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STUDY OF EXISTING RICKSHAW AND POSSIBLE DESIGN MODIFICATIONS

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ABSTRACT

A survey was carried out on rickshaw-drivers of Dhaka city to get feedback, regarding problems they face and possible technical modification of existing rickshaw design, through a structured interview process. A comprehensive study of existing rickshaw is presented by technically specifying its individual components along with their materials, mass and dimensions. Such documentation is hardly available but very important in order to renovate or improve existing rickshaw design. After carefully analyzing the existing design of rickshaw a number of prominent short coming have been identified and possible design modifications have been suggested.

Keywords: Rickshaw, Hpv, Existing Components, Design Modifications.

1. INTRODUCTION

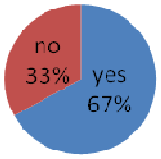
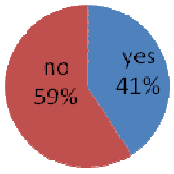
The conventional rickshaw is a good example of a successful human powered vehicle (HPV) which is commercially used in vast numbers in a number of developing countries. Although the three-wheel manually driven rickshaw is one of the most important modes of transportation in Bangladesh, it is not an ideal example of appropriate technology. The design of a rickshaw has practically remained unchanged for decades, although there is lot of scope to improve its performance. But before taking any attempt to modify the rickshaw design it is important to study the existing structure and know about the feedback form the users and stake holders, especially the rickshaw drivers regarding the operation and use of existing rickshaw. For any fruitful attempt of upgrading the rickshaw design a complete list of all the parts of rickshaw with their dimensions and weight and other specification is essential to start with. Unfortunately there is hardly any document about the existing design and components of rickshaw. Such information is essential for - analysis, modification and optimization of the existing conventional rickshaw design. This work involves firstly a survey carried out on rickshaw pullers of Dhaka city, some times termed as the rickshaw capital of the world. The survey is aimed gathering feedback form one of the most important stake holders, regarding the structure and performance and need of modification of the vehicles they run everyday. In the second part a detailed study and documentation of all major components of the existing conventional rickshaw is carried out. Based on these two studies, a number of modifications on the existing design have been recommended.

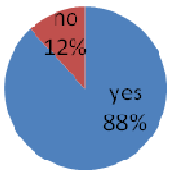
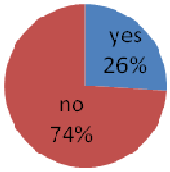
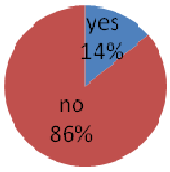
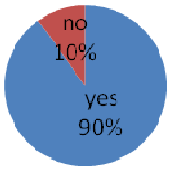
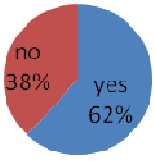
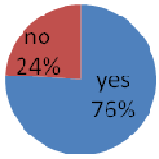
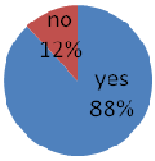
2. SURVEY OF RICKSHAW DRIVERS

Over one hundred rickshaw drivers from different parts of Dhaka city have been interviewed for the survey. The carefully catered questioner of the survey covered a wide range of aspects - technical (specially related to possible design modifications), physiological as well as socio-economical aspects of running rickshaws.

2.1 Response of the Rickshaw drivers regarding possible design changes

Some findings of the survey regarding possible design modifications are shown in Table-1 below:

SURVEY QUERRY : Do you face any physical problem from driving rickshaw?	
Will there be a problem if the position of the pedal or gear ratio is changed to get mechanical advantage?	

Do you think the suspension system of rickshaw needs be improved?	
Will there be any problem if the extended portion of the rear shaft is reduced?	
If the base of the passenger carrier is made flat will there be any problem?	
Is it necessary to bend the hood lower to reduce air drag?	
Is the box beneath the passenger seat necessary?	
Do you think the weight of rickshaw should be reduced?	
Is it necessary to add headlamp and taillights to rickshaw to ensure traffic safety?	

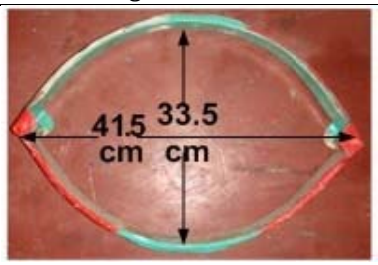
The survey also revealed first hand information regarding the socio-economic scenario of running rickshaws in Dhaka. The daily income of the rickshaw driver depends on a number of factors: the age of rickshaw driver, working hours per day, government holidays etc. The working hours per day range from 8-12 hours. The average daily income varies from Tk. 200-600. Aged rickshaw drivers (above 45) earn less (in the order of Tk. 200-300 per day) than the young counterparts as the passengers prefer young drivers. Rickshaw drivers generally take one or two off days a week and their monthly income varies from Tk.4000-8000 excluding maintenance cost. Although the owners bear the major maintenance and repair cost, the rickshaw drivers generally have to spend Tk. 150-300 monthly in oiling different parts, inflating the tires, minor repairs etc. Near 45% of the total population of Bangladesh lives under the poverty line. Rickshaw driving can be a head start for many of them to improve their socio- economic condition. According to this survey 76% rickshaw drivers are found to be satisfied about their job. They believe that they are doing better than before they came into this profession.

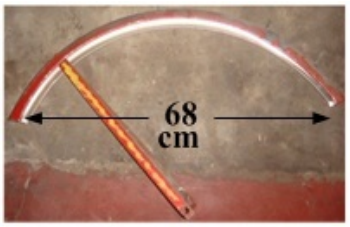
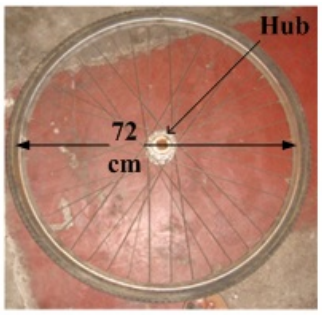
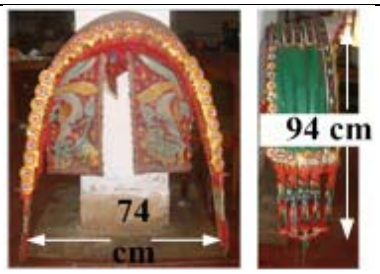
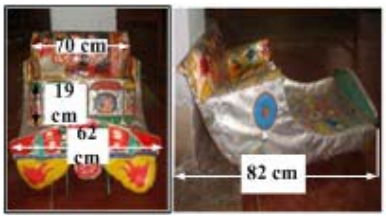
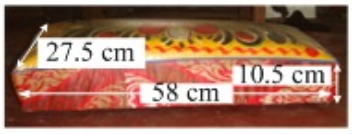
Analysis of the survey findings reveal that the response of the rickshaw drivers towards possible improvement of rickshaw design is generally very positive. It was found that some of them have objections about certain changes in rickshaw and some were found to be indifferent. But this is mainly because their lack of technical knowledge. For example some of them thought that if the suspension system is changed or the weight of the rickshaw is reduced it will essentially reduce the strength of the rickshaw structure. This may not be the case, if properly redesigned. In spite of a few objections the overall response from the rickshaw drivers was found to be very enthusiastic regarding technical modifications. A more representative result could be obtained by running a survey all over Bangladesh.

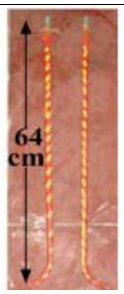
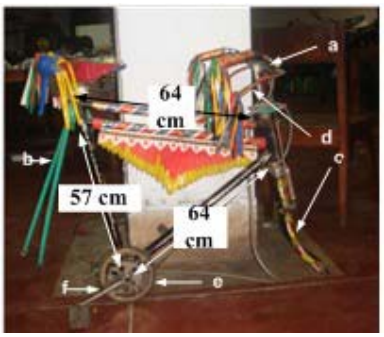
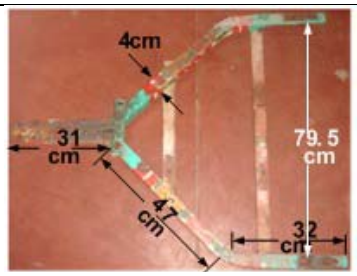
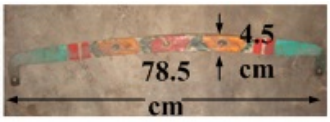
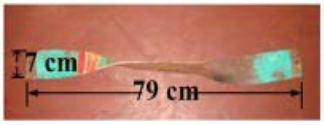
3. EXISTING COMPONENTS OF RICKSHAW

Rickshaw is a pedal operated tricycle mostly made out of bicycle components. In order to improve the rickshaw design it is necessary to identify the existing components of the rickshaws. The structure and components of rickshaws slightly vary to some aspects in different parts of the country. A typical passenger rickshaw typically in Dhaka was dismantled and each component was carefully analyzed. The major components of this rickshaw, their materials, mass and dimensions are listed below:

Table 2: Major components of a passenger rickshaw

Component	Image/ Dimensions
Component name: Elliptical spring **Material:** Mild steel **Mass:** 3.8×2 = 7.6 kg	 Width: 50.7 mm, Thickness: 9.2 mm
Component name: Rear axle with bearings and free wheel **Material:** Mild steel **Mass:** 6.3 kg	 Shaft Diameter: 2.54 cm

Component name: Mudguards **Material:** Galvanized steel **Mass:** 2.4 kg (3 mudguards in total)	
Component name: Wheel **Material:** Tire (steel wire, fabric, rubber),Rim (Steel), Spokes(steel) **Mass:** 11.1 kg (all 3 wheels)	
Component name: Hood **Material:** Bamboo, Rexene **Mass:** 6.3 kg	 Bamboo length: 242 cm Bamboo Width: 4 cm Bamboo thickness: 1.1 cm
Component name: Passenger carrier (without seat) **Material:** Wood **Mass:** 16.3 kg	 Wooden Plate Thickness: 21.5 mm
Component name: Passenger seat **Material:** Coconut Coir, Rexene **Mass:** 4.1 kg	

Component name: strengthening rods for front forks **Material:** Mild steel **Mass:** 1.2 kg	 Diameter: 10.2 mm
Component name: Bar **Material:** Mild steel **Mass:** 1.8kg	 Width: 5.3 cm Thickness: 5 mm
Component name: Front frame including a. Handlebars b. Rear stays c. Front fork d. Brake levers e. Chain wheel f. pedal crank **Mass:** 12.3 kg	 Tube Diameter: 2.54 cm Driving: Driven sprocket : 48:22 teeth
Component name: Sub-frame **Material:** Mild steel **Mass:** 11.1 kg	 Angle Bar: 38.7×38.7×6 mm
Component name: Connecting bar(lower) **Material:** Mild steel **Mass:** 1.8 kg	
Component name: Connecting bar(upper) **Material:** Mild steel **Mass:** 1.1 kg	 Thickness: 3 mm

Component name: Hood latches, wooden blocks, bearing holders and nuts and bolts **Mass:** 3.5 kg	
Component name: Decorations **Material:** Wood, steel, Plastic **Mass:** 2.6 kg	

Table-2 could be useful to anyone who wants to study or renovate the existing rickshaw components or design. Table-3 shows the typical overall dimensions of a rickshaw. The data is based on measurements of only few rickshaws, investigating a larger number of rickshaws manufactured or assembled in different parts of Dhaka city could reveal the range of deviation of physical specifications.

Table 3: Typical Overall Vehicle Dimensions

Total weight	90 kg
Wheelbase	166 cm
Overall length	238 cm
Track width	100 cm
Overall width	110 cm

4. SOME LIMITATIONS OF RICKSHAW DESEIGN AND POSSIBLE MODIFICATIONS

A number of limitations of existing rickshaw design were detected during the study; some of these were also reflected in the feedback collected from the survey carried out on the rickshaw pullers of Dhaka city. Some of these short comings can be addressed with locally available technology. This section identifies the major problems and suggests possible ways of improvements. Some of the suggestions made here have been experimented, the findings of which will be published in another paper.

4.1 Excess Weight

The rickshaw which had been dismantled in BUET lab weighed 89.8 kg. Of this, 7.6 kg (8.46%) are in the almost rigid solid springs, which are practically ineffective. Passenger carrier without the seat weighs about 16.3 kg (18.15% of total weight) and is very solidly constructed out of wood. The sub frame is made out of two pieces of mild steel angle bars which weighs 11.1 kg (12.36% of total weight). This shows that there is lot of scope of weight reduction in the present design.

The excess weight problem can be significantly addressed by replacing parts like the solid wooden passenger carrier and angle bar chassis by a properly designed tubular frame.

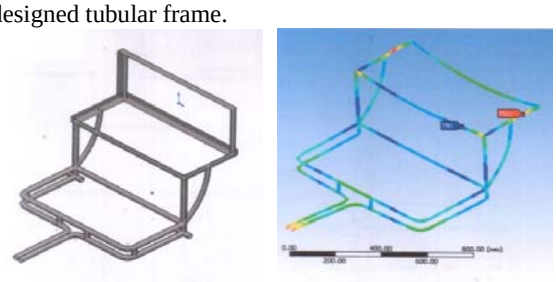


Fig 1. Stress analysis of tubular chassis frame

The preferred chassis could be made of tubes of adequate diameter and thickness. The key point is to get mass away from neutral axis of the chassis components. When cornering torque is applied to the chassis it causes it to twist. The typical engineering solution of this problem is simply a tube. A normalized measure of stiffness efficiency is specific stiffness which is found dividing the area moment of inertia by weight. As tube has large specific stiffness it is one of the good choices to reduce vehicle weight without hampering the strength. Solid modeling like ANSYS was used for identifying the optimum chassis dimensions (figure-1).

4.2 Week Wheels:

The bicycle wheels used in rickshaw are not suitable for heavy loads. The load carried in a rickshaw can be as high as 400 kg. As a result they lose their roundness and alignment. Loss of roundness causes energy loss. According to the estimation of Fred Willkie on a heavily loaded rickshaw a wheel is 1/8″ out of round could add 5% to the effort required for pedaling. Loss of alignment causes high friction loss of energy [1].

There could be several ways to improve the wheel strength:

- Thicker spokes (radial spokes of thick rod instead of tangential spokes of steel wire).
- Thicker tires.
- Stronger wheel rims (Endrick wheel rims can be used instead of Westwood F wheel rims).

4.3 Poor Suspensions:

Every rickshaw has a pair of elliptical springs underneath the body of the passenger seat. But as they are built very rigidly, they are ineffective as springs. According to race and Thomas, the springs provide only 5% of the rickshaw's suspension. The majority (73%) comes from the frame flexing, and from the tires (22%) [1].

Suspension system can be improved by -

- Designing proper semi elliptical leaf springs.
- Designing a swing arm suspension unit with coil over shock unit.
- Introducing rubber blocks under the seat.

4.4 Inappropriate Gear Ratio:

Rickshaw drive has only one gear having a gearing ratio of 48:22 teeth making an effective wheel diameter of 157cm [Transmission (2.18) × wheel diameter (72 cm)], typical for a standard bicycle. But a rickshaw has to carry much heavier load. A range of gears can be provided that will allow choosing the most suitable combination of strength and speed to meet a particular situation.

Even if rickshaws do not have a range of gears (eg. like mountain bikes), it would still be worth giving it at least a two-step gear option with appropriate gear ratios. One could be used for starting or uphill climbing and the other for cruising. Experimental work on a simple and robust two-step mechanical gear selector mechanism is being developed in order to provide adequate starting and cruising torques.

Table 4: Gearings for different conditions and speeds

Gearing	Conditions	Speed
33 cm - 54 cm	Very heavily laden	5 km/h
51 cm - 84 cm	Moderately laden on flat ground	8 km/h
76 cm -124 cm	Lightly laden	12 km/h
94 cm - 157 cm	Empty at full power on flat ground	15 km/h

Amos race and Terry Thomas suggested the following gearings as the most appropriate [1]. According to the above suggestion rickshaws should have a gearing around 76 cm- 124 cm of effective wheel diameter. That can be easily accomplished either by using a smaller chain wheel or a bigger free wheel (or both).

4.5 Poor Steering

Rickshaws have steering geometry which is suitable for bicycle. The front forks steering axis intersects the ground a short distance ahead of where the wheel touches the ground. This is known as trail and it allows us to guide the bike. As a result one can steer a bicycle with no hands, simply by leaning to left or right. But rickshaws have three wheels, it cannot be leaned. But the trail still tends to pull the front wheel to one side whenever a sideways force (such as bump, side wind, and slope) is encountered.

During pedaling by the driver, especially when they exert the full body force by getting off the seat, noticeable side wise forces were observed to be active on the rickshaw chassis frame. The frame tends to move in a resultant direction opposite to the pedal that is pressed down. Since each pedal is pressed alternatively, it creates alternative repetitive stresses on the chassis which is not desirable. In a tricycle the necessary force at the handle bar to prevent swerving, is proportional to the trail [2]. This problem can be improved by using a fork with zero trails as shown in figure-2.

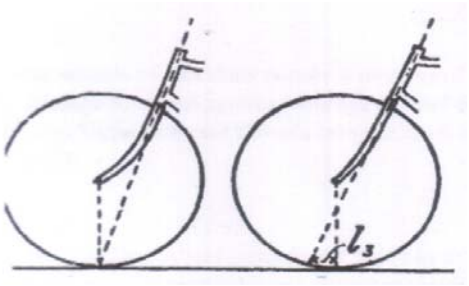


Fig 2. Zero trail and Positive trail.

4.6 Air Drag

The power needed to overcome wind resistance is proportional to the cube of the relative velocity of wind. Hence a small increase in wind speed causes a big increase in the power required to overcome it. This could be very significant for a rickshaw even at relatively lower speed, when it is moving against the wind flow.

Whitt and Wilson [3] estimated that for an ordinary bicyclist travelling at 8 km/h, the effect of an 8 km/h head wind is to increase the rider's energy requirements by 55%. For a rickshaw, the increase would be higher.

To decrease the air resistance the frontal area should be reduced. Making the rickshaw out of tubular frame, allowing air passage through the inclined foot-step support, lowering the hood or introducing a smooth aerodynamic front cover could reduce the air drag by significant amount. Such options will be explored in the modified design under construction. In order to evaluate the actual air drag in rickshaw a wind tunnel test or 'two slope' test [4] can be performed.

4.7 High Center of Gravity

High center of gravity causes poor stability of rickshaw. Such stability can be vital during turning conditions. Bi-cycle or motor bike riders can improve turning stability by allowing the leaning of vehicle using their body weight, while taking turns. This process is not possible with rickshaws since it has three wheels. Stability can be improved by lowering the height of the passenger seat. However passengers might not like to sit lower than the puller. Passenger psychology and social aspect can be of significant importance in this issue.

4.8 Extended Axle Shaft

Extended axle shaft beyond rear wheels of rickshaw causes a number of problems like side-collision between rickshaws, damage to wheel spokes, damage to road side walls etc. A modified design has been developed by machining internal threads and hexagonal nut, washer and spring lock washer [5]. Such modifications have shown satisfactory performance in road trials. For improving the wheel locking safety spring washers were

used, alternatively these could be replaced by automotive wheel-stud threads.

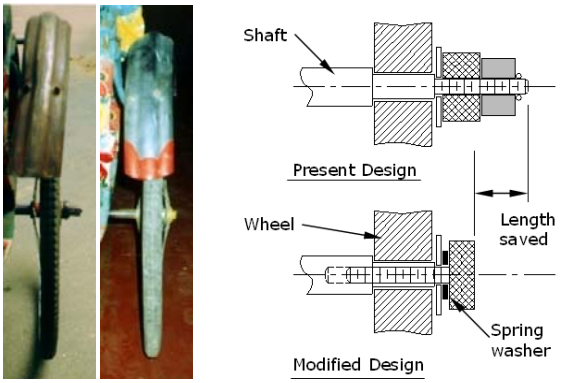


Fig 3. Modified design of rear shaft axle[5].

4.9 Inadequate Brakes

The braking system of rickshaw is very poor with only front brake. This almost same as a bicycle, although the loads involved are significantly higher. Thus when going downhill with high speed, sudden braking produces a catapult-effect, which results in overturning of rickshaw. The solution can be introducing rear wheel breaking system with adequate capacity as well as ease of operation.

4.10 Only One Rear Wheel is driven

When a rickshaw rounds a curve the outer wheel turns faster as it has to travel further. To allow for this, one wheel is rigidly fixed on to the rear axle, but the other rotates freely. However, it means that driving force is applied to only one wheel.

A differential system can be developed by introducing two half axles. Each half axle carries a freewheel and a sprocket. One of the sprockets is driven by the chain and the other is connected to the first sprocket by means of six pins. The effect is that during normal condition both wheels are driven, but when rickshaw turns a corner the inner wheel is driven and the outer wheel freewheels as it turns faster. Again in case of slippery condition if one wheel slips the other drives as in case of a limited slip differential. [4]

A differential can bring the following advantages:

- Driving force is applied to both of the wheels.
- Better traction
- Less wear and tear on the wheel hub of the non fixed wheel.

4.11 Other Modifications

The front fork supports are not strong enough and it provides little spring and damping effect, in order to give better performance small shock absorbers could be used with the front wheel.

A chain tensioner can be provided to reduce the risk of chain slipping under tension or small misalignments. It would also reduce the power and time lost in chain stretching or resetting.

A small DC battery, charged by the pedal drive or solar power can be used for LED lighting of the rickshaw. This would significantly improve the signaling for vehicle maneuver, making it a vehicle much safer to ride especially at night.

5. CONCLUSIONS

- The overall response from the rickshaw drivers of Dhaka regarding modification of rickshaws was very positive. Most of them agreed to the need of technical modifications of rickshaw design to mitigate the existing problems.
- The technical modifications needed to mitigate the problems prevailing in the existing rickshaw design, must be appropriate, robust and cost effective. A specification datasheet containing the images, dimensions, materials and mass of individual components of existing rickshaw was developed. Such comprehensive information is rarely available in public domain. This is essential to anyone intending to renovate or improve the existing rickshaw design.
- The existing design of rickshaw was carefully analyzed, a number of prominent short coming have been identified and possible design modifications have been suggested. A number of these suggestions are actually being tried out at this stage.

6. REFERENCES

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