An O-D Approach of Estimating Energy Demand and CO_2 Emission for the Luzon Road Transport using Inter-Regional Passenger and Freight Flow Data.

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Abstract: The study estimates energy demand and CO_2 emissions from the Philippine road transport using inter-regional Origin-Destination data. Mathematical approach in estimating energy demand and CO_2 emissions is presented. Reference or "Do-Nothing" scenario for energy demand and CO_2 emission was compared to three fuel sensitive policy options. Study shows that reference scenario substantially increase the overall vehicle carbon dioxide emissions from 32.10MtCO_2 in 2013 to 214.15MtCO_2 in 2050. Public mode of transport substantially contributes to the overall CO_2 emissions for inter-regional travel as compared to private and freight. Fuel sensitive policy options were compared in terms of overall reduction in CO_2 emissions. Shifting to better alternative fuels for private and public transport yield the highest reduction of CO_2 emissions. Switching to revitalized and modernized inter-regional railway system provide the second highest CO_2 emissions reduction. Better logistic management systems for freight transport have the least impact in reducing CO_2 emissions.

Keywords: Energy, Demand, CO_2 Emission, Origin-Destination, Trips, Vehicle-Kilometer

1.INTRODUCTION

One of the major considerations pertaining transportation planning and development is the overall reduction of energy consumption and emissions produced from the transport system during its implementation and operation. Land transport vehicles are considered one of the leading consumer of energy and also a major contributor of greenhouse gas emission worldwide. In the Philippines, land-based transport is the most dominant mode of transport representing 98% and 58% of passenger and cargo travel, respectively (DOTC 2010). From 2000-2012, the country's total number of registered motor vehicles has doubled from around 3.7 million to 7.5 million. The total number continues to rise as registration of new MVs increased by an annual average of 6% from 2004 to 2012(LTO, 2012).

In 2010, the Philippines' energy consumption from the transport sector accounts for about 37% of its total, and is generating about 32% of the total GHG emission into the atmosphere (World Bank 2010). The emissions from transport sector have increased threefold since 1990 from about 10MtCO_2e to more than 35 MtCO_2e in 2010. This is due to the continued increasing trend of motorization in Philippines making the country 27% higher compared to global energy consumption from the same sector (DOTC, 2010).

The IEA estimate that the global transport sector is responsible for 23% of all energy-related carbon dioxide (CO_2) emissions. This is due to the fact that the transport sector is still

94% oil-based. Although nearly half (47%) of the total transport energy consumption is in light duty vehicles mostly passenger cars, but trucks and passenger buses account for a significant share of 27% worldwide as reported by Whyte et al. (2013). If this trend will continue, it will have serious consequences on the energy supply and the environment. In a study by Bentley in 2002 revealed that world conventional oil supply is not unlimited and will soon be at physical risk as it is approaching to its maximum unless drastic programs and policies will be implement that would reduce energy consumptions and CO_2 emissions from motor vehicles.

The Philippine Government created several laws, decrees, acts and programs as a measure to efficiently utilize its energy supply and resources from the transport sector. Example of which is the Executive Order No. 472, Series of 1998 which mandated the transport sector to rationalize the present pattern of gasoline and fuel consumption in order to promote efficient utilization and thus, save foreign exchange expenditures on fuel and reduce fossil fuel emissions detrimental to the environment. In a similar manner, an Administrative Order No. 126 Series of 2005 was also issued directing all sectors in the government to enhance the implementation of its energy conservation program which was launched in August of 2004. Its primary objective is to make energy conservation a way of life for every Filipino through the theme 'Energy Conservation Way of Life' DOE (2009). The government also launched the Natural Gas Vehicle Program for Public Transport (NGVPPT) designed to promote the utilization of compressed natural gas (CNG) in the transport sector in consonance with the goal of ensuring fuel supply diversification and supply security and help improve urban air quality through the reduction of harmful vehicular emissions. The program is primarily geared toward the utilization of Malampaya gas deposit in offshore Palawan (DOE, 2011).

To be able to efficiently assess the impact of different plans and programs of the government in its effort to fight against global warming, appropriate methods or technique of estimating energy consumption and its corresponding emissions must be readily available to the public. At present, the Philippine government used the top-down method of estimating energy demand from the total sales of petroleum as mandated under Memorandum Circular No. 93-03-05 Series of 1993. The top-down approach is suitable only for determining the overall emissions of the transport sector and is therefore useful only for national inventory. This method is considered not reliable in capturing the impact of different transport policies particularly geared towards the reduction of energy demand and vehicle emissions from road transport at the regional level.

There are limited number of studies in the Philippines with emphasis on national energy demand and CO_2 emissions from the transport sector such as the study of (Fabian & Gota, 2009; Bayot *et al.*, 2006; WB, 2010). In 2006, Bayot et al, conducted an analysis and update of the national energy demand from the transport sector but the analysis for road transport did not consider O-D trips as important determinant variables to estimate energy demand. The study of Fabian & Gota (2009) use the Activity-Structure-Intensity-Fuel (ASIF) approach which are the most common framework for transportation CO2 analysis, and compare implications to reduce vehicle emissions from different policy options at the national level such as fuel efficiency for personal cars and light-commercial vehicle, better jeepney engine technology and operations, demand management and improvement of public transportation and non-motorized transport, better logistics for HCV, and better fuel efficiency of HCV.

Likewise, common policies and technologies that were tested to have potential impact in reducing CO2 emissions under the study of World Bank (2010) were fuel efficiency, low-carbon fuels, demand management, promotion of mass transit systems and non-motorized transport.

The study of ADB (2010) followed the same general (ASIF) approach and evaluate CO2 impacts with emphasis on profound energy policy interventions from different projects such as rural roads, urban roads, bikeway projects, expressways, light rail and metro rail transit (MRT) projects, bus rapid transit (BRT) projects, and railways. Attempt to develop a new approach of estimating energy demand and CO_2 emissions at the inter-regional level using origin-destination data from the inter-regional passenger and freight flow survey is considered very valuable in our effort to evaluate low carbon measures.

In order to address this gap, availability of practical approach in estimating inter-regional energy demand and CO_2 emission must be sought to provide fast and reliable result in the assessment of strategies to realize low-carbon transport in the country.

2. OBJECTIVES OF THE STUDY

The aim of this study is to develop a disaggregated macroscopic approach in estimating and forecast energy demand of the inter-regional passenger and freight transport system in the Philippines using Origin-Destination Data. It will also assess the potential implications of selected policies in the overall reduction of CO_2 emissions from the Philippine road transport sector.

3. STUDY METHODOLOGY

3.1 General Approach of the Study

The general approach of this study is to estimate energy demand and CO_2 emissions from the Philippine road transport sector using bottom up method. Origin-Destination data from the inter-regional passenger and freight flow survey conducted in 2004 by the DOTC was used to determine annual passenger trips, average occupancy by vehicle type, annual vehicle trips, average trip length, vehicle distribution by class and fuel type, and annual vehicle kilometer travel.

The generated O-D matrix of annual passenger trips for private and public transport vehicle will be multiplied by the corresponding O-D matrix of the computed average occupancy factor to generate annual vehicle trips O-D matrix. The average vehicle KM travel per trip from the same vehicle category was determined by measuring the actual length of route taken for each vehicle from origin town/city of one region to destination town/city of the other region. Route finder using Google maps were utilized to approximate actual distance traveled for each vehicle route or trip. The computed total annual vehicle-kilometer travel or VKT for each region is then disaggregated using the modal share of traffic derived from actual traffic count survey.

Appropriate fuel efficiency factor and CO_2 emission factor for each vehicle category is then applied to estimate total energy demand and CO_2 emissions. CO_2 emission factors for all types of fuel were based from the 2006 IPCC Guidelines for National Greenhouse Gas Inventories. Traffic growth rate was taken from Volume 1 of the Highway Planning Manual of the Department of Public Works and Highways, and was used in projecting energy demand and CO_2 emissions to future scenarios.

The Fuel Efficiency Factor (FEF) for freight transport was derived from actual fuel consumption survey using full tank method for heavy vehicles ranging from 3 or more axles. The FEF for other light duty vehicles, especially 2 axles, were based from literature survey.

For public transport, The Fuel Efficiency Factor (FEF) was also derived from actual fuel consumption survey using full tank method but is limited to large (aircon) and small buses (non-aircon) only.

The FEF for all other types of vehicles such as private passenger cars, taxi, utility van, jeepney, etc. was taken from literature survey. FEF for LPG and CNG were taken from past studies done by Abaya *et al* (2014) and Chandler *et al*. (2006), respectively. Figure 1 shows the conceptual approach for estimating energy demand and CO_2 emissions for this study.

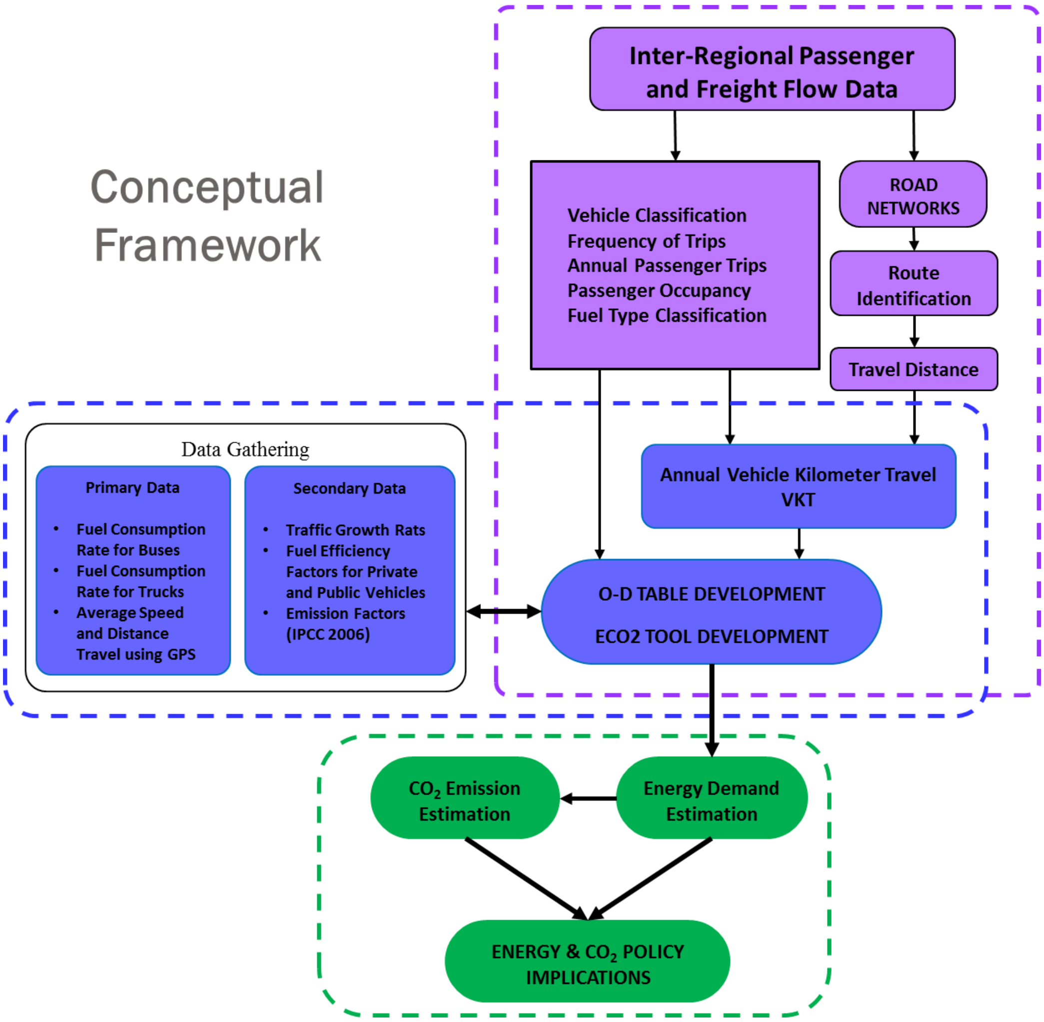

Figure 1. Conceptual framework of the study

3.2 Identification of Primary Inter-Regional Routes

The study area selected is the entire Island of Luzon comprising of seven (7) regions which includes Region I also known as the Ilocos Region, Region II also known as Cagayan Valley Region, Region III or the Central Luzon, CAR or the Cordillera Autonomous Region, Region IV also known as the Southern Tagalog Region, Region V or the Bicol Region, and Metro Manila or the National Capital Region (NCR). Figure 2 shows the political boundaries of these seven regions.

In identifying the primary routes used for inter-regional travel, this study basically follows the one identified by IRPAFF survey final report. The major routes for each mode of transport for both commodity and passenger flow were formally identified based from data provided by the Land Transportation Franchising and Regulatory Board (LTFRB). Only major highways linking the regions within the main island of Luzon were considered in the analysis. It was assumed that all inter-regional trips took place from these routes. Majority of the country's inter-regional buses and trucks are operating within the island of Luzon with Metro Manila as the hub.

The Northern Luzon routes are those serving Metro Manila and the provinces north of the metropolis comprising of Regions I, II, III, and Cordillera Autonomous Region (CAR). The Southern Luzon routes are those serving Metro Manila and the provinces south of the metropolis comprising of Region IV and V. Figure 3 shows the map of Luzon showing the inter-regional transportation road networks.

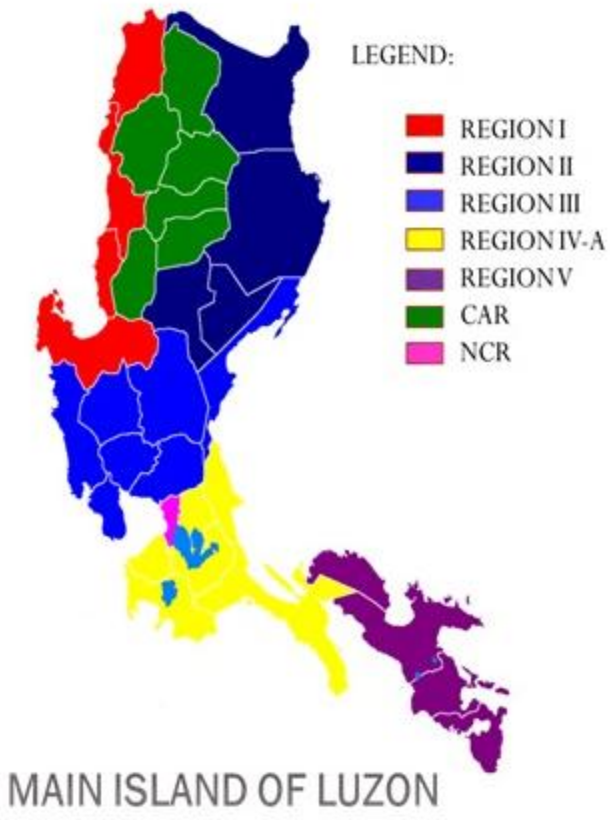

Figure 2. Regional and political boundaries of the main island of Luzon

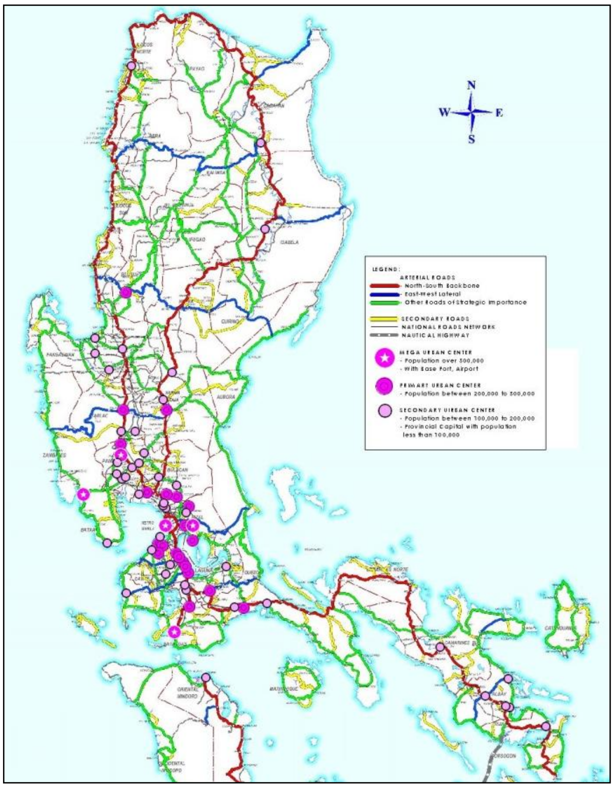

Figure 3. Inter-regional road networks of the main island of Luzon (*Source: DPWH, 2010)*

3.3 Development of Annual O-D Trips Table from IRPAFF Report.

Secondary data of annual passenger trips for private and public transport and the annual vehicle trips for freight transport were taken from the most recent national survey of inter-regional passenger and freight flows (IRPAFF) conducted in 2004 under the Department of Transportation and Communication (DOTC) and funded by JICA. In the IRPAFF survey, the volume counts and roadside interview surveys were done simultaneously from 7AM to 5PM (10 hours) for five consecutive days (Thu-Mon). The selection of five contiguous days assumes to capture a unique passenger and freight flow pattern in a week including the fluctuation of traffic based from the result of pilot survey. The 10-hour sample data was expanded to 24-hour population data, by applying some expansion factors.

The procedure of expanding 10-hr data to 24-hour population is as follows: (a) prepare passenger OD table from samples of 10-hour survey (for vehicle type i for both directions); (b) compute factor f_1 (% of number of passenger interviewed during the 10-hour survey); (c) compute factor f_2 (% of stopped vehicle for interview during the 10-hour survey), which also called as the sampling rate of vehicles; (d) Expand 10-hour sample to equivalent 10-hour population by multiplying sample OD for 10-hour survey by factors f_1 and f_2; (e) Compute factor f_3 established using 24-hour occupancy data from survey undertaken at several provincial bus terminals and multiply to the computed 10-hour population to expand OD table to 24-hour population.

It may be noted that if the average occupancy for the 10-hour sample is representative then this portion will tend cancel out. This case assumes that the occupancy pattern is similar between the survey duration and the rest of the day which was taken as a first approximation.

The 24-hour population data for the weekday and weekend were combined to form a typical weekly OD table, which subsequently expanded to annual values by multiplying to the total number of weeks in a year. Finally, the annual OD tables for all survey sites were integrated to form annual OD trips table for each pair of regions. The preparation of freight OD tables and expansion from 10-hour sample data to 24-hour freight population data follows the same procedure for passenger trips except that the average weight per commodity and vehicle type were used to derive freight's annual OD by trips and by weight. Figure 4 shows the diagram for the general procedure of expanding 10-hour passenger OD Table to annual OD table**.** It should be noted that the approach used in the analysis is relatively simple and can easily be updated once latest data are available.

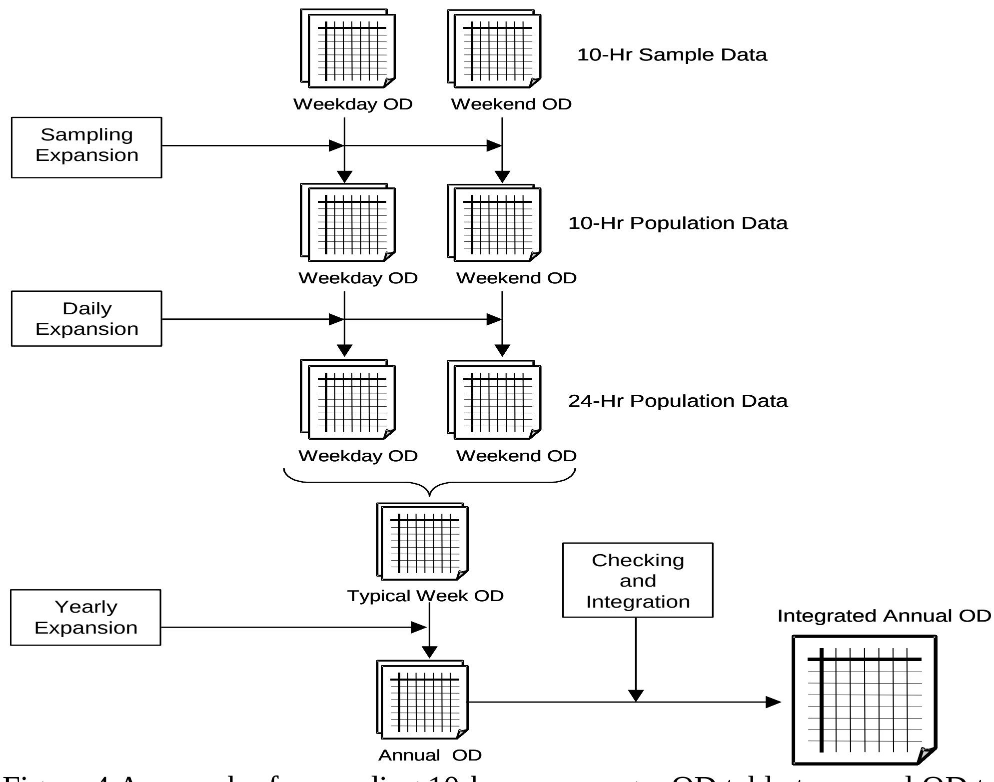

Figure 4.Approach of expanding 10-hour passenger OD table to annual OD table**.**
(*Source: IRPAFFS Final Report, 2006)*

3.4 Interviews and Survey Locations

As a background, the derived OD table was extracted from the results of IRPAFF OD interview survey conducted in 2004 from a randomly selected vehicles to gather pertinent travel information data such as point of origin and destination, time and frequency of travel, and many more. The author participated in one of the IRPAFF pilot surveys. Table 1 shows the number of inter-regional trips interviewed conducted from 16 survey location sites within the Island of Luzon.

It should be noted that due to the randomness of vehicles selected for interviews, it was inevitable that both inter- and intra-provincial trips would be obtained from the roadside surveys. Intra-provincial trips (i.e., those trips that would be made within the province and therefore also within the region) is not being considered in this study.

Based from the results of IRPAFF's O-D interview survey, sampling rates for all locations varies from 2.59% to as high as 70.57%. Thus, the study assumed that this is a good representation on the travel pattern in proportion to the number of trips on each inter-regional travel.

Table 1.Total inter-regional interviews per survey location

No.	Station	Public	Private	Freight	Total
1	Bantay and Vigan City, Ilocos Sur	717	384	497	1,598
2	Bauang, La Union	1,128	909	711	2,748
3	Urdaneta City, Pangasinan	1,376	2,965	1,058	5,399
4	Tuguegarao City, Cagayan	865	608	516	1,989
5	Bayombong, Nueva Vizcaya	414	211	1,151	1,776
6	Baguio City, Benguet	2,511	-	1,769	4,280
7	San Jose City, Nueva Ecija	1,182	537	1,093	2,812
8	Capas, Tarlac	1,136	807	1,089	3,032
9	Pulilan, Bulacan	639	1,204	907	2,750
10	Lubao, Pampanga	1,427	1,640	945	4,012
11	Taytay, Rizal	303	268	250	821
12	Calamba City, Laguna	1,964	1,381	1,062	4,407
13	Dasmariñas, Cavite	744	1,139	290	2,173
14	Pagbilao, Quezon	911	836	1,690	3,437
15	Pili, Camarines Sur	946	443	854	2,243
16	Daraga, Albay	1,544	940	1,158	3,642
	TOTALS	**17,807**	**14,272**	**15,040**	**47,119**

Source: IRPAFF Final Report, 2006

4. DATA PRESENTATION

4.1 Modal Share Distribution

As a limitation, the modal share and freight distribution was taken from the same IRPAFF survey as this will represent a more realistic estimate for inter-regional travel demand than the overall mode share found in national statistics. The study did not use current and aggregated national average data on modal share for the different types and classes of vehicles as they vary significantly with inter-regional trips which could result to either over estimate or underestimate the computations. As a solution, the author used the Department of Public Works and Highways (DPWH) forecasted annual traffic growth rate to forecast passenger and freight trips from 2004 to 2013 and onwards. However, there is a plan by the DOTC to update

OD study for the next 2 to 3 years, and the model can be easily updated once latest data are made available.

The distribution by vehicle classes and region for private, public, and freight mode of transport is presented in Table 2 to Table 4. For private mode of transport, utility vehicles (UVs) have the highest share among all regions with an average of 54.69% followed by passenger cars with an average of 38.30%. The least is private bus with an average of less than 1.00%. Large buses dominated the share of public mode of transport for inter-regional trips with a combined average share of 86.10%. It was observed also that small buses with air-conditioning units are not common for inter-regional trips with an average mode share of about 0.50% as compared to small buses with non-air-conditioning units with around 10.00%. For freight mode of transport, trucks with 2-axles dominated the inter-regional travel with an average mode share of 62.09% followed by rigid trucks with 3-axles with an average modal share of 32.97%.

Table 2. Distributions of private mode of transport from inter-regional travel survey

Vehicle Type	REGION							Average
	I	II	III	IV	V	NCR	CAR	
Cars/Jeep	33.45%	34.01%	40.90%	31.73%	51.75%	40.37%	35.89%	38.30%
Private Jeepney	4.09%	5.15%	4.73%	12.11%	2.17%	4.58%	3.66%	5.21%
Utility Vehicle (Vans)	62.20%	60.48%	53.71%	49.48%	45.58%	53.00%	58.36%	54.69%
Taxi/Mega Taxi	0.27%	0.24%	0.56%	6.06%	0.50%	1.62%	1.92%	1.59%
Company Bus	0.00%	0.00%	0.05%	0.14%	0.00%	0.38%	0.17%	0.11%
Private Bus	0.00%	0.12%	0.05%	0.41%	0.00%	0.05%	0.00%	0.09%
Total	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%

Source: IRPAFF Data

Table 3.Distributions of public mode of transport from inter-regional travel survey

Vehicle Type	REGION							Average
	I	II	III	IV	V	NCR	CAR	
Public Utility Jeepney (PUJ)	0.00%	0.00%	0.09%	14.21%	0.00%	3.06%	0.07%	2.49%
AUV, Mega Taxi	0.12%	0.00%	0.60%	4.38%	0.00%	0.19%	0.21%	0.78%
Mini Bus (Non-Aircon)	24.07%	14.07%	2.74%	0.36%	8.24%	0.57%	15.11%	9.31%
Mini BuS (Aircon)	0.53%	0.19%	0.51%	0.00%	1.83%	0.14%	0.07%	0.47%
Large Bus (Non-Aircon)	35.10%	31.30%	26.65%	33.52%	71.17%	34.37%	40.04%	38.88%
Large Bus (Aircon)	38.88%	54.44%	69.32%	47.31%	18.54%	61.66%	40.38%	47.22%
Van	1.30%	0.00%	0.09%	0.22%	0.23%	0.00%	4.12%	0.85%
Total	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%

Source: IRPAFF Data

Table 4.Distributions of freight transport from inter-regional travel survey

Vehicle Type	REGION							Average
	I	II	III	IV	V	NCR	CAR	
Jeep/Van/Pick Up	4.56%	5.42%	6.11%	5.98%	1.22%	6.93%	2.71%	4.70%
Trucks 2-axle	58.38%	55.78%	58.97%	64.72%	70.61%	65.49%	60.65%	62.09%
Trucks 3-axle	22.61%	19.13%	16.88%	18.22%	19.18%	16.73%	29.44%	20.31%
Trucks more than 3 axles	10.32%	16.25%	13.77%	7.29%	6.53%	8.04%	2.61%	9.26%
Tank Lorries	4.04%	2.71%	4.07%	3.35%	2.45%	2.68%	4.49%	3.40%
Others	0.09%	0.72%	0.19%	0.44%	0.00%	0.13%	0.10%	0.24%
Total	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%

Source: IRPAFF Data

4.2 OD table for passenger occupancy, load factor and VKT

The average occupancy of private and public transport by OD regions are shown in Table 5 and Table 6, while the average load factor for freight transport is shown in Table 7. These occupancy and load factor OD tables will be used to generate OD table of annual vehicle trips by mode which will then cross classified to the OD table of the computed average vehicle-kilometer travel (*VKT*) per vehicle trip to generate new OD table in terms of total annual vehicle kilometer travel. The computed average vehicle kilometer travel per trip is shown in Table 8 to Table 10.

Table 5.Private transport passenger occupancy (Source: IRPAFF data)

Origin	Destination Zone						
Zone	I	II	III	IV	V	NCR	CAR
I	0	4.53	3.61	4.15	9.96	3.91	3.77
II	4.93	0	3.97	4.77	-	4.14	7.93
III	4.43	4.93	0	4.96	3.81	4.65	5.57
IV	5.11	4.10	5.52	0	3.43	4.38	6.50
V	-	-	4.33	3.79	0	4.29	
NCR	4.91	4.92	4.86	4.60	3.80	0	4.92
CAR	4.50	5.00	3.33	3.39	3.67	4.11	0

Table 6. Public transport passenger occupancy (Source: IRPAFF data)

Origin	Destination Zone						
Zone	I	II	III	IV	V	NCR	CAR
I	0.00	22.50	29.57	28.24	26.23	26.28	28.93
II	28.00	0.00	20.50	25.65	23.64	21.10	16.69
III	23.58	32.86	0.00	40.08	38.06	49.95	33.34
IV	25.36	20.00	29.75	0.00	19.24	26.03	23.27
V	-	-	26.04	26.17	0.00	26.94	23.72
NCR	24.68	23.92	25.13	30.20	26.17	0.00	20.50
CAR	28.07	23.00	29.34	32.60	30.59	35.00	0.00

Table 7.Freight transport average load factor in metric tons (Source: IRPAFF data)

Origin	Destination Zone						
Zone	I	II	III	IV	V	NCR	CAR
I	0.00	10.23	6.77	13.28	0.00	14.24	10.10
II	16.35	0.00	5.79	4.91	0.00	5.19	5.59
III	16.40	8.51	0.00	5.04	10.92	5.42	3.72
IV	51.01	4.47	5.13	0.00	7.76	4.89	10.91
V	0.00	0.00	7.72	3.45	0.00	3.86	6.00
NCR	15.39	7.30	14.06	1.66	8.57	0.00	5.41
CAR	4.90	10.32	4.88	15.89	5.50	20.73	0.00

Table 8.Average VKT per vehicle trip (Private) (Source: IRPAFF data)

	Destination Zone						
Origin Zone	I	II	III	IV	V	NCR	CAR
I	0.00	126.11	103.64	273.28	719.00	280.77	80.98
II	277.71	0.00	258.05	448.09	0.00	410.79	150.04
III	76.69	225.32	0.00	147.65	581.97	113.86	165.96
IV	224.92	464.55	137.34	0.00	299.95	65.39	289.56
V	0.00	0.00	568.95	296.02	0.00	431.13	0.00
NCR	239.47	390.54	113.57	71.94	403.35	0.00	264.54
CAR	88.41	147.45	188.59	300.99	715.36	262.80	0.00

Table 9.Average VKT per vehicle trip (Public) (Source: IRPAFF data)

	Destination Zone						
Origin Zone	I	II	III	IV	V	NCR	CAR
I	0.00	334.39	202.41	0.00	0.00	315.82	77.83
II	233.61	0.00	201.00	0.00	0.00	389.84	199.50
III	118.22	220.10	0.00	175.29	0.00	133.30	184.34
IV	341.30	381.00	148.20	0.00	319.42	77.43	283.00
V	0.00	0.00	596.00	339.57	0.00	442.02	0.00
NCR	260.00	389.36	155.36	154.40	403.86	0.00	266.27
CAR	71.74	195.53	173.81	278.00	0.00	262.00	0.00

Table 10.Average VKT per vehicle trip (Freight) (Source: IRPAFF data)

	Destination Zone						
Origin Zone	I	II	III	IV	V	NCR	CAR
I	0.00	323.11	181.53	385.70	0.00	289.39	65.91
II	308.52	0.00	314.73	470.00	0.00	404.20	202.00
III	233.10	329.74	0.00	192.96	469.74	114.11	214.00
IV	351.23	482.88	154.89	0.00	305.17	86.00	338.72
V	0.00	0.00	462.25	313.63	0.00	464.05	771.00
NCR	331.18	414.15	124.82	116.53	443.63	0.00	259.59
CAR	78.47	210.00	199.00	349.50	739.75	272.56	0.00

5. PROCEDURE OF ESTIMATING ENERGY DEMAND AND CO2 EMISSION

In estimating energy demand and CO2 emission from the road transport sector, the study follows the ASIF theory in a more elaborate approach. The formula to estimate energy demand from the private and public transport sectors is shown in equation 1, while equation 2 is intended for freight transport sector. The fuel efficiency factor was derived from fuel consumption survey done in this study, particularly for trucks and buses. Other FEF values were taken from other local studies (Vergel and Tiglao, 2013; World Bank, 2010). Default emission factors were taken from IPCC (2007).

For Private and Public Transport

$$E_m(Pvt, PT) = \frac{P_m}{\hat{O}_m}\, x\, (D_m)(FEF_{i,j})(A_{i,m})(Bi_{i,m,j})(C_j) \tag{1}$$

For Freight Transport

$$E_m(Freight) = \frac{W_m}{\hat{Z}_m}\, x\, (D_m)(FEF_{i,j})(A_{i,m})(B_{i,m,j})(C_j) \tag{2}$$

where:

- E_m :O-D estimates of total energy consumption of vehicle in category *m* in TJ
- P_m :O-D table of the expanded annual passenger trips of all vehicles under vehicle category *m*
- O_m :O-D table of the average occupancy of all vehicles under vehicle category
- D_m :O-D table of the average annual kilometer travelled of vehicle under category *m*, (km)
- $A_{i,m}$:O-D table of vehicle composition factor for each vehicle type *i* and category *m*
- W_m :O-D table of annual gross weight of all commodity in tons
- Z_m :O-D table of average load factor of freight vehicles
- $B_{i,m,j}$:fuel composition factor for each vehicle of type *i* and category *m* using fuel *j*.
- C_j :energy conversion factor of fuel type *j* (in liter or kg) to (TJ)

$FEF_{i,j}$:fuel efficiency factor for each vehicle of type *i*, using fuel *j*
m :vehicle category (e.g., Private, PT, & Freight)
i :vehicle type (e.g., passenger car, taxi, jeepney, bus, etc.)
j :fuel type (e.g., gasoline, diesel, LPG & CNG)

In general, P_m and W_m are the expanded demand analysis as a result of expanding 10-hour sample data to 24-hour population data described in section 3.3, while $D_m$is the average km travel per year derived from the same inter-regional traffic flow data.

Having estimated the energy demand for each category *m* and fuel type *j*, it is now possible to estimate the total energy demand as the sum of all categories as shown in equation 3.

$$E_{TJ}(Total) = \sum_j E_m(Pvt, PT)_j + \sum_j E_m(Freight)_j \quad (3)$$

Likewise, the total CO_2 emissions for each fuel type j, in tones can also be computed by applying the corresponding emission factor as shown in equation 4.

$$CO2_{Tons}(Total) = \sum_j E_m(Pvt, PT)_j (EF)_j + \sum_j E_m(Freight)_j (EF)_j \quad (4)$$

where:
(EF)$_j$:emission factor of fuel type *j*

The computation for estimating baseline energy demand and CO_2 emissions from the inter-regional road transport was performed with the aid of excel spreadsheets. IPCC 2007 standard emission factor for all type of fuel were used in this study, while the fuel efficiency factor were taken from Philippine Department of Energy (PDOE) and other local studies.

Prior to the calculations, an approximation of the actual distance traveled per vehicle was determined using google map's direction finder. All the distances measured from each group of vehicle category is summed up and is divided by the number of vehicles in that category to determine the average VKT per vehicle trips. Table 11 shows the simplified procedure of calculating energy demand and CO_2 emissions from the road transport sector.

Table 11 Calculation procedure of estimating energy demand and CO_2 emission

		A	B	C	D
Vehicle Type	Type of Fuel	Expanded Annual Pass Trips of vehicles under category *m*	Mode Share by Fuel Type	Annual Passenger Trip by Vehicle type	Average Vehicle Occupancy from OD Table
Data Source	IRPAFF	IRPAFF	IRPAFF	A x B	IRPAFF
Unit		Person trips	%	Pass-trips	Pass
Private Mode (Region I to Region II)					
Passenger Car	Gasoline	25,178,000	63.64	16,023,279	1.9
	Diesel		36.36	9,154,721	2.1

E	F	G	H	I
Annual Vehicle Trips from OD Table	Average Annual Kilometer Travelled of vehicle under category *m*	Computed Annual VKT from OD Table	Fuel Eff Factor (li/km)	Estimated Fuel Consumption in Liters
C/D	IRPAFF	E x F	PDOE	G x H
Veh Trips	KM	VKT	li/km	liters
8,433,305	145.3	1,225,359,194	0.179	219,339,295.6
4,359,391	153.6	669,602,436	0.099	66,290,641.1

J	K	L	M	N	O
Density of Fuel	Equiv. KTOE per Ton of Fuel	Fuel Consumption	Estimated Energy Demand	CO_2 Emission Factor	CO_2 Emission
IPCC	IPCC	(I x J x K)/1000	L x 41.868	IPCC	$(M \times N)/10^6$
kg/li	KTOE/Ton	KTOE	TJ	Tons/TJ	$MtCO_2$
0.745	1.01	165.04	6,909.97	69.3	0.4789
0.837	1.05	58.26	2,439.21	74.1	0.1807

6. RESULTS AND ANALYSIS

6.1 Baseline Energy Demand and CO_2 Emission

Figure 5(a-c) shows the baseline energy demand by mode for gasoline fed vehicles, while **Figure** 5(d-f) is for diesel fed vehicles. Study shows that inter-regional travel for road transport whose origin or destination is the National Capital Region or Metro Manila generates the highest energy demand for both gasoline and diesel as compared to other regions.

Inter-regional travel from Region IV to NCR registered the highest private transport energy demand for gasoline feed engine (Figure 5a), while NCR to CAR registered the highest energy demand for public transport using gasoline (Figure 5b). For freight transport using gasoline, inter-regional travel from Region I to NCR registered the highest energy demand. Likewise, for diesel consumption, the inter-regional travel from Region IV to NCR registered the highest energy demand for private transport (Figure 5d), while Region V to NCR for public transport (Figure 5e) and Region I to NCR for freight transport (Figure 5f).

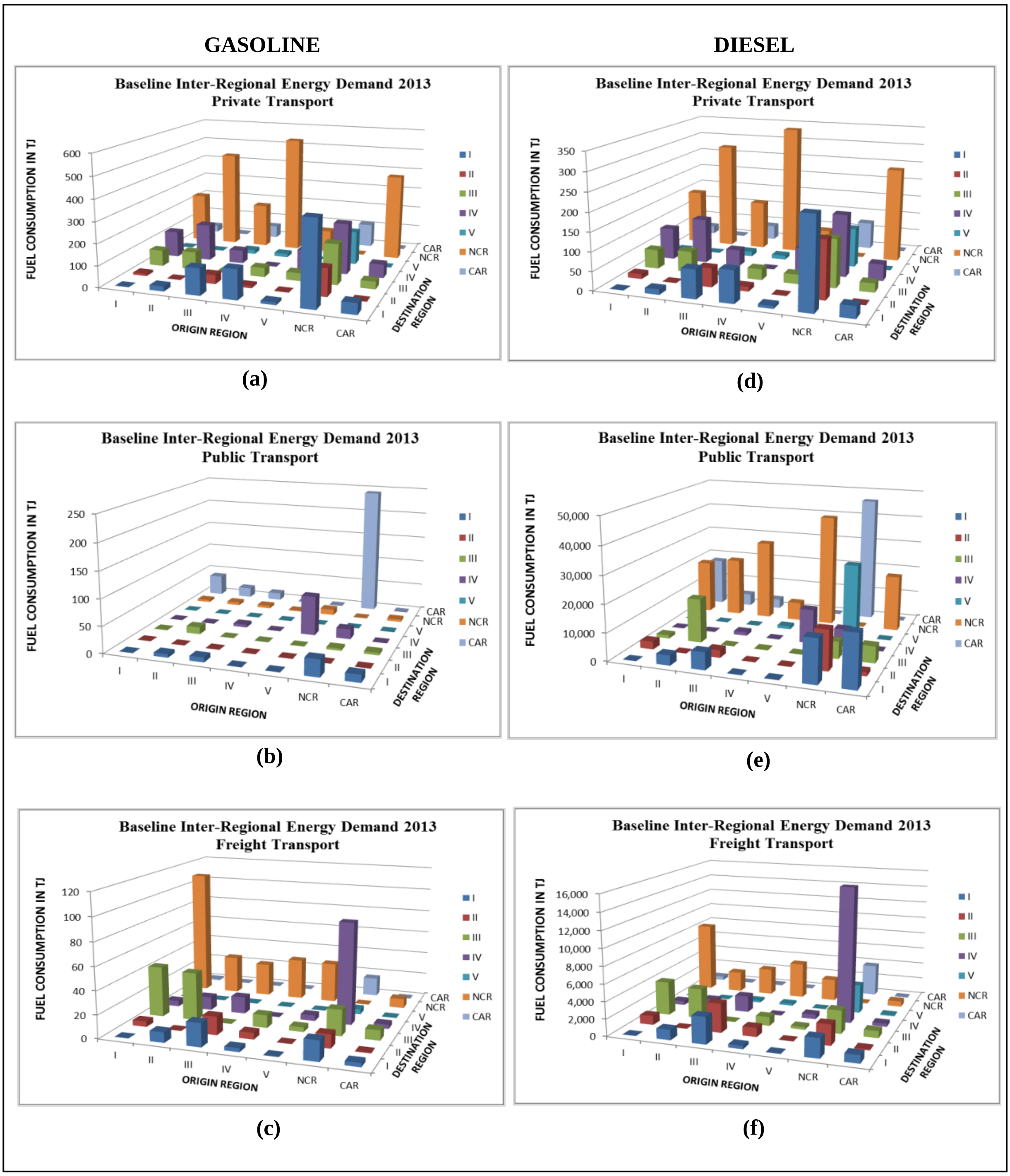

Figure 5(a-f). Baseline inter-regional energy demand by fuel type and by mode

Likewise, the computed baseline inter-regional CO_2 emissions for the seven regions in the island of Luzon are shown in Figure 6(a-f). This will serve as a reference CO_2 emissions for future development. It can be observed that inter-regional travel from and to National Capital Region or Metro Manila generates the highest CO_2 emissions for both gasoline and diesel. Other notable regions with higher CO_2 emissions are from Region I to NCR (Figure 6c), Region IV to NCR (Figure 6d), and Region V to NCR (Figure 6f).

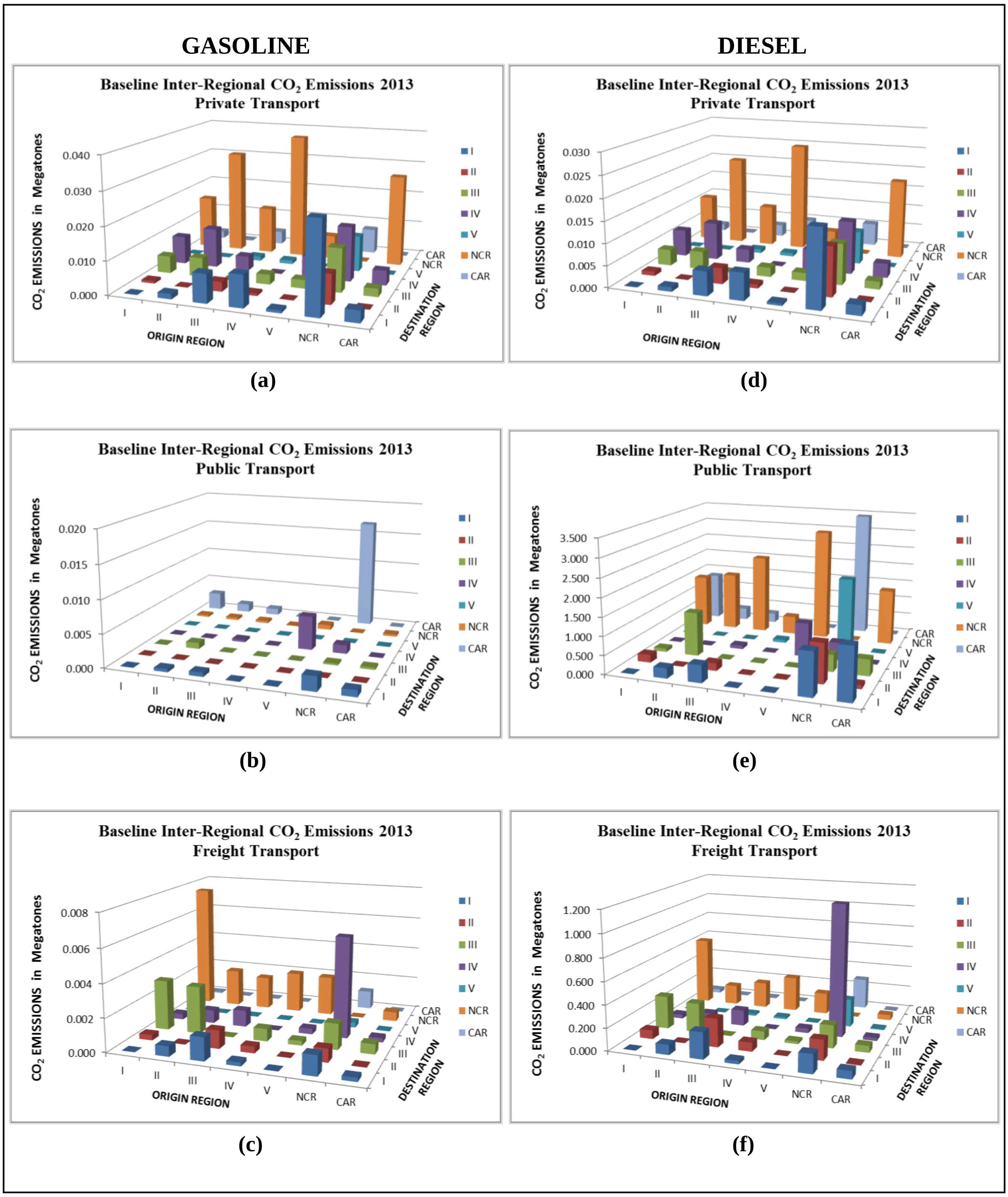

Figure 6(a-f). Baseline inter-regional CO_2 emissions by fuel type and by mode

6.2 Projected Energy Demand and CO_2 Emission

To establish a reference for future scenario analysis, the computed baseline energy demand in 2013 was projected up to 2050. It was noted that under the BAU or reference scenario, the estimated overall inter-regional energy demand in Luzon Island will substantially increase from 433,584.28TJ in 2013 to 806,024.62TJ in 2025 and about 2,896,644.83TJ in 2050 as shown in Figure 7. Likewise, the estimated overall inter-regional CO_2 emissions for Luzon is expected to increase from 32.10MtCO_2 in 2013 to 59.68MtCO_2 in 2025, and will continue to increase in quantum leap by 568% in 2050 at 214.51MtCO_2 under the BAU scenario as indicated in Figure 8.

The rate of increase of CO_2 emissions for road transport sector from baseline to future year scenario is due to higher average traffic growth rate for public transport comprising 7 regions in Luzon at 6% as published in the DPWH manual. However, the speed of increase is consistent with that from Fabian & Gota (2009) and World Bank (2010).

It can be observed that public transport dominates energy demand and CO_2 emissions for the inter-regional travel followed by freight transport, while private transport is almost insignificant. The result presented here is the estimate based from actual proportion of vehicles in the population. It should be noted that private mode has the least energy demand and CO2 emissions compared to public and freight mode of transport. This suggest that public mode of transport is still more preferred by majority of Filipinos people for inter-regional travel as they are perceived to be most economical.

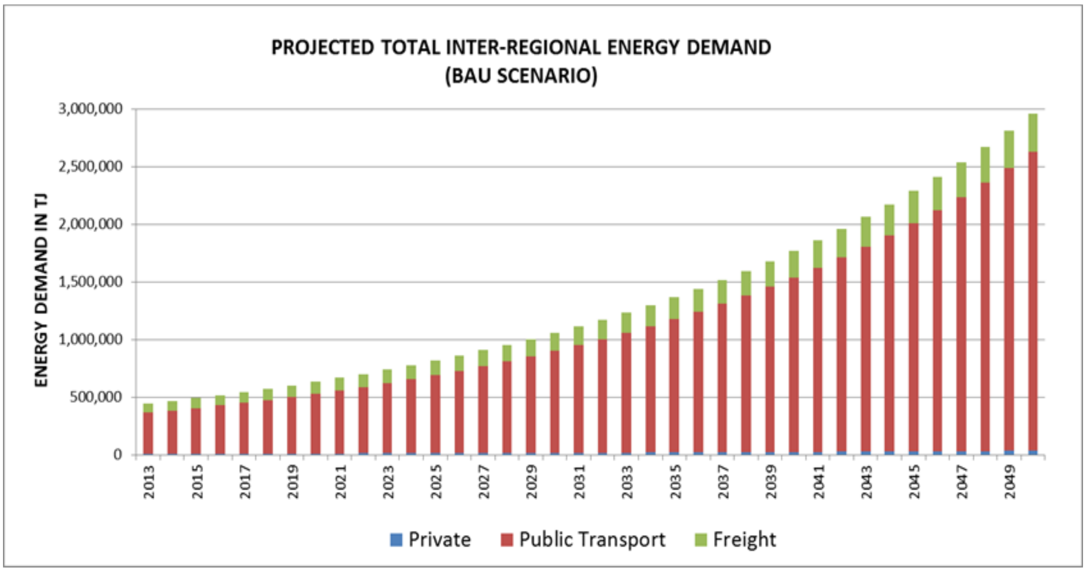

Figure 7.Computed reference overall inter-regional energy demand

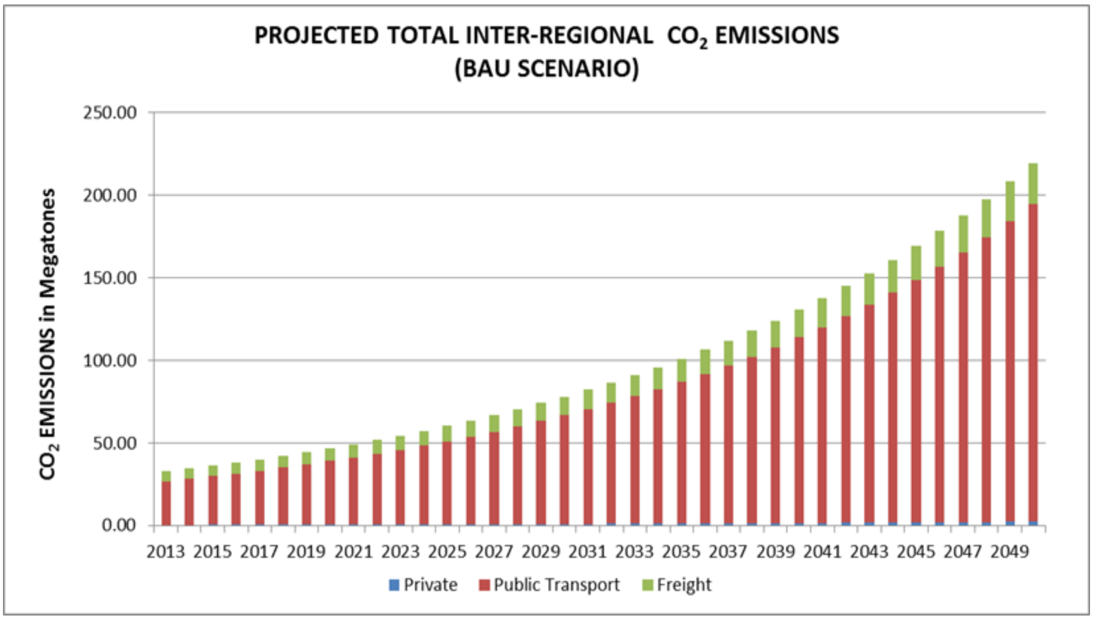

Figure 8.Computed reference overall inter-regional CO_2 emissions

6.3 Alternative Fuel Programs and Mass Transit as Policy Options in Reducing CO_2 Emissions

Since the early 2000, the Department of Energy (DOE) is implementing a long-term Alternative Fuel Program to provide cheaper and more environment-friendly alternatives to the conventional fossil fuels, and to reduce the country's dependency on imported oil. Its main goal is to tap the country's domestic produce as viable sources of energy, DOE Portal (2010).

One of the two major alternative transport fuels being promoted by the Department of Energy is the use of LPG. The DOE conduct regular information, education and communication (IEC) campaign on the operation and conversion of motor vehicles to auto LPG fuel to different transport stakeholders. It also conducts technology validation and assessment of auto-LPG vehicles and dispensing stations in different regions. In 2011, more than 19,000 units of auto-LPG taxis and 217 refilling stations are operating nationwide (DOE, 2011). However, all of these auto-LPG taxis and refilling stations are located and operating within the urban areas, particularly, in Metro Manila.

The other major alternative transport fuel promoted by the Department of Energy is Compressed Natural Gas (CNG). In 2002, the Philippine government launched the Natural Gas Vehicle Program for Public Transport (NGVPPT) designed to promote the utilization of compressed natural gas (CNG) in the transport sector in consonance with the goal of ensuring fuel supply diversification and supply security and help improve urban air quality through the reduction of harmful vehicular emissions. The program is primarily geared toward the utilization of Malampaya gas deposit in offshore Palawan (DOE, 2005; ADB, 2003). As of 2010, there are only eleven (11) CNG buses nationwide and is currently operating from Metro Manila to the province of Batangas only.

In order for the natural gas program for public and freight transport vehicle be realized, the Philippine government should provide appropriate infrastructure support services such as the construction of more CNG and LPG refuelling station to match the expected future supply and demand in the country. In addition, policy measures design to encourage and attract more CNG operators/investors must be prioritized by the government by providing incentive packages which includes but not limited to income tax holiday and zero rate duty on imported NGV equipment, parts, and components.

Another potential policy option tested is the implementation of better logistic system for freight transport which could potentially reduce the annual VKT of about 20% from 2016 to 2025 and 35% in the year 2050. In a study by Fabian & Gota (2009) indicates that by restructuring the logistics and increasing the share of high capacity multi axle trucks including a well-coordinated dispatch operation system by carefully understand the freight demand pattern taking into consideration the interaction between location and volume of goods supply and demand will have a possible reduction in VKT to 20%. Studies by DOTC also shows that the current freight transport in the Philippines is considered energy inefficient as significant share of vehicle fleets typically return from their point of origin empty load (dry run) after delivering their goods to their destination. This also resulted to overloading in many cases in order to recover the economic opportunity loss of traveling dry run. It is in this context that better logistic management could result to reduction in VKT by 20% or more. As presented in section 4.1, the proportion of light duty vehicles for inter-regional travel in Luzon is almost twice compared to high capacity freight vehicles, thus, government policy measures should focus toward this population.

Another candidate policy options that could have a significant impact in reducing CO_2 emissions from the transport sector is to revitalize and enhance the services of the Philippine

National Railways (PNR). This can be done by increasing its carrying capacity and by expanding its services linking all seven regions in Luzon. Reduction in passenger and freight trips for all road-based transport is considered a direct impact from switching to railway, thus reduction travel frequency for all road-based transport. Improved traffic congestion as a result of modal switch from road-based transport to railway is thought to be an indirect effect in reducing CO_2 emissions. Estimating indirect effect as a result of revitalizing and enhancing inter-regional railway system is beyond the scope of this study. It was assumed that the construction and rehabilitation of railway infrastructure facilities will be completed by 2025. A potential 15% passenger trips from private transport and 25% from road-based public transport is expected to switch to railway assuming that PNR will return its full operation by 2030. These proportions are expected to continue to increase gradually to 25% for private transport and 50% for road-based public transport by 2050. Similarly, 15% of freight goods are assumed to shift from road-based to railways in 2025 starting in 2016 and continue to increase by 30% in 2050.

The above mentioned policy measures as part of the Philippines initiatives to fight against global warming will be assessed in terms of its potential impact to reduce CO_2 emissions. Table 12 shows the 4 different policy scenarios and the descriptions on how reduction of CO_2 Emissions will be assessed.

Table 12. Selected fuel sensitive policy measure scenarios

Scenario	Policy Measures	Policy Description
S1	BAU	Do nothing scenario until 2050
S2	Promotion of Alternative Fuel Program	**For light vehicles:** Gradual shift from gas or diesel to LPG by 15% by 2025 starting in 2016 for all light vehicles, then gradually continue to increase until it reaches 35% by the end of 2050. **For heavy vehicles including buses:** Gradual shift from diesel to CNG until it reaches 20% in 2025 starting in 2016, then gradual change continue to increase until reached 50% by 2050.
S3	Better Logistic Management for Freight Transport	Assume 20% reduction in VKT for all Freight Vehicles by 2025 and then increase to 35% until 2050.
S4	Revitalize and Modernize Inter-Regional Service of Philippine National Railways (PNR)	Revitalize and modernize Philippine National Railway (PNR) linking all seven (7) Regions in Luzon and assume a gradual switch of road-based private, public, and freight mode of transport to railways by 15%, 25%, and 20%, respectively in 2025, and continue to increase by 25%, 50%, and 30% in 2050, respectively.

6.4 Implications of Selected Policies to Reduce CO_2 Emission from Inter-Regional Road Transport

For the BAU scenario, the total amount of CO_2 emitted into the atmosphere is from 59.68MtCO_2 I n 2025 to about 214.51MtCO_2 in 2050. The increase is about twice and 6 times higher from the 2013 baseline CO_2 emission of 32.10 MtCO_2, respectively. The comparison of the potential implications of different policy measures to reduce CO_2 emissions is shown in Figure 9.

Comparison of different scenarios shows that promotion to alternative fuel program such as the use of LPG for light vehicles & CNG for buses including heavy trucks provide a more significant reduction in CO_2 emissions as compared to better logistics management and the revitalized and enhanced Philippine National Railway system. It is safe to say therefore that simultaneous or combined implementations of selected scenarios would provide a more substantial reduction in CO_2 emissions as compared to individual implementation of different policy scenarios.

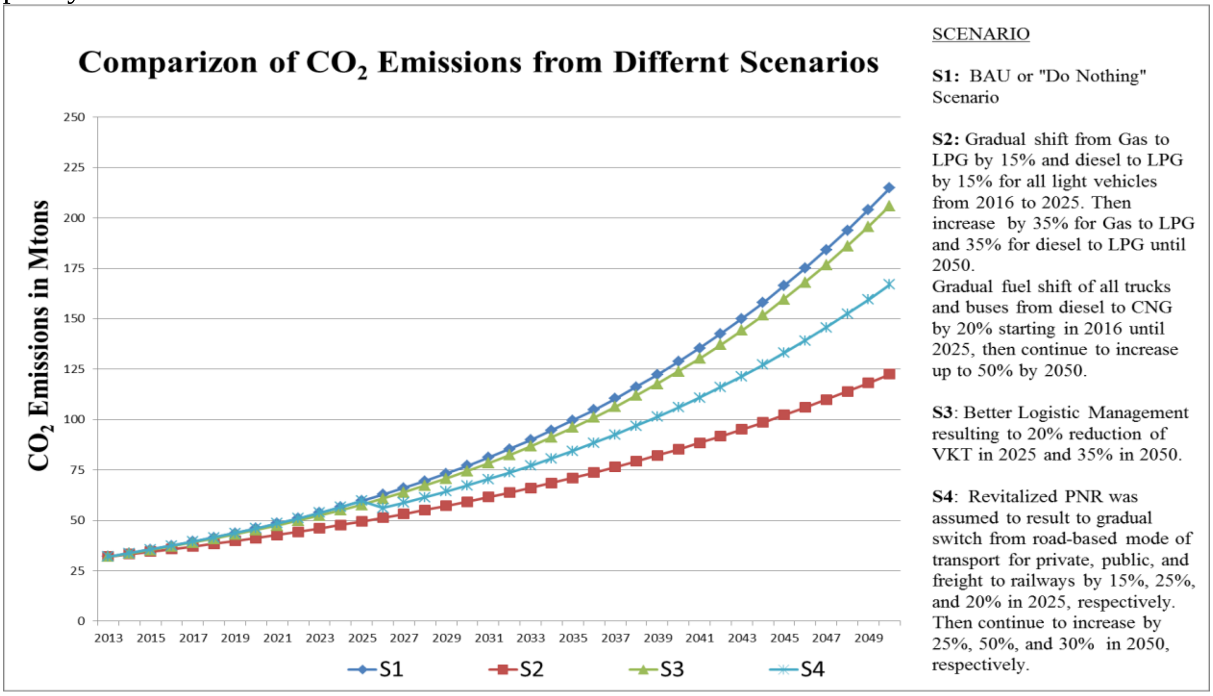

Figure 9. Comparison of Selected Scenarios for the Overall Inter-Regional CO_2 Emissions

By assessing the implications of the different policy measures to reduce CO_2 emissions, the study shows that promotion to alternative fuel programs yield the highest potential reduction in CO2 emissions by 17.04% and 42.94% in 2025 and 2050, respectively (Table 13). It was followed by the full operations of a revitalized and modernized PNR services with 10.07% and 22.30% in 2030 and 2050, respectively. Promotion to provide better logistics management for freight transportation found to be the lowest in terms of reducing CO2 emissions with 3.17% and 4.15% in 2025 and 2050, respectively.

Table 13. Percent Change in final CO_2 emissions from different policy options

Scenario	Policy Measures	Change of CO_2 Emission from S1:BAU	
		2025	2050
S2	Promotion of Alternative Fuel Program for all Light & Heavy Vehicles	17.04%	42.94%
S3	Better Logistic Management for Freight Transport	3.17%	4.15%
S4	Revitalize and Modernize Inter-Regional Service of Philippine National Railways (PNR)	10.07%	22.30%

7.0 Summary and Conclusion

The study presented a new technique and methodology of estimating energy demand and CO_2 emissions from the road transport using inter-regional passenger and freight flow O-D data obtained from the UP-National Center for Transportation Studies. Although the Philippines is viewed as not a major contributor to global warming and climate change, but by looking at the "do nothing scenario", the future CO_2 emissions from the transport sector will become very substantial.

The study presented several practical policy measure scenarios and compared them to the reference "do nothing" scenario for environmental implication. The study shows that the shift to better fuel for public transport such as LPG for light vehicles and CNG for buses including heavy vehicles will have a substantial reduction in the overall CO_2 emission in Luzon. However, if only private passenger cars and light duty vehicles will shift to, say, LPG or CNG, the potential reduction of the final overall CO_2 emission in 2050 may not be significant as private mode has the smallest share of energy demand in terms of inter-regional travel as compared to public and freight transport.

Findings of this study will further strengthen the government's existing policies to promote the utilization of compressed natural gas (CNG) in the transport sector under the Natural Gas Vehicle Program for Public Transport (NGVPPT). This is in consonance with the goal of ensuring fuel supply diversification and supply security and helps improve air quality through the reduction of harmful vehicular emissions. The program is primarily geared toward the utilization of local resources particularly the Malampaya gas deposit in offshore Palawan (DOE, 2011).

The computed total CO_2 emissions from inter-regional travel may not be significant at the moment as far as the overall emission reduction is concerned, but the expansion of the use of alternative fuels to the motor vehicle populations in the country will make a difference. Improvement on vehicle technology including transmission, aerodynamics, tyres and auxiliaries, as well as heat recovery is also known to effectively reduce the overall CO_2 emissions, European Commission (2014).

Likewise, better logistics management can be further enhanced by improved fleet management, better driver training, and superior vehicle maintenance, as well as improved hauling capacity management with the adoption of Intelligent Transport Systems (ITS).

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