SEASONAL EFFECTS ON VEHICLE IDLING DURATION*

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1. Introduction

In 1997, Japan entered into an international agreement to reduce Green House Gas (GHG) emission in 2010 by 6% (base year 1990) in the COP3 (Conference of Parties 3) of the United Nations Framework Convention on Climate Change (UNFCCC) in Kyoto. To achieve the goal of the Kyoto protocol, the government designed measures to lower the energy demand for the industrial, the commercial and residential, and the transportation sector in order to promote energy conservation and to yield an estimated savings of 56 million kL energy in 2010. In 2002, ECCJ performed a national driving field test or actual ride of 'idling-stop' cars to investigate the effects of 'smart driving'. The survey results revealed a total average of 5.8% energy savings (rural=3.4% and urban=13.4%). Thereafter, following the European programs on smart driving, ECCJ started the eco driving promotion dealing on effective and efficient driving execution. Suffice to say, efficient and effective driving enhance fuel economy. Thus, it is imperative to investigate the actual on-road driving conditions, in particular, driving operations and speed modes (acceleration, deceleration, cruise and idling). The focus of this paper will be on the idling mode where evident emission loads are high and where frequency and duration patterns are distinct during traffic and non-traffic conditions. The objective of this study is to quantify and explain the idling conditions of drivers specifically; to quantify the idling condition and duration at the start and end of the drive, to quantify the idling condition and duration during driving, and to identify the factors that affects the idling conditions.

2. Related Literature

Idling-stop is a condition where a vehicle being parked or held in a traffic signal stop is immobile and the engine ignition is being switched-off [2)]. In contrasts is idling condition where engine ignition is running while vehicle remains immobile which contributes to fuel wastage and increase in CO_2 emission. A study on the effect of short idling-stop on fuel consumption, disclosed that increasing the frequency of stops aggravates the vehicle fuel efficiency and furthermore revealing that the amount of fuel saved is proportional to the amount of short idling-stop time[1)]. In line with this, driver's behavior and driving practices were found to aggravate actual idling as revealed in a survey [2)] where 80% of the respondents' carried-out idling-stops when parking, but only 4% are idling-stops during actual driving. Some of the behavioral reasons includes: avoidance of starting time lag, short lifetime of starters, and troublesome ignition key actions. In this case, one study suggested that to reduce fuel wastage, effective technologies should be employed and these include the promotion of vehicles satisfying "top runner standard", hybrid vehicles, and vehicles with "idling-stop" systems [5)]. Furthermore, 80% of the drivers are willing when idling-stops support system on the vehicle is provided. Similar results were found in another study [3)] where, about 58% of the respondents used neutral range at idling position but drivers have difficulty in grasping the effect of idling-stop in relation to engine rpm operation and fuel economy. Thus, drivers' reason for non execution or compliance relates to driving operation discomfort, inconvenience and anxiousness on engine mechanical reliability. A study in Indonesia further revealed another factor for consideration: fuel consumption in residential areas are lower due to lesser traffic congestions and that road network with limited infrastructure and high traffic congestion with specific driver behavior aggravates fuel economy [4)]. This also correspond with the results of study[6)] on fuel consumption during vehicle starting under traffic conditions revealing that urban or city areas have higher frequency of "stop and go" situations attributed to signal waiting condition and traffic congestion where nearly four tenths of fuel consumption are consumed during take-off

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primarily due to engine operation. Overall, the studies mentioned above corroborate the fact that assessing the vehicle idling conditions is vital to quantify fuel consumption, thus, stressing the need to mitigate idling situations to promote fuel savings. Also, there are limited studies revealing the influence of seasonal factors on idling and driving operation.

3. Methodology

The study involves drivers trained under the Energy Conservation Center of Japan (ECCJ) Eco driving program. Two survey set-ups were considered to achieve the study objectives namely; the first methodology set-up which is during start and end stop condition and the second methodology set-up which is during driving condition. Both set-up, involves six drivers and vehicles equipped with on-board data-logging equipment assigned to a specific terminal ID and collects data per 0.10seconds.The stops are characterized by two conditions: idling and idling-stop. Furthermore, idling is characterized by two conditions: neutral (vehicle gear at neutral position) and shift drive (vehicle gear at drive position). Analysis of data on the first survey set-up, examines the duration of starting stop at the beginning of a trip (origin) and the end stop at the end of a trip (destination). The duration of idling were analyzed to understand drivers' behavior before and after a trip. For the second survey set-up, examination of duration and frequency of stop during a trip includes the evaluation of idling and idling-stop and the condition of setting the gear at neutral and shift drive condition. For both methodology set-ups, evaluation of seasonal (i.e., winter, spring, and summer) factor is also evaluated. The analysis of the data is a descriptive statistical analysis namely frequency distribution, central tendency, and variability.

4. Analytical Results

(1) The Start-stop and End-stop Data

The result of the start-stop and end-stop data summary in Table 1 revealed early vehicle take off (short duration of idling) at the start-stop where relatively 32% of drivers idle within 30secs duration and that 54% of all drivers (Fig. 1) take off within 1.0min at an average of 48secs duration. In contrast, during end-stop condition, relatively 23% of drivers idle within 45secs duration and that 64% starts to drive within 1.0min at an average of 49secs duration. Usually driver's drive off as they start the engine, thus 1.0min (or less) idling is considered as an acceptable delay. The idling results on start-stop and end-stop cases have large variability and standard deviations (σ=115 and σ=141) respectively around the means. Idling at start-stop is twice as much as idling during end-stop, to be specific, 20% of drivers idle for more than 2.5mins duration during the start of the drive (Table 1). Thereby saying, at end-stop, drivers` have fewer tendencies to idle and are more "aware" of switching the engine off.

Table 1 Start Stop and End Stop Data Characteristics

	Start Stop	End Stop
Idling Duration	%	%
Idling within 30secs	32%	23%
N, Counts	*2378*	*1556*
Idling within 1.0min	54%	64%
N, Counts	*3995*	*4414*
Idling more than 2.5mins	20%	10%
N, Counts	*1474*	*660*
Statistical Description	**Duration**	**Duration**
Central Tendency		
MEAN	47.95	49.43
MODE	10.00	31.90
Variability		
STAND. DEV.	114.62	140.76
VARIANCE	13138.70	19814.05

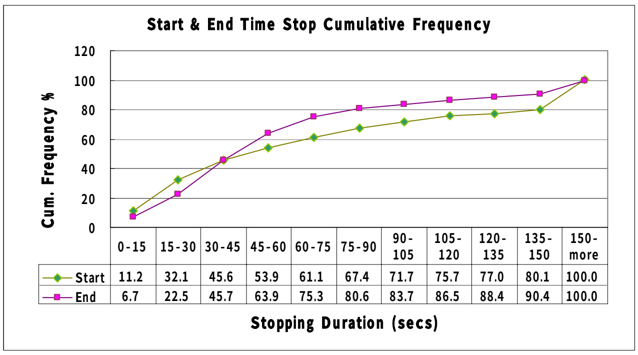
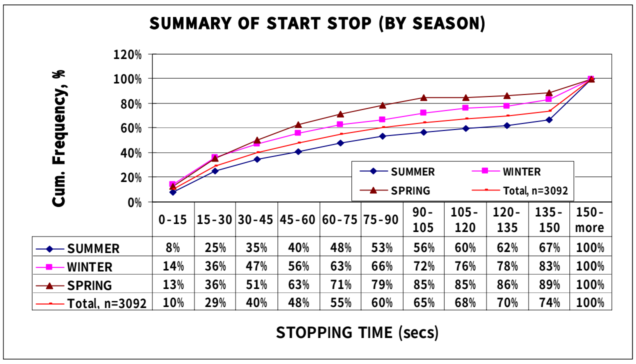


Figure 1 Start-stop and End-stop Curve

(2) Start-stop and End-stop: Seasonal Conditions

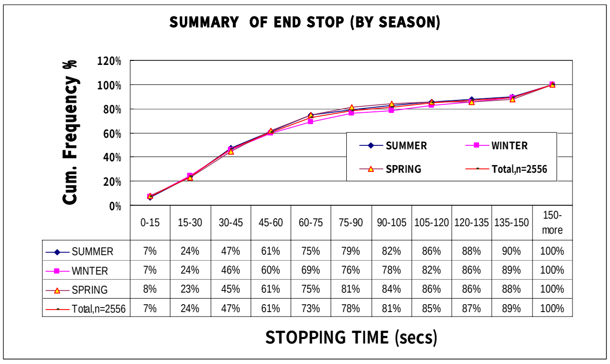
Fig. 2 showed that at summer start-stop have higher idling duration as evident in the cumulative frequency (25%) at 30secs duration. This season also showed lower frequency (40%) at 1.0min duration compared to other seasons. The relative frequencies of this data revealed also summer start-stop at 2.5mins duration to be higher (33%) compared to winter (17%) and spring (11%). In addition, summer and winter seasons have roughly equal and high deviations (σ=157) from the mean, which is an indication of variability in the data. Therefore, seasonal variation affects the start stop condition of driving.

In the case of end stop data (Fig. 3), the frequencies revealed similar trends and then a pronounced deviation after 1.0min (45-60secs range) duration indicating (across the three seasons) slight seasonal variation. This is revealed in the standard deviation of the data where the variability during summer is at σ=249 and spring at σ=108. Nevertheless, all the duration of stops for each season behaves within 1.0min for most drivers.



	0-15	15-30	30-45	45-60	60-75	75-90	90-105	105-120	120-135	135-150	150-more
SUMMER	8%	25%	35%	40%	48%	53%	56%	60%	62%	67%	100%
WINTER	14%	36%	47%	56%	63%	66%	72%	76%	78%	83%	100%
SPRING	13%	36%	51%	63%	71%	79%	85%	85%	86%	89%	100%
Total, n=3092	10%	29%	40%	48%	55%	60%	65%	68%	70%	74%	100%

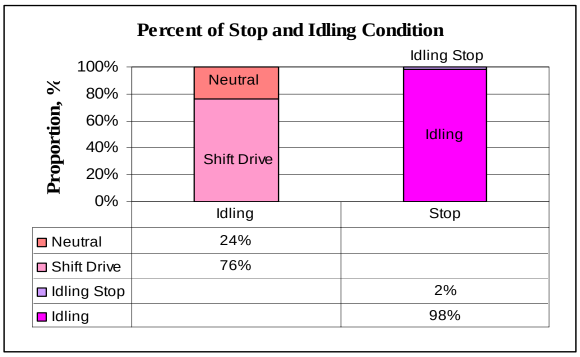
Figure 2 Frequency Profiles of Start Stop Data



	0-15	15-30	30-45	45-60	60-75	75-90	90-105	105-120	120-135	135-150	150-more
SUMMER	7%	24%	47%	61%	75%	79%	82%	86%	88%	90%	100%
WINTER	7%	24%	46%	60%	69%	76%	78%	82%	86%	89%	100%
SPRING	8%	23%	45%	61%	75%	81%	84%	86%	86%	88%	100%
Total,n=2556	7%	24%	47%	61%	73%	78%	81%	85%	87%	89%	100%

Figure 3 Frequency Profiles of End Stop Data

(3) Total stop, Stop, and Idling Data Results

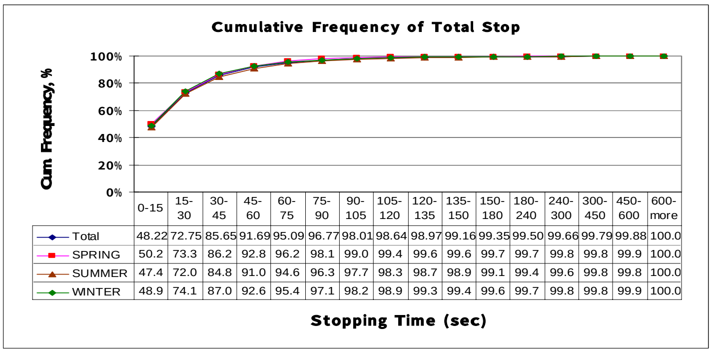


	Idling	Stop
Neutral	24%	
Shift Drive	76%	
Idling Stop		2%
Idling		98%

Figure 4 Proportions of Stop and Idling

Evaluation of stops (n=12094) in a trip is classified by two sets of corresponding characteristics, namely; the value of idling and idling-stop (for the total stop) condition, and the neutral and shift drive (for the idling) condition Results for total stop data in Fig. 4 shows that in most cases, drivers` behavioral tendency when stopping is an idling (98%) condition, and very few considers to turn off the engine (2%). Furthermore, drivers considers setting the engine in a neutral position but roughly 76% of the time they simply set the gear in shift drive position, attributes maybe due to stop-and-go (drivers in a hurry) scenario during signal waiting time.

Fig. 5 shows the relative frequencies profile of total stop based on seasonal variation which reveals a rather closely equal trend of frequencies. This means that across all drivers` and across all seasons` data profiles, seasonal variation is not a factor of the duration and intensity of stops during driving situation, or that, the changes of the season does not affect the drivers` stopping behavior during a trip. The drivers` stops during a trip, therefore, must be attributed to intensity of trips, signal waiting time, and the traffic condition of the chosen route. Furthermore, the frequency of stops decreases along longer duration (time range) of stop which is also pronounced in its cumulative frequency that roughly 47-50% of the frequencies of drivers' stopping duration are within 0-15sec and more than 90% are within 1.0min duration.



	0-15	15-30	30-45	45-60	60-75	75-90	90-105	105-120	120-135	135-150	150-180	180-240	240-300	300-450	450-600	600-more
Total	48.22	72.75	85.65	91.69	95.09	96.77	98.01	98.64	98.97	99.16	99.35	99.50	99.66	99.79	99.88	100.0
SPRING	50.2	73.3	86.2	92.8	96.2	98.1	99.0	99.4	99.6	99.6	99.7	99.7	99.8	99.8	99.9	100.0
SUMMER	47.4	72.0	84.8	91.0	94.6	96.3	97.7	98.3	98.7	98.9	99.1	99.4	99.6	99.8	99.8	100.0
WINTER	48.9	74.1	87.0	92.6	95.4	97.1	98.2	98.9	99.3	99.4	99.6	99.7	99.8	99.8	99.9	100.0

Figure 5 Total and Seasonal Cumulative Frequency of Stop

(4) Idling, Idling-stop, and Neutral Data

Drivers` trip data revealed that the frequency of idling condition (98%) is higher than the idling-stop condition (Fig. 4). Factors influencing this attributes can be: drivers` tendency to drive-off the moment traffic signal green and in-vehicle accessories (i.e., air con, heater, and stereo).The seasonal data of drivers relative frequency curve revealed similar curve trends for idling and idling-stop condition for each season. These reinforce to show that there is no seasonal influence to drivers' stopping tendency and there are fewer drivers tendencies to idling-stop compared to idling condition. As for neutral and shift drive, the drivers` trip data revealed that the frequency of shift drive condition (76%) is higher than the proportion of the neutral (24%) condition. Again, drivers' preference to choose shift drive condition over neutral condition during a signal waiting could be influenced by their need to immediately drive the moment signal turns green. Somehow, in a signal waiting stop-and-go scenario drivers are usually in a hurry, thus the preference of drivers to set the gear in the shift drive position than in neutral. Seasonal data of drivers in Fig. 6 and Fig. 7 revealed similar trends for idling and idling-stop condition that indicates no seasonal influence to drivers' stopping tendency.

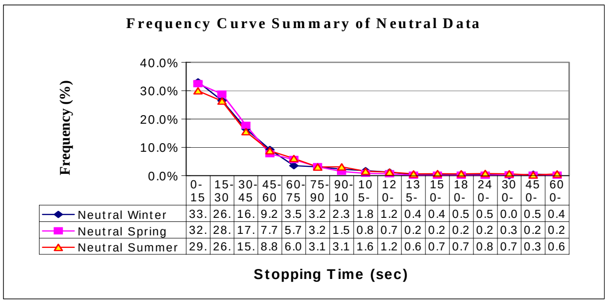


Figure 6 Relative Frequency for Neutral

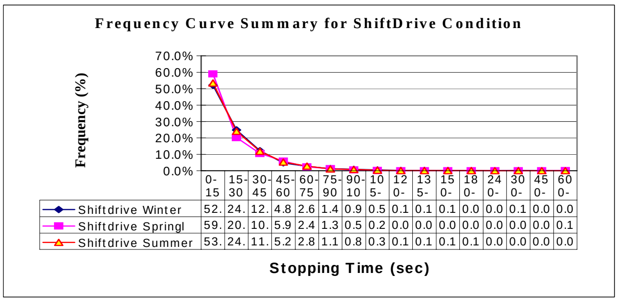


Figure 7 Relative Frequency for Shift Drive

5. Conclusions

The result of idling during start-stop and end-stop revealed that drivers` have higher tendency to idling at the start of the drive than at the end of the drive. And, idling during start-stop shows a variable difference between seasons across all duration while in contrast idling at the end-stop condition differs slightly. Therefore, season variation is a factor of vehicular idling conditions at the start and end of the drive. The seasonal variations of idling can be attributed to drivers` tendency of turning the vehicle ignition to set vehicle heater or cooler. On the other hand, the results of stops during a trip or drive, revealed that drivers` tendency when stopping are usually idling conditions where they set the gear in a shift drive position during signal waiting time. Factors that can influence this attributes in actual driving are; the convenience to drive-off immediately the moment traffic signal turns green and drivers` consideration of the in-vehicle accessories. Results across all drivers, season variation is not a factor of the duration and intensity of stops, therefore, the frequency and duration of stops must be attributed to the intensity of trips and the route, signal waiting time, and the traffic condition of the chosen route. Also, drivers' stopping duration is within 1.0min duration where most of these stops are attributed to traffic signal waiting.

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