The development of low-cost animal-drawn carts

by

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Abstract

Working in Nigeria and the UK, the Development Technology Unit of the University of Warwick has succeeded in generating designs for donkey- and ox-drawn carts and cart component designs which are substantially cheaper and easier to make than existing designs, but which have similar or better performance.

Cost reduction has been achieved by simplification of design. Most new DTU designs for carts avoid the use of drilling altogether in their construction, using only simple hand tools and welding equipment (which is very widely available). The number and difficulty of saw cuts have been severely reduced: all cuts (and there are not many) are normal to the length of the material. The result is that simple carts can be built in only a few hours compared to the days required for more conventional designs.

Most existing carts used in developing countries are made locally using wooden bodies and scrap automotive axles. Such axles are becoming scarce, their quality is falling and their price is rising. Alternative wheels, axles and bearings are required to reduce costs and provide farmers and transport operators, with very restricted capital, access to better transport. The DTU is developing designs for locally constructable roller bearing axles, again requiring only simple hand tools, welding equipment and widely available materials. A family of cast aluminium hubs and split-rim wheels with integral aluminium-race roller bearing provides another development which could allow complete axle sets to be made for only a few tens of dollars. These need only simple tooling, yet provide adequate or good performance at low cost.

With all cart developments low first cost and low repair costs, together with adequate performance, are of paramount importance to the potential purchaser and user. Quick and local repair is therefore important and is facilitated by appropriate designs, such as those mentioned above, which require zero special tooling and investment and make minimal demands on foreign exchange and distant and uncontrolled infrastructure, such as roads and dealer networks.

Introduction

Animal carts and other products intended for the rural and disadvantaged urban markets must be economical and efficient and they must expose both the manufacturer and user to minimal investment and risk. The importance of risk reduction in the uptake of new technology has been discussed by Ellis-Jones and Sims (1994) amongst others. Risk can be reduced if the initial price of the cart is modest and if the availability of the cart is high. However, the cart need not be totally reliable. Conventionally, engineers strive for long 'mean time between failures' for their products. But to achieve this high reliability, high quality materials and components are required which are commensurately more expensive and which must be manufactured in large numbers in only a few locations to achieve the consistency required. Starkey (1988) has discussed the problem of technically excellent products which are too expensive. The cart owner will probably then find difficulty in obtaining spares and difficulty in achieving early and cheap repair if spares and dealer facilities are available only at the end of a very long and muddy road. Long 'mean times to repair' result from this traditional 'mass production' approach, and overall availability suffers. Reynolds (1992) discusses some of these issues surrounding reliability and repairability in the context of rural water pumping.

Thus a more cost effective method of technology provision in low and very low income environments is probably to accept more breakdowns as long as they can be quickly and easily repaired. This opens the way for local production by artisans who then can not only repair the carts, but also manufacture them. The almost universal use of Japanese minibuses in Africa has been ascribed, not only to their low cost (vehicles are scrapped by Japanese owners because of extremely tough roadworthiness laws), but also because such vehicles are easily repaired.

If the economics of a technology are only marginal (as may be the case with tractors) then mean times to repair can become infinite and the technology is usually laid to rest in one of the machinery graveyards which border every developing country town. Rodriguez (1992) points out that taxies, minibuses and trucks will be driving past those same graveyards, maintained by the same societies which are apparently unable to keep tractors working. He suggests that one technology is cost effective whilst the other is not.

After many decades of development it might be imagined that designs of animal cart for emerging nations would be optimal or nearly optimal. Working in Nigeria and the UK however, members of the Development Technology Unit have developed cart components and cart designs which are significantly cheaper than existing designs. These cost reductions have been achieved by rigorous simplification of design, usually by providing only the minimum number of components. Such components as there are, are easy to make, of easily obtainable material and require only the minimum of skills and tooling to produce.

How is this lower cost possible? - the DTU approach to cart design

The requirements for low-cost, locally produced carts translate into profound differences in the approach needed in the design of such products. A number of design rules, features and manufacturing constraints and requirements become apparent:

- use of machine tools in manufacture should be reduced or avoided
- drilled holes should similarly be eliminated or reduced
- complicated joints and materials preparation (for example mitred and angled joints), should be avoided
- the number of operations involved in the production of the product should be severely reduced
- the number of components should be severely restricted
- requirements for high tolerances should be eliminated
- the number and complexity of moving parts should also be severely reduced
- threaded fixings should be avoided wherever possible
- symmetry and modular design is to be preferred so that lengths of components used in a product are similar to or multiples of each other. Asymmetry and handedness should be avoided
- material types and range of sizes used in designs should be reduced (makes stock control easier).

These restrictions may appear to render manufacture of products for the communities mentioned above difficult or impossible, but there are techniques which are technologically feasible but which are not preferred in industrialised countries and which are therefore unfashionable or unknown:

- holes can be produced by welding metal around them, rather than removing metal by drilling, and this can be quick and flexible
- punching holes is the normal method used by developing country blacksmiths
- components can be attached to each other by welding in such a way that the welds can be cut through when the product is required to be disassembled; this may be cheaper than bolting
- steel bar may readily be used for clenched nailing and riveting and other fixings. Its ductility may allow the fixing to undone and remade several times
- components can be bigger than their equivalents might be in industrialised countries and may still be workable at lower speeds and loads with inferior materials.

The section below shows a number of animal carts built from steel and timber and using clenched riveting and welding techniques. Particular features of each design are described.

Lightweight sideless donkey cart

The lightweight cart shown in Figure 1 is intended to be pulled by one donkey and is therefore as light as possible. Also it is intended for bulky loads such as firewood (which will be secured by tying) and hence it is not provided with sides. Only a very few material sizes are used in

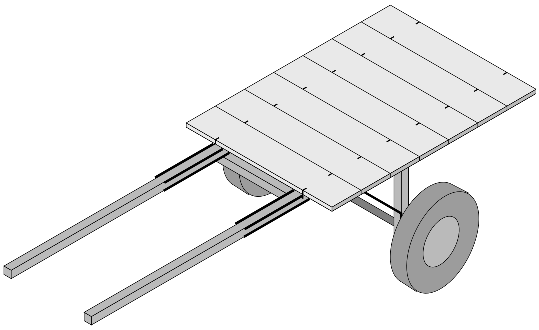


Figure 1: Lightweight sideless donkey cart

this design: 50 mm square box section tubing, 12 mm or similar reinforcing bar, 6 mm re-bar and 25 mm timber planking. All the components are cut off square from the material bars and there is no requirement to work closer than about 5 mm. No drilling is required and there are no moving parts within the design, other than the wheels. Only seven main components provide the chassis and only eight welds are required to join them. No jigs or fixtures are required for manufacture and the cart body can be made in only a few hours, which compares with as much as a week for conventional designs.

Donkey and ox carts with sides

The wooden planking used on the two designs shown in Figure 2 and Figure 3 provides the longitudinal bending strength of these carts. This is particularly helpful in reducing the mass and cost of production by using material more efficiently - two functions are served rather than the usual one by these side planks. The designs use only a few material sizes and again no drilling and cutting at awkward angles are required.

Wooden carts

Figure 4 shows a wooden bodied cart. What is unusual is the method of jointing between components. Most wooden structures (for example furniture) are joined using methods in which large proportions of both meeting components are cut away to make, for example, a mortice and tenon joint. Such joints are time-consuming to make and require high levels of skill, together with a good tool base. The cart shown here uses joints which take only a few minutes to make.

Steel roller bearings – stub axles

Figure 5 shows one particular low-cost roller-bearing hub mounted in an angle iron central axle. The bearing does not give totally reliable performance, with some failures possible after only a thousand kilometers, but the axle is cheap and is readily repairable. With good lubrication some axles have lasted nearly 30 000 km. The method of mounting the wheelnut studs onto the hub tube removes the need for flame-cutting and turning a disc of steel plate and drilling the stud holes. The method also allows minor changes in the pitch circle diameter by simple bending of the struts and of more substantial changes in diameter by changing strut length. The hub can be made without machining and some versions of hub require no drilling either. This design is dictated by

Figure 2: U frame donkey cart

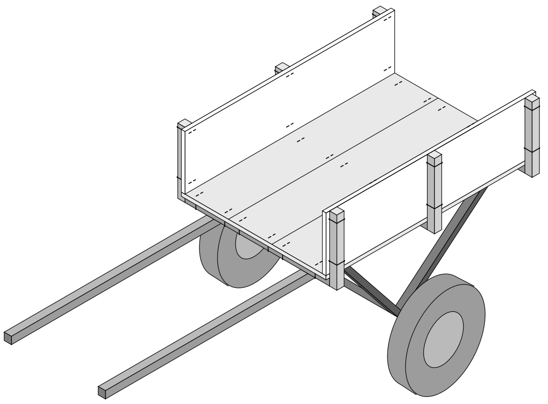
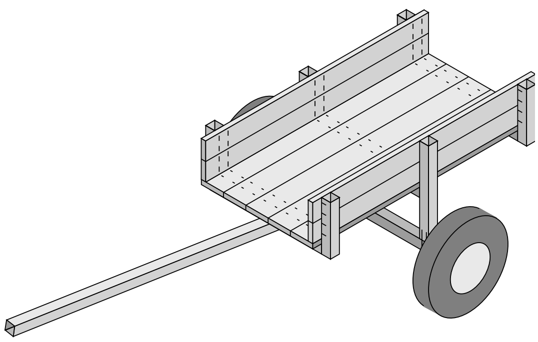


Figure 3: U frame ox cart



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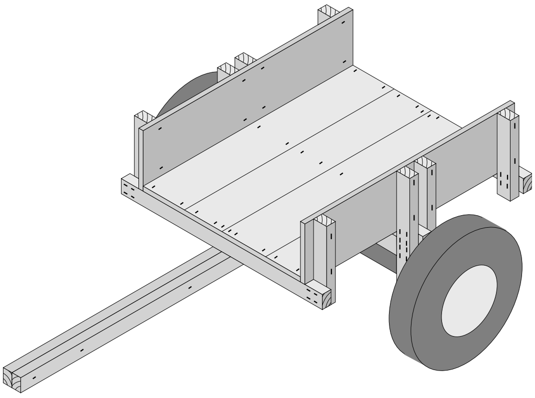


Figure 4: Wooden cart using U frames

the 63 mm hole in the middle of most automotive wheels.

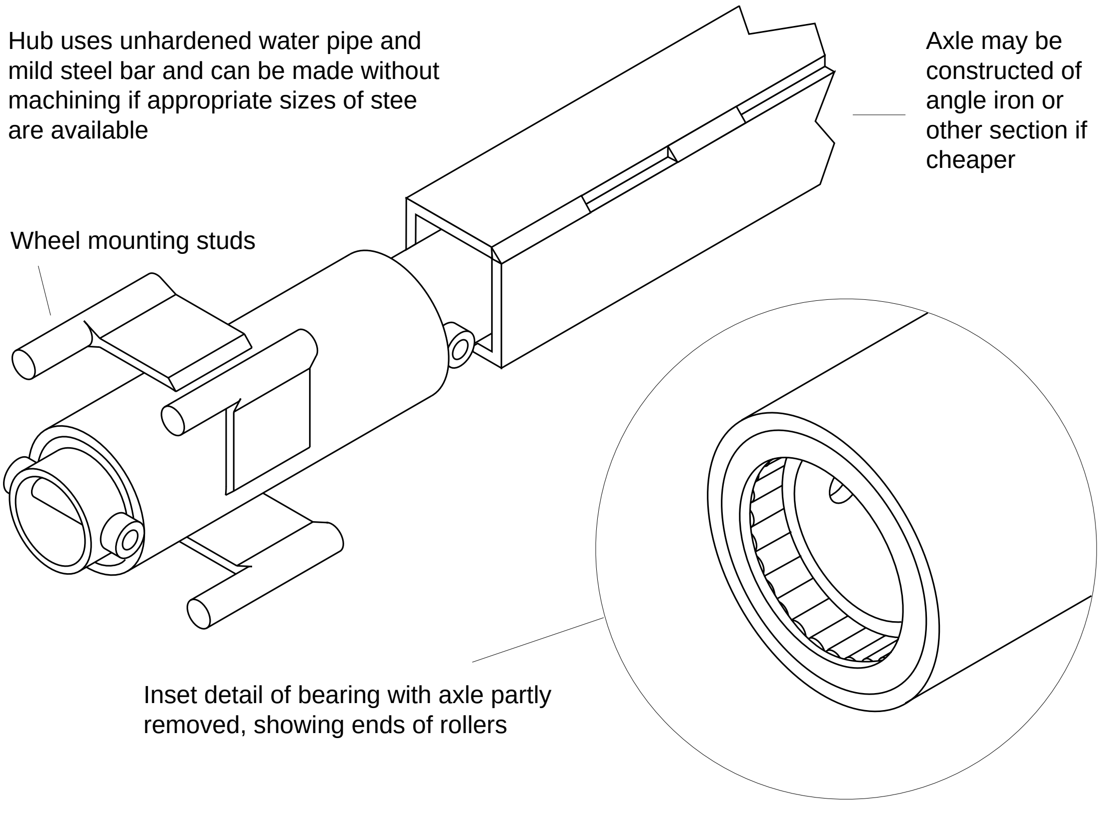
Steel roller bearings - live axles

The separate stub axle system seen in Figure 5 can be difficult to make in some conditions and the performance of bearings with small rollers is not ideal. Unfortunately the hole in the middle of most scrap car wheels usually prevents larger hub tubes than 2" BSP with an outer diameter of about 61 mm. The conventional live axle systems shown in the left of Figure 6 result in short axles and high loads on the bearings. The offset system shown on the right of Figure 6 allows long axles and avoids the need for a bearing mounting point in the middle of the cart. More importantly it allows large diameter bearings. Figure 7 shows how the low-cost pipe and roller bearings of Figure 5 could be modified for offset live axle systems. In these systems axial thrust loads are carried at the ends of the axle.

Aluminium wheel with integral roller bearing

Aluminium casting is quite widely practised in Africa, usually to make cooking utensils and the like. Aluminium wheels with integral roller bearings (Figure 8) could be made by these artisans and would provide a very low cost solution to the wheel and bearing problem. In the laboratory at Warwick and on a cart in a special

Figure 5: Pipe and roller donkey-cart axle



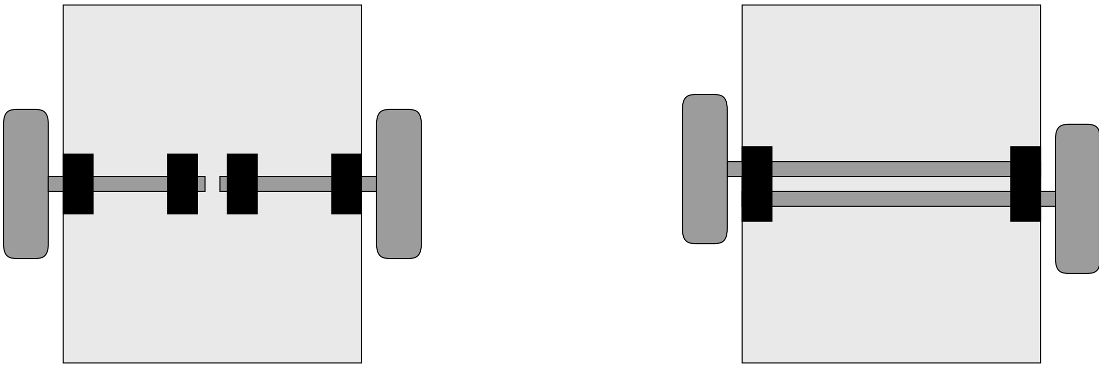
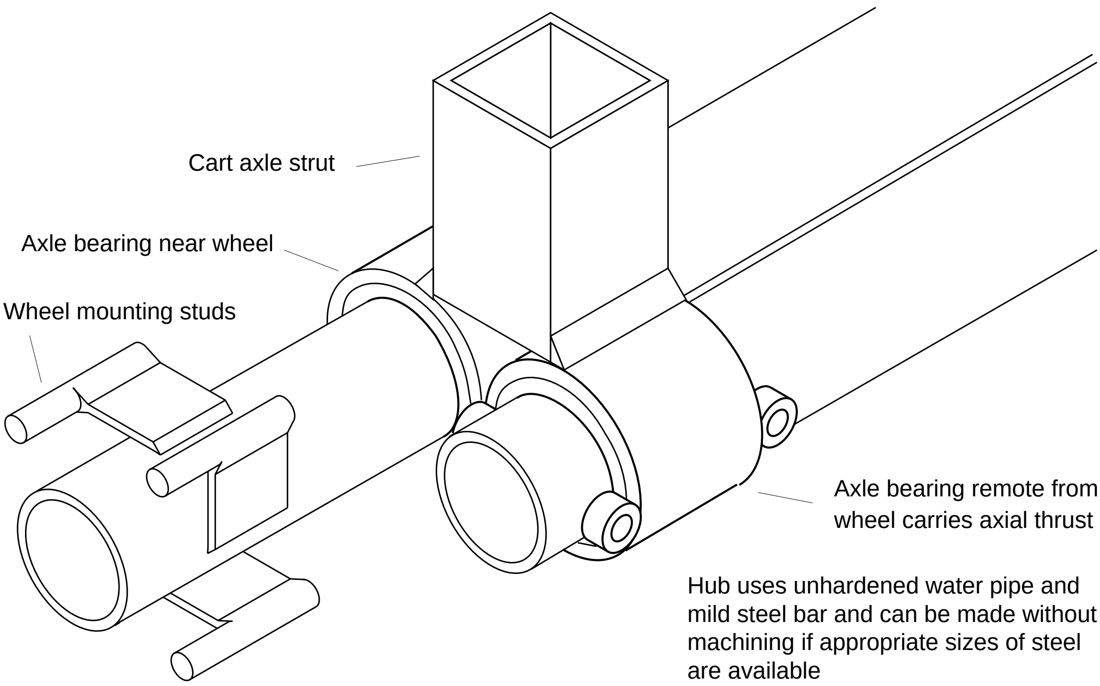


Figure 6: Conventional live axle system (left), offset live axle system (right)

test these bearings work very well – an endurance test was stopped after about 8000 km because of time pressure on the test machine, but inspection of the wheels and bearing surfaces showed little

Figure 7: Offset live axle system using pipe and roller bearings



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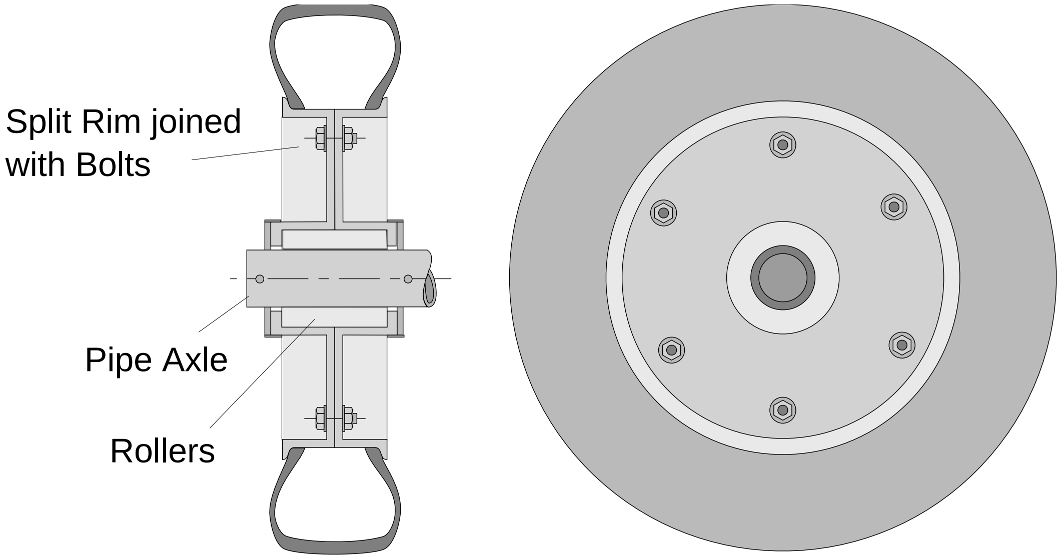

Figure 8: Cast aluminium wheel with integral roller bearing

wear so that these bearings might be expected to last the full life of a cart. Further work will be performed on these wheels.

Artisanal training–examples of non-mass-produced products

A major problem, becoming more and more obvious to observers of the developing world, is the standard of technical education available to artisans in developing countries and moreover the effect that the shortfall in this area has on the ability of artisans to innovate. Conventional production engineering, with an emphasis on the low costs of sophisticated products through large-scale production in dedicated plants, fails frequently in developing countries. Local adaptation to local problems is seen by many of these observers as the only plausible solution to the problem of providing low-cost products to rural and low-income customers. Local designs locally generated stand a good chance of being locally owned, Poston (1990) has discussed many of these 'ownership' issues.

But how is this local adaptation to come about and thrive if the only group in a position to effect the work is struggling with the substantial handicap of inadequate design training – if the only examples of product design are those appropriate for mass production? Technical and design education must be made available to the artisans who can actually use it.

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