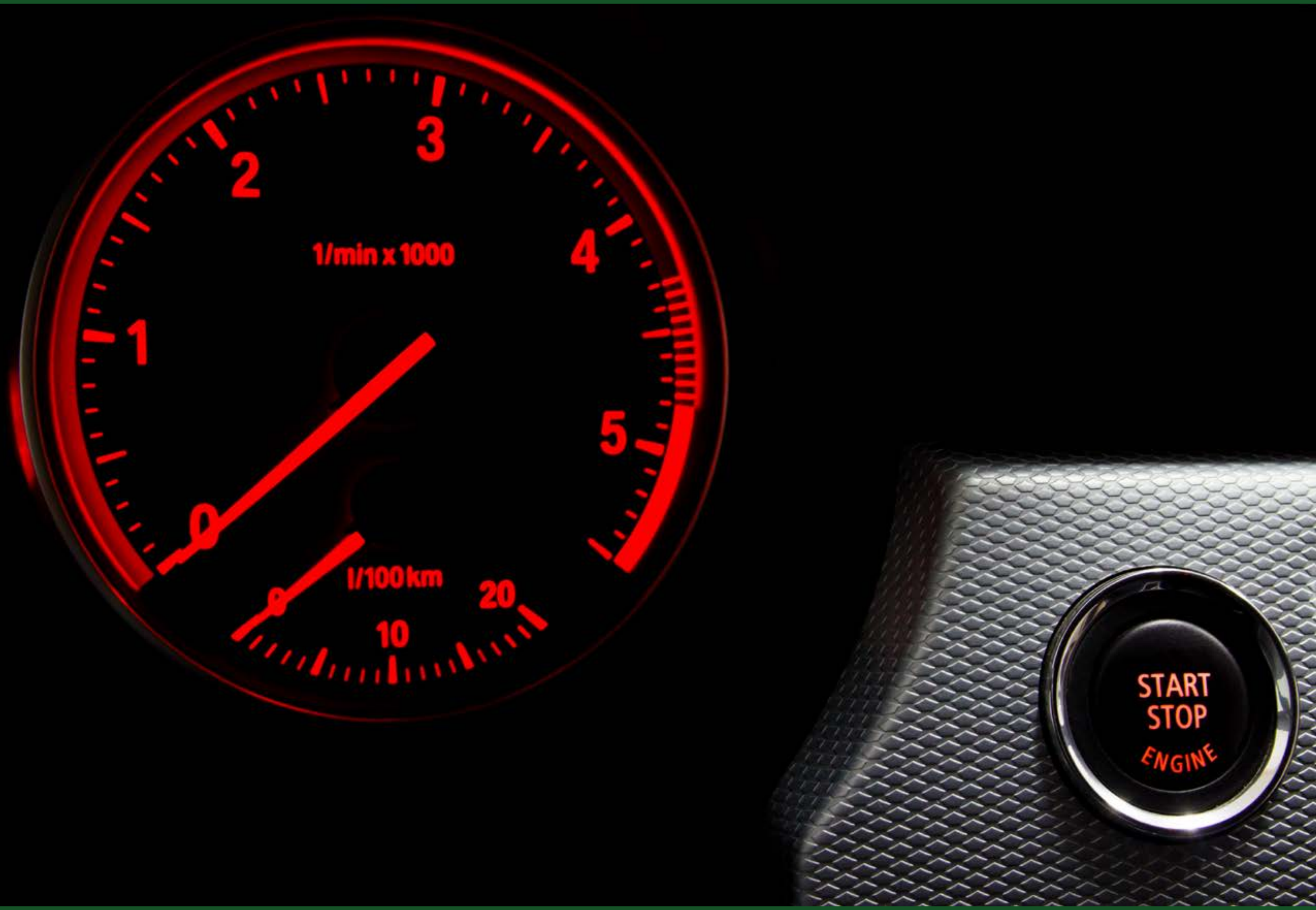
Anti-Idling Technology on Fire Service Vehicles:

An Evaluation of the Benefits



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BC INJURY research and prevention unit

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Executive Summary

This study was designed to support the anti-idling policies of Surrey Fire Service. Two major components were the adoption of fire trucks with Auxiliary Power Units (APUs) and changing behavioural attitudes towards turning off the main fire truck engine whenever possible. As such, the first component of the study aimed to determine the value of APUs. Specifically, to estimate the idle time, cost, and greenhouse gas emissions reduced by APU use. The second component of the study aimed to find determinants of unnecessary idling by examining whether idle times were associated with engine type, distance travelled per incident, number of incidents, firefighter crew, and incident type.

Eleven fire trucks were involved in the study - three were equipped with Smeal SG-09 *"Green Power"* APUs and eight without. The fire trucks responded to a total of 2,236 incidents during the study period from May 1, 2018 to June 4, 2018. Overall, the fire truck engines were engaged for 89.4 hours on average, with idle time making up 41.9% (95% CI: 36.2 – 47.5) of total engine time. APUs were found to reduce idle time by 36.4% (95% CI: 19.7 – 53.0), while providing annual fuel savings of $208.14 (95% CI: 82.18 – 334.10), increased maintenance costs of $1.58 (95% CI: 0.75 – 2.41), and reduced total engine use by 15.0% (95% CI: 6.5 – 23.5).

Taking the full extension of fire truck service life into account, APUs provided annual savings of $4,136.23 (95% CI: 2,050.43 – 6,222.02), and corresponded to a payback period of 20.35 years (95% CI: 20.26 – 20.44) for the $15,000 APU. When just considering the fuel and maintenance costs, APUs provided savings of $221.26 (95% CI: 87.20 – 355.33) per year, which resulted in a payback period of 67.79 years (95% CI: 42.21 - 172.02). This difference, between considering extension of fire truck service life into account or not, is substantial because fire trucks are very expensive while APUs provided no benefit in terms of maintenance costs saved and only a modest 32% increase in fuel efficiency at the assumed 50% load when compared with the fire truck's main engine. The APUs were also found to reduce greenhouse gas emissions by 420.1 kg (95% CI: 165.9 – 674.3) in CO_2-equivalents per year.

Univariate regression models provided evidence to support the assumption that on-scene time was the main opportunity to reduce unnecessary idling and that there may be differences between crews that affect idling behaviour. Medical and emergency incidents were also found to increase idling, while non-emergency incidents reduced idling.

Overall cost savings and reductions in greenhouse gas emissions support the adoption of APUs for all fire trucks and the evidence suggesting that firefighter crews affect the amount of unnecessary idling supports increased focus on policies promoting anti-idling behaviors. In addition, accuracy and reliability between different measures of idling should be tested in order to determine the best metrics to use for performance tracking, especially when combined with the ability to collect real-time data.

Introduction

ENGINE IDLING

Idling occurs when the engine of a vehicle is running while the vehicle is not in motion. For fire trucks, sources of idling include warming up the engine, waiting in traffic, stand-by periods at emergency scenes, supplying heat or air conditioning, and powering auxiliary equipment, including aerial lifts and safety lights.

While some idling events are unavoidable, such as waiting in traffic, idling is avoidable in other situations, such as leaving the engine running while parked at the scene of an incident. These avoidable instances of idling are considered unnecessary and are undesirable, as they contribute to extra fuel costs, additional emission of greenhouse gases, and the need for more frequent engine maintenance.

ANTI-IDLING TECHNOLOGY

Government organizations, including Fire Services, are increasingly adopting anti-idling policies to help meet financial, environmental, and energy sustainability goals. These benefits include: 1) reduced vehicle fuel costs, reduced maintenance costs, and extension of engine life; 2) reduced emission of greenhouse gases and other pollutants into the atmosphere; and 3) contributing towards the low-carbon goals set by Canada's Federal Sustainable Development Strategy (Environment and Climate Change Canada, 2016).

Anti-idling technology refers to devices that when activated turn off the main engine and provide an alternative source of power for heat, air conditioning, and/or electricity, while the vehicle is temporarily parked (Shancita et al., 2014). One such technology for a heavy-duty fire truck is an auxiliary power unit (APU). Although the APU runs on diesel fuel, its fuel use and emissions of carbon dioxide (CO_2) was found to be 36% to 47% lower when compared to the main engine (Frey & Kuo, 2009). These efficiency savings can add up quickly considering that heavy-duty trucks idle 20% to 40% of the time when the engine is running (Hafiz et al., 2007). Other factors that affect fuel use and emission in heavy-duty vehicles include seasonality, geographic location, vehicle characteristics, payload, engine year, and terrain traveled (Hafiz et al., 2007; Frey & Kuo, 2009; National Research Council of National Academies, 2010; Brodrick et al., 2002).

SURREY FIRE SERVICE

Surrey Fire Service has adopted anti-idling policies to reduce unnecessary idling. Two such policies include equipping APUs on fire trucks and changing behavioural attitudes towards turning off the engine whenever possible.

There are currently three active fire trucks equipped with Smeal SG-09 *"Green Power"* APUs in service. These APU systems cost $15,000 each and, after three minutes of idle time when the fire truck is parked, automatically turn off the truck engine and start the APU. As such, the main opportunity for APU activation, and thus reduction in unnecessary idling, is when the fire truck is parked on-scene.

Surrey Fire Service has previously conducted three preliminary studies on the efficacy of APUs. One was a business case analysis conducted in 2012 on three new APU-equipped fire trucks and found that, on average, idle time made up 57% of the total engine time. APUs were also found to reduce greenhouse gas emissions by 11%, and to provide $3.14 fuel savings per idle hour, which resulted in $2,200 in annual fuel savings and an estimated payback period of 6.8 years on the $15,000 APU. The second study was a three-month trial of the Battalion Chief vehicle, fitted with a basic Anti-Idling Device that used a battery instead of a diesel-powered engine, and resulted in annualized fuel savings of $895. The third study compared APU with non-APU fire trucks and showed that APU-equipped fire trucks reduced engine time by 17% and reduced greenhouse gas emissions by 1.59 metric tons of CO_2-equivalents per year.

PURPOSE AND AIMS

This study was designed to support the anti-idling policies of Surrey Fire Service. In support of adopting APU engines, the first component of the study aimed to determine the value of the APU. Specifically, to estimate the idle time, cost, and greenhouse gas emissions reduced by the APU. In support of changing behavioral attitudes, the second component of the study aimed to find determinants of unnecessary idling by examining whether idle times were associated with engine type, distance travelled per incident, number of incidents, firefighter crew, and incident type.

Methodology

FIRE TRUCKS

Eleven fire trucks were involved in the study (Table 1). Three were equipped with Smeal SG-09 *"Green Power"* APUs and eight without. Three of the non-APU engines were used primarily for rescue operations. All fire trucks were powered by Cummins ISL 9-litre diesel engines, with Spartan Cab & Chassis, and Smeal Apparatus. The trucks varied slightly in year of manufacture and maximum horse power, but were otherwise equivalent, including size, weight, configurations, duty cycles, and load.

TABLE 1: PROPERTIES OF FIRE TRUCKS INCLUDED IN STUDY.

Hall Reference No.	APU Y/N	Chassis Manufacturer	Apparatus Manufacturer	Engine Make	Horse Power	Year
E2	Y	Spartan	Smeal	Cummins ISL	450	2015
E10	Y	Spartan	Smeal	Cummins ISL	450	2015
E13	Y	Spartan	Smeal	Cummins ISL	450	2015
R2	N	Spartan	Smeal	Cummins ISL	425	2011
R4	N	Spartan	Smeal	Cummins ISL	370	2008
R10	N	Spartan	Smeal	Cummins ISL	370	2010
E6	N	Spartan	Smeal	Cummins ISL	425	2011
E11	N	Spartan	Smeal	Cummins ISL	425	2011
E12	N	Spartan	Smeal	Cummins ISL	425	2011
E14	N	Spartan	Smeal	Cummins ISL	450	2012
E15	N	Spartan	Smeal	Cummins ISL	425	2011

DATA COLLECTION

Vehicle and incidence response data from all eleven engines were obtained by Surrey Fire Service between May 1, 2018 and June 4, 2018. Three main datasets were used in the analysis: 1) data extracted from the Engine Computer Management (ECM) system provided main engine data, such as idle hours, idle fuel used, engine hours, and distance traveled; 2) data extracted from the APU clock provided total APU hours; and 3) the Incident Response dataset provided incident and time data, such as number of incidents, firefighter crews, incident types, as well as dispatch, on-route, on-scene, and return times.

VALUE OF APU

Both economic and environmental factors were considered in determining the value of APUs; specifically, the amount of money saved and the amount of greenhouse gases reduced. For both economic and environmental aspects, the most relevant measures were total idle time and fuel usage, estimated using a variety of metrics. ECM provided data on total engine idle fuel usage (idle fuel) and engine idle time (idle time). Total APU time (APU time) was used as an estimate for the total idle time saved by APUs. As each engine differed in the number of incidents responded to, idle time per incident (idle/inc) and idle time per on-scene hour (idle/on scene) were also used as standardized metrics. On-scene time was calculated as the difference between the time the fire truck arrived at, and departed from, the scene of the incident.

Idle time and fuel usage metrics were compared between APU and non-APU fire trucks and were used to calculate annual fuel savings due to APU use. In the scenario where outliers were found in the data, two separate comparisons and calculations were conducted – one with all the fire trucks and another with the outliers removed. These annual fuel saving estimates, calculated from each metric, were then further combined into an overall estimate of fuel saved along with a confidence interval (Wald's 95% confidence interval). The overall annual fuel saved due to APU use was then converted to dollar amounts, for return on investment (ROI) calculations, and CO_2-equivalents, for quantifying reduction in greenhouse gas emissions.

Many factors were considered in order to calculate annual APU savings (Figure 1). These include savings from fuel usage, maintenance costs, carbon tax, and from extending the service life of the fire truck. Fuel savings were calculated as the difference between the fuel saved by the main engine and the fuel cost for the APU. At the time of the study, directly measuring APU fuel usage was not possible as both the main engine and APU draw from the same fuel tank. Therefore, an APU fuel consumption rate of 2.4 L/hr at 50% load was used to estimate APU fuel usage. At Surrey Fire Service, engine maintenance was conducted for every 500 hours of engine use for both the main engine and the APU. Thus, maintenance savings were calculated as the difference between the maintenance costs of the main engine and the maintenance cost of the APU, multiplied by the hours of APU use. The average maintenance costs over the past three years were used, which amounted to $0.43 and $0.44 per engine hour for the main engine and APU, respectively. The current British Columbia carbon tax value of $35 per tonne of CO_2-equivalent was used to calculate carbon tax savings. Although convention dictates a fire truck should have a 20-year service life, there are no compelling reasons why this could not be extended provided tests are conducted to ensure safety and efficacy of the vehicle (Opta, 2017). Cost savings from extending the service life was calculated by multiplying the percent reduction of total engine use as a result of the APU with the fire truck cost of $605,400 (according to the most recent purchase by the City of Surrey) divided by the increased service life of the fire truck. As the service life of a fire truck depends on more than just the engine life, annual savings were calculated with and without this factor. ROI was calculated as the years required to recoup the $15,000 cost for an up-to-date APU with advanced features.

FIGURE 1: FACTORS FOR CALCULATING ANNUAL APU SAVINGS

APU Savings	=	Reduced fuel cost of main engine	-	Fuel cost of APU	+	Reduced carbon tax	+	Reduced main engine maintenance	-	Cost of APU maintenance	+	Extension of service life

Calculation of the environmental value of APU use was straight-forward. An emission factor of 2.630 kg CO_2e/L for heavy-duty vehicles was used to convert the annual fuel saved by APU use into an estimate of greenhouse gas emissions reduced (Ministry of Environment, 2016).

DETERMINANTS OF UNNECESSARY IDLING

Four unique crews operated the eleven vehicles involved in the study and were identified as A, B, C, and D. Similarly, incident types were characterized into four categories: medical, structure, emergency, and non-emergency. To determine whether on-scene times differed between different crews for each incident type, cross-tabulation between crew and incident type for average on-scene time was computed with 95% confidence intervals.

Only the non-APU trucks were included in assessing the determinants of unnecessary idling, as the purpose of the APU is to avoid this situation. Linear regression models were conducted to determine whether idle time was associated with engine type, distance travelled, number of incidents, firefighter crew, and incident type. Idle time per incident (idle/inc) and idle time per on-scene hour (idle/on scene) were used independently as the metrics for idle time and the dependent variable for the regression model. Fire truck type was coded as a binary variable of either Engine or Rescue, whereas distance travelled and number of incidents were coded as continuous variables. Crews and incidents were coded in two different ways: 1) as the proportion of the fire truck's total on-scene time the crew or incident type was responsible for; and 2) as the average on-scene time (in minutes) for the crew or incident type per incident.

Only univariate associations were conducted due to the limited sample size. P-values of less than 0.05 were considered as significant and less than 0.2 were considered as a trend. As the two dependent variables (idle/inc and idle/on scene) in the univariate regression models were closely related, variables were only considered significant and of potential interest for further investigation if they were significant in one and at least a trend in the other regression model.

Results

OVERVIEW

All eleven fire trucks operated normally during the study period from May 1, 2018 to June 4, 2018, responding to a total of 2,236 incidents and were operated by four unique crews. Some variations were expected between the fire trucks, but four potential outliers were found (Table 2). E10 had a much higher than normal idle fuel usage rate, but normal power take-off (PTO) fuel usage rate. R4, on the other hand, had lower idle and PTO fuel usage rates. E12 and E14 responded to fewer incidents and had longer distances per incident, likely contributing to longer idle time per on-scene hour and per incident.

TABLE 2: ECM AND INCIDENT RESPONSE DATA SHOWING FOUR OUTLIERS (IN RED): E10, E12, E14, AND R4.

Truck	APU use	PTO fuel	Idle fuel	PTO rate	Idle rate	Distance	PTO time	Idle time	Engine time	Onscene	Idle/ Onscene	Incidents	Onscene/ Inc	Idle/ Inc	Distance/ Inc	Onscene/ Inc
Unit	hr	L	L	L/hr	L/hr	km	hr	hr	hr	hr	hr	#	hr	hr	km	min
E2	23.7	9.5	101.4	6.06	3.44	2171.5	1.6	29.4	100.9	70.2	0.42	251	0.28	0.12	13.9	16
E10	14.2	12.5	134.8	6.32	5.00	1324.6	2.0	26.9	71.7	55.0	0.49	214	0.26	0.13	10.0	15
E13	8.3	14.0	95.8	6.59	3.71	1800.9	2.1	25.8	88.4	65.3	0.39	245	0.27	0.11	11.8	15
E6	0.0	17.0	161.3	8.03	3.18	1835.0	2.1	50.5	117.6	58.2	0.87	175	0.33	0.29	16.9	19
E11	0.0	11.7	66.6	7.00	3.03	1419.4	1.7	21.9	73.7	58.4	0.38	189	0.31	0.12	12.1	18
E12	0.0	12.5	120.8	8.63	4.05	906.9	1.4	29.9	56.2	27.7	1.08	74	0.37	0.40	19.7	22
E14	0.0	6.8	110.9	7.19	3.52	1771.2	0.9	31.5	78.4	30.2	1.04	105	0.29	0.30	27.1	17
E15	0.0	12.5	103.3	8.40	3.29	1816.6	1.5	31.5	94.6	46.1	0.68	187	0.25	0.17	15.6	14
R2	0.0	14.0	164.3	7.72	3.41	1751.6	1.8	48.5	112.9	73.7	0.66	275	0.27	0.18	10.3	16
R4	0.0	7.6	86.7	5.03	2.91	1445.2	1.5	29.8	82.4	60.4	0.49	231	0.26	0.13	10.1	15
R10	0.0	16.3	124.5	8.18	3.48	1977.1	2.0	35.8	106.9	68.1	0.53	290	0.23	0.12	11.0	14

On average, APUs activated 15.4 hours and APU fire trucks idled an additional 27.4 hours, while non-APU fire trucks idled for 34.9 hours. Overall, the main engine was engaged for an average of 89.4 hours, resulting in the idle time making up 41.9% (95% CI: 36.2 – 47.5) of total engine time.

VALUE OF APU

Two separate comparisons and calculations were conducted due to the presence of outliers – one with all the fire trucks and another with E10, E12, E14, and R4 fire trucks excluded.

Comparing APU and Non-APU Fire Trucks

When comparing the 3 APU fire trucks with the 8 non-APU fire trucks, no difference was found for idle fuel used. For the other metrics, reduced idle time was found, ranging from 21.7% to 45.6% less idle time for APU fire trucks. In addition, the difference in idle time per on-scene hour, idle time per incident, and APU usage metrics were significant (Table 3).

TABLE 3: SUMMARY OF COMPARISON BETWEEN APU AND NON-APU FIRE TRUCKS ACROSS THE METRICS OF IDLE FUEL, IDLE TIME, IDLE/ONSCENE, IDLE/INC, AND APU.

Metric	Unit	APU	Non-APU	Idle Reduction (95% CI)	% Idle Reduction
Idle fuel	L	110.66	117.30	6.64 (-31.87, 45.15)	5.7%
Idle time	hr	27.35	34.94	7.58 (-0.63, 15.79)	21.7%
Idle/Onscene	hr	0.43	0.72	0.28 (0.07, 0.50)	39.4%
Idle/Inc	hr	0.12	0.21	0.10 (0.01, 0.18)	45.6%
APU	hr	15.40	0.00	15.40 (6.61, 24.19)	44.1%

With outliers excluded, comparing the 2 APU fire trucks with the 5 non-APU fire trucks, a 20.5% reduction in idle fuel usage was found. For the other metrics, reduced idle time was found, ranging from 26.7% to 43.0% less idle time for APU fire trucks. Only the idle time per on-scene hour and APU usage metrics were significant (Table 4). However, due to the smaller sample size and the fact that the difference just overlapped with zero, the idle time per incident metric should also be considered significant.

TABLE 4: SUMMARY OF COMPARISON BETWEEN APU AND NON-APU FIRE TRUCKS, WITH OUTLIERS EXCLUDED, ACROSS THE METRICS OF IDLE FUEL, IDLE TIME, IDLE/ONSCENE, IDLE/INC, AND APU.

Metric	Unit	APU	Non-APU	Idle Reduction (95% CI)	% Idle Reduction
Idle fuel	L	98.61	124.01	25.40 (-13.02, 63.82)	20.5%
Idle time	hr	27.59	37.66	10.06 (-1.73, 21.85)	26.7%
Idle/Onscene	hr	0.41	0.62	0.22 (0.04, 0.39)	34.6%
Idle/Inc	hr	0.11	0.17	0.06 (0.00, 0.13)	36.3%
APU	hr	16.00	0.00	16.00 (0.91, 31.09)	42.5%

Only the idle time metrics were used to calculate the overall estimates due to an outlier in the idle fuel rate (E10). This resulted in APUs reducing idle time by 36.4% (95% CI: 19.7 – 53.0), providing annual fuel savings of $208.14 (95% CI: 82.18 – 334.10), increasing maintenance costs by $1.58 (95% CI: 0.75 – 2.41), and reducing total engine use by 15.0% (95% CI: 6.5 – 23.5).

Return on Investment

Taking the extension of fire truck service life into account, APUs reduced total engine use by 15.0%, which would indicate a potential increase of 3.0 years (95% CI: 1.3 – 4.7) of service life. Using the $605,400 cost of a new fire truck, extending the service life by 0.35 years (95% CI: 0.26 - 0.44) allowed for a full return on investment for the $15,000 APU, corresponding to a payback period of 20.35 years (95% CI: 20.26-20.44). Assuming the full 3.0 year increase in service life resulted in total annual savings of $4,136.23 (95% CI: 2,050.43 – 6,222.02). If just considering the fuel and maintenance costs alone, APUs provided savings of $221.26 (95% CI: 87.20 – 355.33) per year, which corresponded to a payback period of 67.79 years (95% CI: 42.21 - 172.02). Annual cost savings of APUs for each factor can be found in Table 5.

TABLE 5: SUMMARY OF ANNUAL SAVINGS BY APU FIRE TRUCKS FOR EACH FACTOR OF THE ROI CALCULATIONS.

	Annual Savings per Fire Truck ($)								
	Metric	Engine Fuel	APU Fuel	Carbon tax	Engine Maintenance	APU Maintenance	Extension of Service Life	Total Savings (with service life)	Total Savings (no service life)
All Trucks	Idle Time	376.53	-255.10	8.58	34.65	-35.50	2,365.40	2,494.56	129.16
	Idle/Onscene	780.75	-528.96	17.79	71.84	-73.60	4,525.10	4,792.92	267.82
	Idle/Inc	982.31	-665.52	22.38	90.39	-92.60	5,481.77	5,818.73	336.96
	APU	764.83	-518.17	17.42	70.37	-72.10	4,446.40	4,708.76	262.36
Outliers Excluded	Idle Time	473.73	-338.54	9.55	45.98	-47.11	2,784.95	2,928.56	143.61
	Idle/Onscene	637.60	-455.65	12.85	61.88	-63.40	3,632.72	3,826.00	193.29
	Idle/Inc	687.93	-491.62	13.87	66.77	-68.41	3,882.70	4,091.25	208.54
	APU	753.34	-538.36	15.19	73.12	-74.91	4,200.64	4,429.02	228.37
Overall	Annual Savings (95% CI)	682.13 (311.29, 1,052.97)	-473.99 (-755.69, -225.29)	14.7 (5.81, 23.60)	64.37 (30.60, 98.15)	-65.95 (-100.56, -31.35)	3,914.96 (1,961.98, 5,867.94)	4,136.23 (2,050.43, 6,222.02)	221.26 (87.20, 355.33)

Greenhouse Gas Emissions

APU engines reduced greenhouse gas emissions by 420.1 kg (95% CI: 165.9 – 674.3) in CO_2-equivalents per year.

DETERMINANTS OF UNNECESSARY IDLING

Cross-tabulation of average on-scene time between crew and incident type showed similar on-scene durations across medical, emergency, and non-emergency incidents. However, there was evidence for increased duration used by crews C and D for structure fire incidents (Table 6).

TABLE 6: CROSS-TABULATION OF AVERAGE ON-SCENE TIME (IN MINUTES) BETWEEN FIREFIGHTER CREW AND INCIDENT TYPE.

Incident Type	Medical				Structure			
Crew	A	B	C	D	A	B	C	D
Avg on-scene time (95% CI)	16.7 (13.8, 19.7)	17.4 (15.1, 19.7)	17.2 (15.2, 19.2)	16.3 (13.7, 18.9)	22.1 (16.5, 27.7)	26.9 (15.6, 38.2)	39.9 (17.7, 62.0)	36.7 (30.8, 42.7)
Avg count	32.8	29.6	32.8	36.7	3.5	3.5	1.7	4.1
Incident Type	**Emergency**				**Non-Emergency**			
Crew	**A**	**B**	**C**	**D**	**A**	**B**	**C**	**D**
Avg on-scene time (95% CI)	14.1 (10.9, 17.3)	19.5 (9.9, 29.0)	12.5 (9.5, 15.4)	13.9 (9.1, 18.7)	12.4 (9.3, 15.5)	13.8 (7.4, 20.2)	14.6 (7.4, 21.8)	13.4 (7.6, 19.2)
Avg count	12.0	9.4	8.8	10.1	5.1	4.5	3.5	3.5

Univariate linear regression models (Table 7) showed significant associations between idle time per on-scene hour and distance per incident (increase of 0.037 hrs or 2.2 mins per additional km traveled per incident), number of incidents (reduction of 0.026 hrs or 1.6 mins per additional 10 incidents), crew B on-scene percentage (increase of 0.020 hrs or 2.3 mins per additional percentage of on-scene time crew B was responsible for), crew D on-scene percentage (reduction of 0.016 hrs or 2.4 mins per additional percentage of on-scene time crew D was responsible for), medical incidents on-scene percentage (reduction of 0.016 hrs or 0.9 mins per additional percentage of on-scene time medical incidents were responsible for), and emergency incidents on-scene percentage (increase of 0.032 hrs or 1.9 mins per additional percentage of on-scene time emergency incidents were responsible for). Trends were found for average on-scene time (increase of 0.056 hrs or 3.4 mins per additional minute of average on-scene time), average crew B on-scene time (increase of 0.019 hrs or 1.2 mins per additional minute of average crew B on-scene time), average medical incident on-scene time (increase of 0.050 hrs or 3.0 mins per additional minute of average medical incident on-scene time), average emergency incident on-scene time (increase of 0.035 hrs or 2.1 mins per additional minute of average emergency incident on-scene time), and average non-emergency incident on-scene time (reduction of 0.031 hrs or 1.8 mins per additional minute of average non-emergency incident on-scene time).

TABLE 7: SUMMARY OF RESULTS FROM LINEAR REGRESSION MODELS FOR IDLE TIME PER ON-SCENE HOUR AND IDLE TIME PER INCIDENT. SIGNIFICANT ASSOCIATIONS DENOTED IN BOLD AND TRENDS IN ITALICS.

	Idle/Onscene			Idle/Inc		
Variable	**Estimate**	**StErr**	**p-value**	**Estimate**	**StErr**	**p-value**
Rescue	-0.252	0.177	0.204	*-0.113*	*0.069*	*0.155*
Distance/Inc (km)	**0.037**	**0.009**	**0.008**	**0.014**	**0.005**	**0.029**
Incidents (#/10)	**-0.026**	**0.009**	**0.026**	**-0.012**	**0.003**	**0.011**
Crew A (%)	0.004	0.026	0.875	0.002	0.011	0.866
Crew B (%)	**0.038**	**0.012**	**0.020**	**0.018**	**0.003**	**0.001**
Crew C (%)	-0.006	0.023	0.801	-0.004	0.009	0.658
Crew D (%)	**-0.040**	**0.011**	**0.010**	**-0.018**	**0.003**	**0.002**
Medical (%)	**-0.016**	**0.006**	**0.041**	**-0.007**	**0.002**	**0.026**
Structure (%)	0.028	0.022	0.254	*0.014*	*0.008*	*0.135*
Emergency (%)	**0.032**	**0.009**	**0.011**	**0.013**	**0.004**	**0.011**
Non-Emergency (%)	0.025	0.028	0.417	0.010	0.012	0.429
onscene avg (min)	*0.056*	*0.031*	*0.121*	**0.031**	**0.009**	**0.018**
Crew A avg (min)	0.022	0.034	0.535	0.017	0.012	0.202
Crew B avg (min)	*0.019*	*0.009*	*0.074*	**0.010**	**0.003**	**0.011**
Crew C avg (min)	0.025	0.031	0.443	0.008	0.013	0.556
Crew D avg (min)	0.013	0.034	0.710	0.010	0.013	0.500
Medical avg (min)	*0.050*	*0.024*	*0.084*	**0.025**	**0.008**	**0.020**
Structure avg (min)	0.009	0.009	0.388	*0.006*	*0.003*	*0.150*
Emergency avg (min)	*0.035*	*0.015*	*0.052*	**0.017**	**0.005**	**0.009**
Non-Emergency avg (min)	*-0.031*	*0.015*	*0.084*	*-0.012*	*0.006*	*0.101*

With idle time per incident as the dependent variable of interest, significant associations were found between idle time and distance per incident (increase of 0.014 hrs or 0.8 mins per additional km traveled per incident), number of incidents (reduction of 0.012 hrs or 0.7 mins per additional 10 incidents), crew B on-scene percentage (increase of 0.018 hrs or 1.1 mins per additional percentage of on-scene time crew B was responsible for), crew D on-scene percentage (reduction of 0.018 hrs or 1.1 mins per additional percentage of on-scene time crew D was responsible for), medical incident on-scene percentage (reduction of 0.007 hrs or 0.4 mins per additional percentage of on-scene time medical incidents were responsible for), emergency incident on-scene percentage (increase of 0.013 hrs or 0.8 mins per additional percentage of on-scene time emergency incidents were responsible for), average on-scene time (increase of 0.031 hrs or 1.8 mins per additional minute of average on-scene time), average crew B on-scene time (increase of 0.010 hrs or 0.6 mins per additional minute of average crew B on-scene time), average medical incident on-scene time (increase of 0.025 hrs or 1.5 mins per additional minute of average medical incident on-scene time), and average emergency incident on-scene time (increase of 0.017 hrs or 1.0 mins per additional minute of average emergency incident on-scene time). Trends were found for rescue fire trucks (reduction of 0.112 hrs or 6.8 mins for rescue fire trucks), structure incident on-scene percentage (increase of 0.014 hrs or 0.9 mins per additional percentage of on-scene time fire incidents were responsible for), average structure incident on-scene time (increase of 0.006 hrs or 0.3 mins per additional minute of average structure incident on-scene time), and average non-emergency on-scene time (reduction of 0.012 hrs or 0.7 mins per additional minute of average non-emergency incident on-scene time).

Discussion

OVERVIEW

APU and non-APU fire trucks all operated normally throughout the study period and although some variations were expected, some potential outliers were observed. E10 had an idle fuel usage rate that was much higher than the other fire trucks but its PTO fuel usage rate was similar, which suggests the idle fuel inefficiency may be due to a configuration error. E12 and E14 operated in neighbourhoods that were characteristic of the longer distance per incident and, conversely, reduced number of incidents when compared to other fire trucks. Also of note was the fact that the APU fire trucks were newer models. However, the fuel efficiency of these newer vehicles, with the exception of E10, were similar to the other fire trucks, thus year of manufacture did not appear to play a role in this study.

Overall, idle time was found to make up 41.9% of the total engine time and this was much lower than the 57% reported in the analysis for the 2012 business case. However, this is fairly close to the 20% to 40% figure reported by Hafiz and colleagues (2007) as the idling proportion for heavy-duty vehicles. This discrepancy may be due to the adoption of anti-idling policies by Surrey Fire Service in 2013.

VALUE OF APU

Total fuel usage and total idle time were not found to be significantly different between the APU and non-APU fire trucks. However, differences in idle time per on-scene hour, idle time per incident, and APU usage were significant. The fact that idle time per on-scene hour and idle time per incident metrics were somewhat standardized likely accounted for their significance.

APUs were found to reduce engine idle time by 36.4% and total engine time by 15.0%, which is similar to the 17% reduction in engine time found in a preliminary analysis by Surrey Fire Service. The assumed APU fuel consumption of 2.4 L/hr at 50% load is approximately 32% less than the 3.5 L/hr in average idle fuel rate of the main engine. This is slightly less than the 36% to 47% in lower fuel consumption of the APU reported elsewhere (Frey & Kuo, 2009), but is within range. The annual fuel savings of $208.14 was also much lower than the $2,200 reported in the 2012 business case and the $895 from the trial analysis of the Battalion Chief vehicle. This discrepancy is likely due to the fact that both of the previous analyses assumed no fuel cost for the APU. When just considering the fuel savings of the main engine, this study found annualized savings of $682 (95% CI: 311 – 1,053), which is well within the reported range of the Battalion Chief vehicle. The reported $3.14 fuel savings per idle hour obtained from the 2012 business case is approximately twice the rate of $1.75 reported for the Battalion Chief vehicle, which would help explain the discrepancy between the two reports.

The difference in annual savings between taking the extension of fire truck service life into account or not was substantial: $4,136 versus $221, respectively. This resulted in vastly different return on investment calculations of 20.35 years and 67.79 years for the $15,000 APU. This is due to the fact that fire trucks are very expensive and any extension of service life, up to approximately 3 years in this study, would result in substantial savings over time. On the other hand, the maintenance costs saved by reduced main engine use were offset by the additional maintenance costs of the APUs. In addition, at the assumed 50% load rate, an APU operated at only 32% more efficiency than a fire truck's main engine, resulting in only minor fuel savings. A future study could be undertaken to better estimate APU fuel consumption to allow for a better estimate of the fuel savings. Considering the engine is the critical component that is most likely to fail first, it should be fairly safe to assume that extending the service life of the main engine will also extend the service life of the fire truck. Also assuming that older fire trucks are more costly to maintain, the actual return on investment should be closer to 20.35 years than 67.79 years.

APUs were found to reduce greenhouse gas emissions by 420.1 kg (95% CI: 165.9 – 674.3) in CO_2-equivalents per year. This is considerably less than the 1.59 metric tons found in the preliminary analysis. However, this is also due to the fact that APU emissions were not accounted for in the preliminary analysis. When just taking the reduction in greenhouse gas emissions by the main engine, the 1.41 metric tons (95% CI: 0.67 – 2.15) of CO_2-equivalent emissions per year matches well with the preliminary analysis. For context, a typical passenger car emits approximately 4.6 metric tonnes of CO_2-equivalent emissions per year.

Also of note was how similar the estimates stemming from the idle time per incident, idle time per on-scene hour, and APU metrics were. This suggests that these may be the better metrics to use, as opposed to the metrics of total idle time and idle fuel usage extracted from the ECM. In addition, the consistency in the estimates between all fire trucks, and the subset the outliers excluded, indicates great robustness in the data collected.

DETERMINANTS OF UNNECESSARY IDLING

In general, the on-scene times of the different firefighter crews were similar across the incident types, with the exception of structure fire incidents, where crews C and D had longer average on-scene times. However, the actual counts for these incidents were low, thus the discrepancies may simply be due to a few outliers.

Average on-scene time was found to increase idle time, which meant the assumption that on-scene time being the main opportunity for reducing unnecessary idling is likely true. Distance per incident increased idle time, while number of incidents decreased idle time. These two variables were closely related, as longer travel time would result in fewer incidents the fire truck can respond to. These effects were expected as longer distances traveled would result in more opportunities for idling at intersections or in traffic. These idling opportunities could not be differentiated from the unnecessary idling while parked on-scene, thus distance per incident and number of incidents should be considered confounding variables.

Crew B was found to increase idle time as the percentage of on-scene time they were responsible for and their average on-scene time increased. In contrast, crew D was found to reduce idle time as the percentage of on-scene time they were responsible for increased, while no association was observed for the average on-scene time. No associations were found for crews A and C. This suggests the possibility of behavioural differences in crew B that resulted in longer idle time the longer they were on-scene. Conversely, there may be potential behavioural differences in crew D that resulted in reduced idling.

The average on-scene duration of medical and emergency incidents increased idle time, while non-emergency incidents decreased idle time. This may be because medical and emergency incidents usually require the use of safety lights while on-scene, thus eliminating the opportunity for the engine to be turned off. Whereas for non-emergency incidents, safety lights may not be required, thus the firefighters have an opportunity to park the fire truck in a less obstructive location and turn off the engine. As such, the medical and emergency incidents are prime opportunities for APUs, as the safety lights can remain on without the main engine being engaged.

LIMITATIONS

Although the data were robust and effects were large enough to show consistency in the estimates and significant differences, the small sample size in this study (three APU fire trucks and eight non-APU fire trucks) is a limitation. This resulted in relatively large confidence intervals and the potential for inaccuracies as the estimates are applied to larger populations. The small sample size also resulted in only univariate associations being conducted, thus adjusting for confounding variables, such as distance per incident and number of incidents, was not possible.

The inability to measure actual APU fuel usage and the rough estimation of the value of increasing the service life of the fire truck also limited our ability to more accurately calculate the cost savings and return on investment for the APUs.

Conclusions

Fire trucks operated by Surrey Fire Service were found to idle 41.9% of total engine time. APUs reduced idle time by 36.4%, provided annual fuel savings of $208.14, increased maintenance costs by $1.58, and reduced total engine use by 15.0%. This resulted in total annual savings of $4,136.23 when considering the full 3 years of extension of service life and a payback period of 20.35 years for the $15,000 APU. Without considering extension of service life, total annual savings were $221.26, resulting in a payback period of 67.8 years. APUs also reduced greenhouse gas emissions by 420.1 kg in CO_2-equivalents per year. Evidence was found to support the assumption that on-scene time is the main opportunity for reducing unnecessary idling, that there may be behavioural differences between crews that affect unnecessary idling, and that medical and emergency incidents would benefit most from equipping fire trucks with APUs.

Recommendations

Overall cost savings and reduction in greenhouse gas emissions support the adoption of APUs for all fire trucks and the evidence suggesting that crews affected the amount of unnecessary idling support continued focus on policies promoting anti-idling behaviours.

If a similar study is conducted in the future, having ECM data per incident or real-time data will dramatically increase the sample size to allow for estimates with tighter confidence intervals and the ability to adjust for confounders. Being able to estimate the load or fuel usage of the APU and the effect of reduced engine usage on the extension of a fire truck's service life will allow for greater accuracy of annual savings and return on investment calculations.

Accuracy and reliability between different measures of idling should be tested in order to determine the best metrics to use for performance tracking, especially when combined with the ability to collect real-time data.

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