Performance Evaluation of Donkey Drawn Carts

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Abstract

This paper describes the comparative study of transport capacities of donkey drawn carts. Three types of rigid wheel donkey drawn carts were used to undertake this study. The carts used for the study include: AIRIC model I, AIRIC model II (raised bed type) and the cart modified at Bahir Dar Agricultural Mechanization Research Center based on AIRIC model I. Load levels used for study are: empty cart condition, 100 kg, 200 kg, 300 kg, 400 kg, 500 kg and 600 kg. The test was conducted on dry, compacted and flat track of length 0.2 km at Bahir Dar. Two mechanical weight sensor transducer dial spring balances (Range 0.20-50.00kg and resolution 0.20 kg) were connected on two draw bar beams with a specially designed universal hitching arrangement. Measurements to collect the data regarding speed and average draft force were taken at each 20 meter interval and five runs were taken for each load level. The result shows that the maximum safe load for transport should not be greater than 300 kg for AIRIC model I cart. But the maximum load limit can be up to 400 kg using the AIRIC model II (raised bed type) and the cart modified at Bahir Dar Agricultural Mechanization Research Center. The test reveals that the modified cart has 12 % improvement of transport capacity over AIRIC model I cart and 6 % over AIRIC model II donkey cart.

Introduction

Transport-the carrying of things-is an important but difficult part of the domestic workload in rural Ethiopia. It is a year round task for both agricultural and non-agricultural purposes. Transport used to move crop harvest, take crop for marketing, deliver farm inputs & farm implements, and carry forage are some of the major activities related to agricultural purposes. Other tasks such as collection of fuel wood and water, transport of grains to and from grinding mills and transport of construction materials are often the biggest transport burdens related to non agricultural purposes, which require significant amount of both time and energy.

The mode of transport in most isolated rural areas of Ethiopia is traditional. It is characterized by low capital cost, low technology, low speed, low capacity, and low skill (Crossely P., 1991). Goods are mainly carried by both human porterage and using equines (mules, donkeys and horses) on footpaths and trails. Women are responsible to carry the biggest transport burden which is very arduous. As there is also a clear division of labor among equines, donkeys are widely used as pack animals in different agro-ecological zones. They are mostly used to carry loads of 20-50 kg within a distance of 20 km with a very low transport capacity of 0.25 ton km/hr (Crossely P., 1991). However, donkeys are used to draw carts in some areas of the country. The most notable area to mention is around Rift Valley located in the central part of the country. At first, donkey drawn carts used in these areas were constructed from wooden axle and steel hubs fitted with steel wheels. Field observation on these carts revealed that loose fittings of wooden

axle has resulted in side movements of the cart and high draft requirement, hence the load transported was not more than 200 kg (Kebede and Bekele, 1990).

Agricultural Implements Research and Improvement Center (AIRIC) at Melkassa has improved the transport capacity and durability of locally used wooden axle donkey drawn carts. Improvement attempt has mainly focused on the wheel axle assembly of the cart. Comparative transport performance study of the improved donkey drawn cart (AIRIC Model I) with the locally used wooden axle cart has revealed that there is 200% improvement over the wooden axle cart. The study report showed that draft requirement of AIRIC model I cart vary from 27.5 N at no load condition to 320.8 N at 600 kg payload on flat dirt track road conditions (Kebede and Bekele, 1990).

An attempt was made to introduce AIRIC model I cart in the main roadside areas of East Gojjam, which are suitable for carting. The road condition of these areas varies from gravel road to farm roads with ruts, holes and stones on it. However, despite the fact that this cart demonstrated a great potential for success in the flat fields of Rift Valley areas, some problems were observed on the use of it in the East Gojjam area.

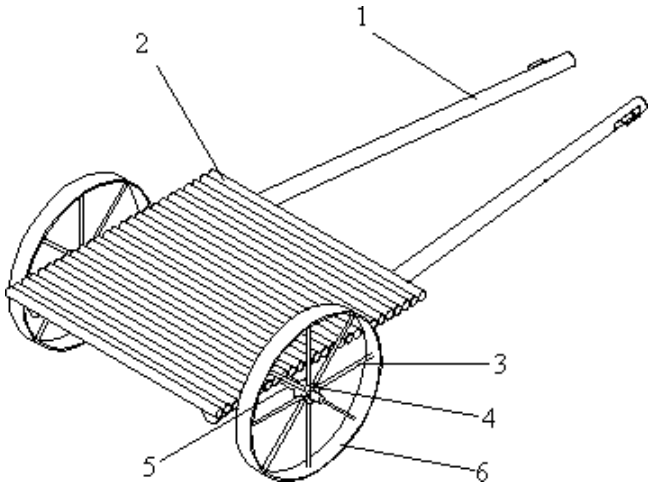
One of the problems was that, when hitched with donkey the cart bed inclines back since the donkey height is greater than the cart height. Because of this, there is a frequent sliding of the load towards the back of the cart. In addition to this, it is difficult to transport fuel wood and other long beams since the height of the cart bed from the ground becomes very low at the back of the cart. The problem is magnified when the cart is operating at fields other than flat and suitable for carting. The second problem was that the large contact area of cast iron bushing with steel axle needs frequent as well as proper lubrication and exclusion of abrasive materials. Seizure was frequently occurred when the cast iron bushing runs on steel axle requiring high draft.

Cognizant of these problems, Bahir Dar Agricultural Mechanization Research Center has improved the wheel axle assembly of the cart and its bed position. Cart modification was started based on field observations on AIRIC Model I Donkey Drawn Cart. Working donkey body size measurement data around East Gojjam area, primarily generated for harness design was used to determine cart bed position and pull beam length. The donkey body measurement, which was conducted in 1998 and useful for modifying the cart include height, length and rib width (at three locations along the rib length), Meanwhile AIRIC also has made improvements on the cart more or less with similar attempts. Thus it becomes necessary to compare the performance of these carts and hence this study aimed to compare the performance of donkey drawn carts and select suitable ones.

Materials and Methods

Description of Carts

AIRIC Model I Donkey Drawn Cart: The AIRIC Model I Donkey Drawn Cart has two pull beams, cart bed and the wheel axle assembly (Figure 1). The cart bed platform is made of eucalyptus plank, which is nailed to the pull beam. The pull beam is attached to the axle using bolts and U shaped plates.



1 Pull Beam
2 Cart Bed
3 Spoke
4 Cast Iron Bushing
5 Axle
6 Steel Wheels

Figure 1: AIRIC Model I Donkey Drawn Cart

The wheel axle assembly consists of axle, bushing, spokes and steel wheel. Galvanized pipe welded with steel stubs are used as axle. Bolts are welded on each end of the cart axle so as to attach the plat form with U shaped plates. Cast iron bushings are used as bearings for the cart and attached to the wheel by steel spokes. Eight steel spokes are welded on the cast iron bushing as well as on the steel wheel.

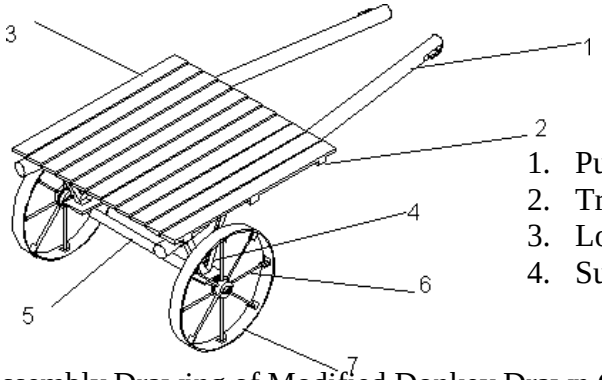
Modified Donkey Drawn Cart

The cart modified at Bahir Dar Agricultural Mechanization Research Center consists of raised cart bed, support frame, and the wheel axle assembly. The cart bed is a platform of wooden structure used to place the live load on it.

It is constructed from three eucalyptus planks of size 1200 mm x 60 mm x 30 mm as transverse battens, which are nailed to the pull beams with about 500 mm distance between each batten. Longitudinal planks of 1200 mm x 100 mm x 20 mm are nailed on the transverse timbers to make the platform (Figure 2). The pull beams are arranged at a center to center distance of 1070 mm and 350 mm at the back and front of the cart respectively. This distance allows adequate space to construct the bed platform as well as to hitch the cart with the working donkey.

The V shaped support frame is used to support the cart bed. It transfers the load coming from the cart bed to the wheel axle assembly and keeps the cart bed at suitable height from the ground. The support frame is constructed from 40 mm x 40 mm x 4 mm angle iron and mild steel sheet plates, which are welded on the top and bottom of it. The top plate is used to attach the cart bed and the bottom plate is used to bolt it with the wheel axle assembly.

The wheel axle assembly is the main component of the cart, which helps the cart to roll on the ground. It consists of the axle unit, the bearing housing and the spoked steel wheel. The axle is made from galvanized pipe of 2" in diameter fitted with stepped round steel stubs at each end. Mild steel plates are welded on the axle so as to fix the support frame bottom plate.



1. Pull beam
2. Transverse plank
3. Longitudinal plank
4. Support frame
5. Axle
6. Spoke
7. Wheel

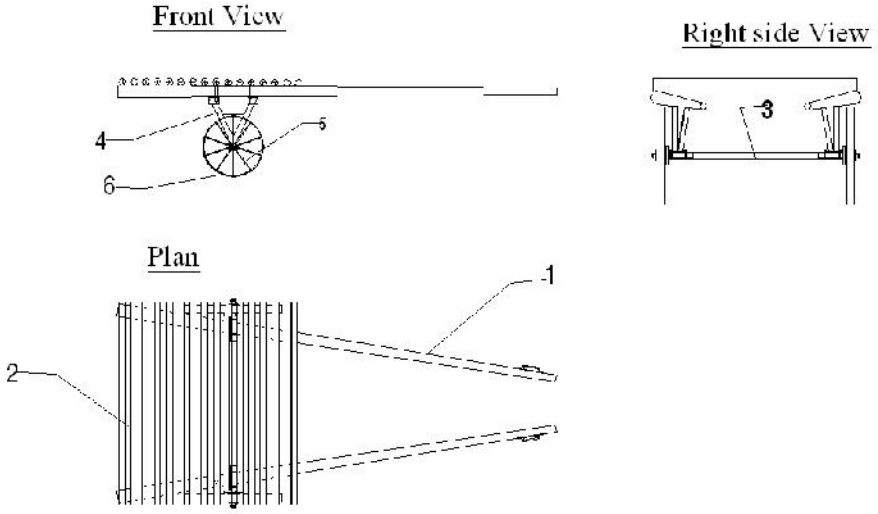
Figure 2: Assembly Drawing of Modified Donkey Drawn Cart

Vehicle rubber scrap is sandwiched between the axle plate and support bottom plate to minimize the strains coming from rigid wheel. The bearing housing is made from a specially turned and bored steel bar of 80 mm in diameter so as to accommodate double row ball bearings in each side. Eight spokes of diameter 14 mm and length 305mm are welded at each wheel where one end of the spoke is welded on the steel hub and the other end on the steel wheel. The steel wheel constructed from flat iron has a diameter of 700 mm which is sufficient to overcome ruts, holes and field obstacles.

AIRIC Model II Donkey Drawn Cart

The overall construction of the AIRIC Model II Donkey drawn cart is similar with the modified cart. The difference lies on the size of some cart components. It consists of raised cart bed, support frame, and the wheel axle assembly (Figure 3).

The cart bed is made of eucalyptus timber and nailed on the pull beams. It lies on the support frame and fixed with bolts and nuts. The V-shaped support frame is used to support the cart bed. It transfers the load coming from the cart bed to the wheel axle assembly and keeps the cart bed at suitable height from the ground. The support frame for this cart is also constructed from 40 mm x 40 mm x 4 mm angle iron and mild steel sheet plates, which are welded on the top and bottom of it. The top plate is used to attach the cart bed and the bottom plate is used to bolt it with the wheel axle assembly.



1 Pull beam
2 Cart bed
3 Axle
4 Support frame
5 Spoke
6 Iron wheel

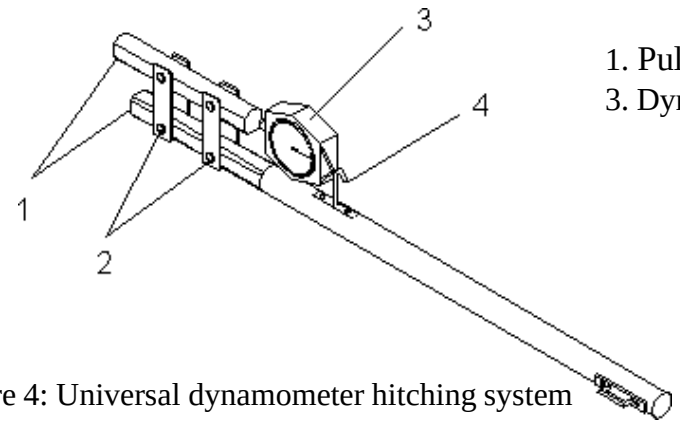
Figure 3: AIRIC Model II Donkey Drawn Cart

Testing

Three types of donkey drawn carts were used for the test purpose. The carts used for test include: AIRIC's donkey drawn cart (AIRIC Model I), AIRIC's donkey drawn cart (ARIC model II) and modified donkey drawn cart at Bahir Dar Agricultural Mechanization Research Center. These carts were hitched with a male working donkey of weight 117 kg using saw back saddle harness developed at Bahir Dar Agricultural Mechanization Research Center. The harness was used with sufficient padding to minimize strain on the working donkey due to fluctuating load coming from the steel wheel.

The test was conducted on dry, compacted and flat track of length 0.2 km at Bahir Dar. Measurements to collect the data were taken at each 20 meter interval and five runs were taken for each load level. Load levels of empty cart condition (no load), 100 kg, 200 kg, 300 kg, 400 kg, 500 kg and 600 kg were used for the test purpose.

The average draft force used to draw the cart at various load levels was measured using two mechanical sensor transducers of dial spring scales (SALTER Model 235 6S, range 0.20 kg -50.00 kg and resolution 0.20 kg), which are connected on two draw beams. The universal hitching system was developed to attach the scales to the beams for recording the draft requirement (Figure 4).



1. Pull Beam 2. Swinging Links
3. Dynamometer 4. Hook

Figure 4: Universal dynamometer hitching system

Result and Discussion

Each donkey cart was subjected to load levels of empty cart condition, 100 kg, 200 kg, 300 kg, 400 kg, 500 kg and 600 kg. The corresponding draft and speed were recorded. The power required to draw the cart and transport capacities were calculated based on these conditions. The results of draft and speed as well as calculated values of power and transport capacity for three types of donkey drawn carts are summarized in Tables 1,2, and 3.

The data in Table 1 shows that draft requirements of AIRIC Model I donkey drawn cart. It varies from 33.42 N at empty cart condition to 291.1 N at a payload of 500 kg. Draft recorded for the cart exceeds the optimum recommended draft range at the load level of

400 kg as draft force requirements for donkey drawn equipment is recommended in the range for single donkey to be 130-230 N (Betker and Kutzbach, 1991).
The results obtained for this cart vary with the results obtained at Melkassa on dirt track condition. This variation is thought to be due to difference in pull angle condition. Donkey height in Rift Valley areas is greater than donkey height around Bahir Dar area; hence increase in pull angle decreases draft.

Table 1: Draft Performance Results of AIRIC Model I Donkey Drawn Cart

	Load levels					
Parameter	**Empty cart**	**100kg**	**200kg**	**300kg**	**400kg**	**500kg**
Draft (N)	**33.42(2.78)**	**68.6(2.36)**	**121(3.72)**	**179.1(4.12)**	**239.6(3.89)**	**291.1(5.16)**
Speed (m/s)	**1.14(1.2)**	**1.0(0.2)**	**0.89(0.12)**	**0.88(0.15)**	**0.7(0.1)**	**0.59(0.1)**
Power (W)	**38.09**	**68.6**	**107.69**	**157.6**	**167.72**	**171.75**
Capacity (tons km/hr)	**-**	**0.36**	**0.64**	**0.95**	**1.0**	**1.06**

Note: The values in parentheses are standard deviations

As seen in Table 2, the draft requirement for AIRIC model II donkey drawn cart varies from 29.6 N at empty cart condition to 273.66 N at load level of 500 Kg.

Table 2: Draft Performance Results of AIRIC Model II Donkey Drawn Cart

	Load levels					
Parameter	**Empty cart**	**100kg**	**200kg**	**300kg**	**400kg**	**500kg**
Draft (N)	**29.6(3.2)**	**65.73(1.6)**	**111.5(2.41)**	**165.3(3.22)**	**219(4.62)**	**273.66(3.53)**
Speed (m/s)	**1.18(0.2)**	**1.1(0.14)**	**0.92(0.3)**	**0.9(0.17)**	**0.74(0.1)**	**0.61(0.1)**
Power (W)	**34.92**	**72.3**	**102.58**	**148.77**	**162.06**	**166.89**
Capacity (tons km/hr)	**-**	**0.39**	**0.66**	**0.97**	**1.06**	**1.09**

Note: The values in parentheses are standard deviations

From Table 3, the draft requirements of modified donkey cart ranges from 26.22 N at empty cart condition to 254.9 N at 500 kg payload. The draft requirement of all carts at load level of 600 kg exceeds 350 N, where the working donkey has made only a short walk and refused to pull the cart.

Table 3: Draft Performance Results of Modified Donkey Drawn Cart

	Load levels					
Parameter	**Empty cart**	**100kg**	**200kg**	**300kg**	**400kg**	**500kg**
Draft (N)	**26.22(1.18)**	**63.73(1.56)**	**107.4(2.27)**	**141(4)**	**199(4.18)**	**254.9(2.7)**
Speed (m/s)	**1.2(0.2)**	**1.11(0.1)**	**0.98(0.1)**	**0.92(0.14)**	**0.78(0.12)**	**0.64(0.06)**
Power (W)	**31.46**	**70.7**	**105.25**	**129.72**	**155.22**	**163.13**
Capacity	**-**	**0.39**	**0.7**	**0.99**	**1.12**	**1.15**

(tons km/hr)

Note: The values in parentheses are standard deviations

The highest working speeds of 1.14 m/s, 1.18 m/s and 1.2 m/s were recorded at empty cart condition for AIRIC model I, AIRIC model II, and modified cart, respectively. At load level of 400 kg, the working speeds recorded were 0.7 m/s, 0.74 m/s and 0.78 m/s for the respective carts. An increase in payload increases the net draft which decreases the working speed. The maximum power out put was calculated as 167.72 W, 162.06 W and 155.22 W for AIRIC donkey model I donkey cart, AIRIC model II donkey cart and modified cart respectively at load level of 400 kg.

The transport capacities of carts at 400 kg load level were calculated as 1.0 tons km/hr, 1.06 tons km/hr and 1.12 tons km/hr for AIRIC model I, AIRIC model II, and Modified cart, respectively. There is a slight transport capacity variation between these three carts. The Modified cart had 12 % improvement of transport capacity over AIRIC model I cart and 6 % over AIRIC model II donkey cart. In spite of having ball bearings in their wheel axle assemblies for both Modified and AIRIC model II carts, there is a slight variation on their transport capacity. This variation is mainly due to the structural difference in track width, bed size, and pull beams length, which affects cart dead load.

Modified donkey cart weighs 90 kg and AIRIC Model II cart weighs 113 kg. Draft is a function of dead load, live load, wheel axle assembly, soil condition, and draft angle. This increase in dead load also increases the net draft, thereby reducing the transport capacity.

Conclusions and Recommendations

Modified donkey cart and AIRIC model II donkey cart have showed better performance and hence could be used on flat areas of the region on gravel and farm roads. These carts can be manufactured by small workshop owners with exception to the steel hub, which requires lath. The total cost for manufacturing theses carts is estimated as 7000 ET. Birr.

The following points should be considered while using these donkey drawn carts.

- Pay loads should not exceed 400 kg as the draft requirement is recorded beyond the capacity of average working donkey.
- Sufficient padding should be used with suitable harness so as to minimize strain to working donkeys due to fluctuating loads.
- Loads should be uniformly placed on the cart platform and tied with rope to ensure cart stability.
- Use of smooth or padded straps is recommendable as there is excessive strain to animals

The rigid steel wheel transmits fluctuating loads to working donkey as well as cart components. The strain affects the work output of donkey and cart spokes are likely susceptible to the strain as a result the steel wheel may collapse. These loads can be minimized by introducing some cushioning materials to the wheel, suspension or hitching assembly of the cart. Future work has to focus on developing rubberized steel wheels (RSW) with suitable rims and suspension as well as hitching components. Selection of durable, low cost and weight cart materials with suitable cart component size need great attention.

References

Adarsha M.S., Harsha H.D. and Kurup T.N.K. (2003). Rubberized steel wheels-an innovative design for better use of animal energy in India. *Draft Animal News,* 39, 28-32. Center for Tropical Veterinary Medicine, University of Edinburgh.

Betker J. and Kutzbach H.D. (1991). The role of Donkeys in agricultural mechanization in Niger-potential and limitations. In *Donkeys, Mules and Horses in Tropical Agricultural Development* (eds D.Fielding and R.A.Pearson). Edinburgh: Alexander Ritchie & Son Ltd. pp. 223-230.

Colin Relf. (1998). Obvious, but not easy. Promoting non-motorized means of transport. g*ate,* 3, 20-30. Eschborn, Fedral Republic of Germany.

Crossely P. (1991). Transport for rural development in Ethiopia. In *Donkeys, Mules and Horses in Tropical Agricultural Development* (eds D.Fielding and R.A.Pearson). Edinburgh: Alexander Ritchie & Son Ltd. pp. 48-61.

Kebede A. and Bekele D. (1990). Improvement of transport capacity of donkey carts. *Draft Animal News*12, 17-20. Center for Tropical Veterinary Medicine, University of Edinburgh.

Smith D.W., Sims B.G. and O'Neill D.H. (1994). Testing and evaluation of agricultural machinery and equipment. Food and Agricultural Organization of the United Nations. Agricultural Service Bulletin 110. Rome.

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