HUMAN AND ANIMAL POWERED TRANSPORT IN RURAL COMMUNITIES IN SUB-SAHARAN AFRICA

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1. The Role of Transport

Transport for domestic and agricultural purposes plays a very important role in the lives of rural communities in developing countries. Studies in a number of SSA countries (carried out by I.T. Transport for the World Bank SSA Transport Programme) have yielded the following typical data on transport patterns in rural communities:

		Hours per Year
1.	Time spent in transport per household:	
	(i) domestic transport - mainly collection of water and firewood	600 to 1,500
	(ii) agricultural transport - production and marketing of crops	200 to 450
	(iii) social purposes - health, education, social visits etc	180 to 600
	Total time spent in transport per household	1,200 to 1,500
	Total time spent in transport per adult	280 to 900

2.	Transport effort per household in tonne-km per year:	
	(i) domestic transport	20 to 60
	(ii) agricultural transport	6 to 10
	Total effort per household	30 to 65
	Total effort per person	7.5 to 25

This data is in general agreement with data previously collected in areas of Tanzania and Ghana(1) and shows up the following features:

- an adult may spend, on average, up to 3 hours per day on transport activities and transport goods up to an equivalent of 100 kg-km every day of the year;
- a large proportion, at least 65%, of this transport burden is carried by women.

Women typically spend around 20% of their active time on transport.

- the collection of water and firewood constitutes the major proportion of the transport burden. Transport associated with agriculture makes up only about 12 to 25% of the total;

- about 75% of the transport activity involves short trips, less than 6km, in and around the village e.g. to and from the fields.

Trips outside the village, to health centres, market, grinding mill etc. are usually less than 15km. The majority of the trips therefore take place away from the highway network on earth roads, tracks and paths.

The various transport tasks are briefly discussed below:

Collection of Water: this comprises 30 to 35% of the total transport task. It is most often carried out by women using headloading. Sometimes younger boys in the family may collect water using wheelbarrows or animal-drawn carts - but this will take second priority to agricultural activities. An effective approach to reducing this task is to increase and/or re-locate sources of supply in order to reduce the distances to be travelled. There is also some potential for low-cost carrying devices such as a one-wheeled push-along device with frames to support containers on either side of the wheel, or pannier frames to support containers on either side of the rear wheel of a bicycle.

Collection of Firewood: this also constitutes 30 to 35% of the total transport task and again is mainly carried out by women using headloading. There is some evidence to suggest that the introduction of vehicles to carry out this activity tends to encourage the use of greater volumes of firewood, therefore accelerating deforestation. Methods of alleviating this transport burden should attempt to slow down or reverse the process of deforestation, for instance the introduction of more fuel efficient stoves and/or planting of wood-lots to provide supplies of firewood close to the village, rather than improved methods of transport.

Agricultural Transport: this involves such tasks as collection of seeds and fertiliser from sources of supply, transport of these materials and manure to the fields, transport of crops from the field to the household and transport of surplus produce to the market or truck collection point. The extent of the transport burden is dependent on a number of factors including - farm size, geographical layout, types of crops grown, the degree of usage of fertilisers and manure and particularly on whether farming is carried out at subsistence level or surplus produce is produced for marketing. The latter can significantly increase the need for transport. Much of the transport is carried out by head or back-loading but this may only be suitable for farm sizes up to 2 or 3 ha and above this there will be an increasing need for the introduction of low-cost vehicles. The lack of adequate transport can limit the area farmed because of constraints on the amount of produce that can be moved, and can restrict availability of labour at peak periods, such as cultivation or harvest times, thus detrimentally affecting the timeliness of these activities and reducing productivity of crops.

The introduction of improved methods of transport into rural communities will generally reduce the time spent on transport activities, reduce the burden for household members, particularly women; and allow larger quantities of materials to be moved. This can have the following benefits for agricultural productivity:

- o it allows larger areas of land to be farmed, bringing non-farmed land into cultivation. Transport enables farmers to travel further out from the village, expanding the boundary of the land farmed from the village;

- o time released from transport tasks can be used more productively in other areas, for instance in introducing more productive farming methods;

- o availability of transport at harvest time reduces the exposure of crops to the weather and pests and hence increases the efficiency of crop production by reducing deterioration and losses of produce.

2. Modes of Transport

The various modes of human and animal powered transport used in SSA are listed in Table 1 together with typical capabilities and capacities. The characteristics and uses of these forms of transport are discussed in the following sections.

2.1 Human carrying methods

Headloading: this is the most common mode of transport used in SSA Ergonomic studies indicate that it is an efficient method of carrying loads up to 30kg and suggest that African women adopt a walking gait which minimises the vertical movement of the load and hence the energy expended in carrying the load. The problems of headloading are the strain it imposes on the vertebral column and the restriction it imposes on the movement of the body. There is evidence to suggest (2) that habitual lifting and carrying of heavy loads over long periods of time can result in damage to the spine, the joints, the muscles of the limbs and trunk, and to internal organs. This seems to be an area where further studies are needed.

Backloading: this method is not widely used for carrying loads in SSA, probably because it is not as convenient for women who often carry babies on their backs. Back carrying with shoulder support of the load is an effective method of load carrying, requiring a similar level of energy expenditure to head loading. The main disadvantage is the need to lean forward to balance the load. Research studies suggest the most efficient method of human load carrying is balanced loads on the front and back of the body, but this reduces ventilation of the body which is not desirable in hot climates. Simple back-frames, such as the chee-geh which is widely used in Korea, can provide significant advantages in allowing bulky and awkward loads to be comfortably carried on the back. However, these are seldom found in SSA, possibly because they are more applicable for men, and it may require a shift in cultural attitudes to load carrying for them to be more widely used. Support of the load with a head-strap is sometimes used, but this is not recommended as it imposes considerable pressure on the vertebral column and has a higher risk of injury.

Shoulder poles: these are widely used in Asian countries but are not common in SSA. They are an efficient method of load carrying if the loads are supported on both shoulders to balance the load on the body and reduce contact pressure on the shoulder. Springy poles, which reduce the bounce of the load, are claimed to be more efficient but this does not appear to have been proven by tests. A two-person, double pole arrangement allows quite heavy and bulky loads to be carried and could be quite effective for transporting agricultural produce.

In general human load-carrying methods provide a limited transport capacity and require the highest level of energy expenditure per unit load moved. Through necessity, persons in developing countries often carry much more than the recommended maximum loads (about 40% of body weight) and this can lead to injury and ill health. It is to be hoped that there will be an increasing shift from human load-carrying to less demanding modes of transport such as simple wheeled vehicles and animal-based transport.

2.2 Wheelbarrows and Handcarts

The efficiency and capacity of these modes of transport are very much dependant on the quality of the wheel and axle assembly. The human energy needed to move a load on an efficient wheeled vehicle on a firm, smooth surface is about 10 to 20% of that required to carry the load (3). This margin tends to decrease as surfaces become rougher or softer, and for less efficient wheels.

These simple vehicles can provide a significant increase in human transport capacity but at the same time they involve a large jump in cost over carrying methods. The wheel and axle assembly will generally comprise at least 50% of the cost and low cost versions of the vehicles will usually have crude, inefficient wheel/axle assemblies. The procurement or manufacture of the wheel axle assembly will also constitute the major problem for production of these vehicles in developing countries, particularly in smaller workshops.

The most efficient assembly is a pneumatic-tyred wheel with ball or roller bearings. However, these components may not be available or may be unaffordable and therefore alternatives have to be used which increase the energy needed to propel the vehicle. For the same wheel size, the power needed to move a load of 100kg on a vehicle with rigid tyres, steel or solid rubber, will be of the order of 20 to 30 watts more than for pneumatic tyres wheels. In addition wheels with bush-type bearings - wood, cast iron etc. - will require up to 10 watts more than wheels with rolling contact bearings, and more if they are not properly lubricated. An accepted power output for the average person for continuous effort is about 75 watts and therefore it can be seen how important it is to have efficient wheel axle assemblies on human powered vehicles.

TABLE 1: MODES OF HUMAN AND ANIMAL POWERED TRANSPORT

Mode of Transport	Typical Load (kg)	Average Speed (km/hr)	Feasible Daily Range (km)
Human Carrying:			
Head	In practice up to 80		
Back		4 to 5	15 to 20
Shoulder-Pole	Recommended maximum 30 to 40		20
Wheelbarrow	80	3 to 4	5 to 6
Handcart 1 person	200 to 250	3 to 4	10 to 12
2 person	400 to 500	3 to 4	10 to 12
Cycle with Carrier	30 to 40	12	40
Cycle Trailer	200 to 250	10	30
Donkey Pack	50 to 70	4 to 5	20
Cart (single donkey)	300	4 to 5	20
Ox-Drawn Sledge (2 oxen)	200 to 300	2 to 3	15
Ox-Cart (2 oxen)	800 to 1,000	3 to 4	20

"Western-style" Wheelbarrow: this is the conventional form of wheelbarrow with a sheet steel or wooden load tray located above and behind the single wheel. The operator has to support 25 to 30% of the load, which, being quite tiring on the arms, makes this type of wheelbarrow only really suitable for operation over relatively short distances. However, it is maneouverable and suited to use on narrow paths and is quite commonly found in rural areas in SSA.

"Chinese-style" Wheelbarrow: in this type the load is carried more directly over the single wheel so that the operator supports only small portion of it, may be 10 to 15%. It is therefore suited to operation over longer distances with larger loads but on the other hand it is considerably more difficult to balance and control. Although this type is seldom found outside China it would seem to have good potential as a small farm vehicle if users could be persuaded to persevere in learning to overcome its handling problems.

Handcarts: these usually have a single axle with two wheels although large, four-wheel versions are also used in some areas. A variety of 2 wheel versions are used in SSA, designs depending mainly on the types of wheels and axles which are available - these may range from bicycle wheels to scrap car axles. Because the load is carried mainly on the axle, almost all the operator's energy can be put into propulsion and therefore handcarts can have high load capacities. They are also easily adapted for operation by two or more persons so that capacities up to 600kg are possible. Their wheel track width of 0.8 to 1.2m makes them unsuitable for use on narrow paths and they therefore tend to be found mainly in urban areas. However, there are many rural areas in which they could be used and it is felt there is potential for much greater use of handcarts as small farm vehicles.

2.3 Pedal-Operated Vehicles

Bicycles are widely used in SSA, both for personal transport and for carrying loads. Loads of up to 50 to 60kg can be carried whilst riding and higher if the bicycle is pushed. Even quite bulky loads such as firewood and sacks of charcoal or produce are often carried. Loads are usually carried on a carrier above the rear wheel and in addition loads may sometimes be carried in panniers mounted either side of the rear wheel. A simple arrangement for the latter is to strap two pieces of wood or bamboo across the carrier from which bags can be suspended either side of the wheel. The disadvantage of carrying loads in these ways is the extra strain it puts on the bicycle, particularly the rear wheel, and this is likely to significantly increase maintenance costs. However, the fact that the bicycle is such a versatile and efficient vehicle that is suitable for use on narrow rural paths creates a demand for even greater load-carrying capacity and it is felt that there is considerable potential for modified bicycles which provide more space for carrying loads, for example extended frames with larger carriers. (A prototype of this innovation can be seen at the IAE/ITDG transport project at the Institute of Agricultural Engineering, Harare). These load-carrying bicycles will need to have strengthened frames and wheels.

Other methods of increasing load-carrying capacity are use of tricycles, trailers and side-cars.

Tricycles are widely used in Asia, but mainly in urban areas. They do not cope well with rough earth tracks and are not considered very suited for use in rural areas.

Cycle Trailers are considered more versatile and appropriate for load-carrying than tricycles. The combined cost of cycle plus trailer is likely to be less than for a tricycle and a trailer allows the bicycle to continue to be used separately. The trailer can also be unhitched and used as a handcart which is a good advantage around the home and fields and also at market. Its main disadvantages are cost, (usually around 50 to 60% of bicycle cost), it constitutes an extra load which has to be towed and the fact that it is not suited to operation on narrow tracks. However, it is considered that bicycle trailers offer considerable potential for increasing load-carrying capability in situations where bicycles are already widely used. They are already being used on a small scale in Ghana, Malawi and Tanzania.

Side-cars have been used with bicycles in the past but are seldom found today. The advantage they have is that since they only require one wheel they are cheaper than trailers. However, they are more difficult to couple to the bicycle and do not offer the versatility of being used as handcarts. They may be appropriate in some situations but considerable development work would be needed to evaluate their operation on rough earth tracks.

On firm tracks and paths, the bicycle is the most efficient means of human-powered transport. It also has the significant advantage of being the only practical means of achieving higher speeds therefore providing the potential to reduce travelling times and/or travel longer distances. There is little that can be done to improve the ergonomics of bicycles without significantly increasing their complexity but bicycles in developing countries in general could benefit from attention to the pedal drives, either to reduce drive ratios or to introduce simple, robust methods of gearing. It is considered that there is considerable scope for increasing the use of bicycles in SSA and also for improving the load-carrying capability of these bicycles.

2.4 Animal-powered Transport

The use of animals for transport relieves the human burden and releases human energy for more productive tasks. The human task becomes the care and control of the animals. This is often carried out by male members of the household, thus relieving women of their transport burden. However, the use of animals also involves a range of other problems such as nutrition needs, disease prevention, security of the animals, harnessing etc..., and introducing animal-powered transport into regions where animals are not already kept by communities involves considerable difficulties.

Using animals for transport can have a number of benefits for the overall farming system:

- It can improve the productivity of the farm in the ways outlined earlier in this paper;
- Increased transport capacity allows more widespread distribution of manure to the fields, thus improving crop production;
- the animals are used more uniformly through the year, thus increasing their productivity and tending to maintain their level of training;
- the farmer can often hire out his/her transport facility thus providing an additional source of income.

The main drawback is the need to maintain the extra energy requirements for work over a longer period of the year which may put pressure on grazing facilities and/or fodder supplies.

The main forms of animal-powered transport used in SSA are: pack donkeys (horses are quite widely used in some of the more northerly countries such as Ethiopia), ox-drawn sledges and donkey or ox-drawn carts. Oxen are used for transport mainly as an adjunct to their use in cultivation activities and there are few instances of them being used solely for transport. However, donkeys may be kept for transport only, although they may sometimes also be used for cultivation work. Donkeys have a number of advantages over oxen - they are hardier and more able to cope with drought; they are less costly to purchase and keep; and their meat is not generally recognised as being eatable and therefore they are less likely to be stolen. However, they have less status than oxen and there may be cultural resistance to using them - they are sometimes regarded as the "poor farmers'" work animal. There appears to be considerable scope for increasing the use of donkeys in farming in SSA, particularly for transport tasks, and for upgrading the skills needed to keep the animals in satisfactory condition and to use them effectively.

Pack-donkeys: donkeys can comfortably carry loads up to about 20% of their body weight on their backs. Loads may be carried in sacks slung over the donkey's back, or simple frames may be strapped in position on the flanks to carry more awkward loads such as water containers or bundles of firewood. The load needs to be properly balanced on the back on either side of the spine, not carried directly on the spine, and should be stabilised by straps around the belly, breast and rear. Harnesses can be made out of low-cost, readily available materials and should be properly padded to avoid creating pressure spots and sores. Pack donkeys are particularly suited for operation on hilly or difficult terrain where wheeled vehicles would be difficult to use.

Ox-drawn Sledges: these are a very low-cost means of animal-powered transport, often comprising little more than a forked branch of a tree attached by a chain to the yoke of the oxen. Because of the high draught force needed to pull them, they have a relatively low carrying capacity. It is also claimed, probably accurately, that they cause erosion of tracks and paths, and for this reason their use is discouraged in some countries, for example Zimbabwe. However, they are commonly used throughout SSA, often for carrying ploughs to or from the fields.

Donkey or Ox-drawn Carts: these are by far the most effective mode of animal-powered transport. The relatively high load capacity of carts greatly reduces the number of trips needed to move materials and therefore can achieve substantial savings in transport time. The comfortable draught force of oxen is about 10 to 12% of their body weight, whilst for donkeys it is slightly higher at 12 to 15%. To make the most efficient use of the available draught, carts need to be as light as possible and to have efficient wheel and axle assemblies. The situation regarding these latter components is similar to that for handcarts, in that the most efficient assembly is a pneumatic-tyred wheel with rolling contact bearings, but often these are either not available or are unaffordable and therefore a range of alternative solutions of widely varying quality are found on carts in the region. It is likely that upgrading the design of wheel-axle assemblies and the ability of workshop to procure or manufacture improved assemblies will have a more significant impact on improving cart performance than other areas of development such as improved harnessing, although there are also needs for development in this latter area, particularly for

donkeys. This will be one of the main issues discussed in the workshop of the Animal Traction Network for Eastern and Southern Africa (ATNESA) to be held directly following this workshop.

3. SUMMARY

This paper has briefly discussed the types, uses and characteristics of human and animal-powered modes of transport found in the region. These have been discussed mainly from a technical point of view, but there are non-technical issues that are equally important in addressing the problem of improving farm transport. Constraints relating to affordability, acceptability and availability of credit may often be more difficult to overcome than the technical problems. It is therefore imperative in development work that a broad approach is taken which encompasses all of these issues.