ENERGY CONSUMPTION BY BATTERY OPERATED AUTO-RICKSHAWS

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Abstract: *The paper contains primary data based analysis on the energy consumption aspect of battery operated auto-rickshaws which is one of the crucial issues in the transportation system of a developing country like Bangladesh. Several aspects associated with the mode such as its energy consumption rate, effects of recharging of the mode on local town's energy provision capacity, and the mode's contribution in attenuation of transport related emissions are explored in the paper. The paper with scientific research outcomes would provide guidelines to the policy makers of a country regarding whether and how to incorporate the mode in the local town's transportation system.*

Battery operated auto-rickshaw offers lower travel cost than rickshaw and greater travel comfort than other urban para-transits like auto tempo, nosimon and public transport like minibus, and therefore attracts urban passengers significantly from those modes. Around 88% of people living in a city where battery operated auto-rickshaws are available, use the mode now to meet their travel demand. Through attracting passengers from fuel operated vehicles, thus the mode replaces them at great extent. A considerable percentage of daily electricity demand of local towns is consumed by the mode which creates pressure on local electricity supply in turn. However, considering the duration and period of load shedding caused due to recharging the mode, energy consumption by the mode can be negotiated as the mode is liable only for 1.53 hours of load shedding a day which takes place at off-peak period (between 11:00 PM and 7:00 AM) at night.

Keywords: *Battery operated auto-rickshaw; Duration of consumption; Fuel consumption; Fuel operated vehicles; Load-shedding; Urban emission reduction.*

1. Introduction

Battery operated auto-rickshaw (locally called 'Easy-bike') is a newly added para-transit mode in urban transportation system of Bangladesh. From the very begining of introducing, the mode has become a popular transport mode especially to the lower, lower-middle and even middle income people of urban areas of Bangladesh since the mode involves lower travel cost than other locally available transport modes as well as provides reasonable safety and comfort to the users during travel [1].

The mode involves limited speed and lightweight and hence it does not produce fatal accidents [2]. Typically in an urban area motor vehicle emission can make up over 70 percent of the total emissions of air pollutants [3]. Diesel and petroleum operated vehicles such as auto tempo could be substituted by plug-in hybrid electric vehicle (PHEV) which would result considerable reduction in emission [4].

However, Government of Bangladesh claims that the mode consumes at least 300 megawatts of electricity every day due to recharge their batteries [1]. In order to save the inadequate electricity supply in Bangladesh, government has recently taken decision to ban this mode from urban roads without carrying out any research on the fact [5]. Before taking any decision regarding a crucial issue like battery operated auto-rickshaw, government should have carried out extensive research regarding whether the mode is a major threat to local or national electricity supply.

From this perspective, the study has been undertaken to explore the energy consumption aspect of the mode. The research outcomes might help policy makers of a developing country like Bangladesh where energy is a priority issue, to take decision whether to incorporate this type of energy consumptive mode in local town's traffic mix.

2. Objectives of the Study

The objective of the study is to explore and analyze energy consumption aspect of battery

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operated auto-rickshaws in the context of local towns of Bangladesh.

3. Methodology of the Study

Methodology of the study is described briefly in this segment.

3.1 Study Area Selection

Two study areas are selected for carrying out the study based on two major criteria as following-

i. Number of battery operated auto-rickshaws currently running within the town.
ii. Proximity of the town to Dhaka.

Initially several urban areas of Bangladesh are considered on the basis of availability of data regarding the number of battery operated auto-rickshaws. Among them, two are selected as study areas based upon the criteria mentioned above. Number of battery operated auto-rickshaws running within the town and physical distances (km) of those towns from Dhaka are presented in Table-1.

Table 1 Number of battery operated auto-rickshaws and physical distances of corresponding towns from Dhaka

Name of the Town	Number of Battery Operated Auto-rickshaws Running within the Town*	Distance of the Town from Dhaka (km)**
Comilla	8,687	97
Kushtia	2,521	277
Jessore	1,800	274
Faridpur	1,200	145
Meherpur	1,250	286

*Source: Easy-bike Owner's Association, Kushtia & Faridpur, 2011 [6]; District Traffic Police, Comilla, 2011 [7] The Daily Prothom Alo, 2011 [8]
** Source: Discovery Bangladesh, 2011 [9]

According to the stated criteria and imposing priority on the first one to ensure data quality, Comilla City Corporation Area and Kushtia Municipal Town are selected as study areas.

3.2 Variable Selection and Data Collection

Variables selected to fulfill the objective are presented in Table-2.

Table 2 List of variables

Objective	Parameters	Variables
To explore and analyze energy consumption aspect of battery operated auto-rickshaws in the context of local towns of Bangladesh.	Energy consumption feasibility	Energy consumption rate, User's mode choice, Fuel saving rate, Duration of consumption
	Emission reduction	Emission reduction rate

Data required to fulfill the objective are collected inclusively from user opinion survey, field survey and secondary sources. In addition, data regarding the physical and operational characteristics of battery operated auto-rickshaws are collected from the interview with owners of battery operated auto-rickshaw recharging center. The sample size for user opinion survey is calculated adopting stratified sampling method at 95% confidence level and confidence interval of 5.

4. Literature Review

Momotaz (2009) [10] mentioned fuel consumption rates of different vehicles available in local urban towns of Bangladesh as presented in Table-3.

Table 3 Fuel consumption rates of different vehicles

Modes	Fuel Type	Fuel consumption (liter/veh/km)
Human-hauler*	Diesel	0.1125
Auto-tempo	Gasoline/Diesel	0.04
Minibus	Diesel	0.52 ~ 0.87

Source: Momotaz, 2009 [10]
*Fuel Consumption rate of *nosimons* (a local motorized and three-wheeled para-transit mode in Bangladesh) is assumed equal to human-hauler

Emission generation rates of these fuel operated vehicles are shown in Table-4.

Table 4 Emission generation rates of different fuel operated vehicles in Bangladesh

Mode	Fuel Type	CO (gm/veh/ km	NO_x (gm/veh/ km)	SO_x (gm/ veh/ km	HC (gm/veh/ km)	SPM (gm/veh/km
Human-hauler	Diesel	25.0	1.5	0.4	4.0	1.6
Auto-tempo	Gasoline	39.4	1.6	0.5	4.0	1.0
Minibus	Diesel	20.0	17.0	2.0	4.0	1.6

Source: Momotaz, 2009 [10] & Hasan, 2008 [11]
CO: Carbon Monoxide; NO_x: Oxides of Nitrogen;
SO_x: Oxides of Sulpher; HC: Hydro Carbons; SPM: Suspended Particulate Matters.

Hasan (2008) [11] used the following formulae to calculate the daily emission generation rate of a fuel operated vehicle:

Daily Emission (ton/day) = [(Number of vehicles)*(daily length of operation of vehicle in km/day)* (emission generation rate of the vehicle in gm/veh/km)] / $(1000)^2$.

Occupancy rate of different types of vehicle available in local urban areas of Bangladesh are calculated in Upazilla Town Infrastructure Development Project (UTIDP) conducted by Local Government Engineering department (LGED) as presented in Table-5.

Table 5 Occupancy rate of different types of vehicle

Mode	Occupancy Rate
Human-hauler	8
Auto-tempos	8
Minibus	32

Source: UTIDP, 2009 [12]

As calculated from the power generation data presented in Daily Electricity Generation Reports (2011) [13] of Bangladesh Power Development Board (BPDB), 0.069 gallon diesel or furnace oil is required to produce 1 Kilowatt (KW) of electricity at 25 to 30 percent efficiency of plant.

Mahmood (2011) [14] found from his study that Bangladesh could save between $200 million and $800 million per year, about 0.7 to 3.0% of its gross national product, if air pollution in the country's four major cities was reduced. Around 6.5 million people in those cities suffer from air pollution related diseases each year. Vehicular air pollution is a major cause of respiratory distress in urban Bangladesh. Nearly seven million people in Bangladesh suffer from asthma, more than half of them are children. About 9 deaths in every 10 due to air pollution take place in the developing world, where about 80% of world populations live.

However, battery operated auto-rickshaws do not cause any air pollution. Mader (2006) [4] examined that substituting the diesel and petroleum operated vehicles by plug-in hybrid electric vehicle (PHEV) results 35-50% reduction in nitric oxide and reactive organic gases, 45-65% reduction in petroleum usage and 30-45% reduction in greenhouse gases in city areas.

Dhakal (2005) [15] mentioned in his study- "Role of Government, Private Sector and Civic Society in Promoting Battery Operated Electric Three-Wheelers In Kathmandu, Nepal" that just because the battery operated auto-rickshaw generates least pollution, diesel-operated three-wheelers (the so-called "tempo") has recently been relocated by the Government of Nepal out of the Kathmandu valley to encourage the use of battery-operated auto-rickshaws to curb air pollution.

5. Results and Discussions

Amount of electricity required to recharge a battery operated auto-rickshaw for a single time is on average 7.5 kilowatt as found from the study. Accordingly, total 2521 battery operated auto-rickshaws running within Kushtia Municipal Town consume around 5.9 percent (that is 18.9 Megawatt) of the total daily demand of electricity of the town every day to be recharged. In transposition, demand for electricity per day to recharge the mode in Comilla Town is 17.14 percent of the town's total daily demand. Study shows that in 2011, total 11208 battery operated auto-rickshaws running within study areas altogether consume around 82.90 Megawatt of electricity per day to be recharged.

In turn, the mode attracts passengers at considerable extent from other fuel operated vehicles as shown in Figure-1.

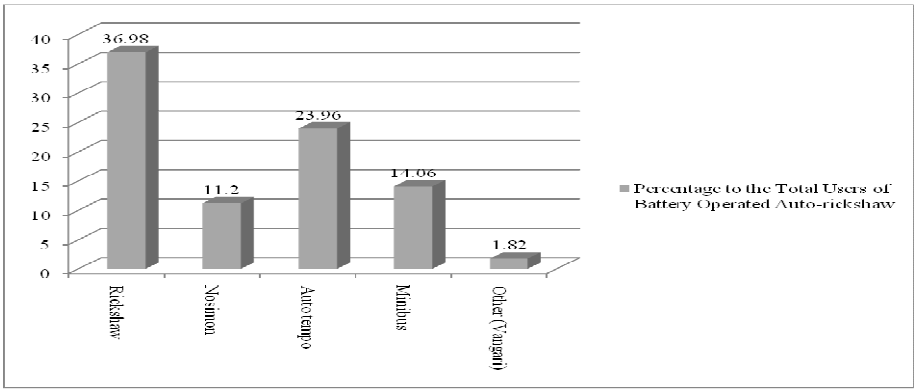

Figure 1: Percentage of passengers attracted to battery operated auto-rickshaws from fuel operated vehicles

Table 6 Characteristics of trips made by fuel operated vehicles in study areas

Mode	Study Area	Route Distance (Avg.) in km	Trip Frequency per Day (Avg.)	Extent of Distance to Serve Study Area (Avg.) in km
Auto-tempo	Kushtia	11.75	6	10
	Comilla	5.64	12	4.07
Nosimon	Kushtia	4.67	8	4.67
	Comilla	0	0	0
Minibus	Kushtia	37.7	5	7.1
	Comilla	30.34	5	2.17

Source: Field Survey, 2011

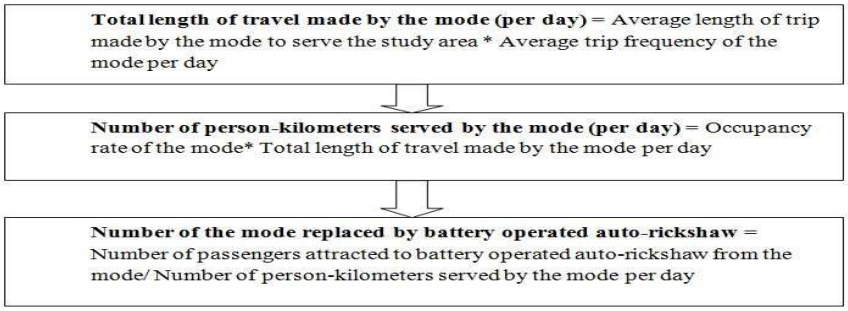

Figure 2: Procedure of calculating number of vehicles replaced by battery operated auto-rickshaws

Table-6 presents several characteristics of fuel operated vehicles e.g. average travel distance, number of trips made and extent of distance to serve the study areas as collected from field survey.

Now, number of these fuel operated vehicles replaced by battery operated auto-rickshaws in 2011 is calculated adopting the procedure presented in Figure-2.

Study shows that battery operated auto-rickshaws replace the daily demand of 94 *nosimons*, 147 auto-tempos and 86 minibuses in 2011 in Kushtia Municipal Town and Comilla City Corporation area through attracting passengers from these modes. Thus, the mode saves consumption of around 3161.99 gallons of diesel and 106.08 gallons of gasoline per day in study areas in that year. The amount of diesel and gasoline fuel saved by the mode could produce daily 47.36 Megawatts of electricity at 25 to 30% efficiency of plant. That means the mode consumes around 0.75 times greater amount of energy than the amount it saves. Therefore, it could be mentioned that fuel

operated vehicles would serve urban passenger's travel demand in energy efficient way in local urban areas of Bangladesh if battery operated auto-rickshaws would not have been introduced.

However, considering the duration and period of consumption, energy consumed by the mode could be negotiable. Data collected from Daily Reports (2011) [16] on demand and supply of electricity from Power Grid Company of Bangladesh Limited, Bottail 132/33 KV Grid Substation, Kushtia, reveals that during summer season electricity demand rate is 14 MWH at off-peak period in the town. This indicates that during that season, deficit of 14 MW of electricity results load shedding of 1 hour at off-peak period. In transposition, load shedding for 1 hour takes place at off-peak period during winter season when there is deficit of 11 MW of electricity [16]. If battery operated auto-rickshaw could be banned from the town, 18.9 MW of electricity would be saved per day at night. That means, banning of the mode would reduce load shedding for 1.35 hours at night during summer and 1.72 hours during winter season. Therefore, the mode is liable for only 1.53 hour of load shedding on average at off peak period of night (Note: The mode is recharged between 11:00 PM and 7:00 AM in local urban areas of Bangladesh as found from the study). It is worth mentioning that Kushtia town suffers from load shedding of 12.43 hours a day during summer and 8.54 hours a day during winter [16]. On average, the duration of load shedding in Kushtia Town is 10.48 hours a day as found from study. Data collected from Kushtia Municipal Office and Power Grid Substation, Bottail, Kushtia reveals that there is no irrigation pump within the municipal area which generally gets priority for electricity supply during night in rural areas. That means, almost all amount of electricity demanded during off-peak period at night is for the household consumption in the town. Therefore, load shedding of 1.53 hour during off-peak period at night occurred due to recharging battery operated auto-rickshaws can be compensated substantially by other benefits the mode involves.

In addition, battery operated auto-rickshaws, through replacing fuel operated vehicles play significant role in attenuating urban transport related emissions. Per day reduction rate of emission and the total amount reduced by the mode in study areas in 2011 as found from the study, are presented in Table-7.

Table 7 Amount of emission reduced by battery operated auto-rickshaw in study areas in 2011

Emission Type	Per Day Reduction Rate (ton/day)	Reduction in 2011 (tons)
CO	6.86322	2505.075
NO_x	2.11836	773.2018
SO_x	0.74941	273.5346
HC	0.24749	90.3335
SPM	0.03303	12.05605

This emission reduction aspect associated with battery operated auto-rickshaw provides logical reasoning to adopt the mode in the transportation system of rapidly flourishing local urban areas of Bangladesh in order to ensure environmentally sustainable growth in there.

6. Conclusion

Battery operated auto-rickshaw is an energy consumptive electric mode. As an urban para-transit vehicle, the mode with better transport service quality attracts urban passengers significantly from other varieties of modes like rickshaw, *nosimon*, auto tempo and even from minibus. However, through replacing fuel operated vehicles, the mode offers transport service in urban areas of Bangladesh at higher energy costs. In comparison to the average daily demand of electricity of local towns the mode consumes considerable amount of electricity to be recharged every day. If the mode would not be introduced, fuel operated vehicles replaced by battery operated auto-rickshaws could serve the travel demand of urban passengers at energy efficient way. However, considering the time of consumption, it is found that energy consumed by this mode has very little and negligible impact on town's load shedding. The mode is liable only for 1.53 hour of town's load shedding a day and this takes place at off-peak period at night between 11:00 PM and 7:00 AM.

A remarkable benefit that the mode involves is to reduce urban transport related emissions. Fuel operated vehicles are characterized by emission generation while battery operated auto-rickshaw

has much potentials to replace fuel operated para-transit modes and hence to reduce urban emissions. Like-wise energy, ensuring environmental sustainability in local urban centers is another crucial issue in Bangladesh to be considered. Battery operated auto-rickshaw could be a viable alternative to other fuel operated vehicles in those growing urban centers of Bangladesh with a view to attaining the environmentally sustainable growth.

7. Recommendations Regarding Battery Operated Auto-rickshaws

- Growth of battery operated auto-rickshaws in local urban areas should be controlled to minimize energy consumption. The number of the mode should be allowed within a town according to its energy provision capacity.
- The design of the mode could be altered as well to minimize energy consumption. The battery could be replaced by renewable energy capacitor such as, solar panel. City authority should offer discount to current operators of the mode in this regard as investment cost for this energy source is too high to be affordable to the low income operators.

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