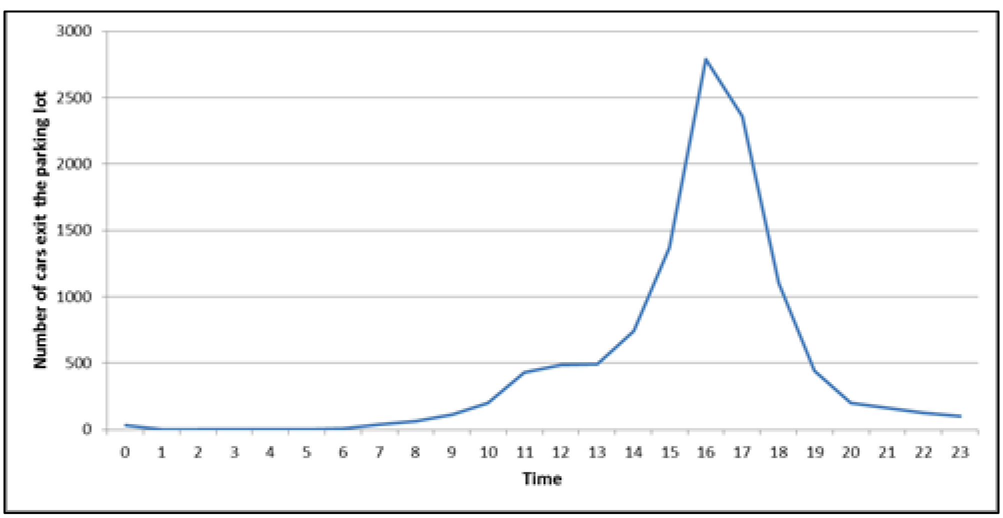

Figure 3. 24 Hour Distribution of Vehicles Exiting Lot 17 Exit 11 (Aug. 2012-April 2013 Average)

Time stamps from the data logs of entries and exits from Lot 17, allowed for interarrival times to be calculated. The queue analysis was set up so that interarrival times of less than 8 seconds would be considered a queue for RFID and interarrival times of less than 13 seconds would be considered a queue for Magstripe. A sample of data collected and its analysis can be seen in Table 2.

Table 2. Sample Queue Analysis

Entry Time	Interarrival Time (second)	Determine RFID Queue	RFID Queue Size	Determine Magstripe Queue	Magstripe Queue Size
7:34:02 AM	20	0	1	0	1
7:34:11 AM	9	0	1	1	2
7:34:17 AM	6	1	2	1	3
7:34:24 AM	7	1	3	1	4
7:34:31 AM	7	1	4	1	5
7:34:36 AM	5	1	5	1	6
7:34:57 AM	21	0	1	0	1
7:35:14 AM	17	0	1	0	1
7:35:37 AM	23	0	1	0	1
7:35:43 AM	6	1	2	1	2
7:36:04 AM	21	0	1	0	1
7:38:03 AM	119	0	1	0	1
7:38:09 AM	6	1	2	1	2
7:38:19 AM	10	0	1	1	3
7:39:10 AM	51	0	1	0	1
7:39:18 AM	8	1	2	1	2
7:39:25 AM	7	1	3	1	3
7:39:31 AM	6	1	4	1	4
7:39:41 AM	10	0	1	1	5
7:39:49 AM	8	1	2	1	6
7:40:16 AM	27	0	1	0	1
7:41:26 AM	70	0	1	0	1

When a queue exists for either permit system, an additional service interval is added for each additional vehicle in the queue because every vehicle behind the foremost vehicle must idle the equivalent amount of time as that foremost vehicle. For example, a queue of 2 vehicles would total to 3 service intervals and a queue of 5 vehicles would total to 15 service intervals as can be seen in the vehicles from 7:34:11 7:34:36 for an RFID queue.

Assumptions used in the data collection and analysis, are listed below:

- Flex permits are used 20% as often as regular permits
- Each permit holder makes only one entrance and one exit per day
- All vehicles have similar emissions rates
- Permit holders are not delayed by other vehicles using public parking
- Data from Lot 17 is applicable to all other UW –Madison campus RFID lots

Results and Evaluation

Total service intervals for Monday through Friday during the months of August 2012 through April 2013 (Fall semester through Spring semester) were summed and adjusted to be displayed as emissions savings per vehicle. The University currently has 4,893 base lot permit owners and 1,218 flex permit holders that utilize RFID. Flex permits are for users who commonly commute using public transportation or walk/bike and only need to have parking access occasionally. This number of regular and flex permits multiplied by the EPA idling emissions rates in addition to the time saved by switching to RFID permits yielded the emissions reductions seen in Table 3.

Table 3. Idling Emissions Reductions from Conversion to RFID

VOC (g)	CO (g)	NOx (g)	CO_2 (g)
12,075	381,514	15,831	9,962,506

When these values are used with the EPA's Greenhouse Gas Equivalency Calculator[1], the resulting savings in carbon dioxide equivalent is 14.9 metric tons. This reduction in emissions equates to the emissions from 1,667 gallons of gasoline or the carbon sequestered annually by 12.2 acres of U.S forest.

These results were compared to results seen by TransCore; a company that specializes in RFID tag use in transportation. According to TransCore's carbon calculator[2], 6,604 kg of CO_2 would be saved in a scenario similar to this project using TransCore products on an annual basis. This amount of savings validates and compares well with the currently implemented RFID technology at campus ramps and garages, which causes a savings of 9,963 kg of CO_2 per fall and spring semester combined.

The daily time savings of roughly ten seconds per vehicle amounts to almost 2,012 hours saved every fall and spring semester combined for all campus RFID parking ramps. This annual reduction in idling time over the course of the fall and spring semesters allows for the reduced fuel consumption of over 1,600 gallons of gasoline and the collective financial savings of over $6,000 for all permit holders combined.

Summary

Parking ramps and garages on the UW-Madison campus are able to significantly reduce idling time at gates by switching from Magstripe permits to RFID permits. This reduction in idling equates to the elimination of 12.2 metric tons of carbon dioxide equivalent per fall and spring semester combined. Permit users don't directly see this reduction, but may experience decreased waiting times for lot entry and exit, lowered fuel consumption, and increased comfort and safety due to the elimination of the need to roll down windows when entering or exiting a ramp. RFID is a convenient technology that has positively affected parking at University lots and will see continued use and implementation in the future.

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[1] http://www.epa.gov/cleanenergy/energy-resources/calculator.html#results
[2] http://www.transcore.com/carboncalculator/carboncalculator.html

References

Idling Vehicle Emissions for Passenger Cars, Light-Duty Trucks, and Heavy Duty Trucks, EPA report 420f08025, 2008