Improving animal traction technology

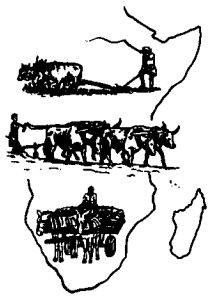

Photo: Paul Starkey

Animal-powered transport

Improving animal-based transport: options, approaches, issues and impact

by

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Abstract

The use of draft animals for rural transport is an important complement to their use in agriculture. The movement of agricultural and subsistence goods is a major burden in time and effort for rural households. The majority of movements take place at farm and village level, often by walking. The use of animals can improve the efficiency of transport, alleviating constraints on farm productivity and aiding agricultural development. However, the potential role of animal-based transport is still largely unrealised in eastern and southern Africa.

This paper discusses the options for animal-based transport. Carts have the greatest potential for improving rural transport although smaller farmers may not be able to afford them. There is a large unsatisfied demand for carts in the region resulting from problems in production, primarily the limited availability of materials and components, particularly good quality wheel–axle assemblies. The issues involved in improving the production of carts are considered and an integrated approach is recommended to improve the supply of materials and critical components to rural workshops which would construct and assemble carts. It is anticipated that this would develop an effective infrastructure for supply and maintenance of carts and provide carts to farmers at minimum cost.

Affordability and profitability of animal-based transport are key issues in its wider dissemination. Experience from many parts of Africa suggests that the availability of credit facilities is of great importance to successful dissemination programmes. The issue of access to transport facilities by women is of major significance in improving the impact of these programmes.

Introduction

Recent years have witnessed increased dissatisfaction with conventional approaches to rural transport planning in developing countries. Growing evidence points to the existence of a significant off-road transport burden undertaken by rural households. At the same time the economic crisis set ever tighter limits on budgets for the construction and maintenance of roads and for the import of motor vehicles. As a result of these trends, increasing attention is being focused on the exploration of alternative options for addressing rural transport problems. Animal-based transport is increasingly seen as having high potential in this respect, particularly as a complement to the use of draft animals in farming systems.

This paper summarises the main issues of animal-based transport and the role it could play in alleviating the transport burden of rural households in eastern and southern Africa. In particular, it identifies ways in which the production and dissemination of animal-drawn carts could be improved. In another paper in these proceedings, the same authors consider some technical aspects of cart design (Dennis and Anderson, 1994).

The role of animal-based transport

Transport needs

Conventional transport planning has often overlooked the importance of transport needs at the farm and household level in rural areas. Transport projects have tended to focus on the provision of roads for motorised vehicles. While roads and motor vehicles can play a vital role in connecting rural centres to larger markets, planners are increasingly realising that the "road and motor vehicle" approach has little impact on the daily transport needs of most rural households in Africa. Most rural travel takes place "off-road", usually on foot. Recent surveys, in Ghana and in Makete District in the south-west of Tanzania, show that over three-quarters of the time and effort spent on transport are devoted to movements around the household and fields. Trips to the market, grinding mill, health facilities and other places outside the village represent less than 25% of the annual transport effort in these areas (Barwell and Malmberg-Calvo, 1988; Howe and Zille, 1988).

Data from the Makete surveys showed that the typical household in this area spent on average more than 2500 hours per year on local transport for subsistence and agricultural purposes (Figure 1; Barwell and Malmberg-Calvo, 1988). This transport burden fell disproportionately onto women, who spent an average of 30 hours a week on local transport, compared with an average of only 10

hours a week for men. These figures are by no means unique. Studies undertaken in Ghana and in Tanga Region of Tanzania reveal similar transport burdens and a particularly heavy burden on women, in terms of both time and load-carrying effort. Other studies (Kaira, 1983; Curtis, 1986) have also shown that the transport of water, fuelwood and other goods for subsistence needs imposes a heavy burden on rural households in many parts of Africa.

Often the only means of moving goods around the farm or village is by headloading, which is slow and inefficient, and can cause spinal injuries and other health hazards (Dufaut, 1988). Animals offer a more efficient way of moving goods over short distances: pack animals and carts have a higher carrying capacity than humans, and can therefore move large loads in fewer trips (Table 1). At seasonal labour peaks, animal-based transport can help to alleviate time constraints on agricultural production and domestic activities. More efficient transport can also facilitate other income generating activities and can potentially bring social or health benefits, particularly to women, by alleviating the burden of moving firewood and water.

Animal-based transport cannot match the speed or carrying capacity of motor vehicles, but it can offer other advantages. For example, rural households can afford it; pack animals and carts can operate on lower quality tracks and paths than motor vehicles; and animals do not require imported fuel. In any case, most farmers rarely need to move loads of more than 1000 kg. In these respects, animal transport provides an attractive "intermediate" option between headloading and motorised transport.

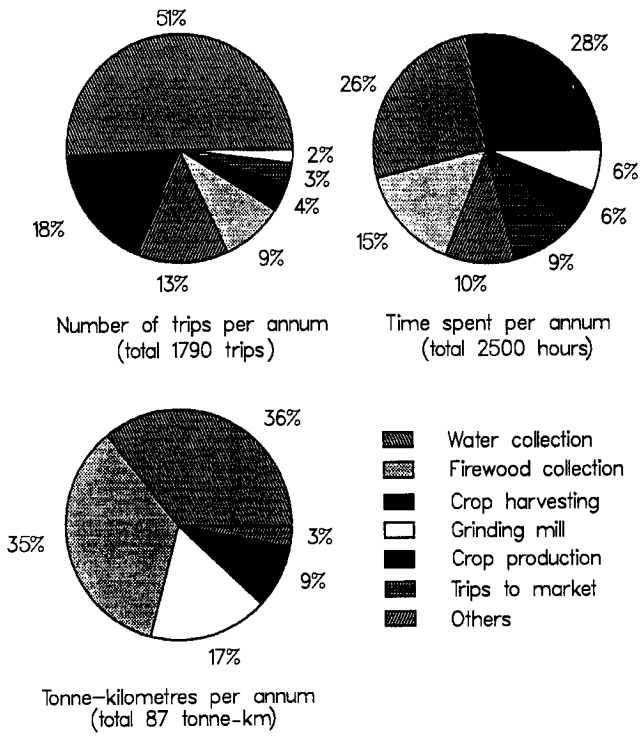


Figure 1: Travel pattern of a typical sampled village in Makete District, Tanzania

Status of animal transport in Africa

Animal transport has been a major feature of traditional economies in many parts of Asia, South America and, until relatively recently, Europe and North America. In India, Sri Lanka and many parts of South East Asia, bullock carts, buffalo carts and sledges play an important role in rural areas. India has around 15 million animal-drawn carts (Photo 1), which transport an estimated 1500–1800 million tonnes of goods per year. This far exceeds the 300 million tonnes of goods transported annually on the Indian railway system (Srivastava, 1989).

In Ethiopia, Sudan and North African countries, donkeys, horses, oxen and even camels have been

Table 1: Comparison of typical loads and speeds of some transport systems

Means of transport	*Load capacity (kg)*	*Typical speed (km/hour)*	*Load carrying capacity (tonne–km/hour)*
Human (headloading)	25	4	0.1
Donkey (pack load)	50	5	0.25
Ox cart	1 000	4	4
Two wheel tractor	1 000	10	10
Tractor/trailer	3 000	20	60
Truck	10 000	50	500

Photo: IT Transport

Photo 1: Bullock carts in India. Animal-drawn carts could play as vital a role in Africa as they already do in Asia

used as means of transport for centuries. Ethiopia has a population of about 6 million oxen, 7 million horses, mules and donkeys, and a million camels (Goe and Abiye Astatke, 1989). The most important feature of animal transport in Ethiopia and neighbouring countries is the use of donkeys to carry packs and horses to pull carts.

Elsewhere in Africa, traditional use of animals for transport is rare. In Kenya and Tanzania only the Masai tribes traditionally use donkeys as pack animals. Wooden animal-drawn carts have been used traditionally in Madagascar, which was influenced by Asian and Arabic trade, but not in other parts of eastern and southern Africa. Animal-based transport was introduced to some other parts of the region during the colonial period, in conjunction with draft animal power for agriculture. In parts of southern Africa, including Botswana, Zimbabwe and parts of Mozambique, use of pack animals and carts has become well established since their introduction earlier this century.

Elsewhere in the region, animal transport is still relatively rare: the total number of animal carts in Africa is estimated to be around 700 000. According to some estimates, for every 10 African farmers who use draft animals for agriculture there is only one who owns a cart (Dawson and Barwell, 1993).

These figures suggest that there is significant under-utilisation of animal power for transport in Africa.

Animal transport in farming systems

Animal-drawn transport can form an important component of an animal traction farming system, complementing animal tillage in many ways. Some of these are outlined below.

Crop harvesting

The use of animal-based transport, rather than inefficient headloading, to move harvested crops from the fields can help reduce labour constraints at harvest time. Animal-based transport has also been observed to reduce post-harvest losses from pests by allowing timely removal of harvested crops from the fields (Scheinman, 1986; Dawson and Smith, 1990). In areas of insecurity (such as parts of northern Uganda) the speedy removal of crops from the fields may also help to reduce theft of the harvest.

Crop marketing

Animal-based transport can play a vital role in transporting surplus produce to marketing depots. Transport for marketing is becoming increasingly important in countries such as Tanzania and Zambia, where policy-makers are beginning to limit the role

of inefficient central marketing boards. While giving farmers more choice in selling their surplus, these policies often give farmers more responsibility for the cost of transporting their surplus to market. In this situation, farmers without efficient transport may market their surplus through visiting traders who operate as entrepreneurs. Various studies have observed that animal carts can enable farmers to get higher prices for their crops, since the farmer can sell directly to market and avoid paying margins to traders (Scheinman, 1986; Malmberg-Calvo, 1992). Müller (1986) also observed that ox carts enabled farmers to reach the market from a radius of 5–15 km, while headloading did not extend beyond a radius of 3–5 km from the market.

Farm inputs

The side benefits of animal traction can be increased if animal manure is used as a fertiliser. A study in Tanzania (Kjaerby, 1989) found that manure was generally only applied to food plots near the household, apparently because the manure was laboriously transported by women in small baskets. However, some farmers who owned carts or sledges were beginning to apply manure in larger quantities to land of low fertility further from the homestead. Greater use of manure by cart owners, with anticipated benefits in terms of yields, was also noted by Scheinman (1986). Animal-based transport can also facilitate the collection of fertiliser and other farm inputs from distribution depots. A study of animal cart use in Kenya noted that fertiliser use was higher among animal cart farmers (Smith and Dawson, 1989).

Transport of implements

Animal-drawn sledges can play an important role in limiting damage to animal traction implements while moving them between the household and fields. Use of sledges to transport plows is common even among farmers who own carts, not only in parts of Africa but also in parts of Asia such as the Philippines.

Year round use of animals

Transport demands tend to be highest in the dry season, when harvesting and marketing are undertaken, and when farm inputs are collected for the next growing season. Studies in Tanzania (Shetto and Kwiligwa, 1988) and Zambia (Müller, 1986) have shown that animal carts are intensively used for agriculture over at least four months of the year, and may be used for other purposes throughout the year. In contrast, use of draft animals for plowing rarely exceeds a season of four to eight weeks per year. The extended use of draft animals for transport can bring benefits by reducing the tendency for animals to forget their training between plowing seasons (Soko, 1990).

Agricultural constraints

The use of animals for transport may have negative, as well as positive, effects on farming systems. Two particular constraints which farming systems may demonstrate are nutrition and financial risk.

Nutrition

Animals which are being used year round for transport work need more food than animals which are only worked for a few weeks of the year for plowing. This may cause problems if there is a shortage of dry season grazing, or if animals do not spend enough time grazing to meet their energy requirements. Where grazing is a constraint, farmers are beginning to use crop residues to supplement feeding for their animals (Kjaerby, 1989). There is scope for complementarity, as animal-based transport can be used to transport groundnut hay and other fodder residues from the field to the household.

Risk

Investment in animals and transport equipment increases the financial risks faced by farmers. The ability of farmers to repay loans on transport equipment depends on the overall profitability of the agricultural system, which is in turn affected by price and other risks associated with the marketing of cash crops. In a marginal system farmers may not be willing to increase their risk exposure despite apparent benefits.

Loss of animals through theft or disease is a risk affecting animal traction farmers in general. Donkeys tend to be less prone to theft than oxen because they have little or no meat value. However, high losses have particularly affected schemes in Malawi and Tanzania where donkeys were introduced as pack animals to farmers who were not familiar with the health or care of these animals. It is important that measures are taken to minimise these risks through training or extension support.

Non-agricultural benefits

Rural transport surveys in Kenya (Smith and Dawson, 1989), Mbeya, Tanzania (Shetto and Kwiligwa, 1988), Zambia (Müller, 1986) and Zimbabwe (Dawson and Smith, 1990; Gaidzanwa, 1991) show extensive use of animal-drawn carts and sledges for non-agricultural purposes. Some of these applications are directly income generating, but others generate benefits by reducing human effort or releasing time for other purposes. While these

non-cash benefits are more difficult to quantify, they are nonetheless real.

Transport services

Animal carts are relatively expensive, and beyond the reach of poorer farming households in most parts of Africa. Most studies of animal cart use have observed transport services and vehicle and/or animal hire markets in operation. This has two important effects: first, it makes the benefits of cart use available to a wider group; and second, it generates income for cart owners, in cash or in kind. It is still fairly rare for non-owners to hire animals and/or carts to transport goods which are not income generating, so most hiring arrangements relate to agricultural transport. The importance of rental income for the profitability of transport investments is discussed further below.

Fuelwood and water

As explained above, the collection of fuelwood and water is often the biggest transport burden for rural households in terms of time and effort consumed. Use of animal-based transport by owners to collect firewood for subsistence is not uncommon, with a few large loads replacing small daily ones. The use of carts and sledges to collect water is less common, depending on whether the people responsible for the collection (usually women) have access to animal-drawn transport. It also depends on the accessibility of the water source to such transport, the distance involved and the availability of a suitable drum to carry water. Müller (1986) found that some cart owners in Zambia still preferred to use sledges to transport water, apparently due to ease of loading and lower risk of spillage.

Traditionally, firewood and water collection tend to be the responsibility of women, so the use of animal-based transport for these tasks is dependent on the level of control which women have over the means of transport. Several studies have observed that young men and boys within a household often control the household cart or pack animal and may assume responsibility for wood collection and other "women's" tasks. Anecdotal evidence suggests that women value the social aspects of water and firewood collection, an additional factor affecting the use of transport in these activities.

Careful interpretation is needed in relation to wood and water transport statistics. A survey of ox cart use by Shetto and Kwiligwa (1988) found that 25–50% of carts were used for firewood collection and 50–90% were used to carry water, but that most of this wood and water was not destined for domestic use but was being transported by men for use in making bricks.

Grinding mill

The transport of maize or other grain to the grinding mill is a time-consuming task for women in many parts of Africa. Animal-based transport can help to remove some drudgery from these tasks, but this again depends on women's access to the means of transport. It also depends on the size of load which needs to be transported, since frequent trips to the grinding mill with small loads may be required to avoid deterioration in stored flour (Urasa, 1990). Some women overcome this problem by combining their small loads with those of neighbours and sharing a means of transport to the mill.

Other income generating activities

Several studies have observed the use of animal-based transport for transport intensive income generating activities. These include brick making, which tends to be a male activity, and beer brewing, which tends to be the province of women. There are some examples, still fairly rare, of cart owners using their vehicles to operate as traders in firewood and other materials (Dawson and Smith, 1990).

Construction

Another activity for which animal-based transport is commonly used is the transport of materials for house construction (Müller, 1986; Shetto and Kwiligwa, 1988). Scheinman (1986) observes that rental income from cart hire is often used to pay for home improvements, so that the cart plays a dual role in generating income and transporting the materials. The causality of such observations is difficult to prove, but they illustrate the way in which animal-based transport can facilitate other activities.

Pack animals

Characteristics

Donkeys, horses, mules and camels can be used to carry substantial loads on their backs, unlike cattle which cannot bear loads on their spines. Donkeys have many useful characteristics, being cheap, hardy and suitable for many types of terrain including hills and dry areas. A further advantage is that women's use of donkeys rarely poses the same cultural or social barriers as women's use of oxen, so donkeys can often help to lighten women's transport burden.

When loaded, donkeys walk at a rate of 3–4 km/hour; trotting is faster but can only be maintained over moderate distances (2–5 km). The load which can be safely carried by a donkey

depends on the size of the animal and the type of terrain. It is not uncommon to see larger animals carrying 70–80 kg over flat terrain, but in hilly areas this has to be reduced. A general rule is that the load should not exceed about one-third of the donkey's body weight, so maximum loads of 50 kg or less may be appropriate for smaller animals. This compares with typical human headloads of 25–35 kg.

Animal care

While donkeys are used extensively as pack animals in North Africa, Botswana and the Masai areas of Kenya and Tanzania, their introduction to Malawi, Zambia, Zimbabwe and other parts of easernt and southern Africa is only just beginning. There is considerable potential for wider use of donkeys in eastern and southern Africa but many farmers are not familiar with the use of donkeys for transport or agriculture (Scheinman, 1986). The introduction of donkeys to a new area requires careful extension support, particularly in training farmers about donkey care and health (Jones, 1990). Animals which are moved between different regions should also be carefully screened for infectious diseases, as animal losses from disease have been a serious problem in several donkey projects (Barwell, 1991).

Design of harnesses and packs

The technology used to attach packs is relatively low cost and simple, and can often be made from locally available materials such as leather, rope, cloth and wood. The University of Nairobi in Kenya has undertaken considerable work on the design and manufacture of donkey harnesses. The Institute of Agricultural Engineering in Zimbabwe has also published a manual on donkey use which covers harnessing in some detail (Jones, 1991). A good pack harness for a donkey should have three straps (belly, breast and rear), and straps should be well padded to avoid sores. The load should be supported by the back on either side of the spine and should not sit directly on the spine itself.

The design of the pack or panniers themselves depends on the type of load to be carried. The simplest pack for agricultural produce and other low density goods consists of one or two sacks tied over the donkey's back, connected by ropes over padding. Baskets or panniers, attached on either side, are useful for bulky goods and can generally be made from local materials. In Ethiopia and Sudan, pack animals are used to carry large water bags made from canvas or goatskin which are slung over the animals' backs (Curtis, 1986). Alternatively, a wooden frame can be used to carry heavy goods such as water cans, fuel cans or construction materials (Photo 2).

Flexibility can be achieved by using a wooden saw-buck saddle to which a number of different

Photo 2: Donkey with water containers on a pack saddle

Photo: IT Transport

types of loads can be attached. As shown in Figure 2, the saw-buck design is small, light and simple to make. Saddles of this type have been used traditionally on horses, donkeys and even yaks in Asia and the Americas.

Sledges

Characteristics

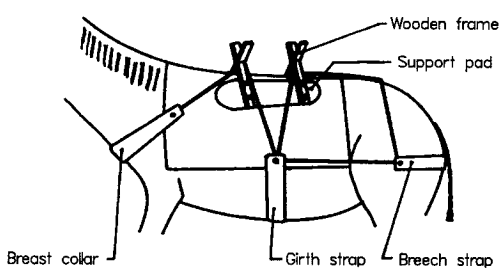
Ox-drawn (and in some areas camel-drawn) sledges can be used to drag loads of 150–350 kg at speeds of 2–4 km/hour, depending on the terrain. Sledges are difficult to pull and have a low capacity, limited range and poor efficiency compared to carts. They are believed to cause erosion of paths and for this reason have been banned in some countries (eg, Zimbabwe). The load is usually unprotected from vibration and dust.

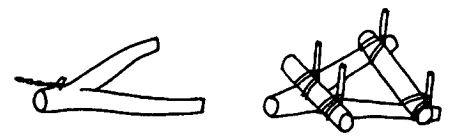
Despite these drawbacks, sledges play a vital role in some areas of Kenya, Tanzania, Zambia and other countries. They can be made by local artisans or farmers, requiring few skills and readily available materials—little more than a suitable Y-shaped piece of wood and a rope or chain attachment. The low cash cost means that almost all ox-owning farmers can afford a sledge, even when a cart is well out of reach. They can also be used on very sandy soils which can be difficult for some wheel designs. Farmers who have access to a cart sometimes still use a sledge for certain tasks, such as transporting the plow to the fields without damage and transporting water barrels without problems of cart loading and spillage.

Sledge design

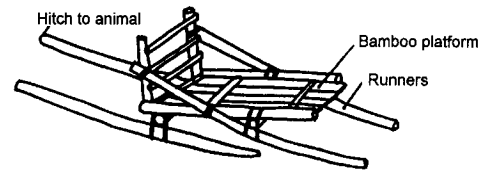
Details of a typical African sledge are shown in Figure 3: the basic design may be developed by building a load-carrying platform on the Y-shaped runners. The performance of this type of sledge has been evaluated by Immers (1988), who measured a tractive force of approximately 50–60% of the load on sandy surfaces (this would be about two to three times larger than for a wheeled cart). A significant

Figure 2: A versatile harness for pack animals





AFRICAN TYPE SLEDGES



PHILIPPINES TYPE SLEDGE

Figure 3: Examples of animal-drawn sledges

proportion of the drag is due to the wide frontal area of the Y-type runner and it would seem that drag might be reduced by using parallel runners. However, tests by Immers (1988) showed that there was no reduction in drag since the reduced frontal area was offset by increased sinkage of the runners. Another problem with parallel runners is that an elevated load platform is needed to avoid contact with the track between the runners: an example is the "Cebu" sledge which is widely used in the Philippines (Figure 3).

It appears that there is a conflict in the best type of runners for different terrains: for firm surfaces the need is to reduce friction and parallel runners are probably best whereas for soft surfaces such as sand the need is to reduce sinkage and a Y-type runner or runners with increased contact area are best. It seems that there may be some potential for improving sledge design to reduce draft requirements and the inherent low cost of sledges may justify some development work in this area. Any research effort involving sledges should also examine ways of minimising damage to terrain by low-cost improvements to the design of sledges or the paths and road crossings which they use. For example, in north-east Zimbabwe sledges have been modified into crude two- or four-wheeled carts by the addition of small wooden wheels which are made by the farmers themselves.

Animal drawn carts

Two-wheeled carts

Most carts pulled by draft animals in Africa have one axle with two wheels (Photo 3). Carts have a high efficiency and capacity relative to pack animals and sledges: an ox cart can carry 600–1000 kg, while a donkey cart can carry about 300–500 kg.

Compared to sledges, ox carts are easier to pull and have a greater range (up to 25 km a day).

Drawbacks of the two-wheeled cart are its high cost compared to pack and sledge technologies, and the relatively complex technology of wheels and bearings. Some types of wheels and bearings can be made from local materials, but there are usually trade-offs in terms of local availability, efficiency, cost and reliability. Careful maintenance is required, and the availability of spare parts in rural areas is often a problem. A further consideration is that carts can only be used on roads and relatively wide tracks and they are not well-suited for used in hilly terrain.

Four-wheeled carts

The use of four-wheeled animal carts is rare outside the commercial farming sector. These carts are generally larger, carrying up to 2000–3000 kg, and are usually pulled by a team of oxen or horses. They put less strain on the animals because the cart is balanced and hence avoids the downward force exerted on the animals by a two-wheeled cart.

However, the cost of a four-wheeled cart is generally more than double that of a two-wheeled cart, because of the need for a second wheel–axle set and for a swivel axle at the front for steering. Given this high cost, the use of four-wheeled carts is likely to be restricted to high load applications in farming, mining, transport services or other sectors. Nevertheless, some organisations do produce four-wheeled carts, including Camartec, (Centre for Agricultural Mechanisation and Rural Technology), Arusha, Tanzania.

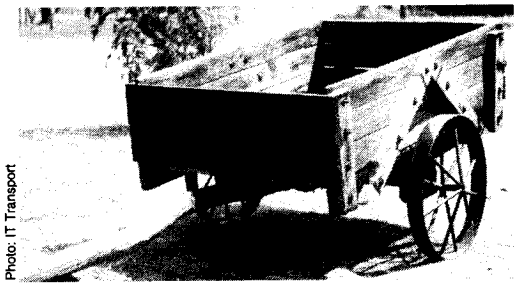


Photo: IT Transport

Photo 3: Steel-wheeled cart. Steel rimmed wheels may be preferred in areas where punctures are frequent

Cart design issues

A two-wheeled cart is basically a very simple vehicle and in an ideal situation would probably comprise an axle having wheels with pneumatic tyres and rolling contact bearings, a steel chassis and a sheet steel or wooden body (Photo 4). However, in most African countries the design and construction of carts is considerably more complicated because of restricted access to materials and components, limited manufacturing resources, severe limitations on affordability of carts by rural households, and a limited infrastructure for repair and maintenance of carts. A fairly wide range of options is therefore needed to meet different situations. Some of the available technologies and issues are discussed in detail in the companion paper of Dennis and Anderson (1994) and the publication of Barwell and Hathway (1986).

Features of good cart design

A well-designed cart is one which performs as efficiently and reliably as possible within the

Photo 4: Two-wheeled ox cart with pneumatic tyres

Photo: IT Transport

Table 2: Average towing capacity of a pair of oxen for different cart designs

	Earth roads		*Rutted sand*	
Cart design	*1 in 20 gradient*	*1 in 10 gradient*	*1 in 20 gradient*	*1 in 10 gradient*
Pneumatic tyres and rolling contact bearings	1880	1150	750	600
Rigid tyres + plain bearings[1]	1300	910	490	420
Rigid tyres + plain bearings[2]	750	600	375	330

[1] This assumes good quality bearings which are properly lubricated and allow no significant wheel wobble
[2] This assumes poor or worn bearings which are inadequately lubricated and allow considerable wheel wobble (tests in Ethiopia by Kebede and Bekele (1990) indicate that poor bearings and substantial wheel wobble can more than double towing resistance)

constraints of affordability and acceptability to rural households. Important features of good design are:

- **efficient performance**: this depends mainly on the wheel–axle assembly—the wheels should have low rolling resistance and the axle bearings low friction
- **smooth operation**: it is recognised that smooth operation has a beneficial effect on the performance of animals (O'Neill, Hayton and Sims, 1989) and therefore it is desirable to minimise impact or fluctuating loads transmitted from the cart. This may be achieved by using pneumatic-tyred wheels or by introducing some cushioning into the suspension or hitch assembly of carts with rigid-tyred wheels. Little work appears to have been done so far in the latter area
- **low cart weight**: since the draft effort available from the animals is relatively low it is important not to waste it in towing unnecessary vehicle weight. It has been recommended that the weight of ox carts should not exceed 200 kg (FAO, 1972). Upper limits for donkey carts may be 100 kg (single) and 150 kg (pair)
- **reliability**: this implies a robust, durable construction requiring minimum maintenance and repair. Of particular importance are low wear of bearings, reliable performance of critical components such as wheels and avoidance of failures or deterioration of frame and body members
- **affordability**: it is likely that material and component costs account for over 50% of cart cost, possibly up to 80% in smaller workshops. It is therefore important to use materials efficiently and as far as possible to use low-cost materials which are readily available. Distribution costs may also be relatively high for centrally produced carts and manufacturing strategies should be devised to minimise these.

It is clear that these desirable features involve conflicting requirements, especially the need to achieve good performance and reliability while minimising the weight and cost of materials and components. The achievement of efficient designs which are also affordable and acceptable is therefore a considerable challenge.

Performance and design

Combining the data on rolling resistance of tyres and friction in bearings, estimates can be made for performance of different cart designs for various operating conditions (Table 2). The estimates are for the total load that can be towed by a pair of oxen producing a draft effort of 150 kgf (1500 N). The weight of the vehicles must be subtracted from the figures in the table to obtain load capacities. The table clearly shows the benefits of good cart design and the need to minimise the weight of the cart. Since the average towing capacity of a donkey is only about 25% of that of a pair of oxen the criteria of good design and low cart weight are even more critical for donkey carts.

Two important issues for cart performance are the weight of the cart body and the choice of technology for the wheel–axle assembly. Wheels with pneumatic tyres and rolling contact bearings are often preferred by users because they offer significantly less rolling resistance than the lower technology rigid wheels with plain bush-type bearings. The maintenance requirements of these technologies also differ: on the one hand, users may have problems with punctures of pneumatic tyres, particularly in areas where repair facilities are scarce or punctures are particularly frequent; on the other hand, rolling contact bearings require much less routine maintenance and lubrication than plain bush-type bearings.

Approaches to cart production

Technology choice for animal carts cannot be made purely on the basis of optimum performance. Other important factors must be taken into account, including:

- farmer preferences
- nature of terrain and types of load transported
- cost and affordability
- sustainability of supply of materials and components
- reliability and ease of maintenance.

This is not an exhaustive list but it indicates that a comprehensive approach must be taken, embracing demand, marketing, production, distribution and maintenance as well as performance. The three main approaches which have been followed to date are outlined below.

Informal sector/scrap

The carts most commonly found in many parts of eastern and southern Africa comprise a scrap wheel–axle assembly, with a rough wooden or scrap steel cart body made by local farmers or artisans.

Advantages: These carts are evidently popular with farmers. The use of scrap pneumatic tyres and roller bearings makes the carts easy to pull on rough surfaces, despite cart bodies which are typically quite heavy. The cost is often 30–50% of commercially produced carts, depending on the cost of the scrap axle. These carts can be made using local skills and materials, provided scrap axles can be found.

Disadvantages: The limited supply of scrap axles often constrains the number of carts which can be made by the informal sector. This is particularly marked in countries where scarcity of foreign exchange has restricted car and truck imports over many years. Another drawback of this approach is the poor availability and lack of standardisation of spare parts.

Aid sector/local materials

Many aid organisations, and some inventive artisans, have focused on minimising the imported materials and skills required to make their cart designs. Over the 1970s and 1980s, Camartec in Tanzania, Kasisi and Katapola in Zambia and many other "supported" organisations have experimented with different designs. These carts tend to use wooden or simple steel wheels, with bush bearings made from wood or other materials

Advantages: These carts can be made mainly from local materials, with low requirements for steel and other imports. The cost of production is generally low (40–50% of commercial cart cost), but there are exceptions to this rule. The carts tend to be fairly robust and are not susceptible to punctures.

Disadvantages: Farmers have not taken up these carts in any great numbers, particularly those with wooden wheels. This may be due to the poorer performance and lower load capacity of these carts and to their old fashioned image. While most materials are locally available, good carpentry skills are required to make bearings and wheels of adequate quality. Bearings also require regular greasing and maintenance.

Commercial/central

In some West African countries, and to a lesser extent Malawi and Zimbabwe, there has been large-scale production of carts by centralised producers in the private or public sectors. These carts generally have roller or ball bearings and pneumatic tyres. They may be produced fully assembled, with sheet steel or wooden bodies, or in kit form to be assembled by rural workshops. Local assembly reduces the cost of transporting the cart from the factory.

Advantages: Many farmers prefer roller bearings and pneumatic tyres. Cart quality is usually higher than that of locally produced carts but this is not always the case.

Disadvantages: These carts tend to be more expensive than other types of cart, particularly when distribution costs are included. Centralised manufacturers in eastern and southern Africa rarely have well developed supply and distribution networks, so it is often difficult for rural farmers to purchase a cart and to obtain spares.

Comparison of approaches

The introduction of carts appears to have been fastest in those countries which have focused on centralised production of good quality carts. Since the 1950s the number of carts in Senegal has reached over 100 000, due largely to the success of the lightweight cart manufactured by the Sismar (Siscoma) factory. This cart has roller bearings and pneumatic tyres. This represents almost one cart for every two plows or cultivators. Similar penetration can be seen in Zimbabwe and in Mali (over 100 000 carts), Burkina Faso (about 40 000 carts) and Malawi (around 20 000 carts) (Starkey, 1989a).

The introduction of carts has been much slower in Tanzania and Zambia, where aid-supported "local material" carts with rigid wheels and bush bearings have had more prominence. The ratio of carts to

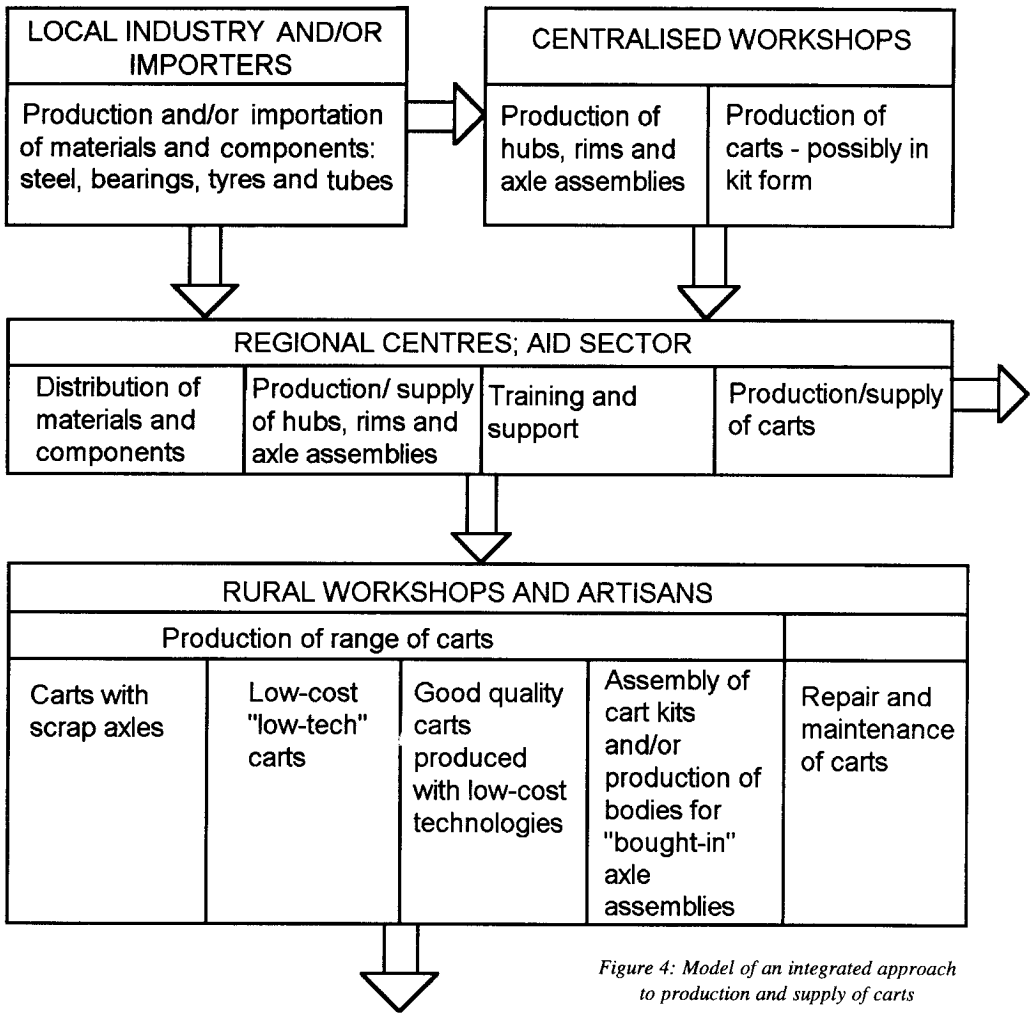


Figure 4: Model of an integrated approach to production and supply of carts

plows/cultivators in Zambia is estimated to be roughly one to 10 (Starkey, Dibbits and Mwenya, 1991). There is little evidence of farmer acceptance of wooden-wheeled carts, and it is evident that most carts use scrap pneumatic-tyred wheels.

This difference in cart introduction rates cannot be explained purely in terms of technology choice, but must be understood within the general economic and policy conditions prevailing in these countries. The overall profitability of agriculture, the status of infrastructure and distribution systems, the existence of rural repair workshops, and the level of extension support are only some of the factors affecting the demand and supply of carts. The centralised production of good quality carts is unlikely to be successful on a large scale unless supply and distribution systems are effective in reaching rural areas. The ready availability of credit schemes has been a particularly important factor in the success of centralised cart production in West Africa, since credit support has helped to create a large-scale effective demand for carts.

Suggested way forward

The way forward for cart production in eastern and southern Africa appears to be a combination of the above approaches. The aim is essentially to create better links between centralised manufacturers, aid workshops and informal sector artisans. There should almost certainly be more than one type of cart design in production, but each sector should focus on producing the components or playing the role for which it is best equipped (see Figure 4). Suggested roles are discussed below.

Role of large-scale commercial sector

There is an evident demand for an increased supply of pneumatic-tyred wheels with roller bearings. In

the short term, this could be met by importing second-hand axles and wheels, but a longer-term solution could be to establish centralised local production of wheel axle assemblies or hub units incorporating imported bearings (following the example of SKF Zambia). It is not yet clear how successful or economic SKF's initiative will be compared to imported hubs.

Centralised production of complete carts would be able to meet a larger proportion of the market if commercial producers improve their distribution and spare part networks. Distribution costs could be further reduced by producing the cart in kit form for assembly by local workshops.

Role of aid sector

The aid sector could play an important role in strengthening provincial depots or workshops to act as centres for the distribution of materials and components (including wheel–axle–hub units) to smaller rural workshops. These provincial centres could also provide training and support to blacksmiths and artisans. There is also likely to be a role for these workshops in producing components and/or carts based on lower technology roller bearing hubs, axles and split rim wheels. However, research, monitoring and sharing of results is still needed to assess farmer acceptance of these products.

Some continued development and testing of cart designs is still required, such as experimentation with puncture-proof cushioning for rigid wheels. However, it is vital that researchers in the aid or government sectors seek and listen to feedback on their designs (eg, farmers' unenthusiastic response to solid wooden wheels in Tanzania and Zambia). Attempts to maximise the use of local materials, or minimise the cost of carts, should not be followed dogmatically if the resulting designs are not acceptable to farmers. A flexible approach to cart design is likely to be more successful, combining some centrally produced or imported components with local resources where appropriate.

Credit and extension support for cart users and producers is another important role for development projects and the government sector. This is discussed in more detail below.

Role of informal sector

Small workshops in the informal sector are well suited to production of carts from scrap wheel–axle assemblies, and to the assembly of carts from kits purchased from large-scale manufacturers or aid workshops. Neither of these activities requires sophisticated tools or skills, except possibly welding.

As an alternative to purchasing cart kits or components, small workshops can manufacture some types of carts themselves. Rigid wheel and some split-rim wheel with pneumatic tyre technologies require only basic skills and low cost tools. Bush bearings can be made by small workshops which have good carpentry skills, but roller bearing hubs generally require investment in a lathe. Such components could still be purchased by small workshops from commercial or provincial workshop centres.

The role of small rural workshops in the production or assembly of animal carts, supported by training and spares distribution services from provincial workshop centres, should create a network of workshops capable of undertaking local repairs on the carts. These workshops are often in a better position than central producers to recognise and respond to the needs of the local community.

Integrated approach to cart production

Some aid organisations which are attempting to create better links between centralised manufacturers, and workshops and informal sector artisans, focusing on improving the supply of pneumatic wheel and roller bearing components and spares to small rural workshops, include:

- Animal Power Utilisation project in Malawi (Ashburner, 1989)
- North West Integrated Rural Development Project in Zambia (Soko, 1990; Starkey, Dibbits and Mwenya, 1991)
- Mbeya Oxenization Project in Tanzania (Shetto and Kwiligwa, 1988, Starkey, 1989b)
- Driefontein/Institute of Agricultural Engineering/Intermediate Technology Development Group training programme in Zimbabwe.

It is hoped that the approach advocated here will lead to the following outcomes:

- a general improvement in the construction and availability of carts and supply of these to rural communities at the lowest possible cost
- an integrated approach to production incorporating manufacture of carts and cart components
- an improved supply of materials and components to artisans and small workshops to develop local construction and assembly of carts
- development of an effective infrastructure for the supply, maintenance and repair of carts.

Socioeconomic aspects of cart dissemination

So far this paper has examined the potential role of animal-based transport in farming systems, the technical options for animal-based transport, and detailed issues relating to the design and production of animal cart. This final section will look in some detail at the economic and social impact of animal-drawn carts on farming households, and the implications for wider dissemination of animal-based transport.

Purchase cost

Animal carts vary widely in price according to type and to the general economic situation in each country. Comparisons of costs of carts between countries are difficult due to varying exchange rates (official and shadow). High quality commercial carts tend to be fairly expensive: the Animal Power Utilisation Project in Malawi supports the purchase of two-wheeled carts from Petroleum Services for around 3000 Malawi Kwacha, which is equivalent to over US$ 1000 per cart (Barwell, 1991). In most countries carts produced from scrap by artisans cost substantially less than commercial carts: in Zambia carts based on scrap axles can be bought for 15–20 000 Zambian Kwacha (ZK), while a commercially produced cart costs at least ZK 45 000 (representing a range of approximately US$ 150–450).

Carts produced by development organisations vary according to design and possible subsidy. In Tanzania, carts produced by Camartec sold for 50–60 000 Tanzanian Shillings (TSh), which is approximately equivalent to US$ 200–260 while TSh 30 000 (US$ 130) was the price for some aid-project carts (Brewis, 1992). There are examples of development projects having higher production costs than centralised workshops, due to costly designs and lack of economies of scale. These cost differences tend to be masked by price subsidies and, to a lesser extent, by easier and cheaper distribution of carts compared to central producers.

Throughout eastern and southern Africa, the cost of wheels, tyres and axles is a major element of the cost of a cart. Scrap wheel and axle assemblies have become increasingly difficult to find and have risen steeply in price in many countries. In 1989, a report for the North West Integrated Rural Development Project in Zambia found that more than 55% of the cost of its ox carts was attributable to the wheel–axle components (Soko, 1990); in the case of artisan-produced carts this percentage may well be higher.

Constraints to demand for carts

At these prices, ownership of a cart is still beyond the reach of many rural households. In areas where agricultural potential is poor, where crop prices are low, or landholdings are small, cart ownership may not be achievable for any but the wealthiest farmers (Becker, 1984; Malmberg-Calvo, 1992). Credit support will improve the affordability of carts to poorer farmers, but there are still likely to be some situations in which a poor farmer cannot afford to service a cart loan. Cheaper means of transport such as pack animals, sledges and bicycles may be more appropriate for ownership by such households. However, poorer households may be able to hire a cart from wealthier neighbours to meet their peak transport demands.

In areas of higher agricultural potential, where landholdings reach 4 ha or more, cart ownership can be both profitable and attractive despite the high cost (Dawson and Smith, 1990). There appears to be an unsatisfied demand for animal carts in many areas but it is unclear whether this demand remains unsatisfied because of supply constraints, lack of access to credit or a combination of these factors. Supply constraints, particularly shortages of wheels and axles, are often cited as the main factors which limit wider dissemination of carts (Harder, 1989; Dawson and Smith, 1990), but perceived demand for carts may be "latent demand" which will be translated into effective demand only if credit facilities are made available to overcome cashflow problems.

Profitability analysis

Several attempts have been made to assess the profitability of cart ownership, with widely differing results. There are examples from Kenya and Tanzania of carts paying for themselves within one or two cropping seasons, through hire income or savings on motorised transport costs (Scheinman, 1986; Smith and Dawson, 1989). Similar findings have been reported in the Mansa area of Zambia (Starkey, Dibbits and Mwenya, 1991) and in West Africa (Harder, 1989). However, other analyses have found that investment in an ox cart appears less profitable than other elements of an ox traction package (Löffler, 1989).

These inconsistencies partly reflect differences between the overall profitability of agriculture in the areas under study: the returns to cart ownership are likely to be higher in productive agricultural areas with good infrastructure. Differences are also partly due to lack of consistency in the treatment of costs: some analyses allocate animal as well as equipment

costs to transport, while others assume no incremental cash cost if animals are used for transport as well as tillage. Where animal costs are attributed to transport, some analyses of cart costs do not allow for appreciation in the meat value of oxen over their working life. Most analyses omit benefits of cart use which do not directly generate cash, and some omit all uses with the exception of crop marketing. Assumptions on hire income also differ widely in their optimism or pessimism. Drawing together these different approaches, a thorough analysis of the economics of animal-drawn carts should consider the following:

Costs:

- cash cost of cart purchase or annual depreciation
- annual cart maintenance costs
- a proportion of the cost of animal purchase (with allowance as appropriate for risk of animal loss, and for appreciation in resale value)
- a proportion of animal maintenance costs (generally low in cash terms, except if additional feeding costs are significant).

Benefits:

- savings on hire payments for transport of own goods
- generation of income by hiring cart to other households
- value of time saved through more efficient transport (if reinvested in agriculture, domestic or income generating activities)
- possible reduced losses from crop deterioration, pest damage or theft through timely transport of harvested crops
- possible increases in producer prices by direct sales to market
- possible profits from trading activities using cart.

In most cases it is found that the profitability of animal cart purchase is highly dependent on the market price for cart hire.

Hire markets

In many parts of eastern and southern Africa there is an active hire market for animal carts. Households who cannot afford or do not own a cart can often hire or borrow a cart from neighbours from time to time. The timing of use may not be ideal, as the cart owner usually has first priority during the peak harvest season, but hire arrangements do allow more households to share the benefits of cart use.

Hire arrangements are most commonly observed for trips which involve some element of cash generation, particularly those related to marketed crops. The data given in Table 3 were collected in a village in northern Zambia where only two households in 42 surveyed owned ox carts (Airey and Barwell, 1991):

Hire charges may vary according to season, distance travelled and trip purpose. Payment may be in the form of mutual obligation or cash, depending on the social relationship between the cart owner and borrower. In Zambia charges of 100 Kwacha (ZK) per 100 kg bag have been quoted for the transport of maize during the peak harvest season (equivalent to about US$ 1 per bag or US$ 8–9 per cartload). Further reports from Zambia (Starkey, Dibbits and Mwenya, 1991) suggest that farmers are paying 10–15% of the value of their maize crop to hire an ox cart for a few kilometres. Much lower hire charges of ZK 20 (US$ 0.20) per load have been quoted for off-season tasks such as firewood collection.

Supply and oversupply

The importance of hire markets for cart profitability has led to some concern over "saturation" of the market for carts. One argument for saturation is that the rental market will tend to become less profitable as cart ownership levels rise, since hire charges may fall due to oversupply. Conversely, demand for cart services is likely to increase as hire becomes cheaper. The implications for cart profitability depend on the elasticity of demand to price, and it is difficult to predict where the equilibrium level for cart ownership would be in any given case.

An analysis by Löffler (1989) suggested that there was already an oversupply of carts in the North West Integrated Rural Development Project area in Zambia. This analysis was based on calculations of the size of cart fleet required to market all the maize surplus during the peak agricultural season. Löffler (1989) identified some crucial assumptions which underlie this analysis: that all farmers have equal access to carts in the "fleet"; that all owners are motivated to hire out their carts to the specified extent; and that other cart uses such as crop

Table 3: Uses of ox carts in a village in northern Zambia

Purpose of trip	*Percentage of households using cart*
Carry harvested crops from field	41
Collection of fertiliser	18
Collection of seeds from depot	6
Firewood collection	2
Water collection (source nearby)	0

harvesting do not conflict with crop marketing during the peak season.

Even if these assumptions were found to be justified, the methodology used in this type of analysis does not allow for the possibility that some cart purchases may be motivated by broader benefits such as the value of time and effort saved through more efficient transport. Further, cart purchase may still be profitable for new entrants even though the cart fleet is theoretically just large enough to transport all the marketed maize. The perceived utility of carts is demonstrated by high levels of ownership in parts of West Africa and of southern Africa: in Senegal it is not uncommon to find ratios of one cart to every two households (Starkey, Dibbits and Mwenya, 1991), and similar levels are observed in some parts of Zimbabwe (Dawson and Smith, 1990). The market for carts will ultimately depend on a number of factors including the cost of carts and draft animals relative to their perceived utility, the levels of disposable income and the availability of credit support.

Credit

As discussed above, animal carts are relatively expensive purchases which poorer farmers may not be able to afford. If the problem is one of limited cashflow, rather than intrinsically poor profitability, then credit assistance may be effective in encouraging dissemination. Evidence from Malawi, Zimbabwe and West Africa suggests that the widespread dissemination of carts is closely linked with the success of government credit schemes for carts (Dawson and Smith, 1990). Supply constraints may also respond to credit initiatives, since producers will be reluctant to develop cart production on a large scale unless they are confident of effective demand, which is often dependent on credit support.

There is evidence that investment in transport equipment may, in some areas, be more profitable than investment in animal traction for agriculture: Starkey (1989a) observed a Malawi farmer who found it profitable to hire his cart and oxen out for transport, while he paid hired labourers to work his own fields. Such evidence of profitability again suggests that carts should be given a high priority for credit assistance.

Some animal traction projects, such as Mbeya, have been reluctant to stimulate demand for carts by offering credit while cart supply cannot satisfy existing demand (Harder, 1989). Others, such as the North West Integrated Rural Development Project in Zambia, initially have offered credit for a complete package including oxen, tillage implements and cart but have changed their credit policy due to supply shortages and high costs for carts. This project now attaches lower priority for cart loans, with loans not being given for an ox cart until a farmer has already invested in a pair of oxen and a plow (Löffler, 1989). Low prioritisation of credit for carts may be appropriate in the short term, in areas where supply constraints are particularly serious. In the longer term such strategies are likely to limit the potential economic benefits from wider cart ownership: the best solution to a supply shortage is surely to improve supply rather than restrain demand.

It should be remembered that the provision of credit does not in itself improve the profitability of investment in animal-based transport equipment. Even if credit is available, there are likely to be some farmers for whom investment in a cart would not be feasible. Some animal traction credit programmes use landholding requirements as a shortcut to assess feasibility: the government agricultural credit system in Malawi, for instance, only lends to farmers holding more than 2 ha (Barwell, 1991). Such rules can become too rigid, effectively excluding poorer farmers and many women from buying carts, even if they would be able to repay loans from hire income. Credit schemes need to take a more flexible approach to the profitability of transport investments, and to investigate mechanisms such as group ownership which could reach poorer farmers and women.

Impact on women

It cannot be automatically assumed that women will benefit from the introduction of animal-based transport. As noted above, households which do not own animals or a cart are less likely to pay hire charges for subsistence transport than for income related agricultural transport purposes. This means that carts are not commonly hired for the transport of wood and water, which often are a major burden on women's time and effort. Even in households which own animal carts, women's access to the carts and other "intermediate" means of transport is often limited (Gaidzanwa, 1991).

As noted above, the introduction of animal transport has in some cases resulted in men assuming responsibility for fuelwood collection or other tasks traditionally performed by women (Doran, 1990; Urasa, 1990). This shift of responsibility is generally in women's interest, but it remains the case that women tend not to have direct control over the means of transport. In some cases, men's assumption of responsibility for water supply and

other services has meant that women lose control over income or become liable to service charges (Howe, 1989). Women's access to, and control over, animal carts is discussed by Doran (1994).

Given the high proportion of local level transport which is undertaken by women, and the constraints which this imposes on women's time during peak agricultural seasons, ways must be found to reach women more effectively. There are a number of possible ways of improving women's access to, and control over, animal-based transport. These include work with women's groups; credit assistance targeted at women; education campaigns to break down taboos against women using simple means of transport, as have been successfully implemented in Burkina Faso and Ghana; and wider use of donkeys, which are regarded as "women's animals" in some parts of southern Africa. In some cases it may be more effective to address women's domestic transport burden by other means, such as non-transport interventions to improve access to essential supplies of water and firewood (eg, water pumps, village woodlots).

Conclusions and future directions

Animals can provide an affordable means of reducing the significant burden faced by rural households in transporting agricultural and subsistence goods at village level. The efficiency of animal-based transport relative to human headloading can increase the productivity of agriculture and other income generating activities. Integration of animal-based transport with animal draft farming systems offers many synergies, particularly in harvesting, marketing and transport of farm inputs, although the use of animals for transport may increase their nutrition needs.

This paper has argued that animal-based transport can make a substantial contribution to rural development in eastern and southern Africa and justifies special consideration in animal draft projects. It has focused particularly on the technical and socioeconomic issues related to carts, pulled by oxen or donkeys. Nevertheless it has emphasised that ox-drawn sledges currently serve a vital function for poorer farmers and that donkeys could be much more widely used as pack animals than they are at present. In many situations the most efficient option for animal-based transport is the two-wheeled cart, offering good performance and high carrying capacity, but at a cost significantly higher than the alternative options.

Carts can offer significant benefits and income generating opportunities in many circumstances, and can act as important catalysts for rural development. Use of carts is adversely affected by supply constraints, high cart prices and cashflow problems. The approach advocated here is a two-part strategy of addressing both supply constraints and cashflow constraints, putting a high priority on credit schemes where cart ownership is intrinsically profitable. Dissemination strategies should be designed so that women and poorer farmers are not excluded.

Some important points have been made in relation to future research and project work:

- policy-makers and project planners should be encouraged to appreciate the importance of local-level transport, and the role which animal-based transport can play
- wider use of donkeys should be encouraged, for pack-carrying and donkey carts. Projects should share experiences on the introduction of donkeys into new areas
- sledges should not be discouraged while carts remain unaffordable to many poor farmers, unless there is an overwhelming case against their use on the grounds of soil erosion
- a flexible approach to cart design and production is needed which is responsive to the local preferences and financial resources of farmers. Localised manufacture or assembly should be encouraged but, where necessary, this should be integrated with centralised or regionalised manufacture of some components such as wheel–axle assemblies
- to support this approach, a major effort is needed to improve the supply of materials and components to workshops involved in production of carts and cart components. This will need to include the importation of some components such as rolling contact bearings
- credit schemes for carts should be given high priority, to translate "latent demand" into effective demand and help to justify large-scale production
- efforts should be made to improve women's access to and control of animal transport, or to address their transport needs through accompanying interventions.

This paper has tried to show that there is no universal formula for the improvement of animal-based transport, in terms of cart design, credit policy or dissemination strategy. Instead, there are learning processes which communities, producers and projects go through in reaction to the changes in their particular circumstances and objectives. The learning process can be speeded up by communicating lessons learnt in other projects,

and by developing careful methodologies for testing new ideas. A good example of shared learning has been the cart testing programme at Magoye in Zambia (Dogger, 1990), which has provided the region with a useful database on the performance of different designs of animal-drawn carts under controlled conditions. It has also demonstrated the importance of well-structured methodologies to involve farmers in the testing and evaluation process. Similar initiatives are needed to evaluate and share information on other aspects of policy and project design, including the assessment of demand, provision of credit and the involvement of women. Ongoing communication of lessons learnt through research, testing and project experience is the most effective way to improve both technical and socioeconomic aspects of animal-based transport in the region.

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