



**DTU**   **KENDAT**

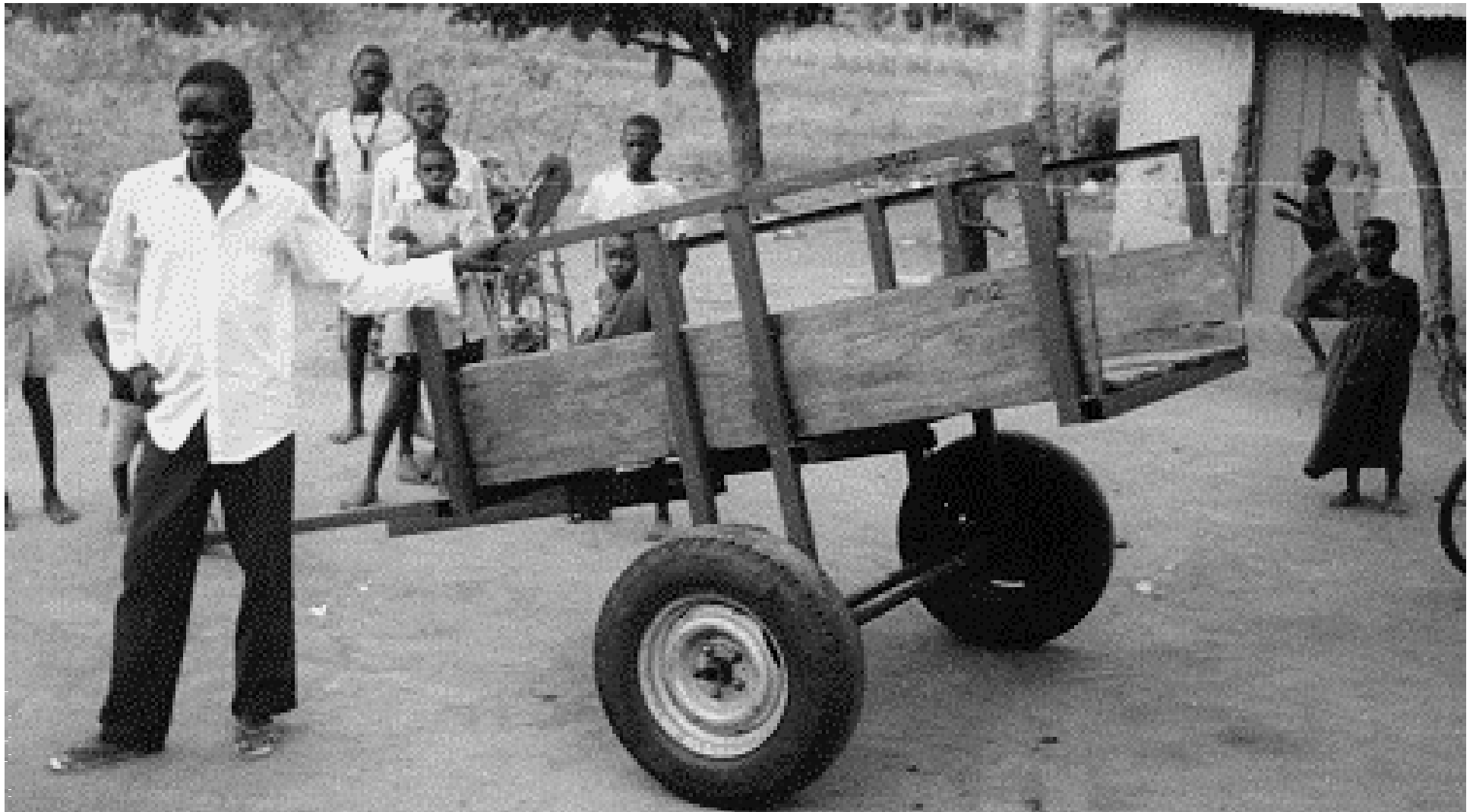
# **Animal Cart Programme**

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TECHNICAL  
**20**  
RELEASE

## **STEEL FOUR FRAME CART FOR ONE DONKEY**

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**Figure 1: four frame cart with extended frames and twin live axles.**

## Steel four frame cart for one donkey

This is a light cart for one donkey or for use as a handcart. It is made from square steel tube welded together and timber planks fixed with clenched studs. The planks are part of the structure of this cart and so must be fitted.

### Suitable axles

We recommend that you use the PVC plain bearing fixed axle described in Technical Release 28 with this cart, or one of the twin offset axle systems described in Technical Release 36, 37 or 41. An alternative is the needle roller bearing axle described in Technical Release 21, but this is more difficult to make.

You should find that you can make the body for about £<sub>UK</sub>50, depending on the cost of the materials and labour. Once you get organised, two men can probably make one body in a day. We've designed these carts to be easy to make.

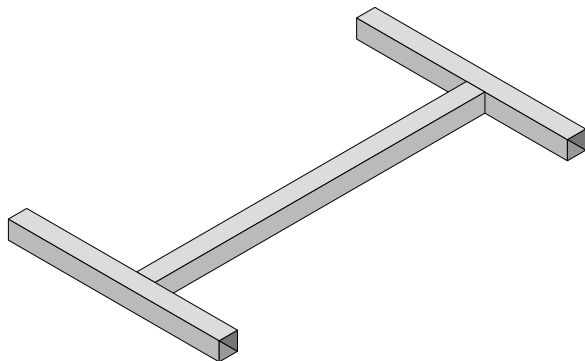


Figure 2: an H shaped centre frame.

To make this cart you must have a simple welder, a woodsaw, a hacksaw, and a hammer.

### Construction step by step

Table 1 shows a cutting list for a complete cart body. Recent (1998) prices of materials in Kenya are shown converted into £<sub>UK</sub>.

- 1) Start by getting all the material together and clear a space to work. Ideally you will be able to work on a flat area of concrete.
- 2) Cut the 50 × 50 box section steel into the right lengths, as in the cutting list, then cut the bottom and side planks. Lastly cut the 6 mm or 8 mm diameter re-bar for the fixings ie studs.

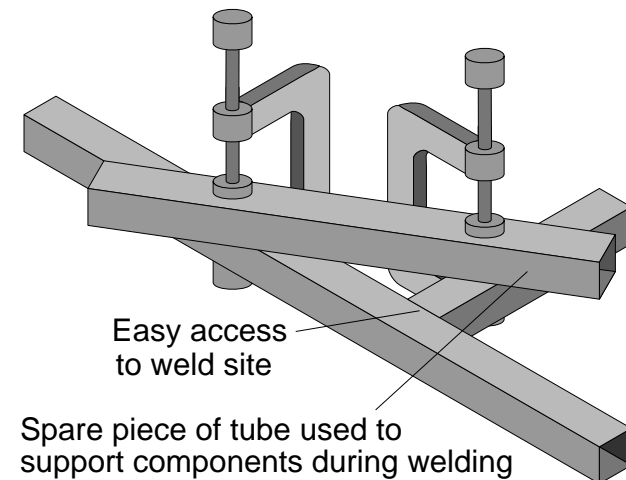


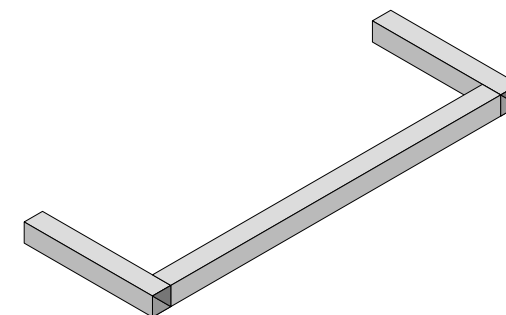
Figure 3: supporting components during welding.

- 3) Next make up the two H shaped central frames which will support the axle. Figure 2 shows one of these. Figure 3 shows how two pieces of square tube may be held in the right place when welding. Once you have made one frame, make the other the same by welding it on top of the first.
- 4) Then make up the U shaped end frames as shown in Figure 4. Again, make them as accurately as you can by building them on top of the H frames.
- 5) Now stand the H frames on the two axle support beams, tack or spot weld them and check that all the joints are square. Figure 5 shows what the finished centre frame assembly should look like.

- 6) Now you can fit the side and the bottom planks to the end frames and then the middle frame. Figure 6 shows how to position these studs and how they can be tightened with a hammer and a weight or another hammer.
- 7) Fix the axle to the axle support beams as described in the Technical Release on the axle you have chosen.
- 8) Nearly there! Now you need to fix the draw poles or 'shafts'. It is best to fix them to the body so they can be taken off and replaced if they get damaged. Figure 7 shows how they can be fixed using short lengths of round bar.
- 9) Figure 8 shows how you can make the ends of the load tray easily removable.
- 10) Paint or creosote the cart. You've finished it!

**Table 1: materials and costs.**

component	material	# lengths & length reqd [#*mm]	total material in cart [mm]	materials cost in Kenya [£uk]
animal shafts	50x50 RHS	2x2200	4400	8.80
body frame bottoms	50x50 RHS	4x1000	3000	6.00
body frame sides	50x50 RHS	4x325	1300	2.60
axle struts	50x50 RHS	4x625	2500	5.00
axle beams	50x50 RHS	2x400	800	1.60
shaft strengtheners	8mm to 12mm round bar	8x600	4800	1.52
draw pole loop	12mm round bar	2x500	1000	0.32
axle strut braces	8mm to 12mm round bar	2x600	1200	0.38
axle fixing studs	M12 threaded rod or bolts	2x100	200	2.00
axle fixing loops	6mm dia re-bar or similar	2x200	400	0.04
plank fixing staples	6mm dia re-bar or similar	30x250	7500	1.25
tray bottom planks	1"x6" or similar timber	6x1800	10800	3.54
tray side planks	1"x6" or similar timber	4x1800	7200	2.36
tray ends	1"x6" or similar timber	4x900	3600	1.18
TOTAL				36.59



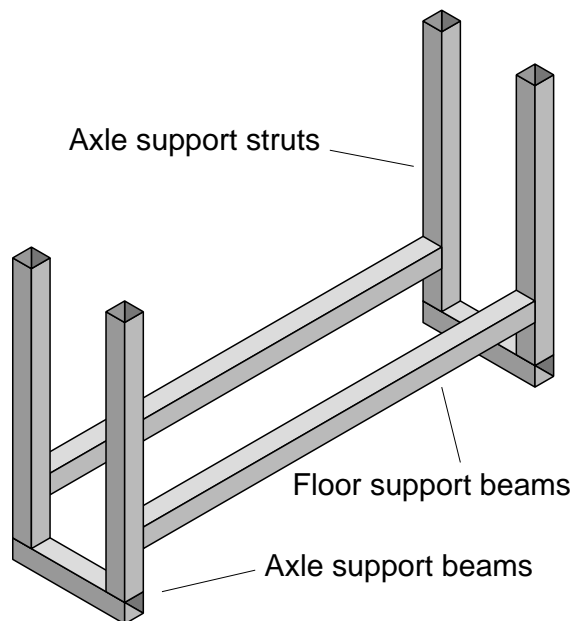
**Figure 4: a U shaped end frame.**

## Modifications

You can try longer or shorter carts and you can make them wider or narrower. When you do this, check the length and width of the planks of wood that you will use to avoid waste. Figure 1 shows a cart made in Uganda with axle support struts extended upwards to carry light foliage.

## Cart Drawings

You will find two drawings on the next pages, the first one gives a general view of the cart, and the second gives a view of the



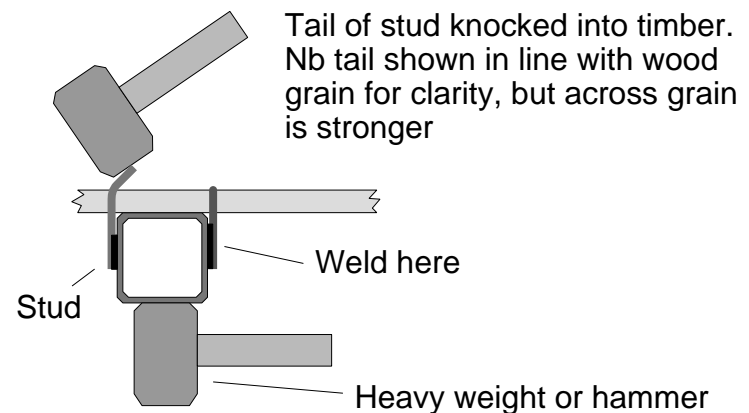
**Figure 5: finished centre frame assembly.**

main components. As we have said you can vary the size of the cart quite a bit.

## Other DTU cart developments

The DTU has been working on a range of cart body types for use with both donkeys and oxen. It has designs for both wooden and steel framed types. The wooden types are cheaper in material terms, but the steel framed ones are easier to make because the joints are more straightforward - but you can make either type of cart in only a day or two.

The DTU has also been working on new designs of wheels, hubs and bearings to bring down their costs and make things more locally manufacturable. We have developed easily made wooden bearings, bearings from PVC pipe, axles using old ball races and axles where you make your own roller bearings.



**Figure 6: fixing planks to frame with clenched studs.**

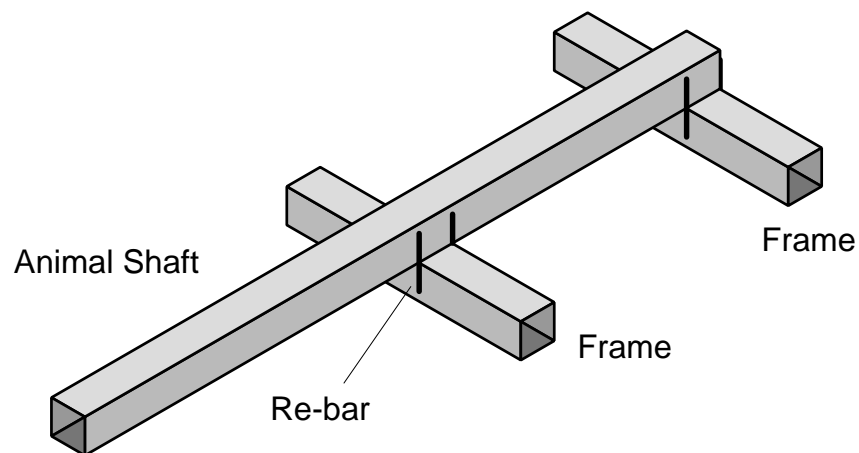
Technical releases for all these are available.

## Acknowledgements

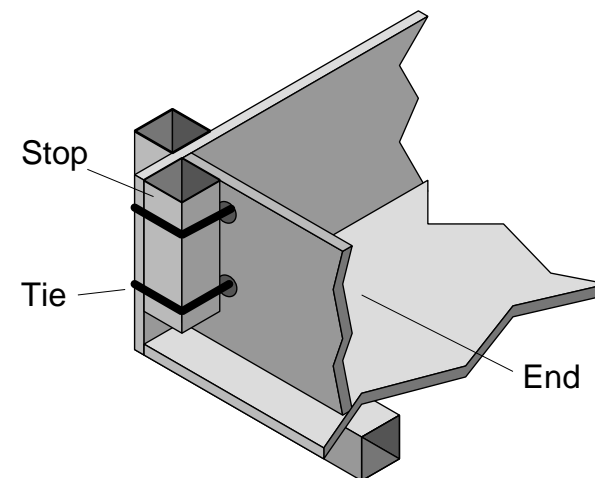
The DTU is grateful to the DFID (British Government) for the financial support necessary to carry out the research and development project under which this product was developed.

The DTU would also like to thank Dr Pascal Kaumbutho of KENDAT in Kenya and Mr Joseph Mugaga of TOCIDA in Tororo, Uganda for their very considerable help with this project. A large number of other people and organisations have contributed to the success of the project, most notably Mr Anthony Ndungu in Kajjado Kenya, Mr JD Kimani in Kikuyu Kenya and Mr Joseph Gitari in Wanguru Kenya in whose workshops most of the development work of this project was performed. Thanks are due also to Mr Stanley Lameria in

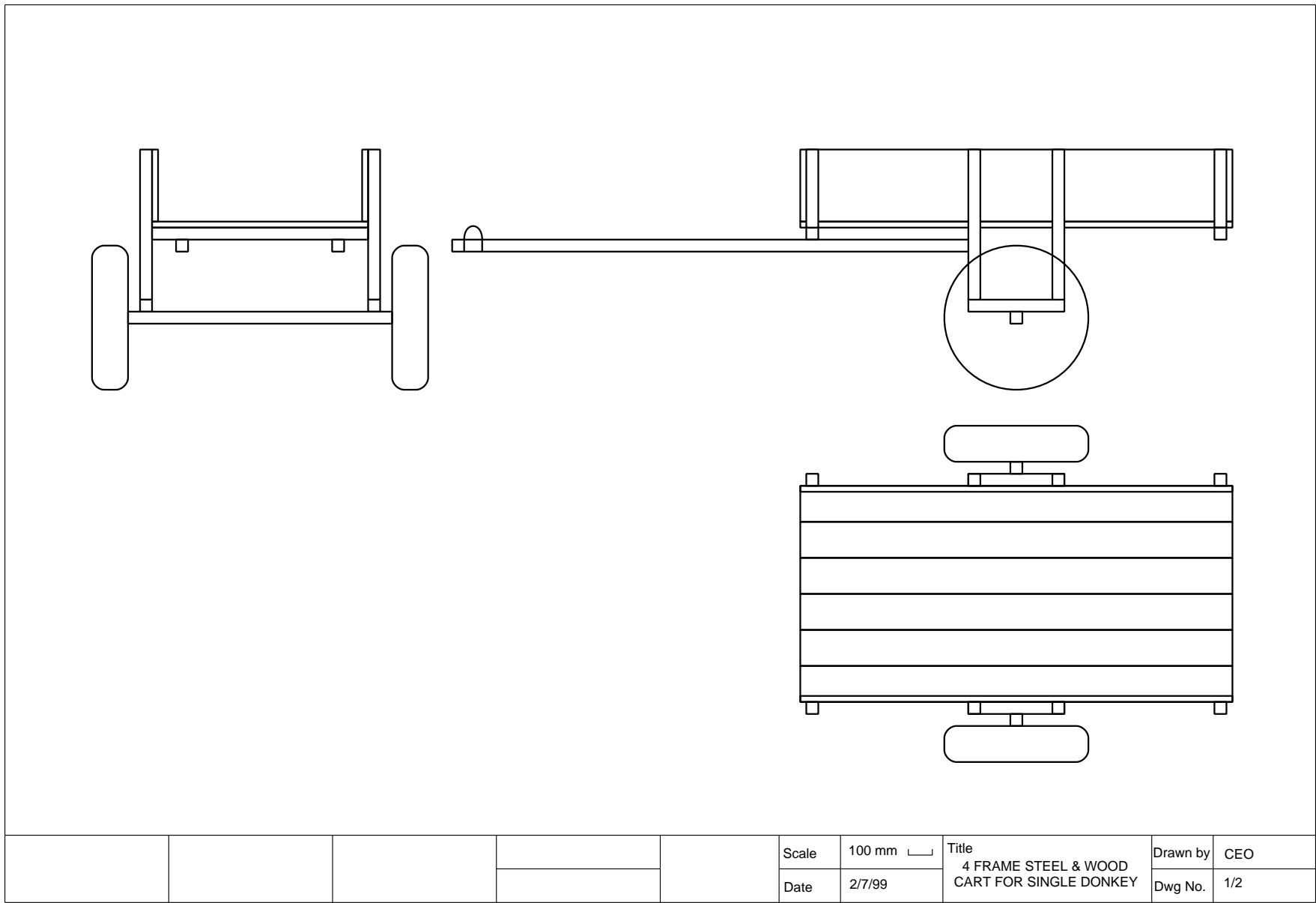
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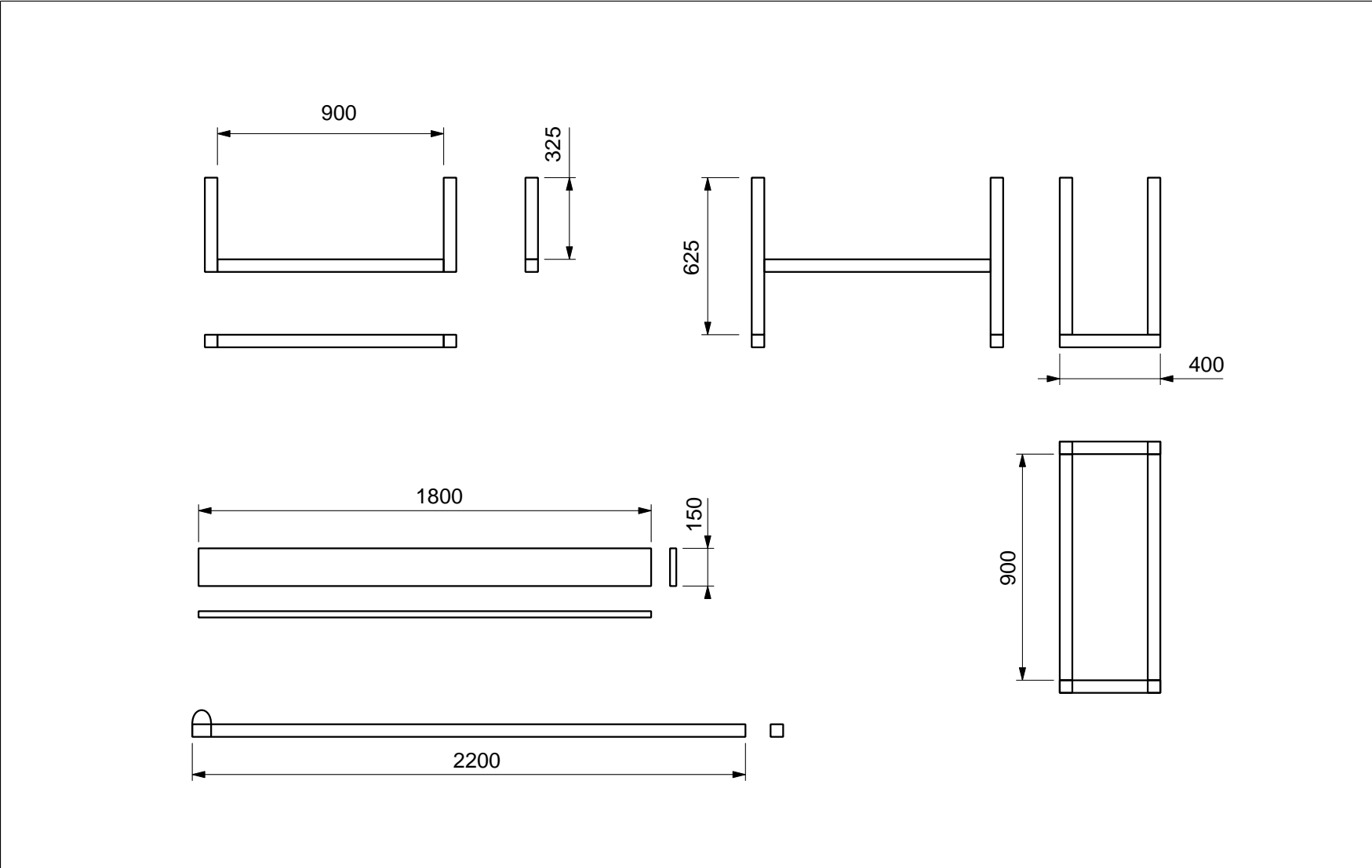


**Figure 7: fixing to frame with studs.**



**Figure 8: method of fixing tray ends with rubber or rope**





					Scale	100 mm	Title COMPONENTS FOR 4 FRAME STEEL & WOOD DONKEY CART	Drawn by	CEO
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TECHNICAL  
**42**  
RELEASE

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# Animal Cart Programme

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## Wooden Flexwheel for Donkey Carts

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**Figure 1: wood wheel for an air pump using old rubber and timber.**



# Wooden Flexwheel for Donkey Carts.

## Introduction

In this booklet we tell you how to make wooden wheels with scrap rubber tyre rims for donkey carts. The idea for these wheels comes from TDAU and Kasisi Mission in Zambia. This type of wheel cannot be punctured and it is quite easy to make. Unfortunately although the wheel itself is made without steel, the fixing to the axle does need welding.

The instructions here do not cover how to make the cart or the axle - you will need to read other Technical Releases from us to find out how to make these.

You should find that you can make a pair of wheels including the bare steel axle pipe for about £30. This cost will depend on the cost of the materials and labour. Once you get organised, two men can probably make a pair of wheels in two days.

## Easy to make design.

This wheel is designed to be constructed without any special tools and jigs, and without any hard-to-get materials. The only tools which you must have are a simple welder, a woodsaw, a hacksaw, and a hammer.

Unfortunately we have only tested one of these wheels in Kenya and Uganda but we had no problems.

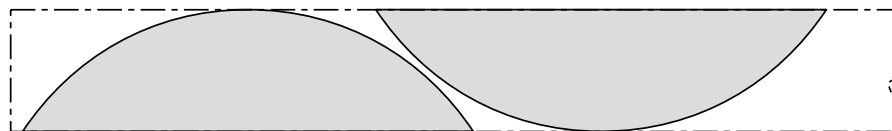
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## Cutting list and costs

Table 1 shows a cutting list for a wheel - recent prices of materials in Kenya are shown converted into £UK.

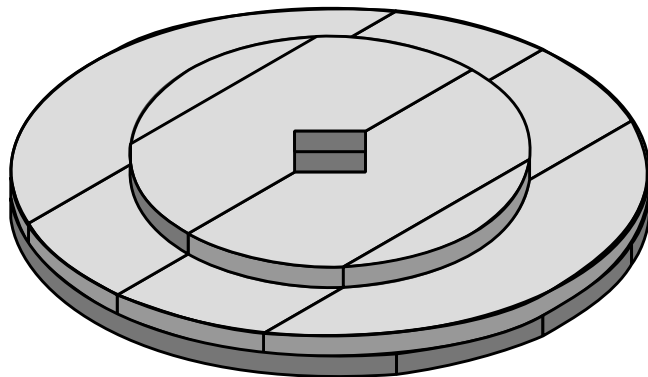
## Construction step by step

- 1) The first job, is to get all the material together and clear a space to work. Ideally you will be able to work on a flat area of concrete.
- 2) Start by cutting the tyre into two pieces around the centre of the tread. You will not be able to cut a tyre with a steel cord in the tread so avoid the steel type.
- 3) Measure the diameter of the tyre rim hole accurately. This is likely to be about 325 mm for a 13" tyre, 350 mm for a 14" tyre or 400 mm for a 16" tyre. Measure the diameter five or ten times in several different positions and take an average.
- 4) Measure the outside diameter of the tyre. This will be about 600 mm for the smaller tyres and 650 to 700 mm for the larger tyres.



**Figure 2: marking out segments to reduce waste.**

- 5) Draw a circle of diameter 30 mm less than the outside diameter of the tyre on a piece of paper or cardboard using a piece of wire to make a compass. On the same centre draw a second circle of diameter equal to the hole diameter. This is to help you mark out the timber, so you should take some trouble over getting it accurate.
- 6) Now use the cardboard template to mark the timber planks. You can prick through the template into the wood and then join the marks with a pen. Figure 2 shows how to mark out the segments to waste the minimum timber.
- 7) Cut out the segments. For each wheel you will need to make two of the discs shown in Figure 3. Each disc is three planks thick as you can see. Make sure that the tyre is a snug fit on the single thickness small disc.



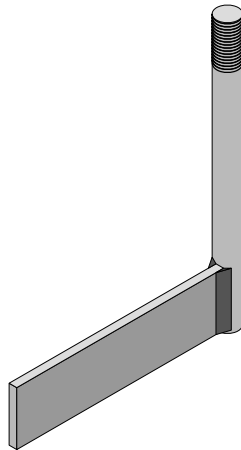
**Figure 3: half of one wheel.**

- 8) Nail the segments together with 60 mm nails clenched over. Make sure that the cutouts for the axle all line up - you can put a short piece of pipe into the notch to help align the segments.
- 9) Carefully mark the position of the bolt holes through the discs and drill the four holes in each disc. It is probably worth making these holes 15 or 16 mm diameter if you are using M12 bolts because it is hard to get all the holes to line up accurately.
- 10) Cut pieces of 40 x 6 mm steel bar 150 mm long to make the wheel stud struts shown in Figure 4. You will need four for each wheel. To make the long bolts cut the heads off 40 mm bolts and weld on pieces of 12 mm round bar 180 mm long. Check how thick your timber is and change the length here to suit if you need to.

**TABLE 1: materials for wooden flexwheels.**

component	material	# lengths reqd [#*mm]	total material for two wheels [mm]	cost [UK£]
wheel studs	50xM12 nuts and bolts	8	8	2.08
wheel stud struts	6 x 40 flat bar	8 x 150	1200.00	0.90
axles	1-½" BSP malleable iron pipe	2 x 1500	3000.00	8.23
small timber discs	150x25mm timber	8 x 360 + 8 x 200	4480.00	1.47
large timber discs	150x25mm timber	8 x 580 + 8 x 400	7840.00	2.57
scrap rubber car tyre	size 185x14	2 reqd	2 reqd	4.00
	TOTAL			19.26

- 11) Next cut the axles from 1-½" black pipe. These will probably need to be about 1600 mm long - it depends on the axle design you are using.
- 12) Position the axle in a pair of discs without the tyre and fit four stud/ struts. Arrange them to lie around the axle as in drawing 1/3 at the end of this document.
- 13) Using a trysquare get the axle square to the wheels and get someone to hold it there while you weld the struts to the axle. Make sure that you weld the struts to the axle strongly.
- 14) Remove the nuts from the studs and the outer wooden disc and fit the two halves of the tyre as shown in drawing 1/3. Replace the nuts and washers and tighten.
- 15) Repeat for the other wheel. You've finished it!



**Figure 4: strut and stud fabrications.**

## Other DTU cart developments

The DTU has been working on new designs of carts and all their components to bring down their costs and make things more locally manufacturable. It has designs for bodies, wheels, hubs, bearings and animal harness all available from DTU as Technical Releases.

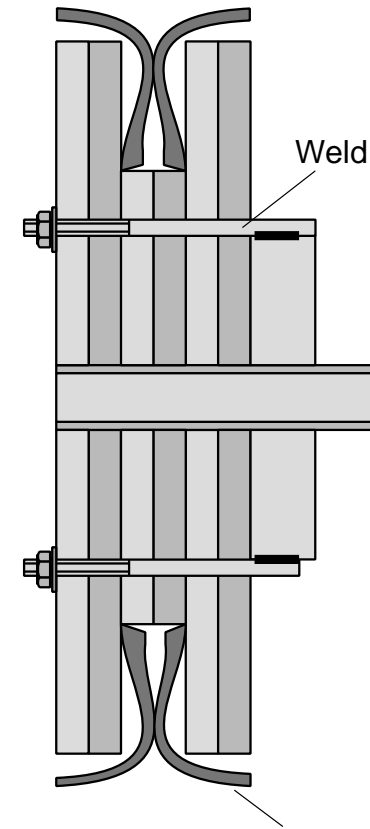
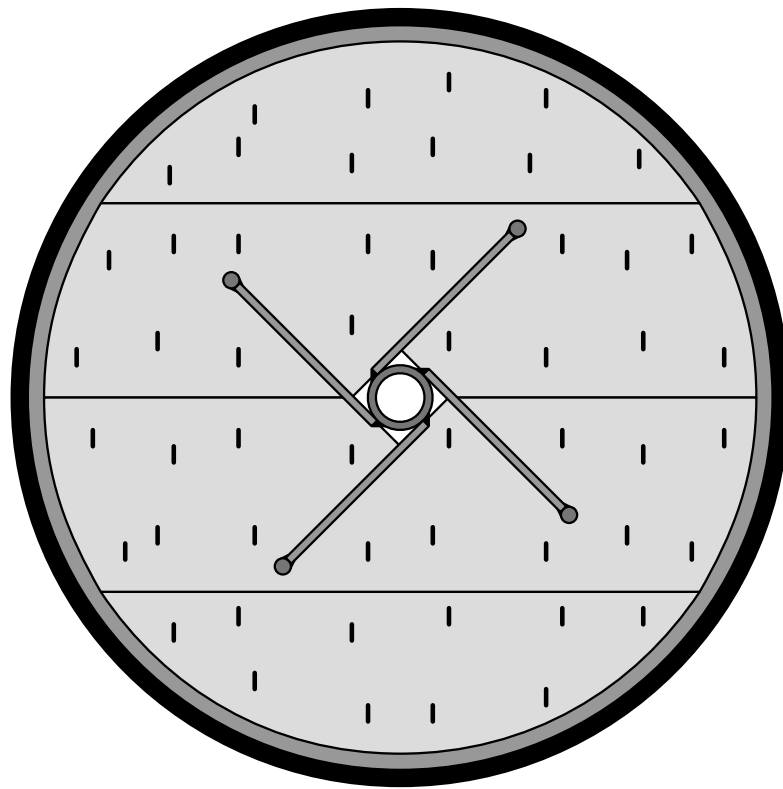
## Drawing

You will find a drawing of the wheel on the next page.

## Acknowledgements

The DTU is grateful to the DFID (British Government) for the financial support necessary to carry out the research and development project under which this product was developed.

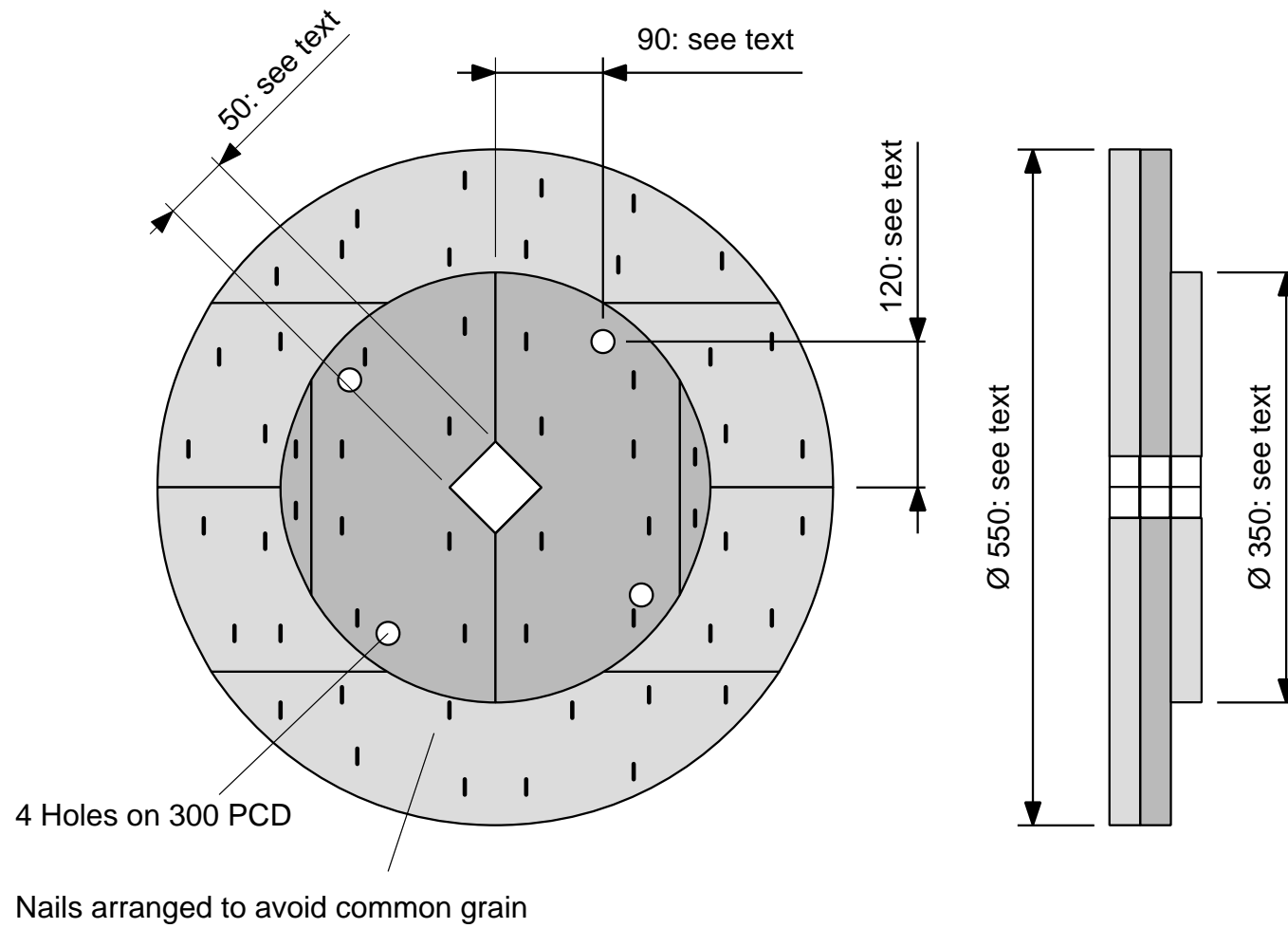
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Scrap car tyre split around circumference

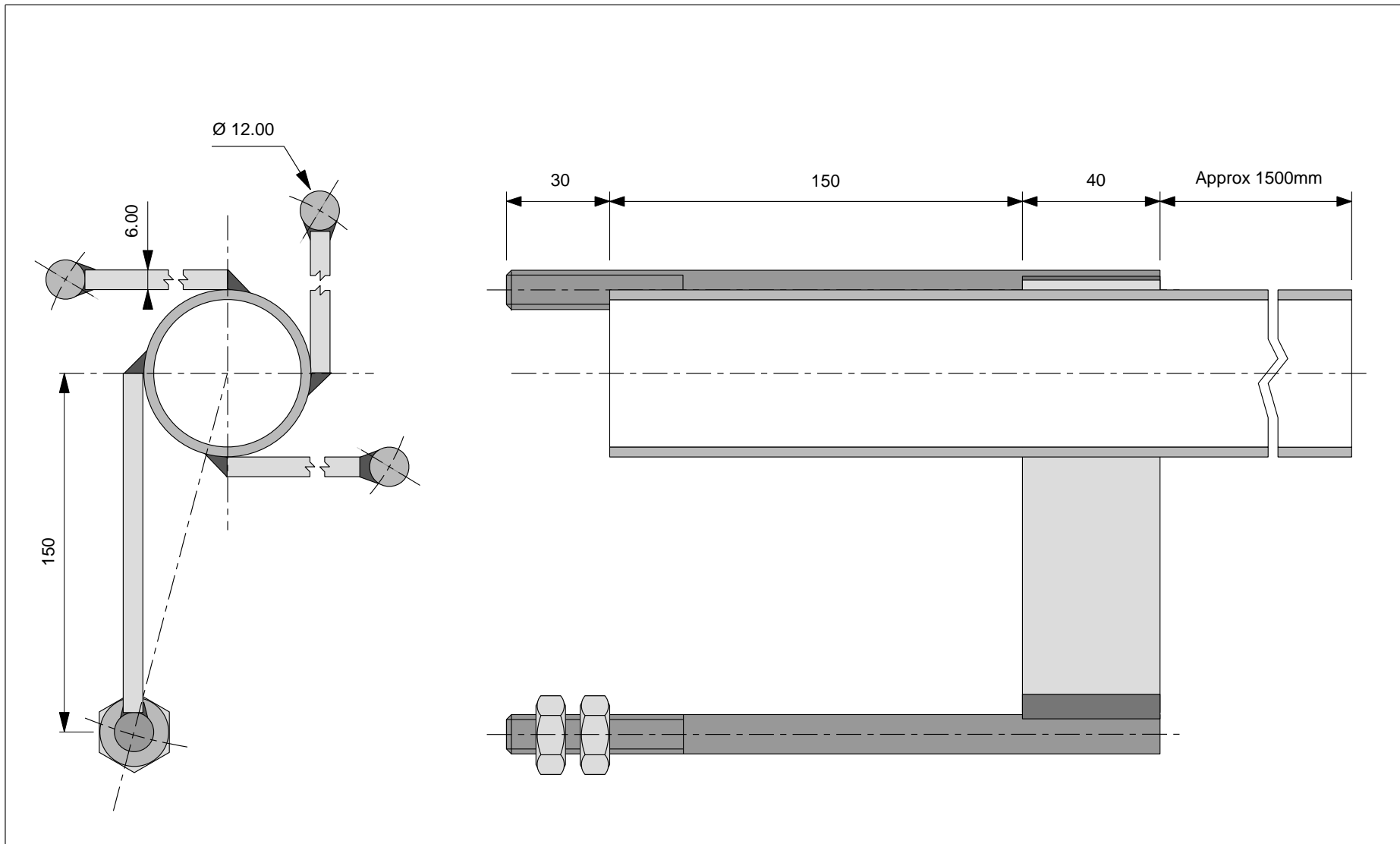
### General Arrangement

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### Wood components

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# AXLE COMPONENTS

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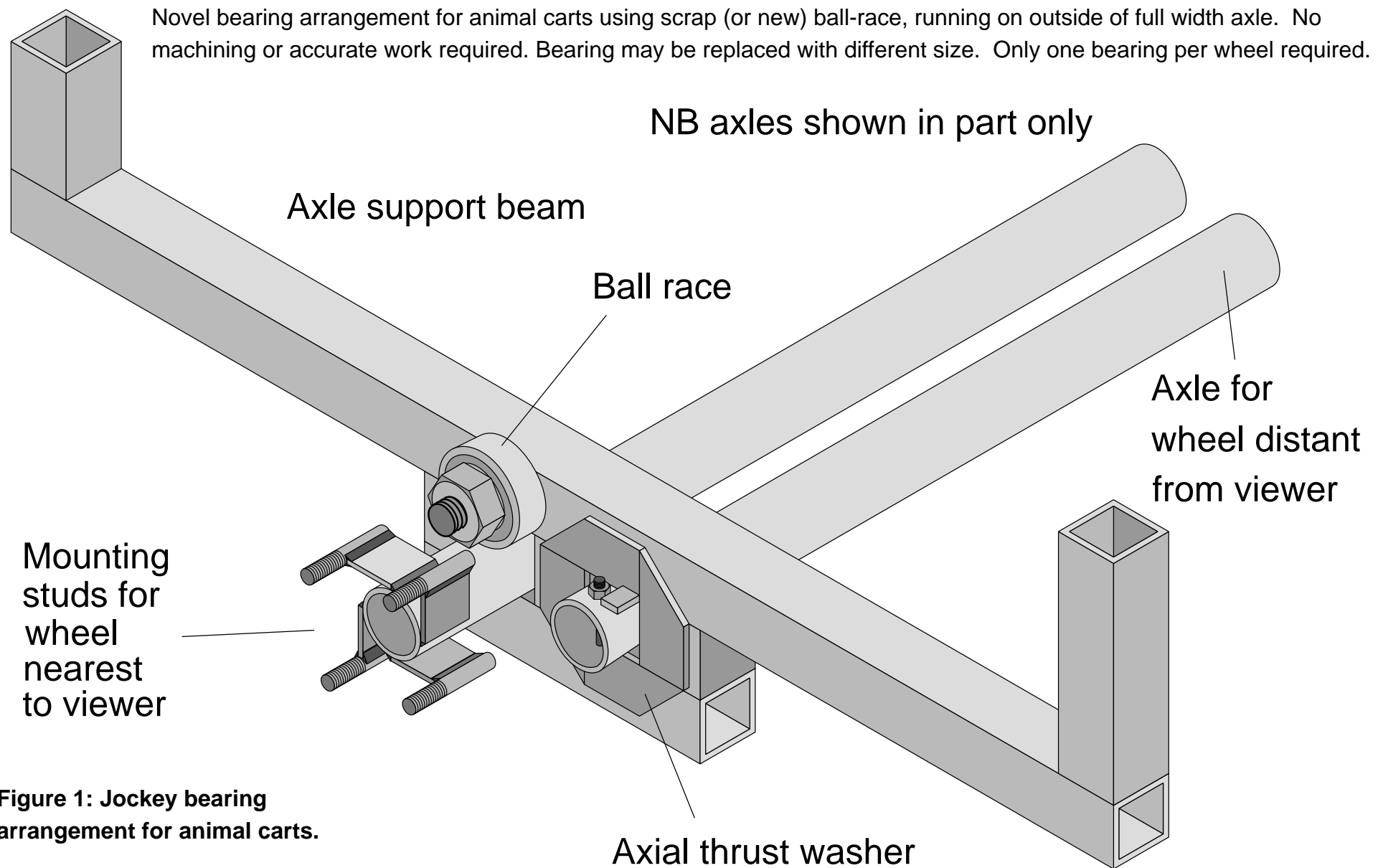
# Animal Cart Programme

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## Twin Ball Bearing Axle for Donkey Carts

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Novel bearing arrangement for animal carts using scrap (or new) ball-race, running on outside of full width axle. No machining or accurate work required. Bearing may be replaced with different size. Only one bearing per wheel required.



**Figure 1: Jockey bearing arrangement for animal carts.**

TR41: 15th April 1999

# Twin axle system for donkey carts using scrap/ new ball bearings.

## Introduction

In this booklet we tell you how to make an axle system for a simple donkey cart from round steel tube and ball bearings. The instructions do not cover how to make the cart itself - you

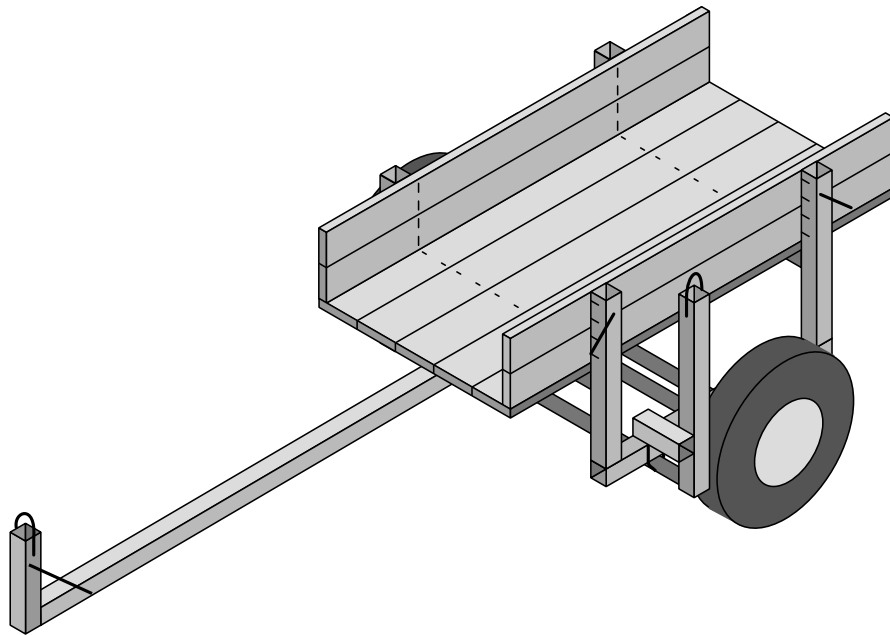


Figure 2: DTU donkey cart fitted with twin axles and PVC bearings.

TR41: 15th April 1999

will need to read other Technical Releases from us to find out how to make the carts.

You should find that you can make the axle system for about £40 including the wheels, tubes and tyres. This cost will depend on the cost of the materials and labour. Once you get organised, two men can probably make and fit one cart with axles in half a day. This is quite a lot faster than it takes to find and a scrap car axle and it will be much cheaper.

In other booklets in this series you can find out how to make other low-cost axle systems and carts.

CONVENTIONAL HALF LENGTH AXLE

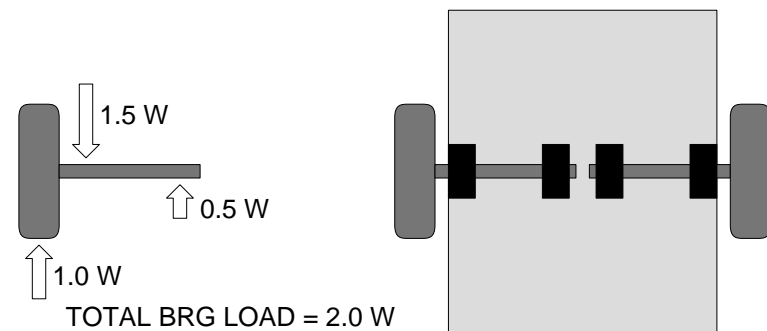


Figure 3: bearing loads in conventional half shaft axle.

## Why have twin axles?

There are two types of axle: fixed axles and stub axles. In a stub axle the wheel-hub rotates on a stationary axle. In a live axle arrangement the axle revolves in stationary bearings.

With the stub axle types the bearings must be inside the wheel. This is easy with expensive ball bearings in a machined hub but more difficult to do in a simple workshop. Really you need two ball bearings per wheel as well. You also need to make things quite accurately or make the hubs quite long to stop wheel wobble. Another problem is that the hubs stick out of the wheel and catch on animal and human legs.

If you would really prefer to make a stub axle we have quite a

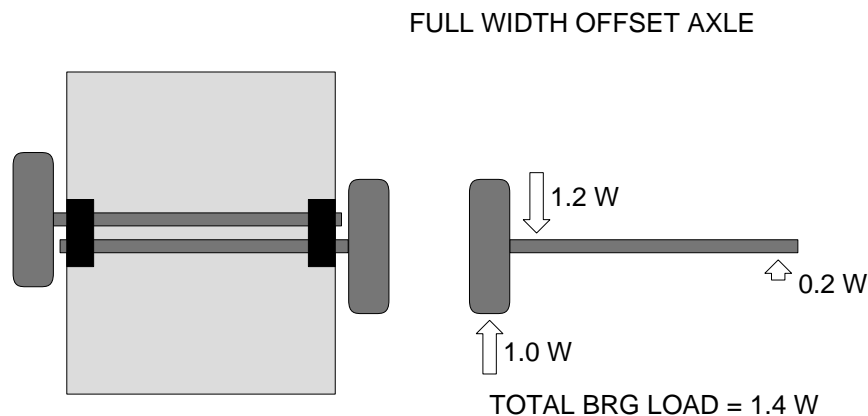


Figure 4: bearing loads in twin offset axles.

TR41: 15th April 1999

good one using plain bearings made from PVC pipe. This axle also has the advantage that you can take the wheel off without a spanner. We also have a system of making your own roller bearings and we can send you Technical Releases on how to make these axles, but we think the twin axle system here is easier to make and a bit better.

Long twin axles reduce bearing loads and require less accurate manufacture. Figure 3 shows the bearing loads of short axles and Figure 4 shows the twin axle method. You will see that bearing loads are about 30% lower. Surprisingly there is no extra steel required either because there would have to be some steel to support the middle bearings anyway.

## Easy to make design.

These axles are designed to be constructed without any special tools and jigs, and without any hard-to-get materials. The only tools which you must have are a simple welder, a hacksaw, and

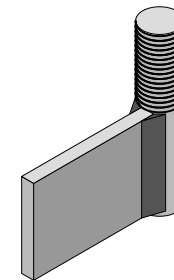
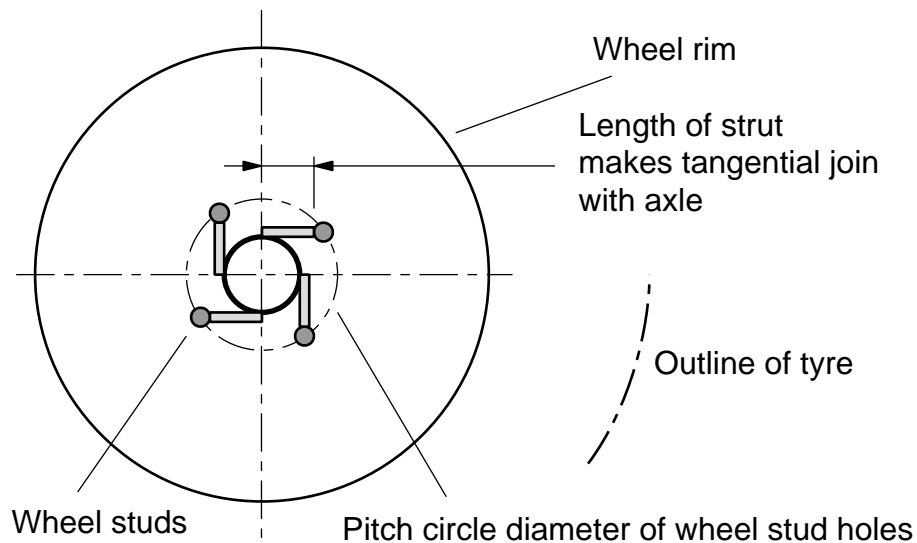


Figure 5: a welded wheel stud and strut fabrication.

a hammer. You might find that a couple of 4" or a 5" G clamps (or something like it) are useful too. We have deliberately designed the axle so that drilling is not required.

We have tested many of these axles in Kenya and Uganda and we have had only a few failures caused by poor welding or incorrect material. We think that they are strong enough, but you can always find someone to break anything. To get a reasonable cost you need to experiment a bit to see how the farmers treat their carts and what they expect them to stand.



**Figure 6: length of wheel strut.**

## Cutting list and costs

Table 1 shows a cutting list for a complete axle - Recent prices of materials in Kenya are shown converted into £UK.

## Construction step by step

- 1) The first job, is to get all the material together and clear a space to work. Ideally you will be able to work on a flat area of concrete.
- 2) Start by getting the two ball bearings you want to use and cleaning them. If they have rubber or steel shields it is probably best to leave the shields in place, but if they are open clean the bearings in petrol or diesel fuel or kerosine. Then re-grease them.

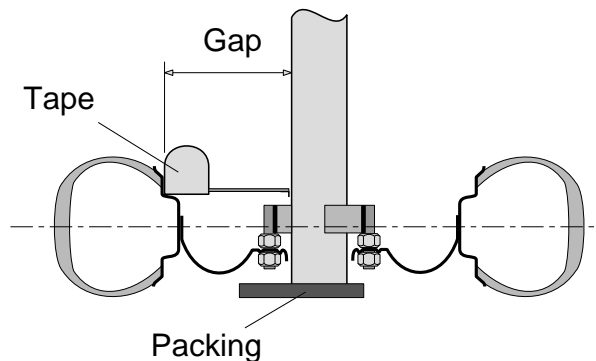
**TABLE 1: materials for ball bearing twin axle.**

component	material	# lengths reqd [#*mm]	total material for one axle [mm]	cost [UK£]
wheel studs	50xM12 nuts and bolts	10	10	2.60
wheel stud struts	6x40 BMS strip	10 x 37	650	0.49
axial thrust washers	6x40 BMS strip	8 x 90	720	0.54
axle cross bolts	75xM12 nuts and bolts	4	4	1.04
axles	1-1/2" BSP malleable iron pipe	2 x 1500	3000	6.00
axle reinforcements	1-1/2" BSP malleable iron pipe	2 x 30	60	0.12
main bearing	scrap ball race eg 6205, 6206	2 off reqd	2	5.00
ball bearing mounting bolts	M24x50 or similar	2 off reqd	2	2.00
bearing box sides	50x50x3 mm square steel tube	6 x 53	318	0.73
bearing box top	50x50x3 mm square steel tube	2 x 252	504	1.16
wheel rims, tyres + tubes	na	2	2	25.00
			<b>TOTAL</b>	<b>44.69</b>

- 3) Now you need to get a large nut and bolt for each bearing. Ideally the bolt should just go through the middle of the bearing, but it can be quite loose as long as the bearing can be held very tightly when the nut is tightened.

If you cannot get a nut and bolt you can use a piece of pipe and a welded ring.

- 4) Next make the wheel stud struts shown in Figure 5. You need to make one of these struts for every stud hole in the wheels you are going to use. Figure 6 shows how to measure the length of the struts. The struts are made from 6x40 flat bar or similar and M12 bolts 50mm or 60mm long. The flat bar should be long enough so that it meets the axle tube tangentially as shown in Figure 6.
- 5) Once you have made these struts, screw a nut onto each one until it touches the 40x6 metal. Then put the thread

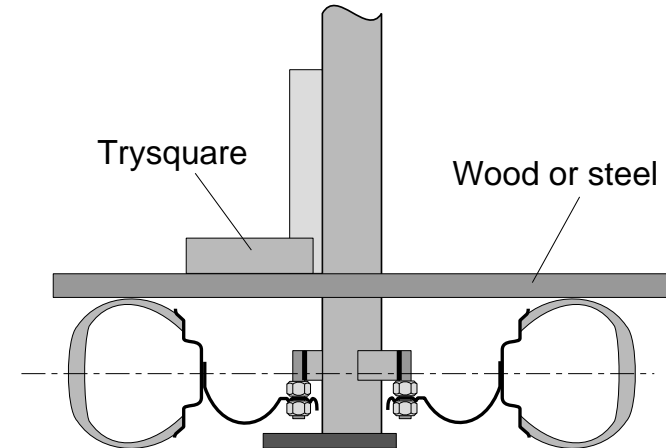


**Figure 7: using tape measure to centre axle in wheel.**

through the hole in the rim and screw another nut onto the thread. Tighten this nut lightly with a spanner. Repeat for all the struts so that they all point the same way round the axle, as in Figure 6, and leave a gap for the axle.

- 6) Now centre the axle in the rim and get it square using a tape measure, a trysquare and a plank or piece of steel resting on the tyre.

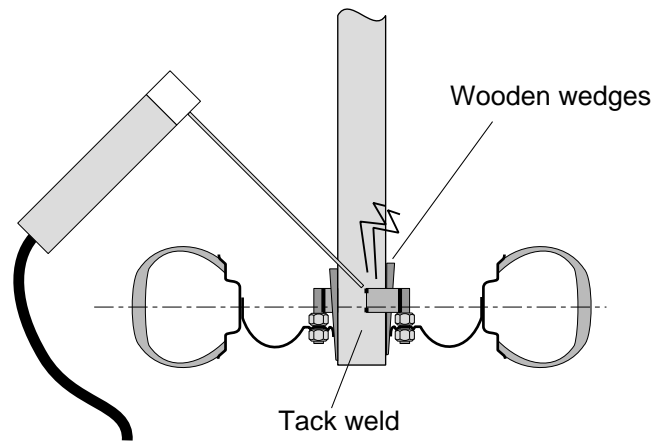
Put the wheel rim on the floor and put the axle in place in the middle. You should put something under the end of the pipe to get it in the right position as shown in Figure 7. Get an assistant to hold the top end of the pipe and tell him to



**Figure 8: using trysquare to get axle square to wheel.**

keep very still! Use your tape to measure from the outside of the pipe to the inside of the rim as Figure 7 shows. Measure in one place and then measure the gap opposite. Move the axle pipe over until it is central. Repeat this for the other direction at right angles. You could use wooden wedges as shown in Figure 9 to hold it.

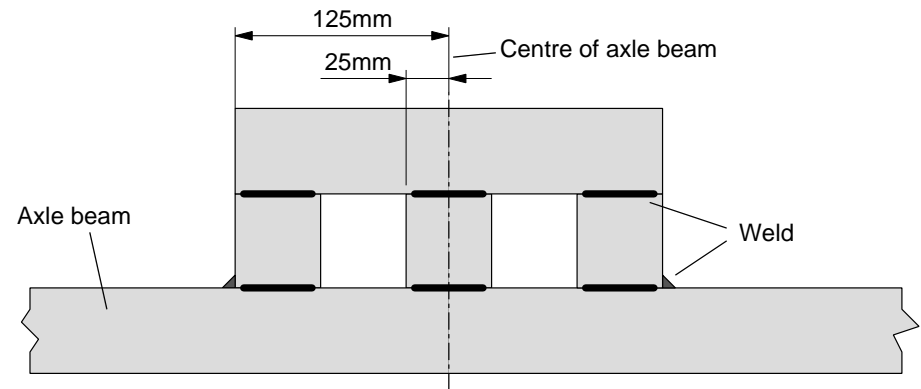
Now use the try-square and a piece of wood to get the axle square to the rim as shown in Figure 8. You put the wood on the tyre or rim so that it is flat and you put the try-square on the wood. You have to move the axle until it is straight with the try-square and your assistant must hold it without



**Figure 9: tyre, wheel and axle tube during tack welding stud support struts**

moving. Check it several times - its hard to correct afterwards!

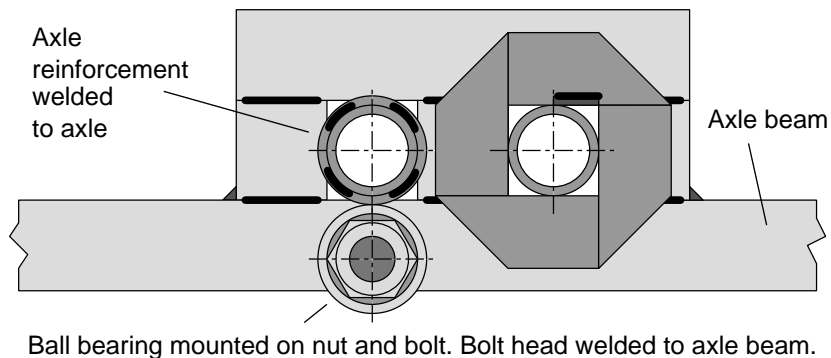
- 7) Once you have it in position, tack weld the ends of the struts to the axle tube as shown in Figure 9. Then weld the struts on properly. Do as much welding as you can without taking the axle out of the wheel because the metal changes size as it heats and cools and it may move out of place.
- 8) Next cut six 53 mm pieces of square tubing for the bearing boxes. Mark the centre of the axle support beam of the cart and put marks on the beam 25 mm and 125 mm either side of this. You need to weld the 53 mm pieces on to the axle beams as shown in Figure 10. Weld a 252 mm piece of



**Figure 10: position of bearing support blocks - nb the cart is upside down here.**

square tubing across the ends of the 53 mm pieces as shown in Figure 10.

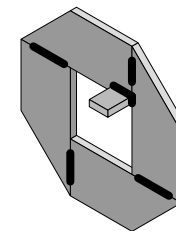
- 9) Make four axial thrust washers from 40x6 or 40x3 or similar flat bar like those shown in Figure 12. You must remember to weld on a tag made of a 20 mm length of bar to each ring as shown in the drawings. This makes the washers go round with the axle and stops wear in the wrong places.
- 10) Assemble the axles and thrust washers as shown in Figure 13 but without the crossbolts. Put the wheels onto the axles, lightly tighten the nuts and position the axles so that there are 50 mm gaps between the tyres and the axle beams.
- 11) Now mark the position of the cross bolt holes. Remember that the nuts will have to be turned so do not make the



**Figure 11: ball bearing mounting and axial bearing washer.**

holes too close to the thrust washers - centre about 15 mm away is fine. Use the welder to blow the holes.

- 12) Cut the excess axle off about 40 mm from the thrust washer. To mark a line around the pipe to cut it square, wrap a strong piece of paper or thin card around the pipe, get the edge in line and use the edge to guide the felt tip pen or scribe as you mark the line.
- 13) Mark the place on each axle where the bearing will roll. Cut 30 mm pieces of pipe, slit them so they can be opened and placed on the outside of the axles and weld them in place where you have marked.
- 14) Now assemble the ball bearings on their bolts and lightly tighten the nut. Position each bearing under the middle of the axle as shown in Figure 11 so that the axle is held 2 or 3 mm away from the axle beam as in General Assembly 1. Then tack or 'spot' weld the ball bearing bolt to the axle beam. Remove the bearings from their bolts and weld fully.



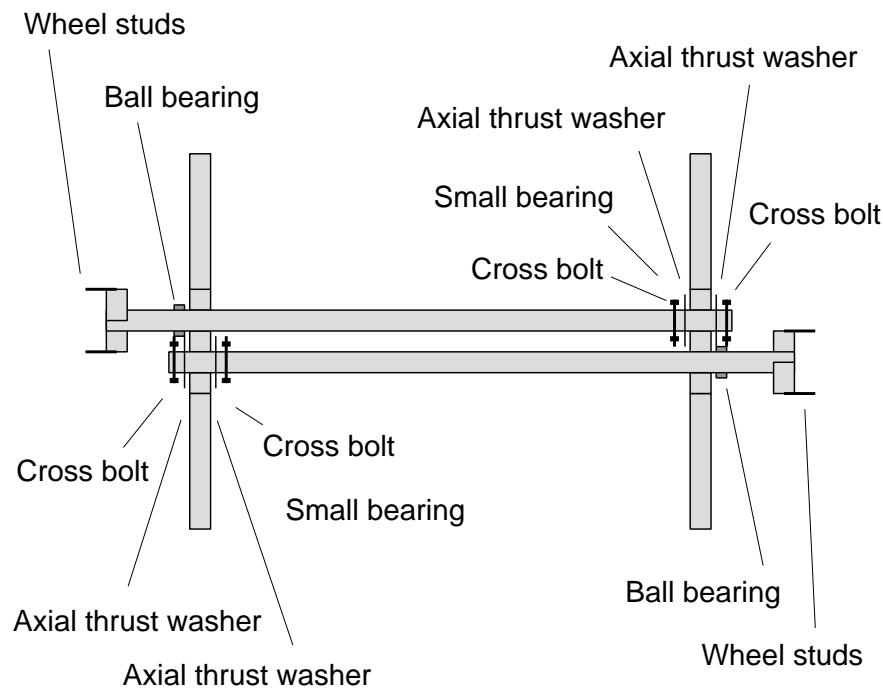
**Figure 12: axial bearing washer.**



- 15) Apply grease to the axles where they rub on the axle beams, replace the bearings on their bolts and tighten the nuts, fit the thrust washers and crossbolts and tighten.
- 16) You've finished it!

### Other DTU cart developments

The DTU has been working on new designs of wheels, hubs and bearings to bring down their costs and make things more



**Figure 13: axle and bearing arrangement.**

locally manufacturable. It has designs for twin axles with wooden bearings and twin axles with bearings made from PVC water pipe. And it has two systems of fixed axle: one with PVC bearings and another using needle roller bearings which you can make yourself. No machining is necessary for any of these axles.

Other hub designs using, for example aluminium castings, have been in production in Nigeria and we are trying to reduce or eliminate the machining in these. Also wheel designs in steel sheet, cast aluminium and timber are under development. We have a design for solid steel rim wheels in which the rim is made from round bar and does not need any hammering.

The DTU has also been working on a range of cart body types for use with both donkeys and oxen. It has designs for wooden and steel framed types. The wooden types are cheaper in material terms, but the steel framed ones are easier to make because the joints are more straightforward - nevertheless you can make either type of cart in only one or two days, if you are reasonably set up with tools and materials.

### Drawings

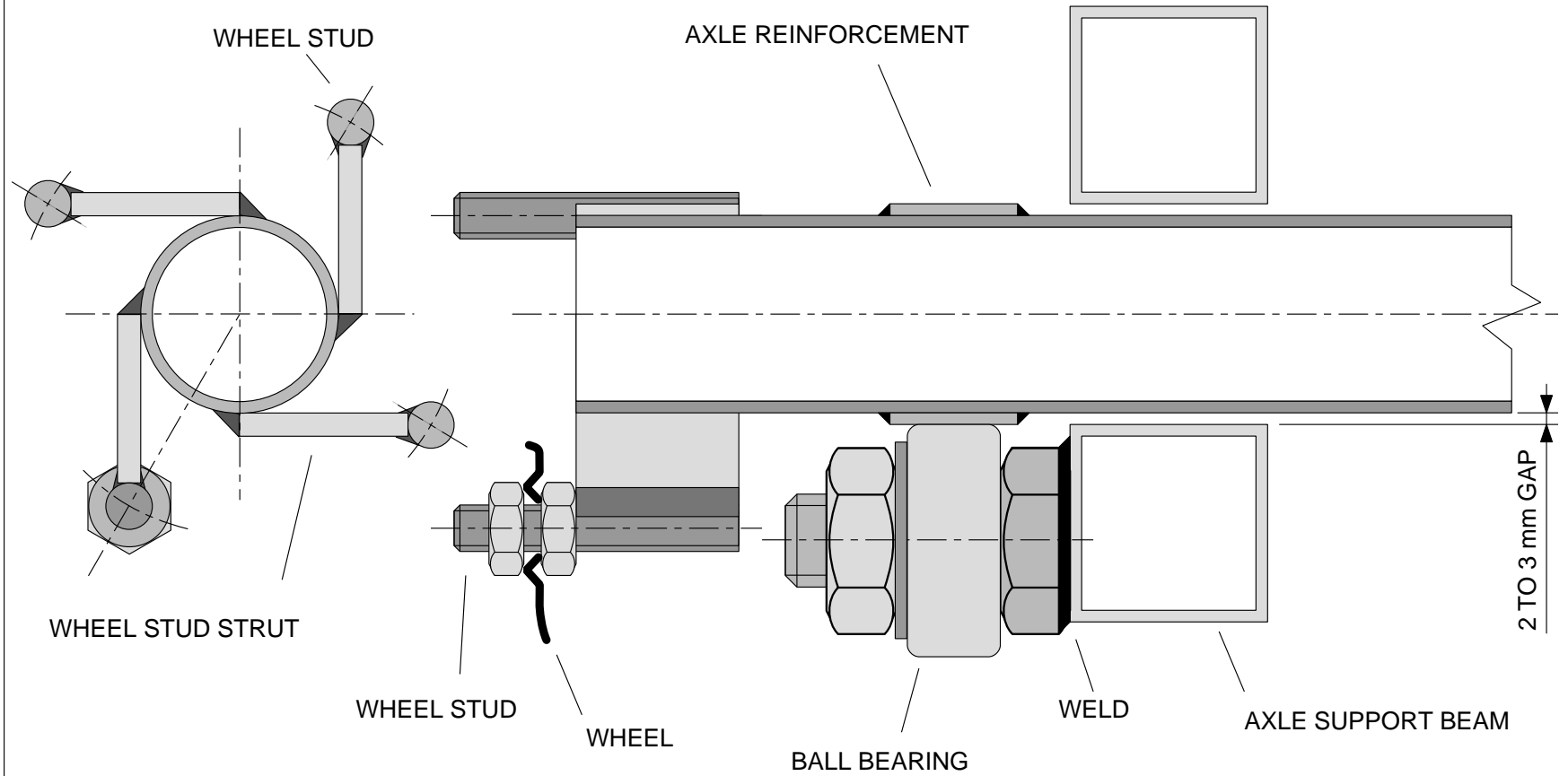
You will find four drawings on the next pages, the first two give a general section view of the axle. The third gives a view of the components of the axle itself and the fourth a drawing of the thrust washer.

## **Acknowledgements**

The DTU is grateful to the DFID (British Government) for the financial support necessary to carry out the research and development project under which this product was developed.

The DTU would also like to thank Dr Pascal Kaumbutho of KENDAT in Kenya and Mr Joseph Mugaga of TOCIDA in Tororo, Uganda for their very considerable help with this project. A large number of other people and organisations have contributed to the success of the project, most notably Mr Anthony Ndungu in Kajiado Kenya, Mr JD Kimani in Kikuyu Kenya and Mr Joseph Gitari in Wanguru Kenya in whose workshops most of the development work of this project was performed. Thanks are due also to Mr Stanley Lameria in Kajiado, Mr Patrick Gitari in Wanguru and Mr Mathew Masai in Machakos for their assistance.

NB CART IS UPSIDE DOWN IN THIS VIEW

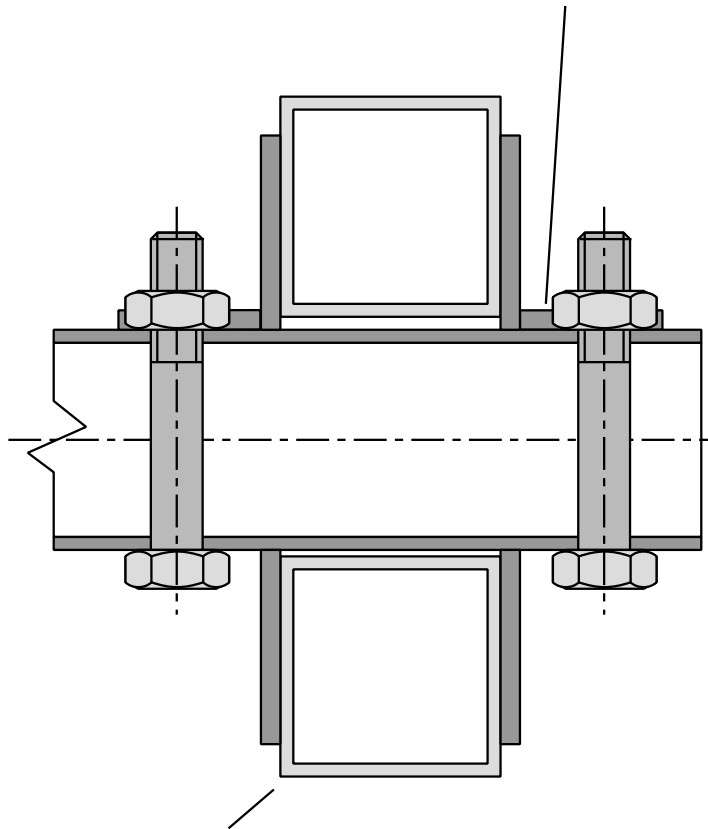


GENERAL ASSEMBLY DRAWING 1

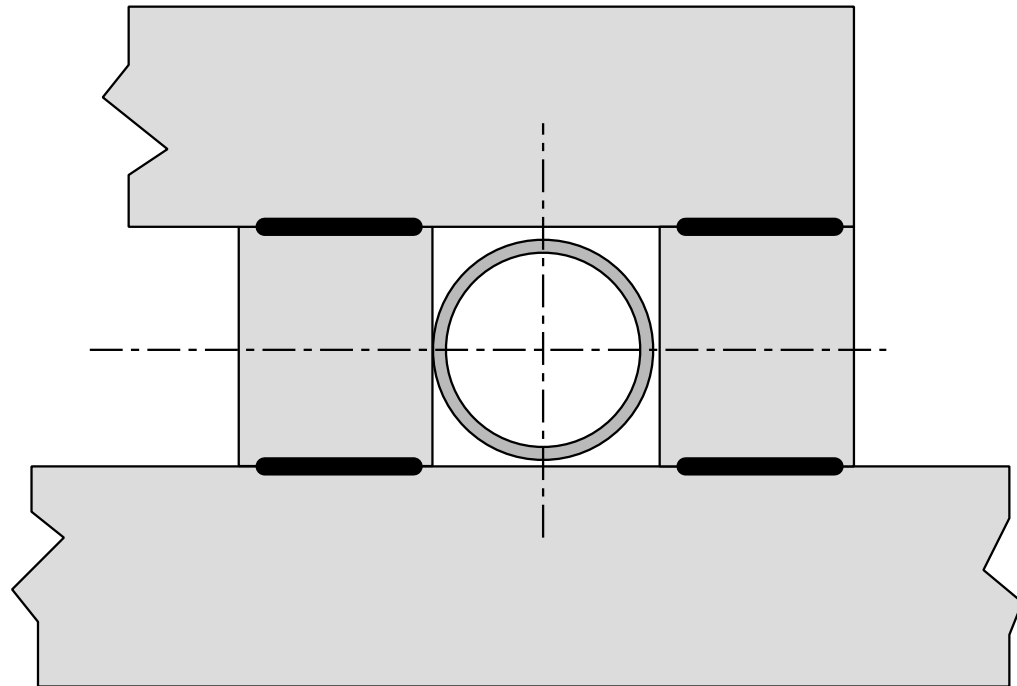
Scale	10mm <input type="checkbox"/>	Title	Ball BEARING TWIN	Drawn by	CEO
Date	1-4-99	Title	DONKEY CART AXLE	Dwg No.	1/4

AXIAL RESTRAINT WASHER TAG

NB CART IS UPSIDE DOWN IN THIS VIEW



AXLE SUPPORT BEAM



END VIEW - THRUST WASHER AND BOLT REMOVED

# GENERAL ASSEMBLY DRAWING 2

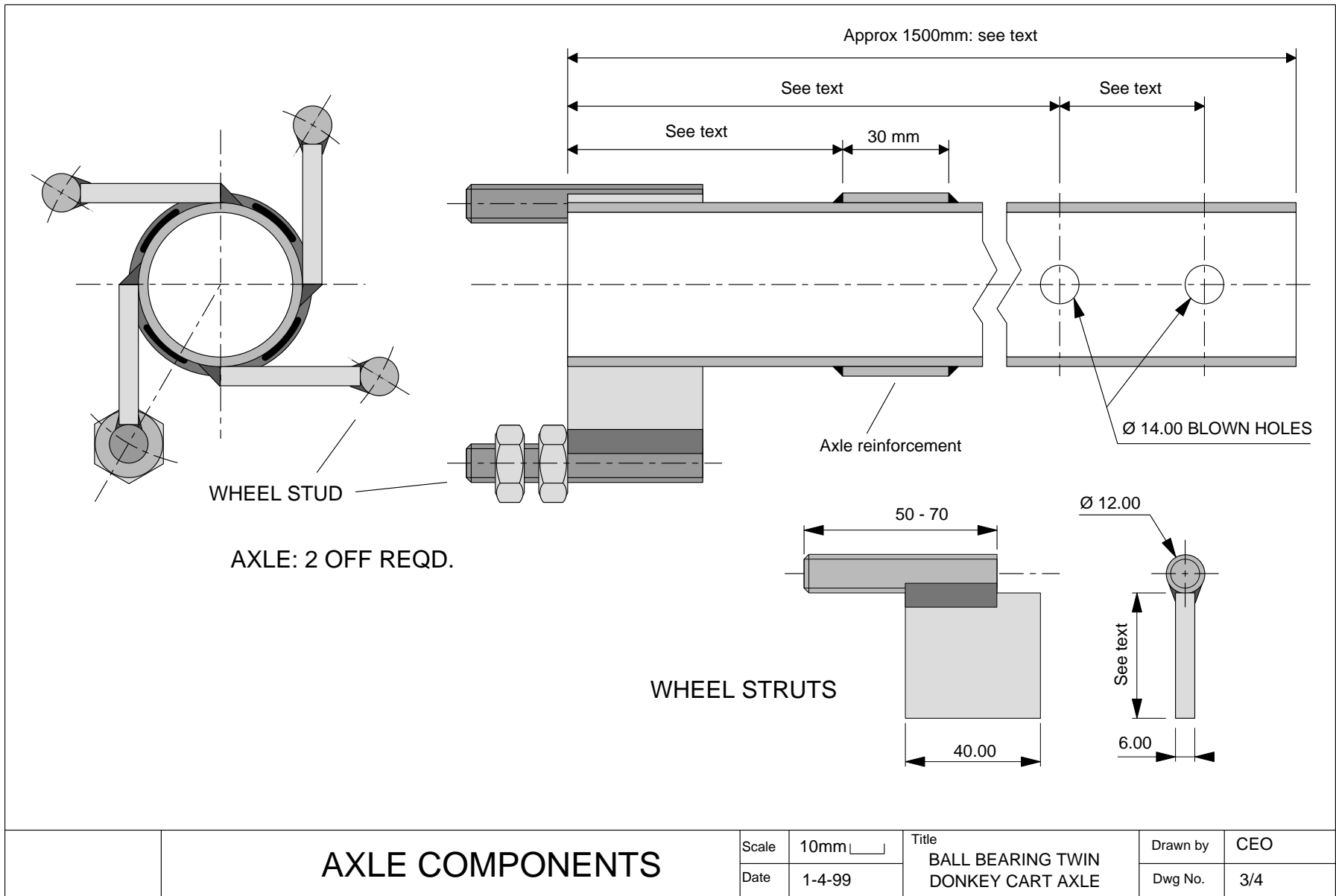
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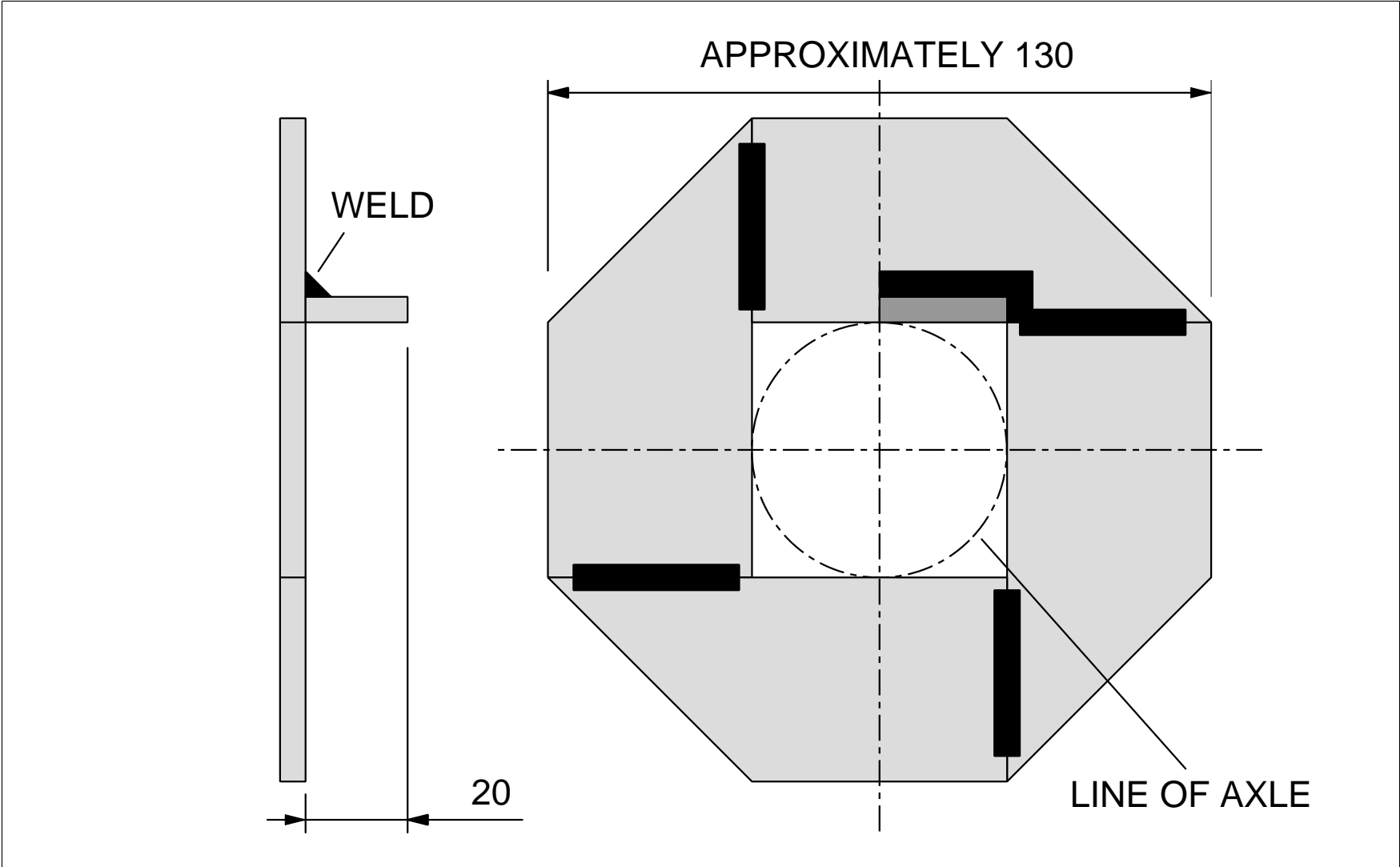
Date 1-4-99

Title  
BALL BEARING TWIN  
DONKEY CART AXLE

Drawn by CEO

Dwg No. 2/4





AXIAL THRUST WASHER: 4 REQD

Scale	10mm	Title BALL BEARING TWIN DONKEY CART AXLE	Drawn by	CEO
Date	1-4-99		Dwg No.	4/4



# Animal Cart Programme

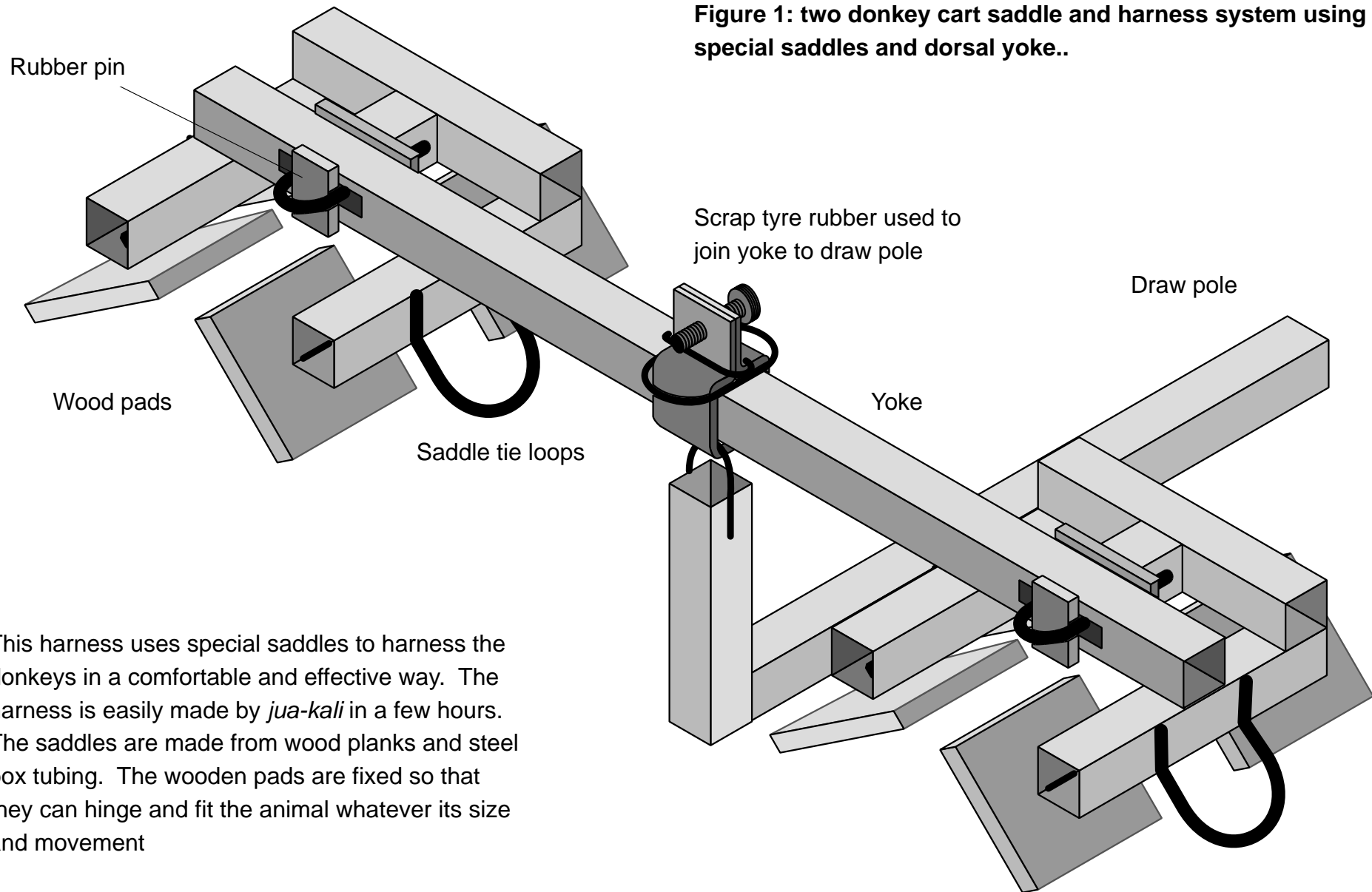
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## Double Donkey Harness for Cart Pulling

TECHNICAL  
**40**  
RELEASE

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**Figure 1: two donkey cart saddle and harness system using special saddles and dorsal yoke..**



This harness uses special saddles to harness the donkeys in a comfortable and effective way. The harness is easily made by *jua-kali* in a few hours. The saddles are made from wood planks and steel box tubing. The wooden pads are fixed so that they can hinge and fit the animal whatever its size and movement



# Donkey Harness for Carts Made From Steel Box Tubing, Timber and Canvas/Sacking

## Introduction

This Technical release tells you how to make a saddle and harness system for two donkeys to pull a cart with a single draw pole. Another Technical Release tells you how to make a saddle for single animal use.

You should find that you can make the whole harness for two

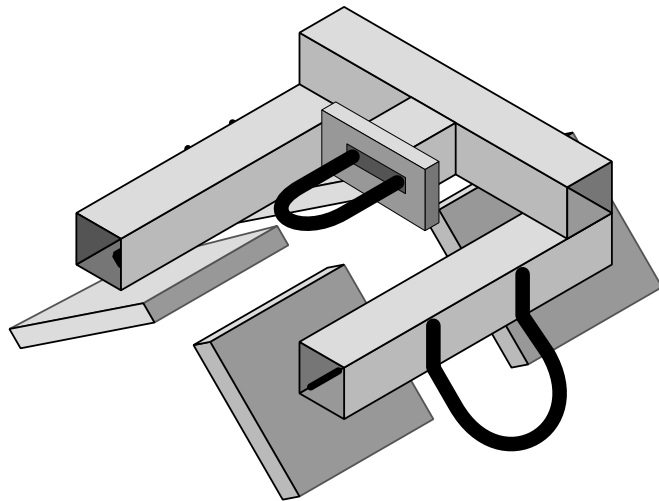


Figure 2: single donkey saddle.

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donkeys for less than £<sub>UK</sub>15, depending on the cost of the materials and labour. Once you get organised, two men can probably make a complete set of harness in four hours - we have designed this harness to be easy to make.

Other booklets in this series tell you how to make simple low-cost axles and carts: we have designs for steel framed and wooden framed carts and for many different kinds of axle. All carts and axles can be made without special tools - even drilling metal is not required.

## Idea Behind Design

Saddles are used in many countries to hitch animals to carts. Our saddles provide strong points on the animals' backs and a yoke can easily be fixed to them to carry the end of the cart

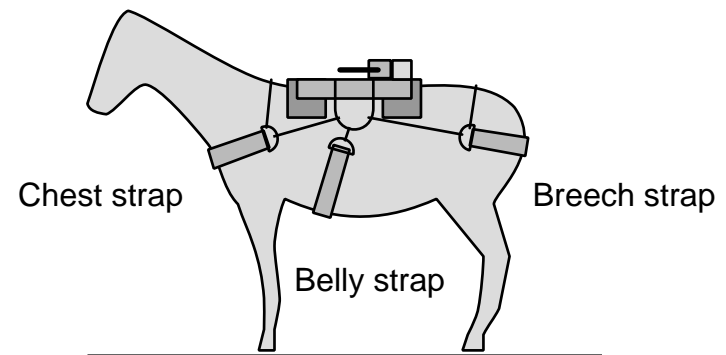


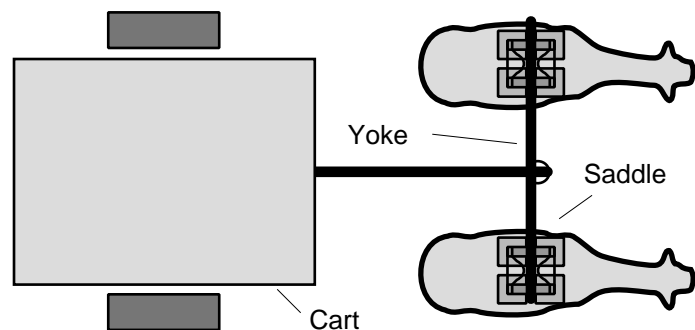
Figure 3: saddle secured to donkey with straps.

draw pole. Using this harnessing method carts can be pulled, steered and braked, and stabilised if the load is too far back on the cart body. This harness allows animals of different sizes to be used together and does not need them to walk exactly side by side. We have even had donkeys jump over a hedge pulling a cart with this harness!

Special tools and jigs and hard-to-get materials are not required. The only tools which you must have are a simple welder, a woodsaw, a hacksaw and a hammer.

The saddle frame is welded and the wooden pads are fixed to the frames with nails which are put through holes in the steel frame and welded so that they are loose and allow the pads to follow the shape of the animal.

These saddles have been tested in Kenya and work well but we



**Figure 4: two donkeys harnessed to cart.**

would like to test them more. Really we need to test them for a year or two to see how the animals react.

## Cutting list and costs

Table 1 shows a cutting list for a complete harness - recent prices of materials in Kenya are shown converted into £<sub>UK</sub>.

**TABLE 1: harness materials cutting list.**

component	material	# components	total mat [mm]	mat cost [£ <sub>UK</sub> ]
main frames	50x50 box tubing	2x3x300	1800.00	2.11
yoke attachment stub	50x50 box tubing	2x1x60	120.00	0.13
yoke	50x50 box tubing	1x1x1400	1400.00	1.52
yoke fixing loops	12 mm re-bar	2x2x350	1400.00	0.45
strap loops	12 mm re-bar	2x2x300	1200.00	0.39
load pad pivots	12 mm re-bar	2x4x20	160.00	0.05
load pads	25x150 timber	2x4x150	1200.00	0.28
pad fix nails	nails/ 6mm re bar	2x8x50	800.00	0.08
strap rings	6mm re bar	2x6x180	2160.00	0.22
strap clenchers	6mm re bar	2x6x120	1440.00	0.14
strap hooks	6mm re bar	2x6x150	1800.00	0.18
straps	CC5 canvas	2x3x4x65	1560.00	3.94
strap chains	dog chain	2x3x300	1800.00	1.40
saddle/ yoke buffer pad	scrap tyre rubber	2x60x110	120.00	0.20
yoke/ saddle locking pin	scrap tyre rubber	2x90x100	180.00	0.20
yoke/ cart attach strap	scrap tyre rubber	1x70x400	400.00	0.50
			<b>TOTAL =</b>	<b>11.79</b>

## Construction step by step

- 1) The first job, is to get all the material together and clear a space to work. Ideally you will be able to work on a flat area of concrete.
- 2) Make up the U-shaped frame as shown in Figure 5. If you have a G clamp you can use it to hold two pieces of the frame together during welding.
- 3) Then weld the tie loops and the yoke attachment stub and loop onto the U frames so that the frame looks as shown in Figure 6.
- 4) Next cut the wooden load pads and round off all the edges so that there are no sharp corners to stick into the donkey.

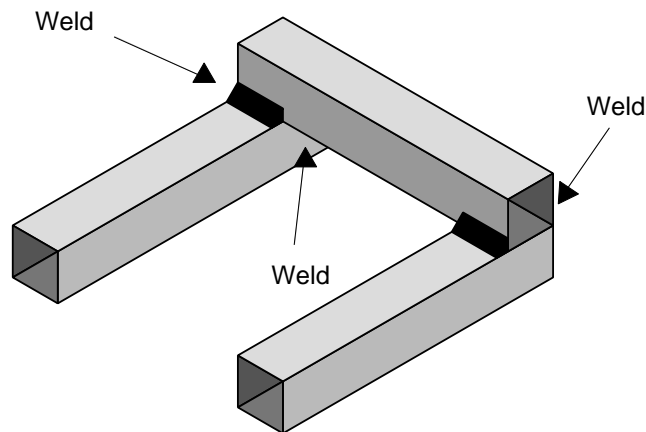


Figure 5: welding of frame cross piece.

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Hammer two nails through each of the pads in the positions shown in the drawings. With some timbers you may need to drill holes for the nails to avoid splitting or burn the holes with a hot nail. Then cut the nails so that about 30 mm projects from the timber as shown in Figure 9.

- 5) Now mark the position of the holes required to accommodate the pad nails in the steel tubing. These holes should be 15 mm and 65 mm from the ends of the square tube as shown in Figure 7. Blow the holes through with the welder at maximum current setting or use an angle grinder or file or hacksaw.
- 6) Next you can weld on the pad pivot blocks as shown in

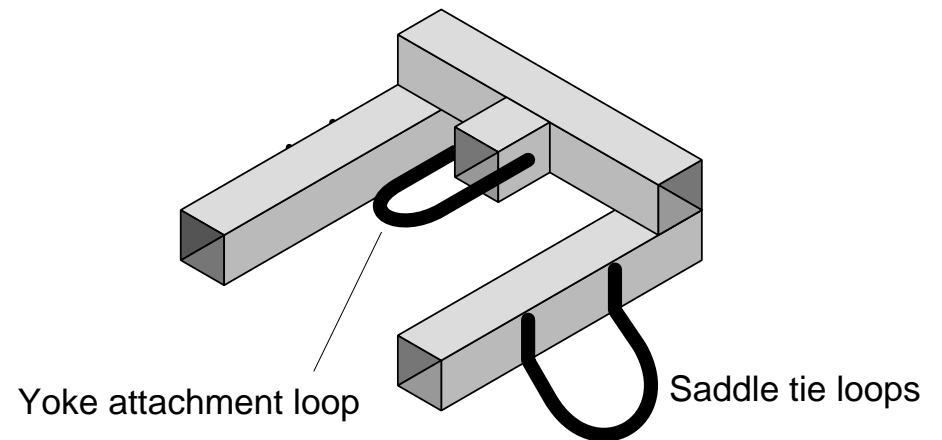


Figure 6: links and yoke loop welded to U- frame.

Figure 7.

- 7) Now put the nails through the blown holes and weld a piece of nail across the ends of the nails as shown in Figure 10. Welding down inside the tube looks difficult but skilled workers can weld the pads in about one minute.

An alternative way of doing it is to cut slots 70 mm long along the corners where the holes would be as shown in Figure 8. The slots should be 8 mm wide so that the nails are very loose in them. Make up the pads as shown in Figure 9, put the nail loop into the slot in the right place and weld the pad pivot blocks into place across the slot so that they are in the same place as in Figure 7.

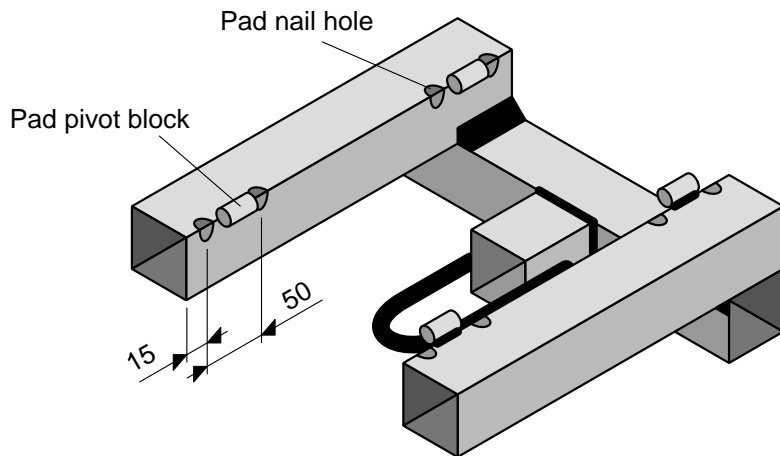


Figure 7: pad nail hole positions and pad pivots.

- 8) Next you need to make up the six straps to hold the saddles onto the donkeys. The D rings at the end of the straps can be made from 6 mm diameter concrete reinforcing bar as shown in Figure 11. A separate piece of the re-bar is clenched over the strapping using hammer blows to fix the D rings to the ends of the straps as shown.

The straps themselves can be made from heavy canvas or hessian sacking. You should use three or four thicknesses of material for them to make them strong enough and soft enough not to hurt the donkey.

- 9) Make the strap chain hooks from more 6 mm re-bar as shown in Figure 12 and fit the fixed ends to the saddle tie loops.

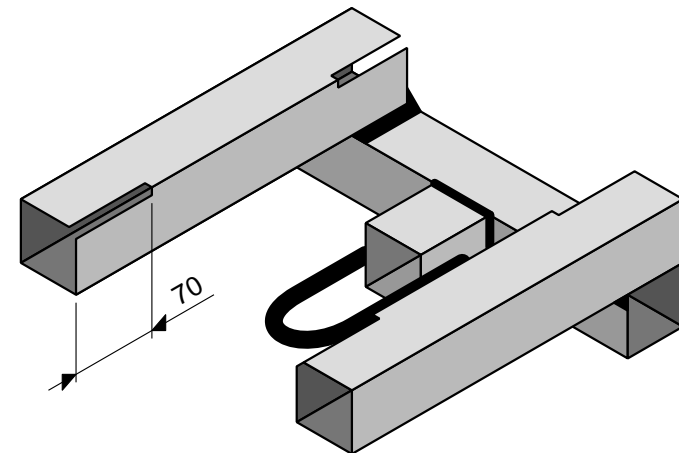
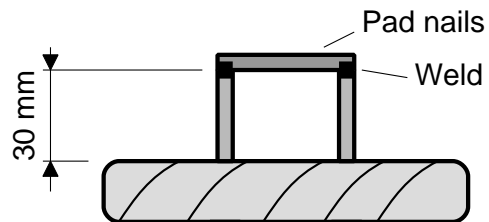


Figure 8: pad nail slots.

- 10) Cut the yoke to length. You can make the yoke different lengths but we have found that a longer yoke helps the animals turn in a narrow track. Make the slots in the ends with a grinder and welder and file. Weld the central tie loop shown in the drawings.
- 11) Cut two rubber yoke fixing pins and the buffer pads to the shape shown in the drawings.
- 12) Cut another piece of scrap tyre rubber about 400 mm long and 70 mm wide. Make a hole about 15 mm diameter about 40 mm from each end. Make a loop of 6 mm diameter steel reinforcing bar about 70 mm long as shown in Figure 14 that will just go over two thicknesses of the rubber strip.
- 13) Paint and creosote the saddle. You've finished it!

### Method of harness use

Harness each animal separately, then fix the yoke to the



**Figure 9: welded pad nails.**

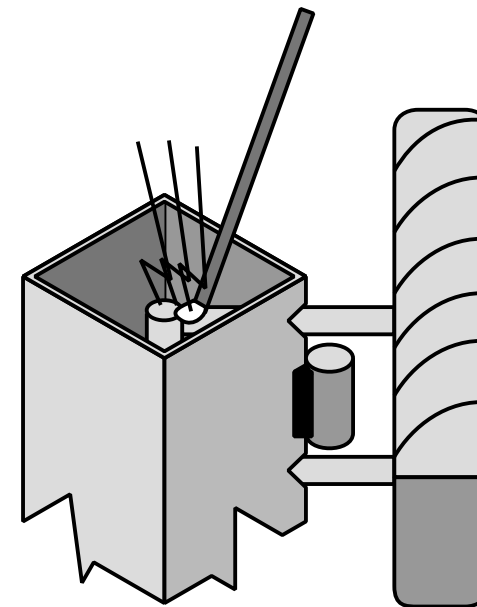
TR 40: 7th April 1999

saddles, then fix the yoke and animals to the cart.

- 1) First put a blanket or two folded hessian or jute sacks (not plastic) onto each donkey's back to protect them.

Remember that protecting the donkey will save money because it can work harder if it is comfortable and will not get sick from skin wounds.

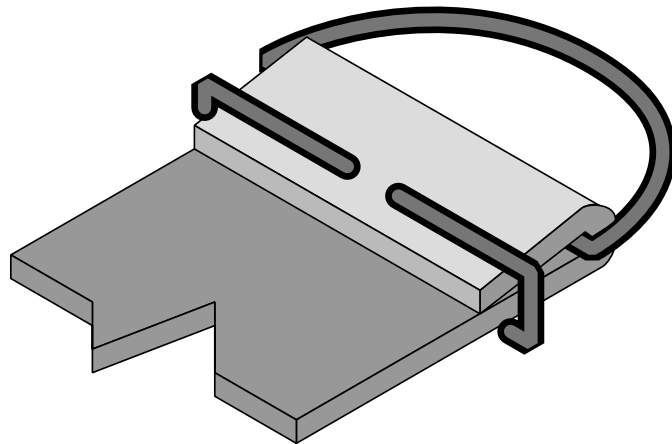
- 2) Put the saddle on so that the fronts of the wood pads are about 100 mm behind the animal's shoulder blades. This



**Figure 10: welding re-bar to frames for wooden load pads.**

means that the saddle should never come near parts of the animal's back which move.

- 3) Next hook the breaching strap to the loops hanging from the side of the saddle. It should be tight enough to tend to pull the saddle a little rearwards. Make sure that the breaching strap is pulled up high so that it does not rub the backs of the legs. But it should not be so high that the animal cannot defecate. Tie a piece of thin rope across the animal's back between the rings of the strap to hold the strap up.
- 4) Now hook the chains for the belly strap onto the hooks fixed to the saddle tie loops. The strap should be 50 mm or

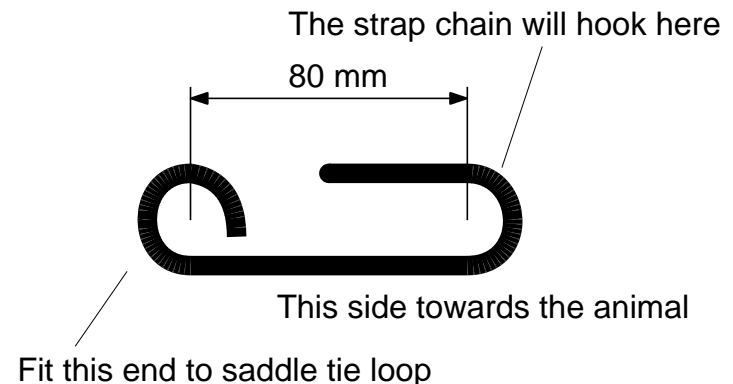


**Figure 11: D rings for straps made from re-bar.**

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100 mm behind the front legs - check that the legs do not rub on the strap when the animal walks. Tighten the strap so that you can just get a couple of fingers under it between the strap and the animal. This will be much tighter than the other straps.

- 5) Hook the chest strap to the loop and adjust the tension so that it is a little loose. Use another short piece of rope to hold the chest strap up so that it is just below the wind pipe. The strap goes tight when the animal pulls really hard. We have noticed that the belly strap and breaching strap are nearly enough without the chest strap and so we leave the chest strap a bit loose.
- 6) Saddle the second animal in the same way. You should be able to saddle an animal in only a few seconds when you



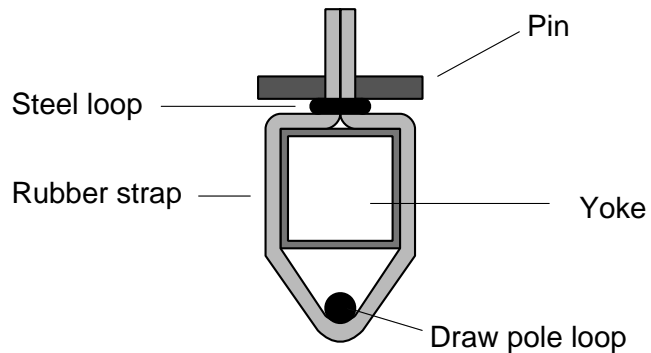
**Figure 12: chain hooks for straps.**

get practised.

- 7) Get the two donkeys in position side by side and put the yoke across the two saddles pushing the slots in the yoke over the loops on the saddles as shown in Figure 1. Secure the yoke by pushing the rubber pins into place.
- 8) Lastly connect the cart to the centre of the yoke using the 400 mm long rubber strap, the 80x15 loop and a bolt as shown in Figure 13.
- 9) You are ready to go!

### Saddle Drawing

You will find drawings of the saddle and yoke on the last pages



**Figure 13: using rubber strap to join cart draw bar loop to yoke.**

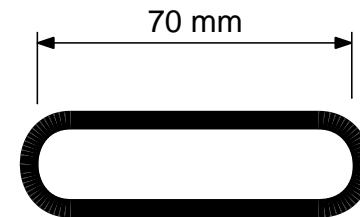
of this Technical Release.

### Other DTU cart developments

The DTU has been working on a range of cart designs for use with both donkeys and oxen. It has designs for wooden and steel framed types. You can make either type of cart in only a few hours, if you are reasonably set up with tools and materials.

The DTU has also been working on new designs of wheels, hubs and bearings to bring down their costs and make things more locally manufacturable. It has a system of axles with bearings made from PVC pipe, another with wooden bearings and a third using scrap ball bearings. None of these axles need machining and they only take two men a day to make.

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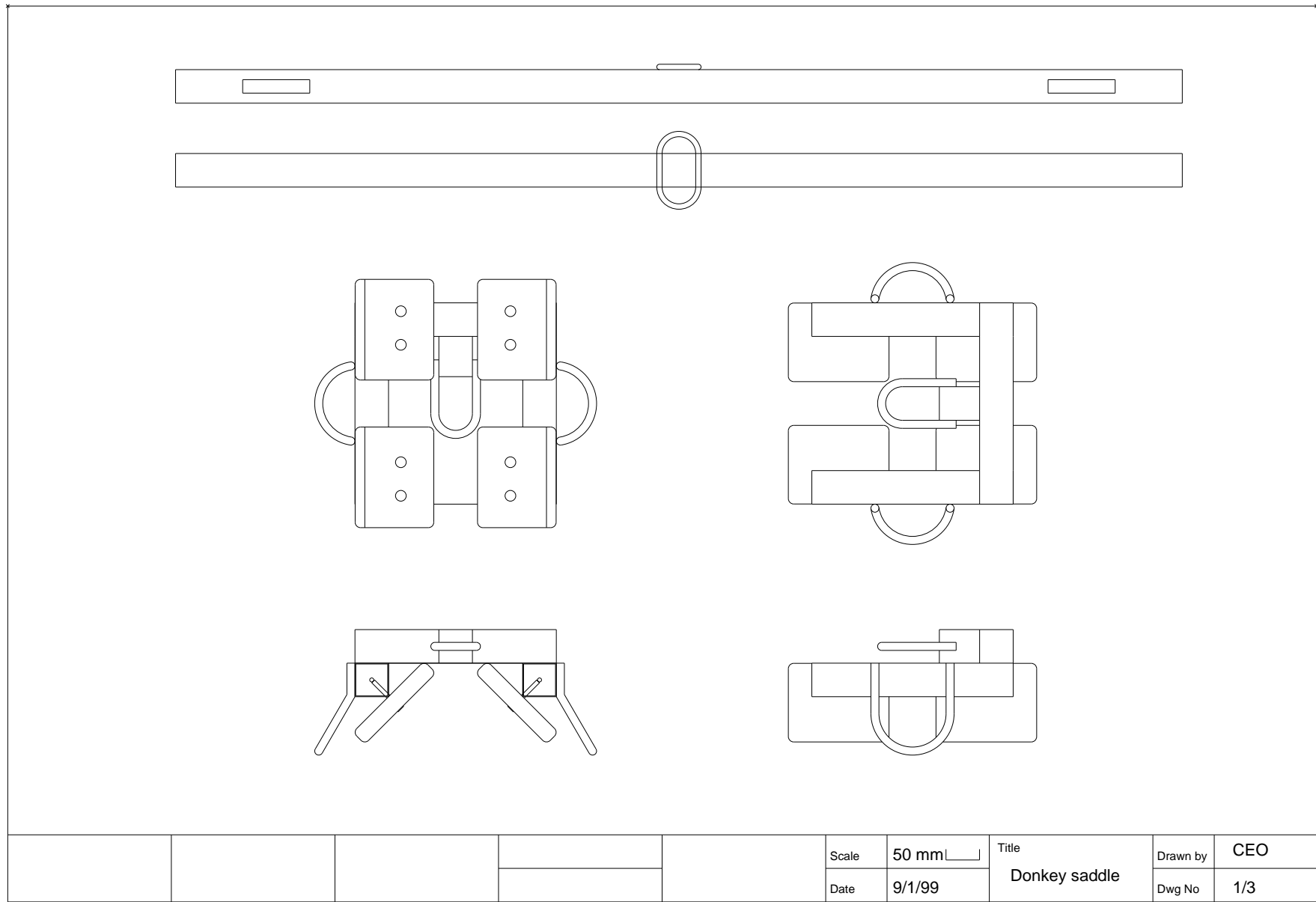
**Figure 14: loop for yoke to drawpole strap (R6 steel bar).**

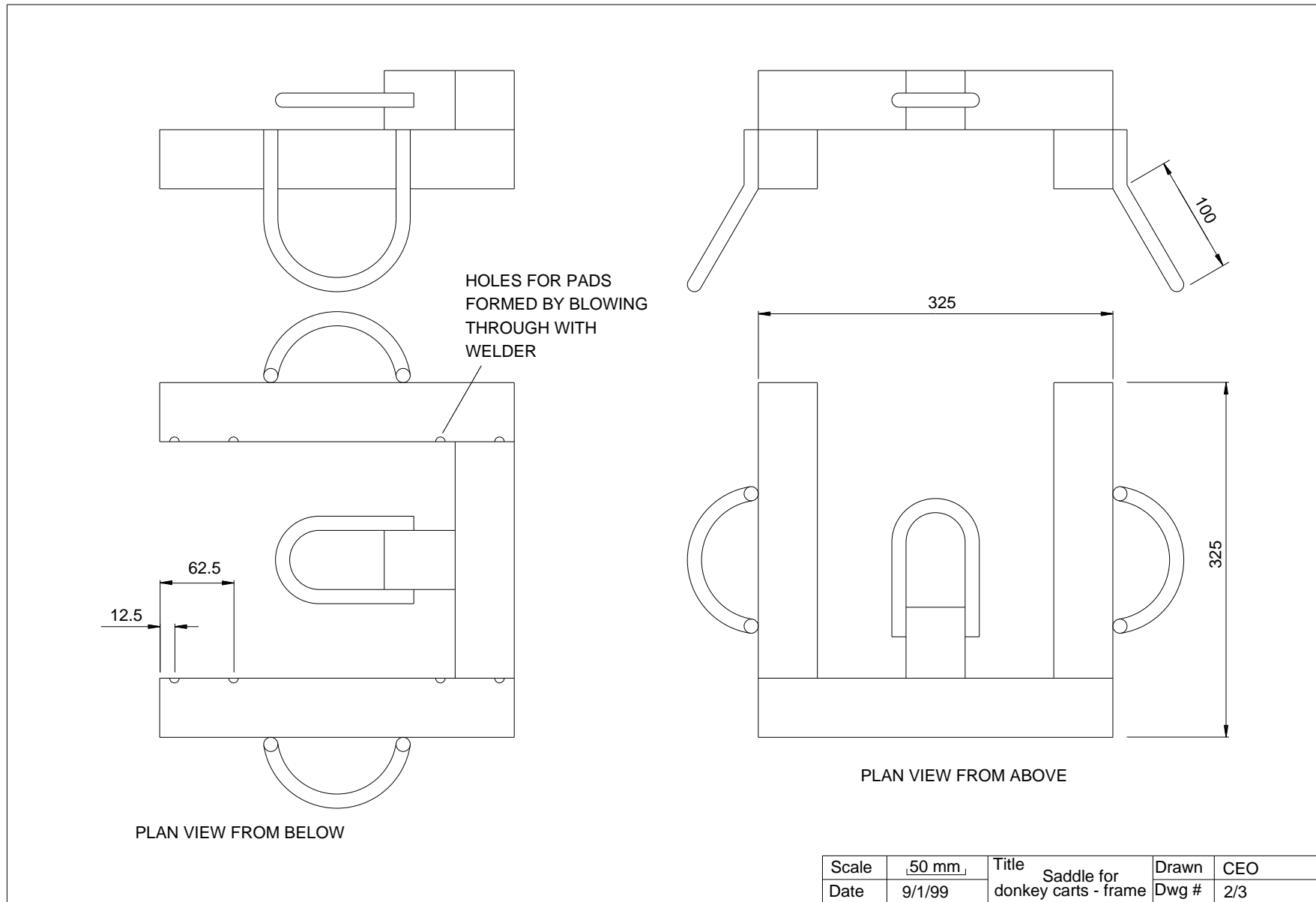
## **Acknowledgements**

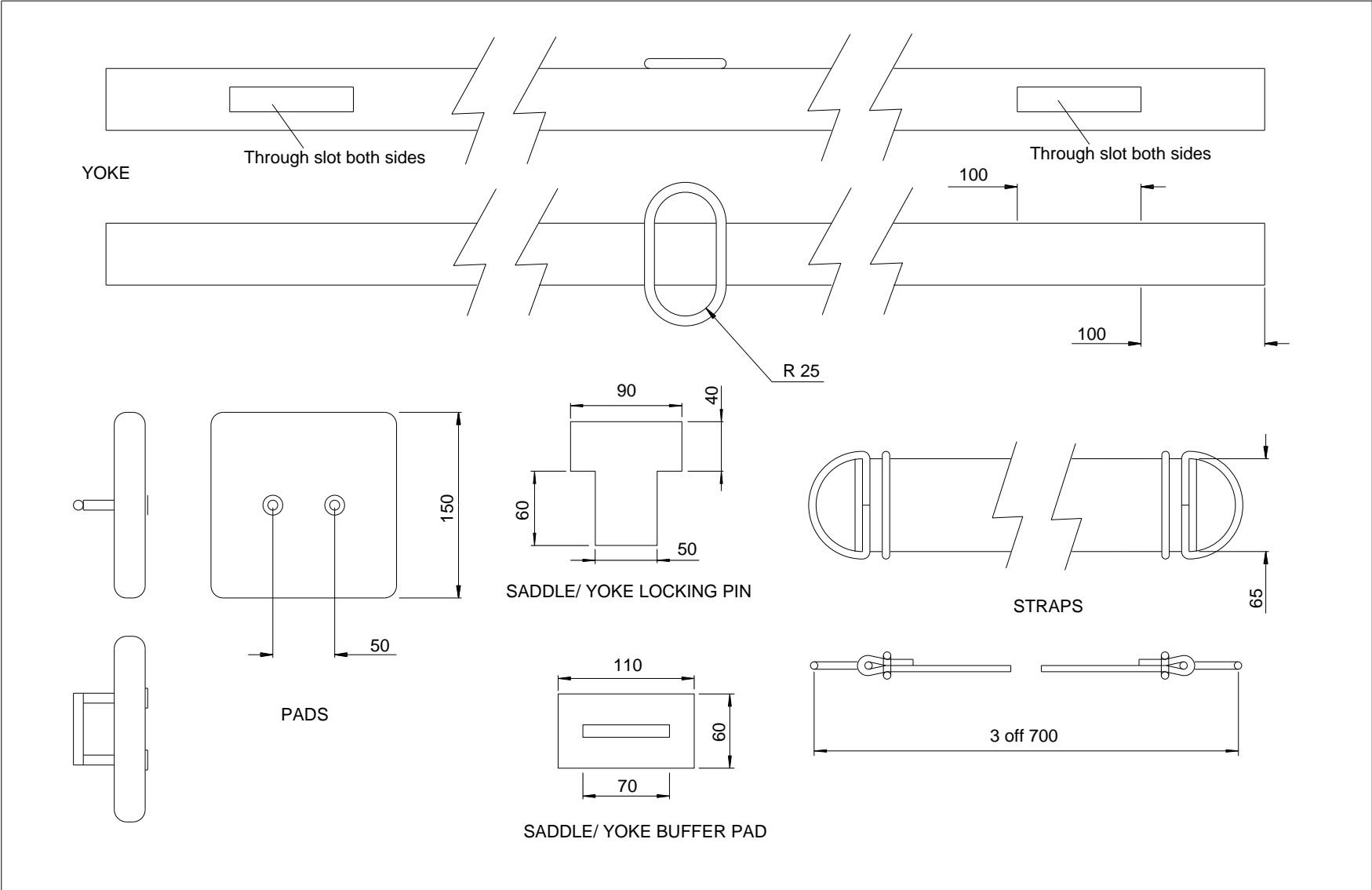
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				Scale	50 mm	Title Yoke, saddle pads, straps, for donkeys	Drawn	CEO
				Date	9/1/99		Dwg #	3/3

TECHNICAL  
**39**  
RELEASE

**DTU**   **KENDAT**

# Animal Cart Programme

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## Steel Wire Rim Wheel for Donkey Carts

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Figure 1: wire rim wheel for animal carts.



# Steel Wire Rim Wheel for Donkey Carts.

## Introduction

In this booklet we tell you how to make steel wire or bar rim wheels for donkey carts. The instructions do not cover how to make the cart or the axle - you will need to read other Technical Releases from us to find out how to make these.

The advantages of this type of wheel are that it cannot be punctured and that it is quite easy to make.

You should find that you can make a wheel for about £12. This cost will depend on the cost of the materials and labour. Once you get organised, two men can probably make a pair of wheels in half a day.

## Easy to make design.

This wheel is designed to be constructed without any special tools and jigs, and without any hard-to-get materials. The only tools which you must have are a simple welder, a hacksaw, and a hammer.

Unfortunately we have only tested one of these wheels in Kenya and Uganda but we had no problems. A good modification is to cut the tread from an old tyre and bolt it to the outside of the wheel. Then it is quiet on tarmac roads.

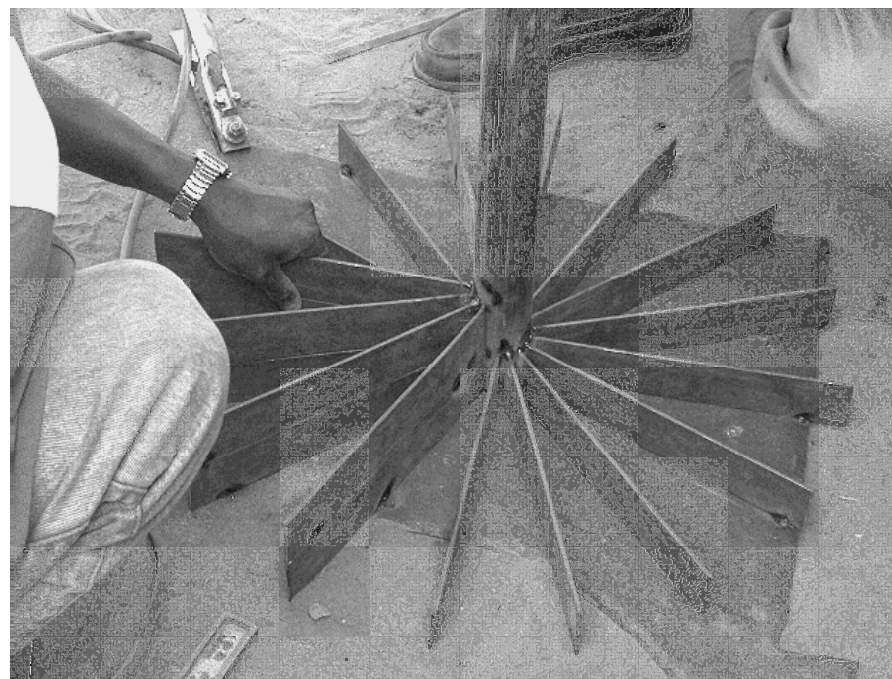
TR39: 4th April 1999

## Cutting list and costs

Table 1 shows a cutting list for a wheel - recent prices of materials in Kenya are shown converted into £UK.

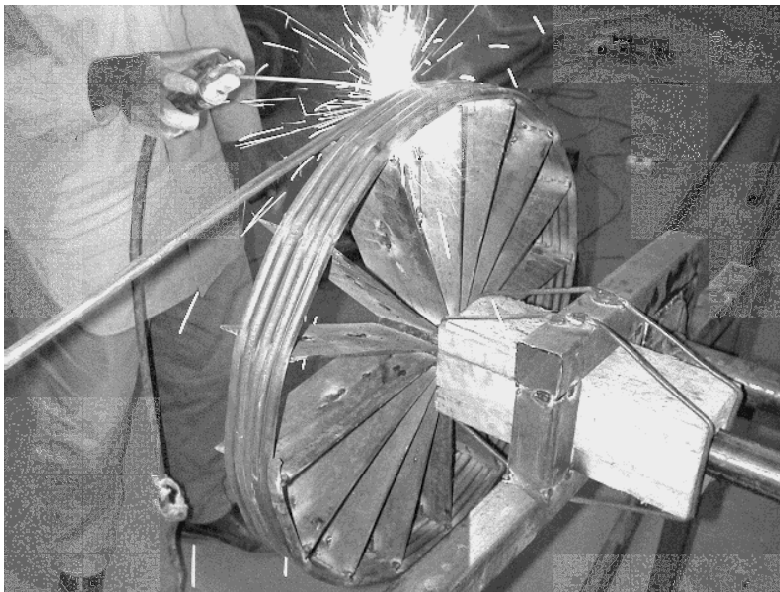
## Construction step by step

- 1) The first job, is to get all the material together and clear a space to work. Ideally you will be able to work on a flat area of concrete.



**Figure 2: welding spokes to axle.**

- 2) Start by cutting the 16 spokes each of which needs two pieces of flat bar. If you want to make the wheel an exact size subtract the axle radius and the wire diameter from the required radius for example if you want the diameter to be 600 mm ie a radius of 300 mm and the axle is 50 mm diameter and the wire is 10 mm diameter then the spokes should be  $300 - 25 - 10 = 265$  mm.
- 3) Next cut the axles from 1-½" black pipe. These will probably need to be about 1500 mm long.



**Figure 3: welding steel wire rim wheel for donkey carts. Also shown is wooden bearing.**

- 4) Using a try-square or a piece of wood or metal to check that the spokes are square to the axle weld the spokes evenly around one end of the axle as shown in Figure 5. Weld one on, then the opposite one, then one at right angles to the others, then the one opposite it and so on.
- 5) Then mount the axle horizontally as shown in Figure 3 so that it can rotate. Straighten the round bar out and then bend about 500 mm of one end so that it fits around the wheel spokes neatly. Weld the end of the wire to the end of a spoke so that it is flush with the outside of the spokes. Weld the wire to the next spoke keeping it flush with the outside of the wheel.

Continue welding the wire to each spoke in turn rotating the wheel as you go. Soon you will start bending the straight part of the wire, but you should find this ok. It is easiest if one person pushes the wire as another welds.

Continue pushing and winding and welding until the wire is the full width of the spokes. You will probably need to start a second length of wire to finish the wheel. Just weld it onto

**TABLE 1: materials for torsion tube brake.**

description	length m	#	total m	cost £UK
100 wide strip 600 dia single thickness	18.85	1	18.85	3.93
50x3 strip spokes 270 long	0.27	32	8.64	6.62
			TOTAL	10.55

the end of the first piece of wire and continue.

- 6) When you reach the other side of the wheel and you cannot get any more wire on you've finished it!

### **Other DTU cart developments**

The DTU has been working on new designs of carts and all their components to bring down their costs and make things more locally manufacturable. It has designs for bodies, wheels, hubs, bearings and animal harness all available from DTU as Technical Releases.

### **Drawing**

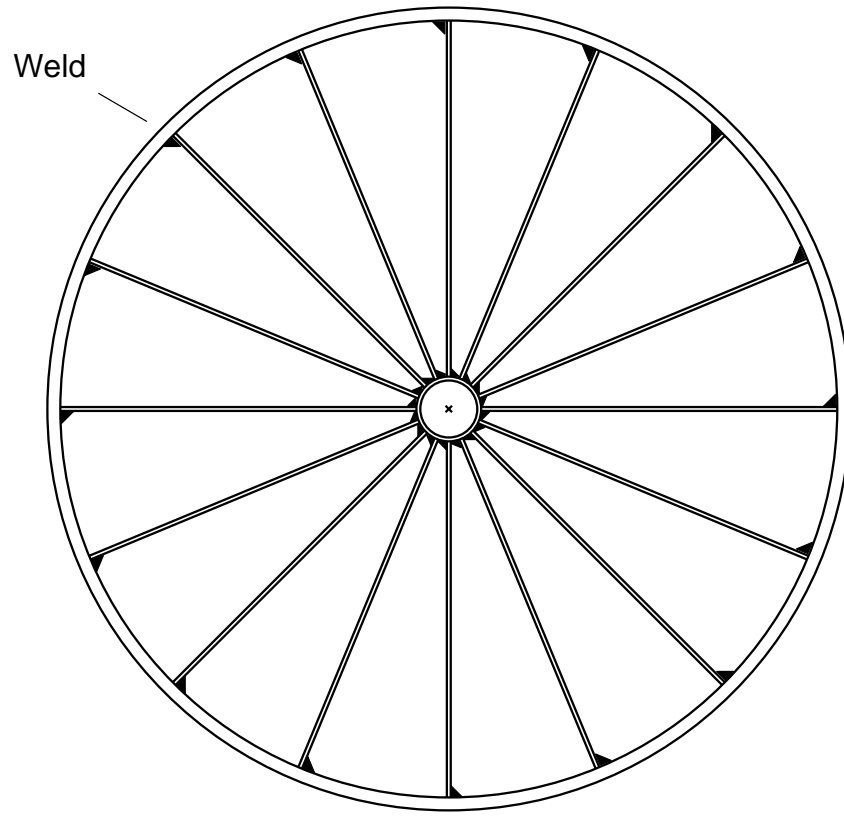
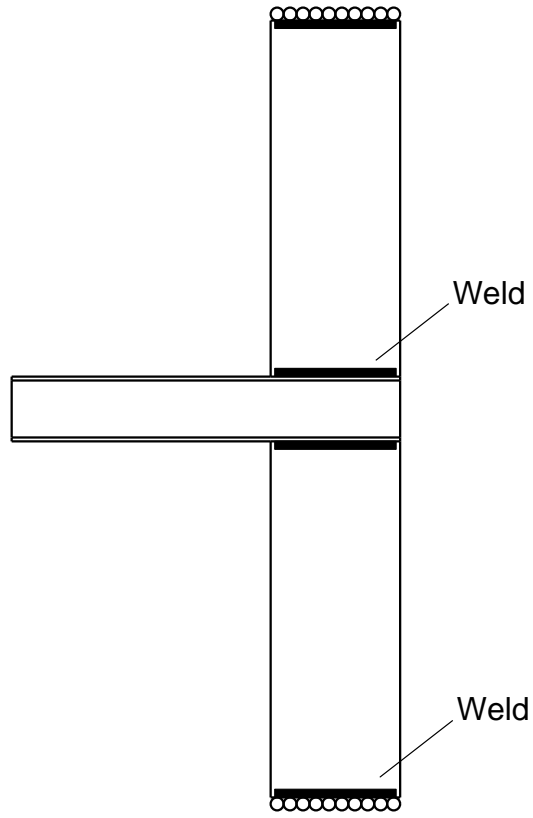
You will find a drawing of the wheel on the next page.

### **Acknowledgements**

The DTU is grateful to the DFID (British Government) for the financial support necessary to carry out the research and development project under which this product was developed.

The DTU would also like to thank Dr Pascal Kaumbutho of KENDAT in Kenya and Mr Joseph Mugaga of TOCIDA in Tororo, Uganda for their very considerable help with this project. A large number of other people and organisations have contributed to the success of the project, most notably Mr Anthony Ndungu in Kajiado Kenya, Mr JD Kimani in Kikuyu Kenya and Mr Joseph Gitari in Wanguru Kenya in whose workshops most of the development work of this project was performed. Thanks are due also to Mr Stanley Lameria in Kajiado, Mr Patrick Gitari in Wanguru and Mr Mathew Masai in Machakos for their assistance.



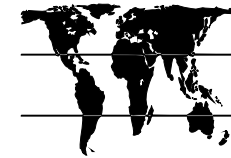


General Arrangement

Scale	10mm <input type="checkbox"/>	Title WIRE RIM WHEEL FOR DONKEY CARTS	Drawn by	CEO
Date	4-4-99		Dwg No.	1/2

KENDAT

DTU



# Animal Cart Programme

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TECHNICAL

38

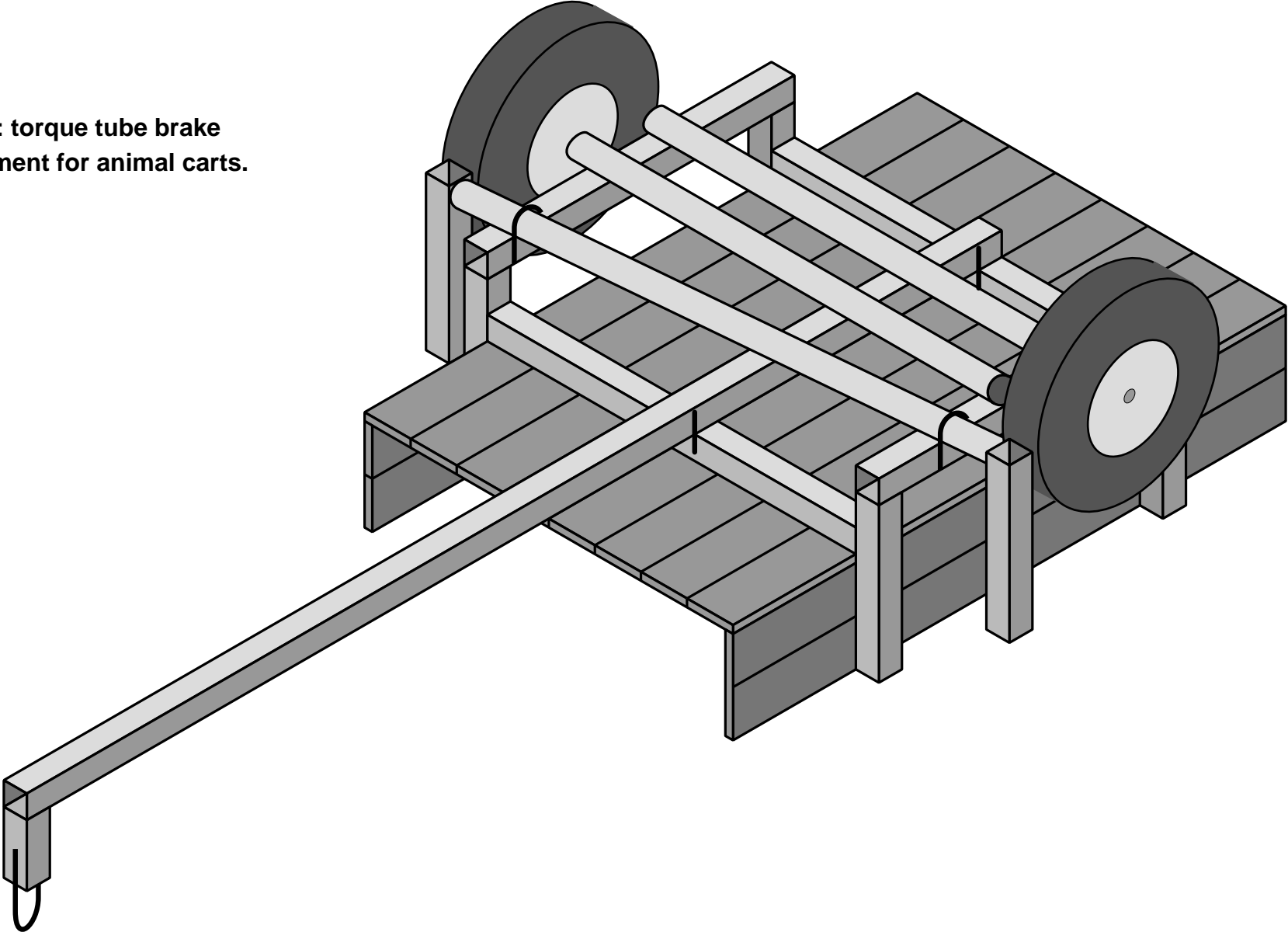
RELEASE

## Simple Low-cost Brake for Donkey Carts

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**Figure 1: torque tube brake arrangement for animal carts.**



# Simple low cost torque tube brake for donkey carts.

## Introduction

In this booklet we tell you how to make a brake for a steel framed DTU donkey cart from round and square steel tube. The instructions do not cover how to make the cart or the axle - you

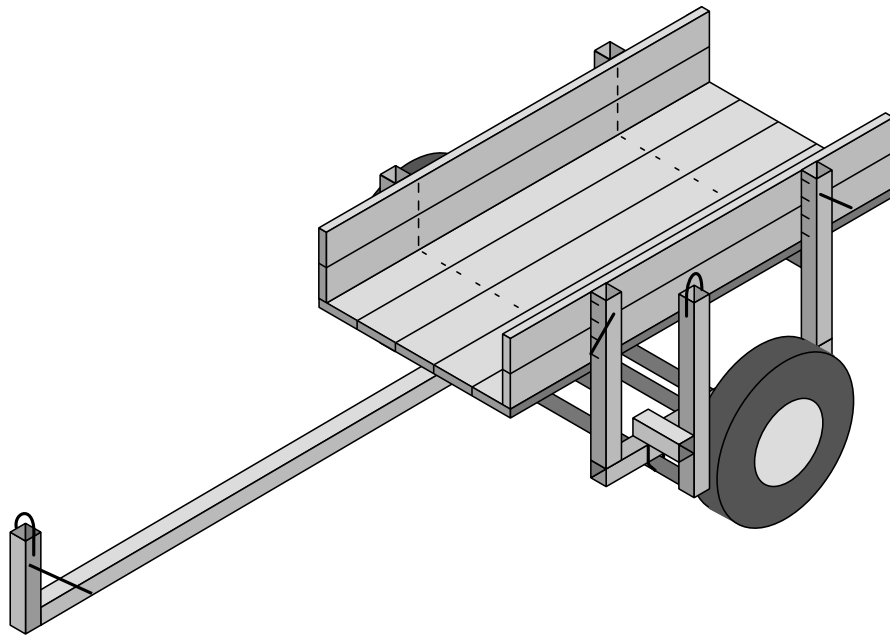


Figure 2: DTU donkey cart fitted with twin axles and simple low-cost brake.

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will need to read other Technical Releases from us to find out how to make these.

You should find that you can make the brake for about £6. This cost will depend on the cost of the materials and labour. Once you get organised, two men can probably make and fit a brake in an hour.

## Easy to make design.

This brake is designed to be constructed without any special tools and jigs, and without any hard-to-get materials. The only tools which you must have are a simple welder, a hacksaw, and a hammer. We have deliberately designed the brake so that drilling is not required.

We have tested these brakes in Kenya and Uganda and we have had only a few criticisms - if the mud is very sticky it jams

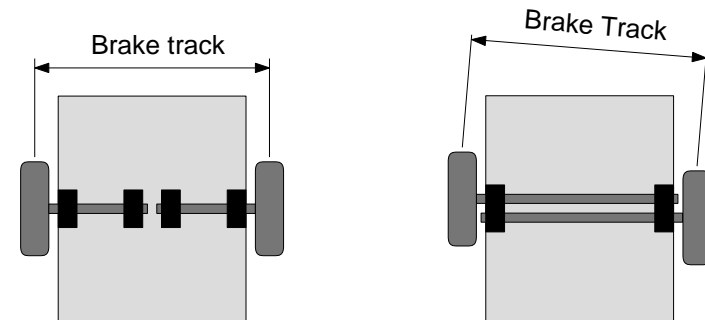


Figure 3: brake track measurement for a conventional half shaft axle and for a twin offset axle.

the brake and makes the cart hard to pull. One modification is to make the brake so it can be removed in bad conditions.

### Cutting list and costs

Table 1 shows a cutting list for a brake - Recent prices of materials in Kenya are shown converted into £UK.

### Construction step by step

- 1) The first job, is to get all the material together and clear a space to work. Ideally you will be able to work on a flat area of concrete.
- 2) Start by measuring the required brake track as shown in Figures 3 and Figure 4.
- 3) Cut a piece of 1-½" black pipe to this brake track length **minus 50 mm** so for example if the brake track is 1500 mm

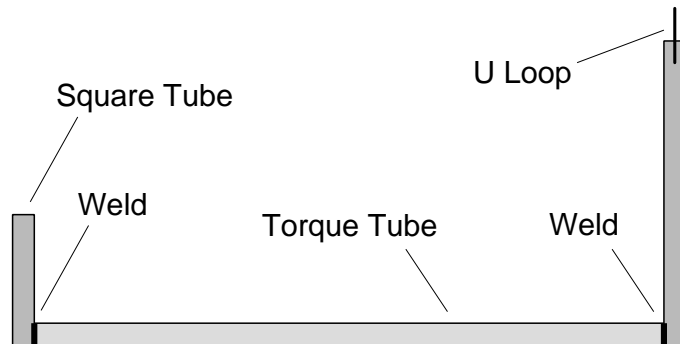


Figure 4: welded brake fabrication.

TABLE 1: materials for torsion tube brake.

component	material	# lengths reqd [#*mm]	total material for one brake [mm]	cost [UK£]
torque tube	1-½" BSP malleable iron pipe	1 × 1500	1500	3.00
brake pad	50x50 mm square steel tube	1 × 300	300	0.69
brake lever/ pad	50x50 mm square steel tube	1 × 700	700	1.62
brake torque tube loops	R 12 = 12 mm re-bar	4 × 250	1000	0.31
			TOTAL =	5.62

make the pipe 1450 mm long.

- 4) Cut a piece of 50 mm × 50 mm × 3 mm wall thickness square tube 300 mm long and another about 700 mm long.
- 5) Weld the pieces of square tube onto the ends of the round pipe as shown in Figure 5. A trysquare will help you get it square.

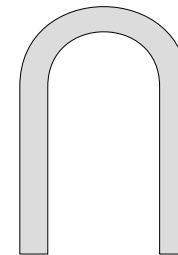
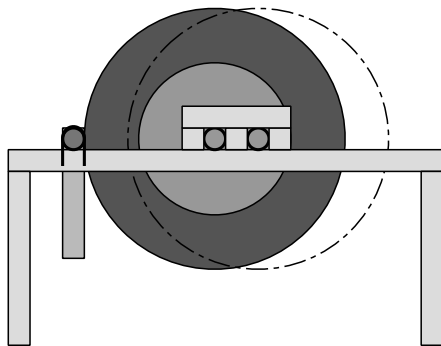


Figure 6: U loop.

- 6) Make five U shapes from R12 (that is 12 mm round steel bar) each piece 250 mm long as shown in Figure 6.
- 7) Weld the first U loop onto the end of the 700 mm square tube as shown in Figure 5. A rope tied to this loop can be used to work the brake remotely for safety.
- 8) Now turn the cart upside down, put the brake in position and place the remaining four U-loops over the brake torque tube as shown in Figure 7 and Figure 8.
- 9) Once you have the brake beam in position, tack weld the ends of the loops to the axle support beam, check that the brake can be released clear of the tyres and then weld the loops on properly.
- 10) Next cut two pieces of R 12 about 25 mm long and weld them to the brake torque tube either side of a support loop



**Figure 7: brake beam position.**

so that the brake beam cannot move endwise.

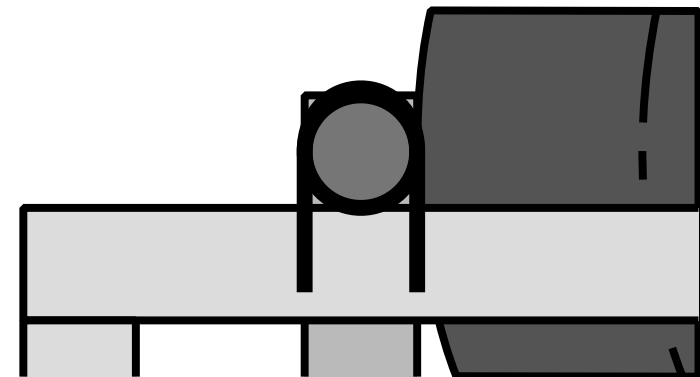
- 11) You've finished it!

## Other DTU cart developments

The DTU has been working on new designs of carts and all their components to bring down their costs and make things more locally manufacturable. It has designs for bodies, wheels, hubs, bearings and animal harness all available from DTU as Technical Releases.

## Drawings

You will find two drawings on the next pages, the first gives a general view of the brake and the second gives a view of the components of the brake itself.



**Figure 8: brake beam position - detail.**

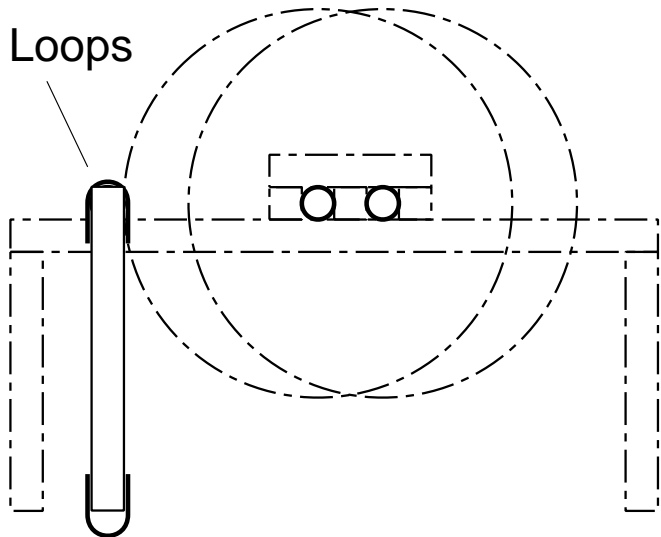
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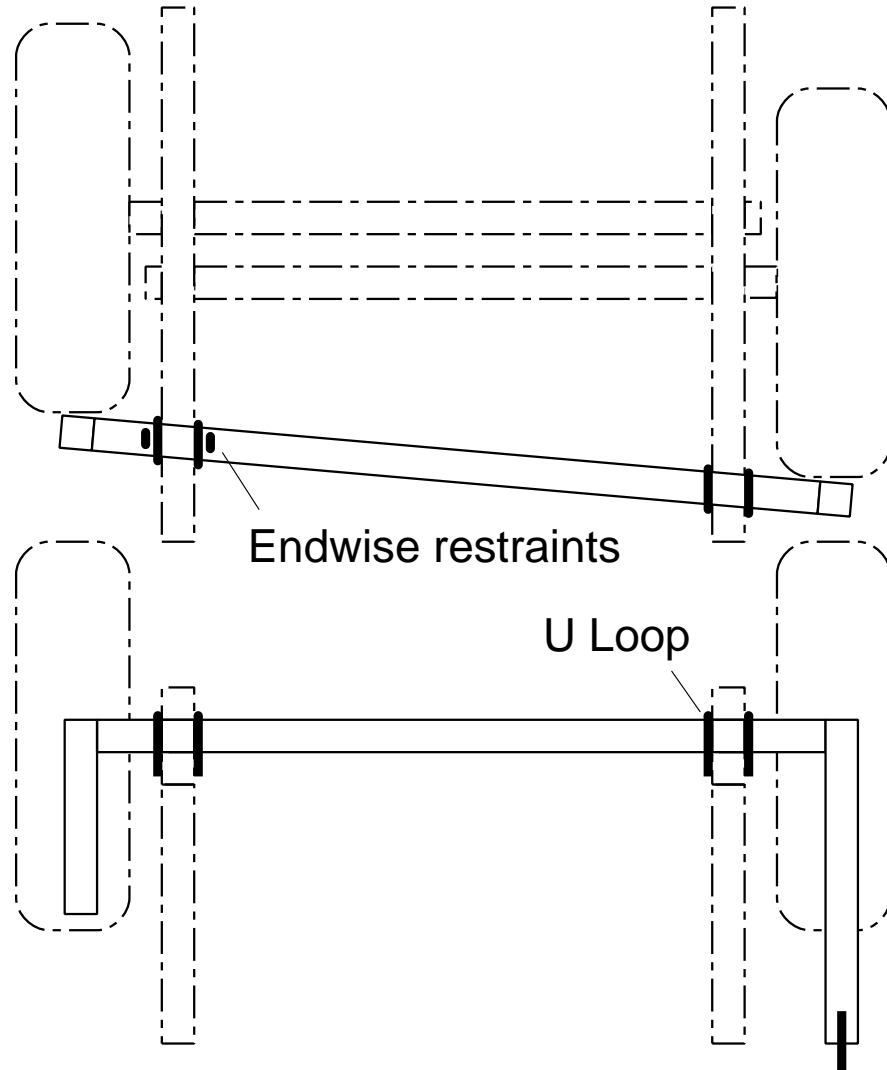
NB cart shown upside down

U Loops



Endwise restraints

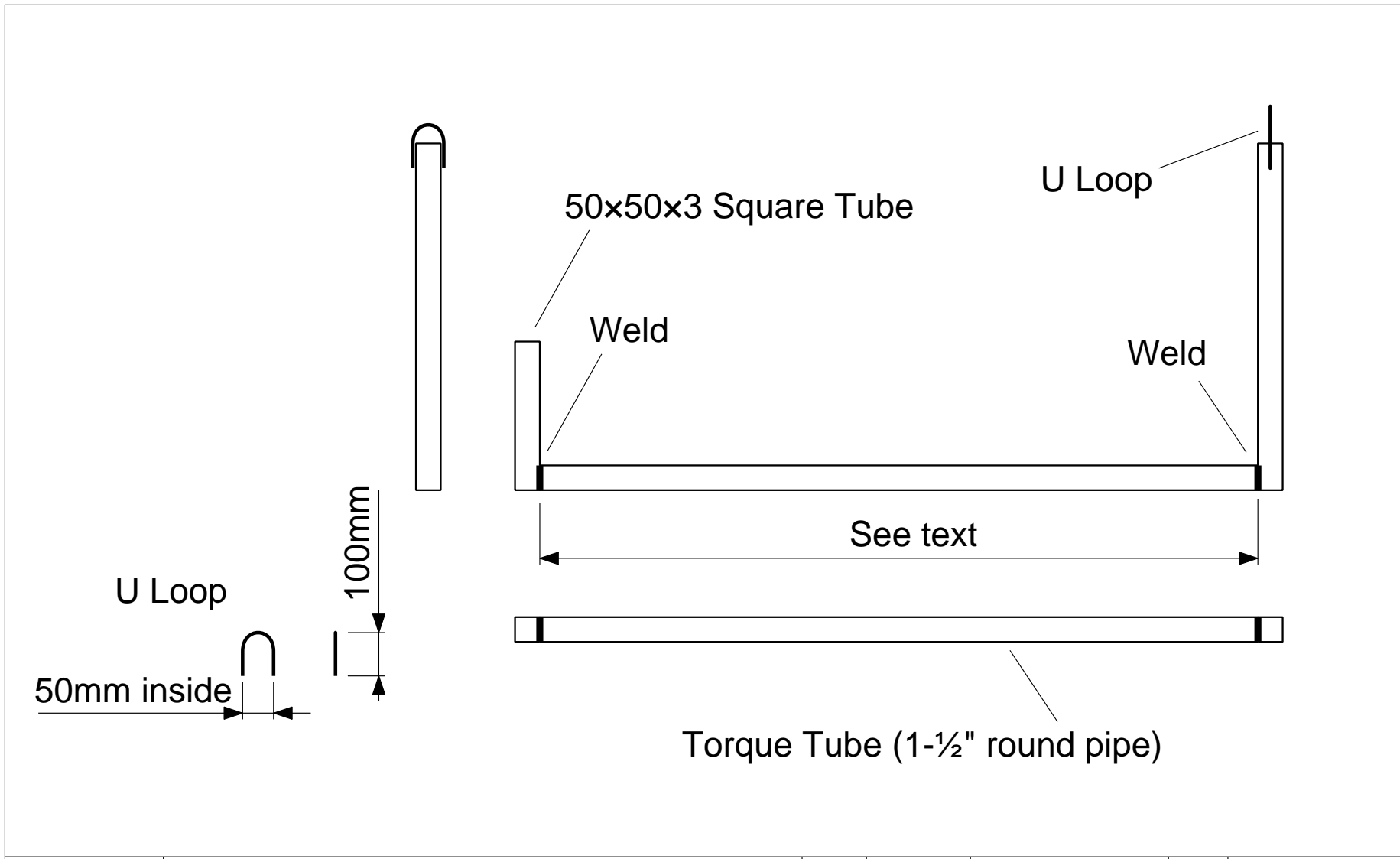
U Loop



### Torque Tube Brake

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Date	2-4-99		Dwg No.	1/2

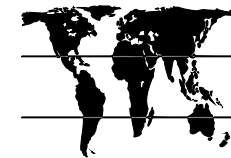




<b>Brake Components</b>	Scale	10mm <input type="checkbox"/>	Title	Drawn by	CEO
	Date	2-4-99	TORQUE TUBE BRAKE FOR DONKEY CARTS	Dwg No.	2/2

KENDAT

**DTU**



# Low-Cost Animal Cart Programme

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## Twin Wood Plain Bearing Axle for Donkey Carts

TECHNICAL

**37**

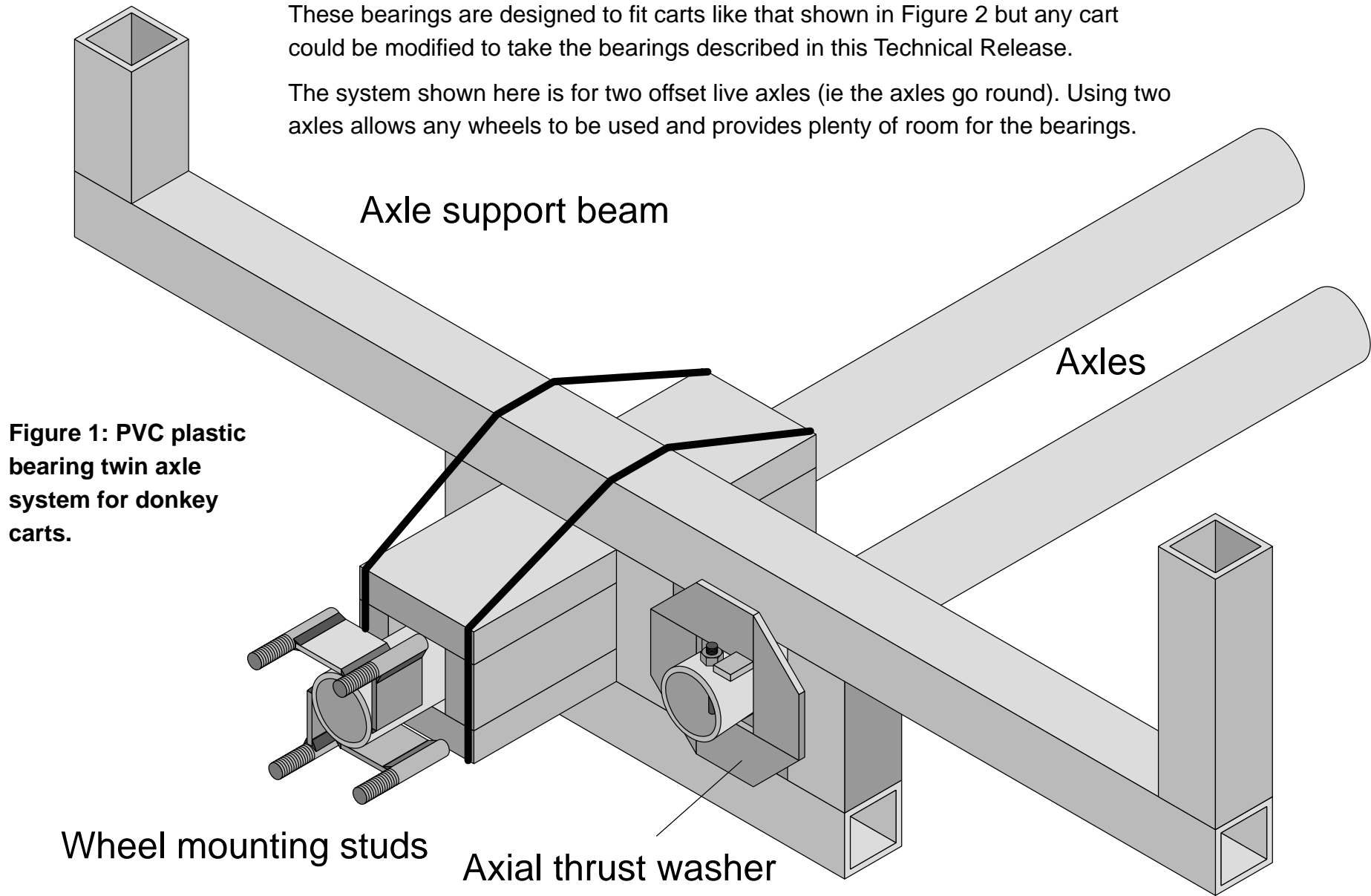
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Development Technology Unit, Department of Engineering, University of Warwick, Coventry, CV4 7AL UK, tel: +44 (0)203 523523 extn 2339, fax: +44 (0)203 418922, email: [esceo@eng.warwick.ac.uk](mailto:esceo@eng.warwick.ac.uk)

KENDAT, PO Box 61441, Nairobi, Kenya, tel/fax: +254 2 766939, email: [kendat@africaonline.co.ke](mailto:kendat@africaonline.co.ke)

These bearings are designed to fit carts like that shown in Figure 2 but any cart could be modified to take the bearings described in this Technical Release.

The system shown here is for two offset live axles (ie the axles go round). Using two axles allows any wheels to be used and provides plenty of room for the bearings.



**Figure 1: PVC plastic bearing twin axle system for donkey carts.**

# Wood plain bearing twin axle system for donkey carts.

## Introduction

In this booklet we tell you how to make an axle system for a simple donkey cart from round steel tube and wooden planks. The instructions do not cover how to make the cart itself - you

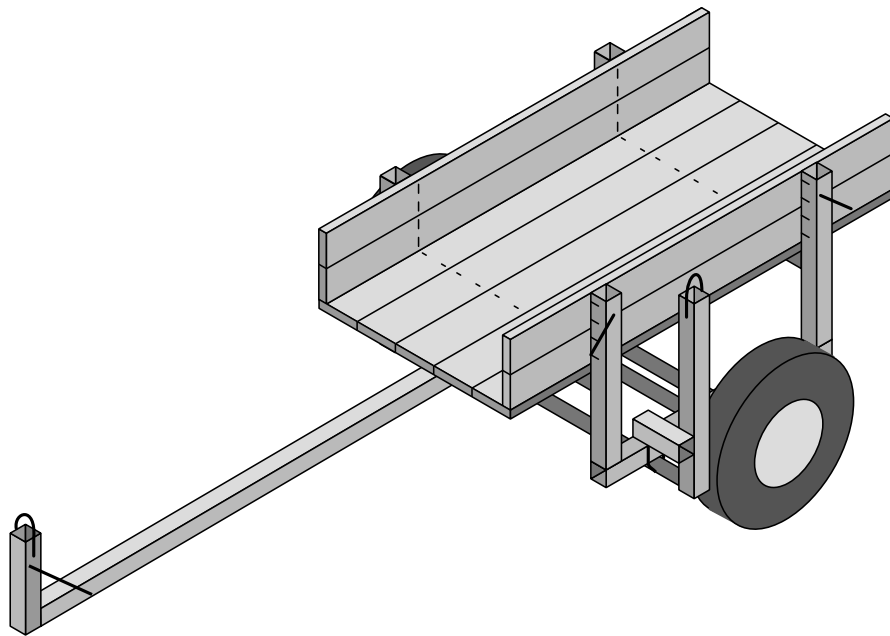


Figure 2: DTU donkey cart fitted with twin axles and PVC bearings.

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will need to read other Technical Releases from us to find out how to make the carts.

You should find that you can make the axle system for about £40 including the wheels, tubes and tyres. This cost will depend on the cost of the materials and labour. Once you get organised, two men can probably make and fit one cart with axles in half a day. This is quite a lot faster than it takes to find and a scrap car axle and it will be much cheaper.

In other booklets in this series you can find out how to make other low-cost axle systems and carts.

CONVENTIONAL HALF LENGTH AXLE

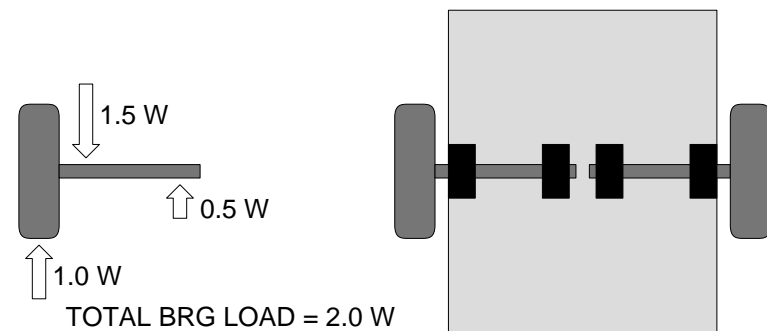


Figure 3: bearing loads in conventional half shaft axle.

## Why have twin axles?

There are two types of axle: fixed or stub axle - the wheel hub rotates on the stationary axle; live axle - the axle revolves in stationary bearings.

With the stub axle types the bearings must be inside the wheel. This is easy with expensive ball bearings but more difficult with cheap wooden bearings. You need to make them quite long to stop wheel wobble and so they stick out of the wheel. It is also quite difficult to make without jigs and special tools. If you really want that type we have quite a good system using PVC tube for the bearing. We can send you a Technical Release on how to do it.

Twin axles allow much bigger bearings and do not require such

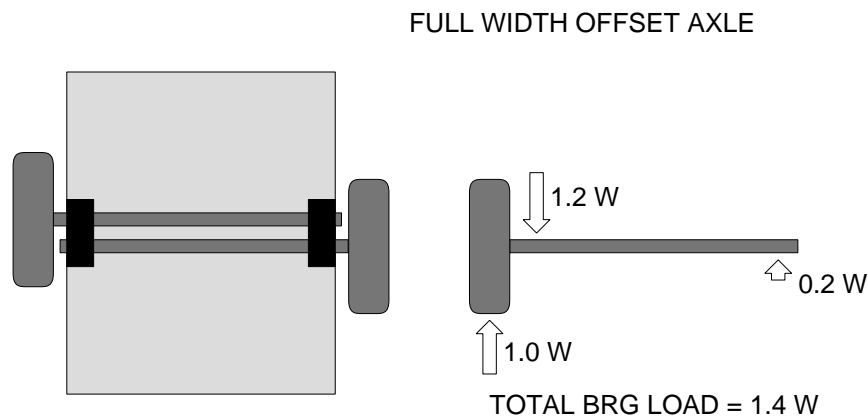


Figure 4: bearing loads in twin offset axles.

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great accuracy in manufacture. Figure 3 shows the bearing loads of the usual way of doing it and Figure 4 shows the DTU method. You will see that bearing loads are 30% lower. Surprisingly there is no extra steel required either because there would have to be some steel to support the middle bearings anyway.

## Easy to make design.

These axles are designed to be constructed without any special tools and jigs, and without any hard-to-get materials. The only tools which you must have are a simple welder, a hacksaw, and a hammer. You might find that a couple of 4" or a 5" G clamps (or something like it) are useful too. We have deliberately designed the axle so that drilling is not required.

We have tested many of these axles in Kenya and Uganda and we have had only a few failures caused by poor welding or

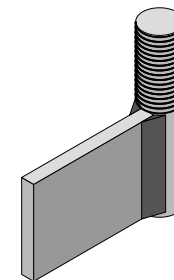


Figure 5: a welded wheel stud and strut fabrication.

incorrect material. We think that they are strong enough, but you can always find someone to break anything. To get a reasonable cost you need to experiment a bit to see how the farmers treat their carts and what they expect them to stand.

It is important to grease the bearings every few weeks.

### Cutting list and costs

Table 1 shows a cutting list for a complete axle - Recent prices of materials in Kenya are shown converted into £UK.

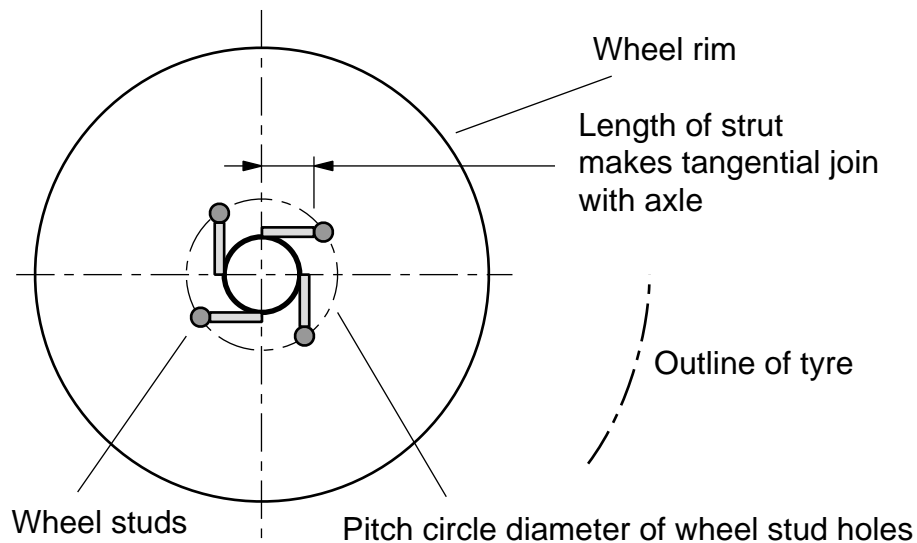


Figure 6: length of wheel strut.

### Construction step by step

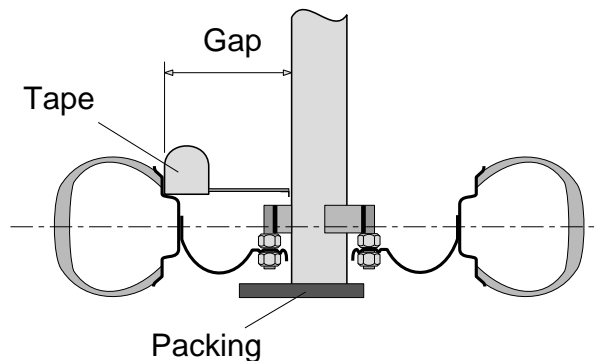
- 1) The first job, is to get all the material together and clear a space to work. Ideally you will be able to work on a flat area of concrete.
- 2) Start by making the wheel stud struts shown in Figure 5. You need to make one of these struts for every stud hole in the wheels you are going to use. Figure 6 shows how to measure the length of the struts. The struts are made from 6x40 flat bar or similar and M12 bolts 50mm or 60mm long. The flat bar should be long enough so that it meets the axle tangentially as shown in Figure 6.

TABLE 1: materials for wooden bearing twin axle.

component	material	# lengths reqd [#xmm]	total material for one axle [mm]	cost [UK£]
wheel studs	50xM12 nuts and bolts	10	10	2.60
wheel stud struts	6 x 40 flat bar	10x65	650.00	0.49
axial thrust washers	6 x 40 flat bar	8x90	720.00	0.54
axle cross bolts	75xM12 nuts and bolts	4	4	1.04
axles	1-1/2" BSP malleable iron pipe	2 x 1500	3000.00	6.00
bearing block restraint loops	R 8 re-bar	8x430	3440.00	0.56
main bearing top + bottom	100x25mm timber	4x300	1200.00	0.20
main bearing sides	50x25mm timber	4x300	1200.00	0.20
small bearing top + bottom	100x25mm timber	4x50	200.00	0.03
small bearing sides	50x25mm timber	4x50	200.00	0.03
wheel rims, tyre + tubes				25.00
			<b>TOTAL</b>	<b>36.69</b>

- 3) Once you have made these struts, screw a nut onto each one until it touches the 40x6 metal. Then put the thread through the hole in the rim and screw another nut onto the thread. Tighten this nut lightly with a spanner. Repeat for all the struts so that they all point the same way round the axle, as in Figure 6, and leave a gap for the axle.
- 4) Now centre the axle in the rim and get it square using a tape measure, a trysquare and a plank or piece of steel resting on the tyre.

To do this put the wheel rim on the floor and put the axle in place in the middle. You should put something under the end of the pipe to get it in the right position as shown in Figure 7. Get an assistant to hold the top end of the pipe and tell him to keep very still! Use your tape to measure from the outside of the pipe to the inside of the rim as

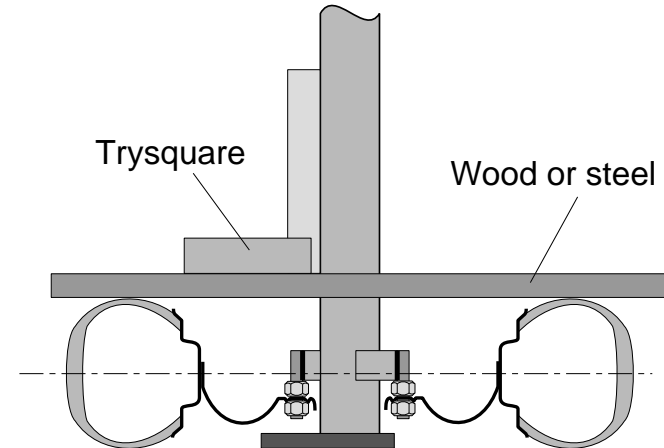


**Figure 7: using tape measure to centre axle in wheel.**

Figure 7 shows. Measure in one place and then measure the gap opposite. Move the axle pipe over until it is central. Repeat this for the other direction at right angles.

Now use the trysquare and a piece of wood to get the axle square to the rim as shown in Figure 8. You put the wood on the tyre or rim so that it is flat and you put the trysquare on the wood. You have to move the axle until it is straight with the trysquare and your assistant must hold it without moving. Check it several times - its hard to correct!

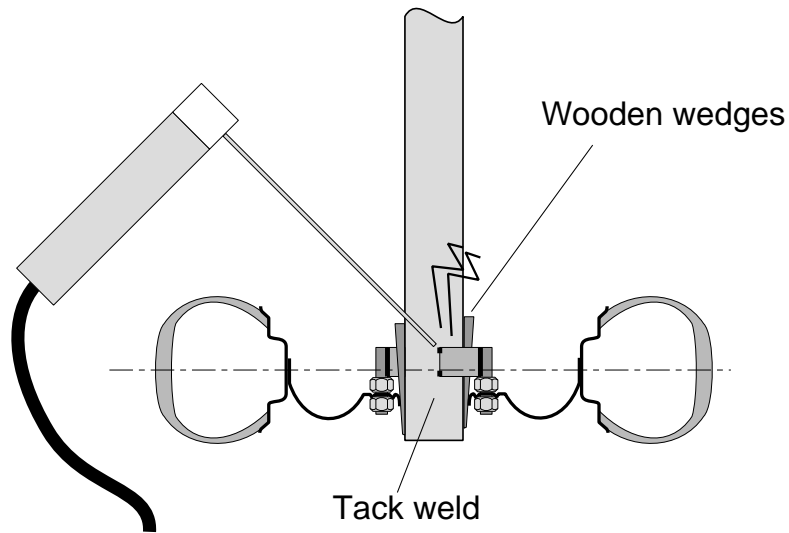
- 5) Once you have it in position, tack weld the ends of the struts to the axle tube as shown in Figure 9. (As Figure 9



**Figure 8: using trysquare to get axle square to wheel.**

shows, you can use wooden wedges to hold the axle in place in the rim.) Then weld the struts on properly. Do as much welding as you can without taking the axle out of the wheel because the metal changes size as it heats and cools and it may move out of place.

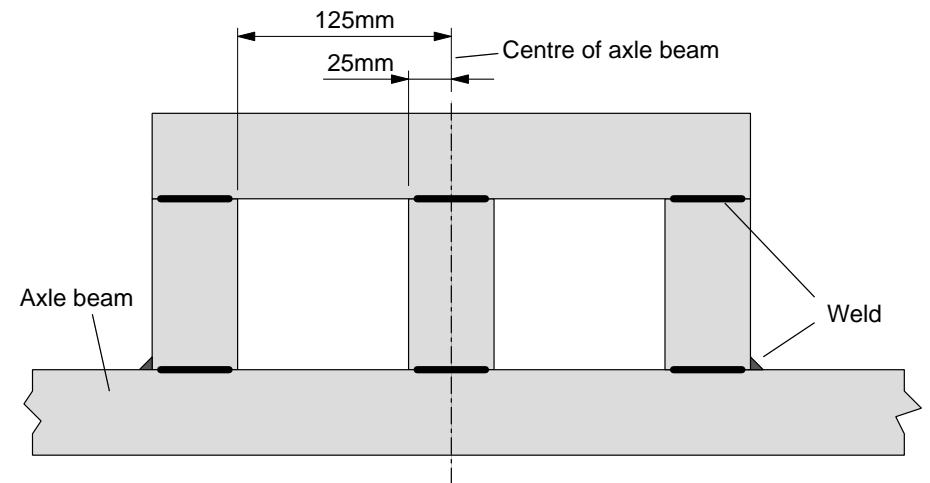
- 6) Next make the bearing blocks from 100x25mm timber and 50x25mm timber to the lengths in the cutting list.
- 7) Cut six 105mm pieces of square tubing for the bearing boxes. Mark the centre of the axle support beam of the cart



**Figure 9: tyre, wheel and axle tube during tack welding stud support struts**

and put marks on the beam 25mm and 125mm either side of this. You need to weld the 105mm pieces on to the beams as shown in Figure 10.

- 8) Fit the bearing blocks and fix them in place with loops of 8 to 12mm round bar as shown in Figure 1 and Figure 11.
- 9) Make four axial thrust washers from 40x6 or 40x3 or similar flat bar like those shown in Figure 12. You must remember to weld on a tag made of a 20mm length of bar to each ring as shown in the drawings. This makes the washers go round with the axle and stops wear in the wrong places.
- 10) Insert an axle into its large bearing but not its small bearing

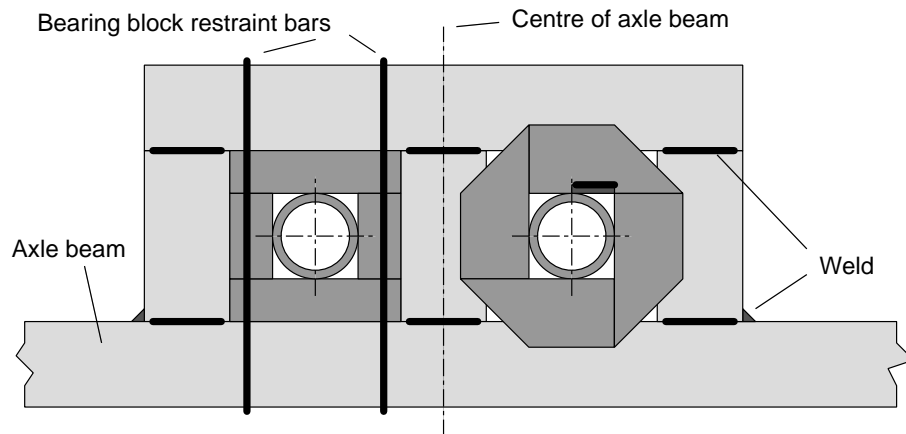


**Figure 10: position of bearing support blocks.**



and then put on one of the axial bearing washers with the tag away from the small bearing. Then push the axle all the way through until there is a 20 mm gap between the wheel stud struts and the bearing blocks. Put the second axial ring on to the axle. You should now have an axial washer either side of the small bearing as shown in Figure 13.

- 11) Now mark the position of the cross bolt holes. Remember that the nuts will have to be turned so do not make the holes too close to the washers - centre about 15mm away is fine. Use the welder to blow the holes.
- 12) Remove axles from the bearing, apply lots of grease and refit the axles, washers and cross bolts.



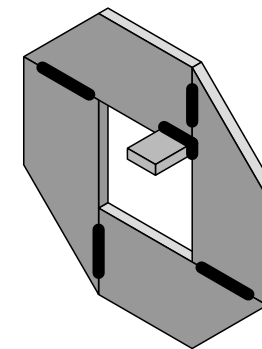
**Figure 11: axial bearing washer.**

13) Cut the excess axle off about 40mm from the washer. To mark a line around the pipe to cut it square, wrap a strong piece of paper or thin card around the pipe, get the edge in line and use the edge to guide the felt tip pen or scriber as you mark the line.

14) You've finished it!

### Other DTU cart developments

The DTU has been working on new designs of wheels, hubs and bearings to bring down their costs and make things more locally manufacturable. It has designs for twin axles with wooden bearings and twin axles with scrap or new ball bearings which do not need any machining. And it has two systems of fixed axle: one with PVC bearings and another

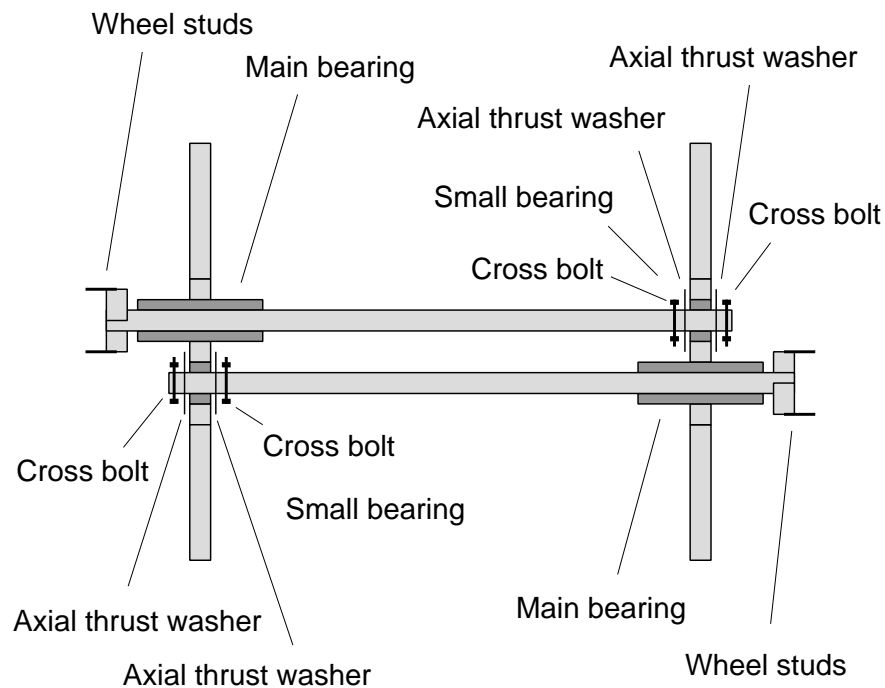


**Figure 12: axial bearing washer.**

using needle roller bearings which you make yourself. Again for these needle roller bearings no machining is necessary.

Other hub designs using, for example aluminium castings, have been in production in Nigeria and we are trying to reduce or eliminate the machining in these. Also wheel designs in steel sheet, cast aluminium and timber are under development.

The DTU has also been working on a range of cart body types for use with both donkeys and oxen. It has designs for wooden



**Figure 13: axle and bearing arrangement.**

and steel framed types. The wooden types are cheaper in material terms, but the steel framed ones are easier to make because the joints are more straightforward - nevertheless you can make either type of cart in only a few hours, if you are reasonably set up with tools and materials.

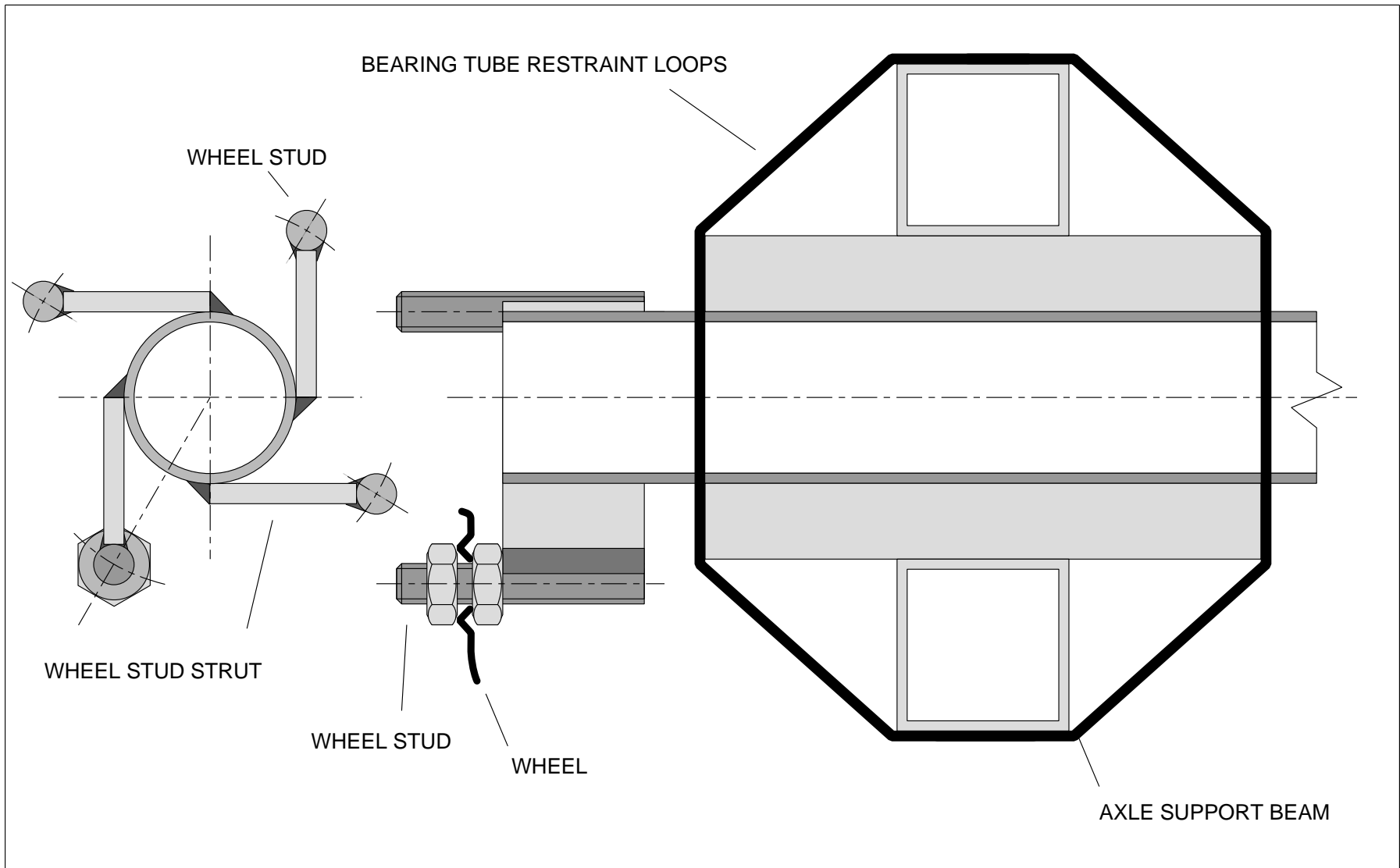
## Drawings

You will find four drawings on the next pages, the first two give a general section view of the axle. The third gives a view of the components of the axle itself and the fourth a drawing of the thrust washer.

## Acknowledgements

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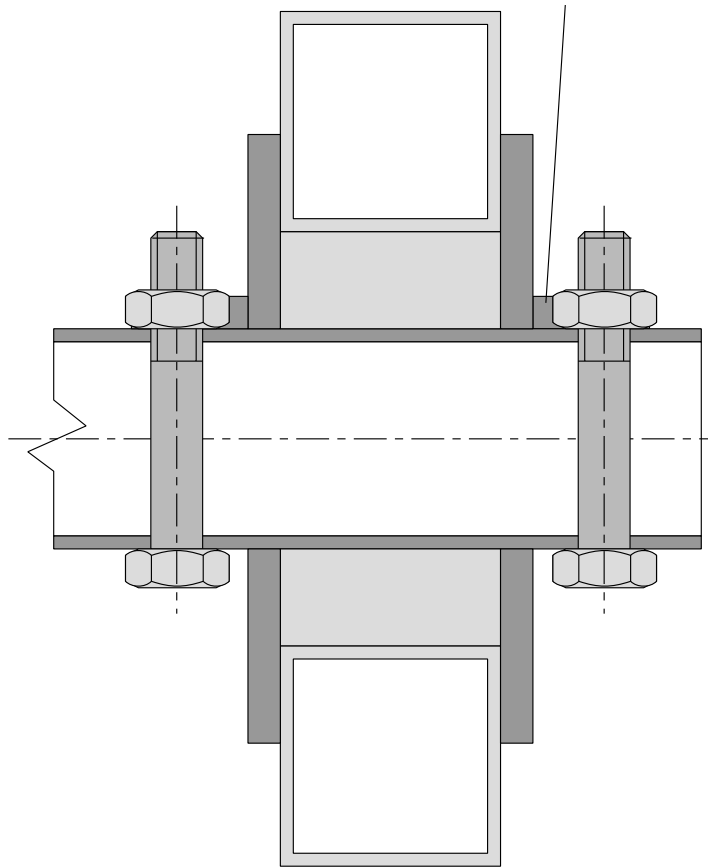
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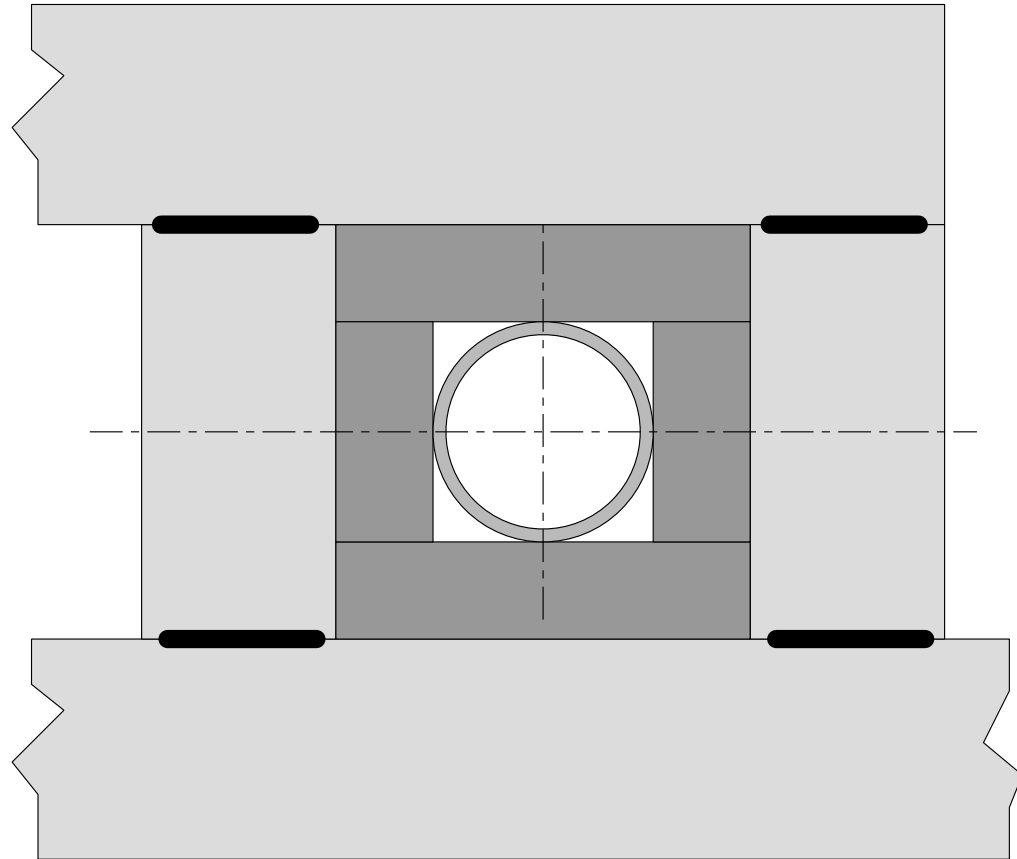
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AXIAL RESTRAINT WASHER TAG



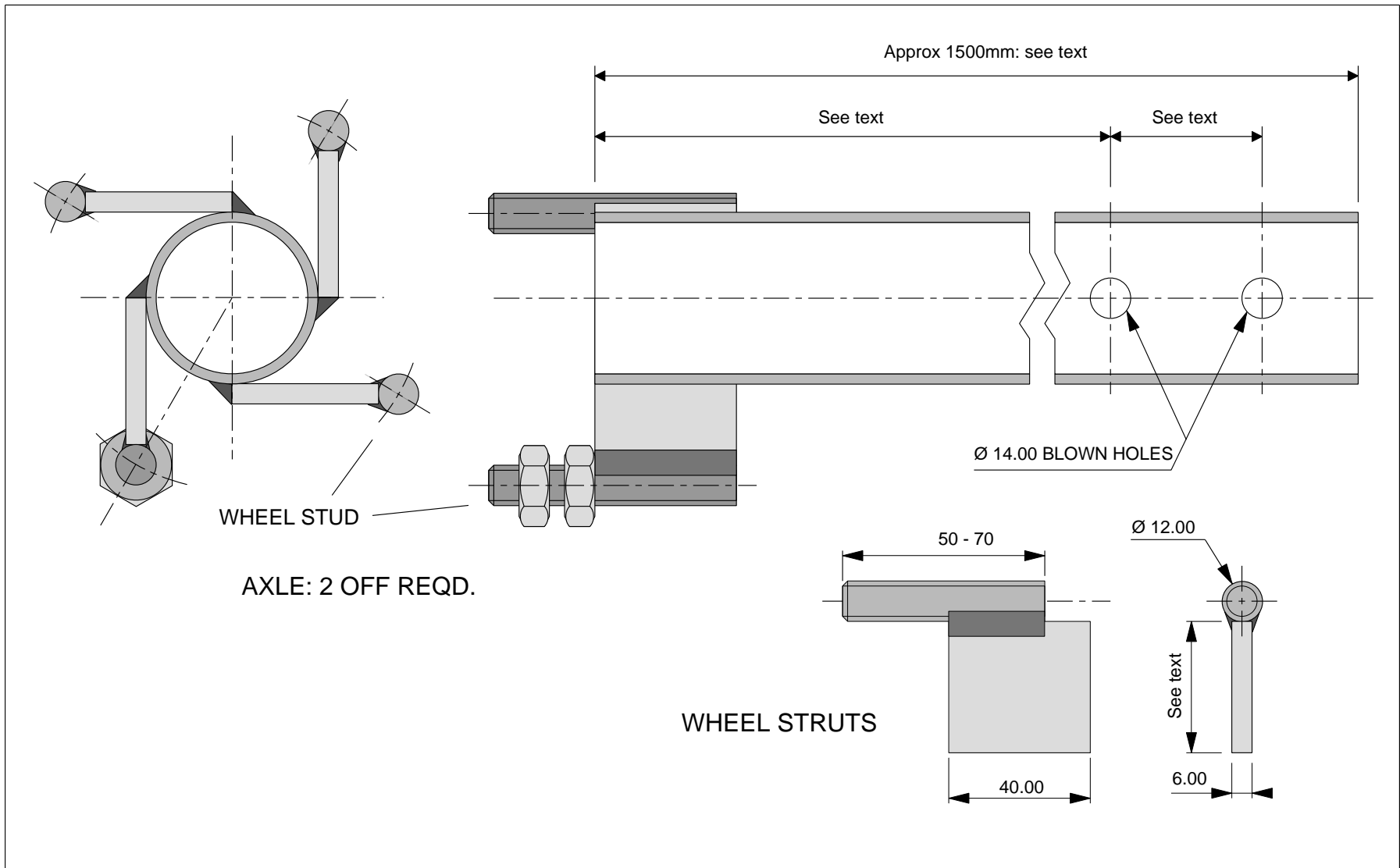
AXLE SUPPORT BEAM



END VIEW - THRUST WASHER AND BOLT REMOVED

**GENERAL ASSEMBLY DRAWING 2**

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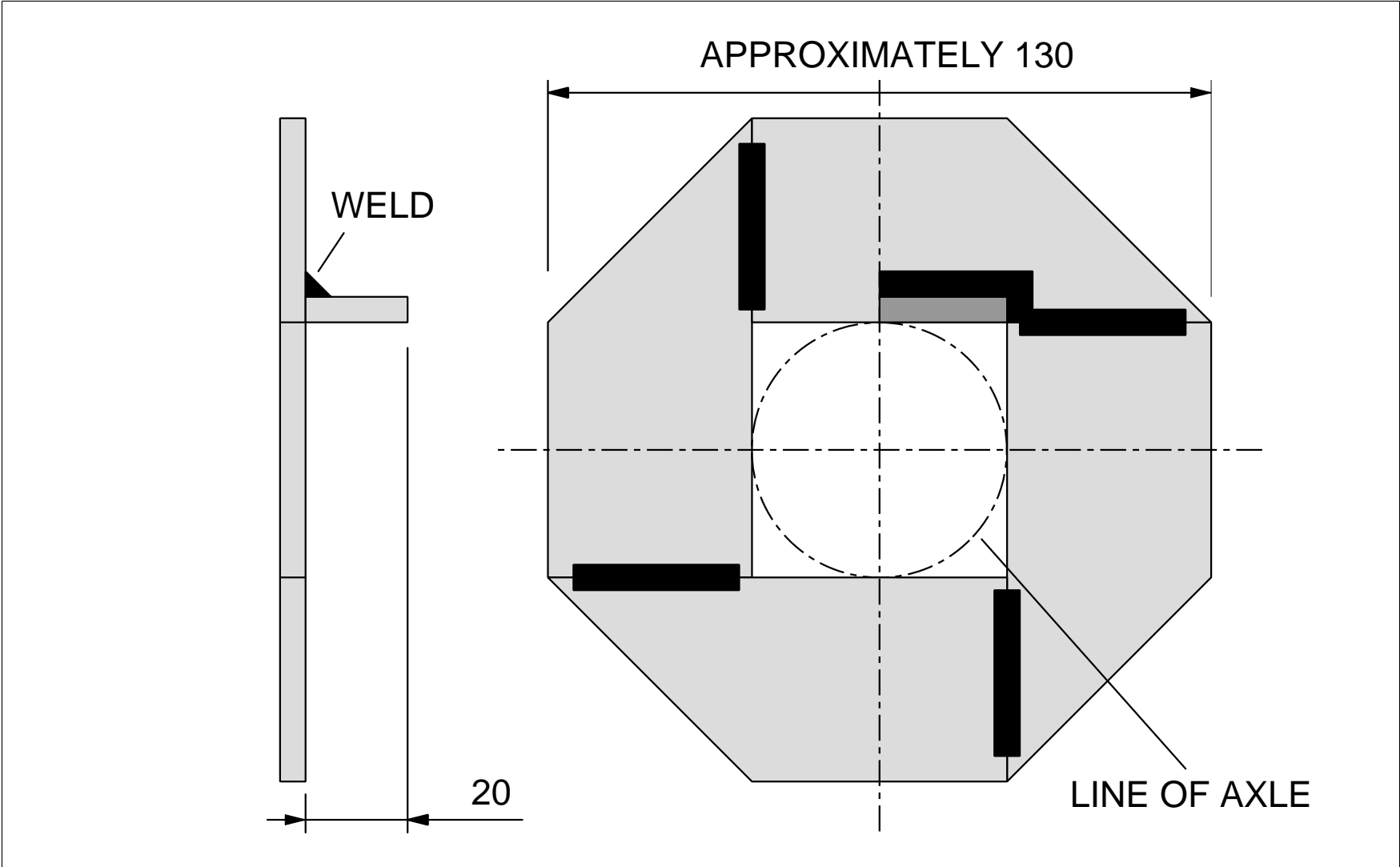


# AXLE COMPONENTS

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Dwg No.	3/4



AXIAL THRUST WASHER: 4 REQD

Scale	10mm	Title WOOD PLAIN BEARING DONKEY CART AXLE	Drawn by	CEO
Date	16-3-99		Dwg No.	4/4

KENDAT



# Low-Cost Animal Cart Programme

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## Twin Plastic Plain Bearing Axle for Donkey Carts

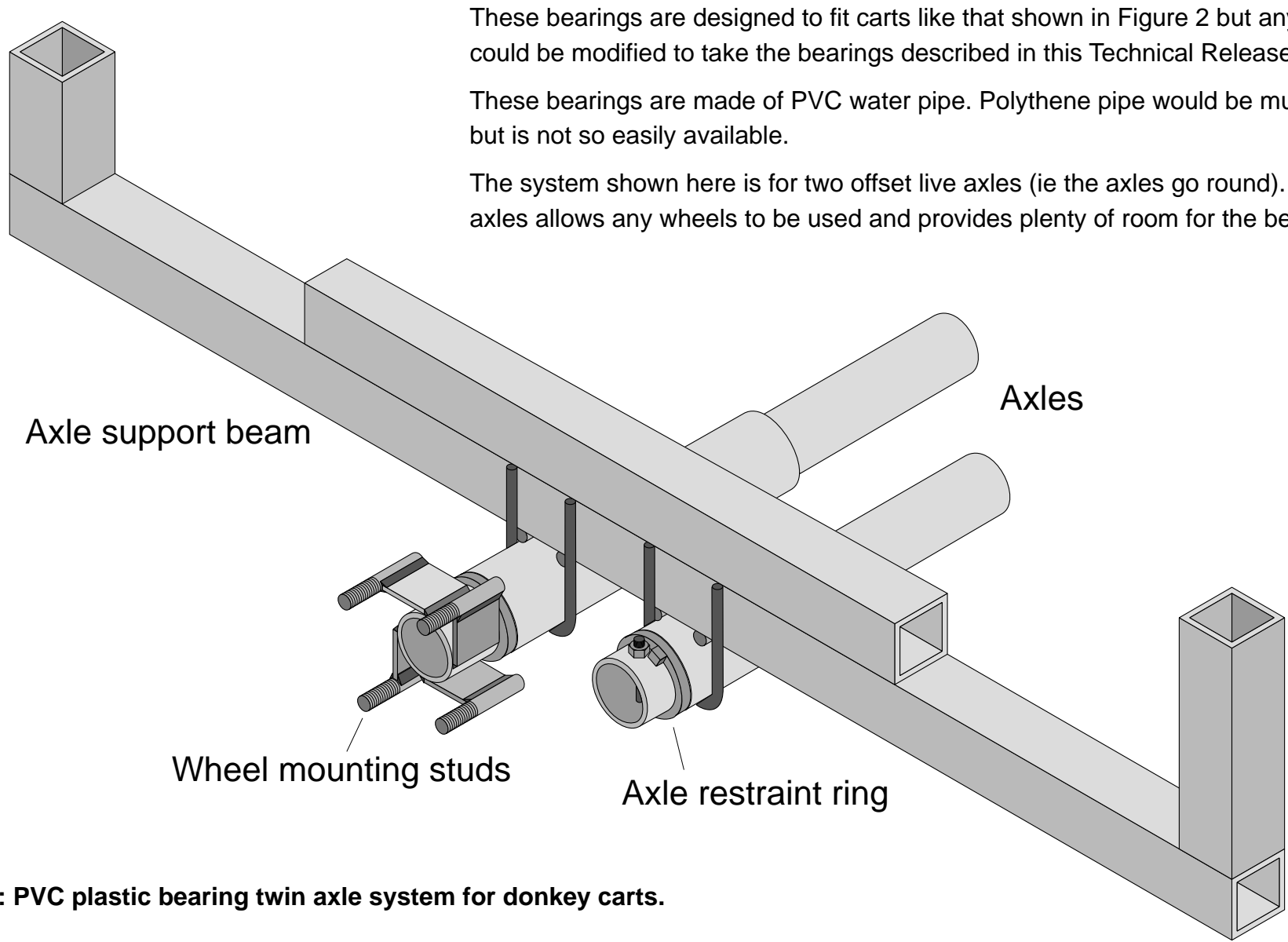
TECHNICAL

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RELEASE

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These bearings are designed to fit carts like that shown in Figure 2 but any cart could be modified to take the bearings described in this Technical Release.

These bearings are made of PVC water pipe. Polythene pipe would be much better but is not so easily available.

The system shown here is for two offset live axles (ie the axles go round). Using two axles allows any wheels to be used and provides plenty of room for the bearings.

Axle support beam

Axles

Wheel mounting studs

Axle restraint ring

**Figure 1: PVC plastic bearing twin axle system for donkey carts.**



# PVC plastic sleeve plain bearing axle system for a donkey cart.

## Introduction

In this booklet we tell you how to make an axle system for a simple donkey cart from round steel tube and PVC plastic pipe. The instructions do not cover how to make the cart itself - you

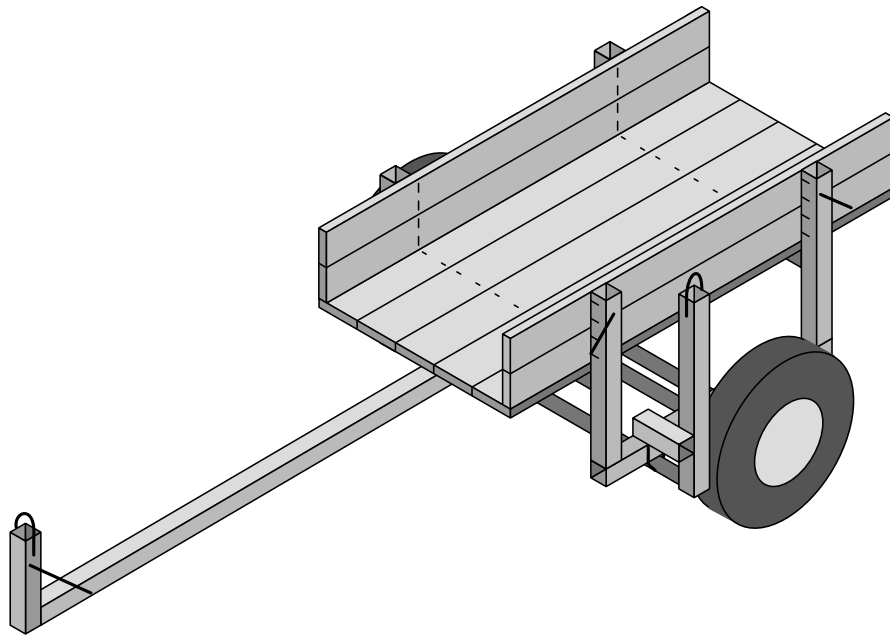


Figure 2: DTU donkey cart fitted with twin axles and PVC bearings.

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will need to read other Technical Releases from us to find out how to make the carts.

You should find that you can make the axle system for about £50 including the wheels, tubes and tyres. This cost will depend on the cost of the materials and labour. Once you get organised, two men can probably make and fit one cart with axles in half a day. This is quite a lot faster than it takes to find and a scrap car axle and it will be much cheaper.

In other booklets in this series you can find out how to make other low-cost axle systems and carts.

CONVENTIONAL HALF LENGTH AXLE

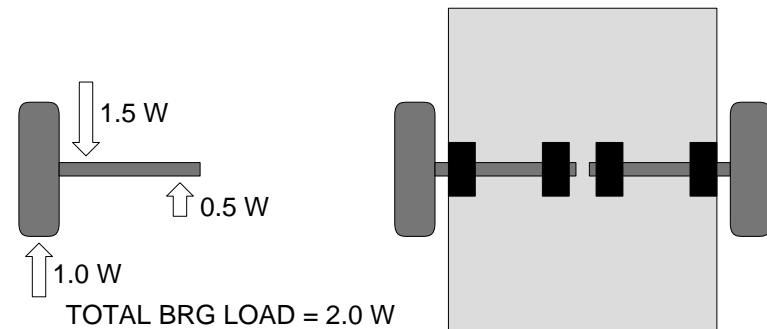


Figure 3: bearing loads in conventional half shaft axle.

## Why have twin axles?

There are two types of axle: fixed or stub axle - the wheel hub rotates on the stationary axle; live axle - the axle revolves in stationary bearings.

With the stub axle types the bearings must be inside the wheel. This is easy with expensive ball bearings but more difficult with cheap wooden bearings. You need to make them quite long to stop wheel wobble and so they stick out of the wheel. It is also quite difficult to make without jigs and special tools. If you really want that type we have quite a good system using PVC tube for the bearing. We can send you a Technical Release on how to do it.

Twin axles allow much bigger bearings and do not require great

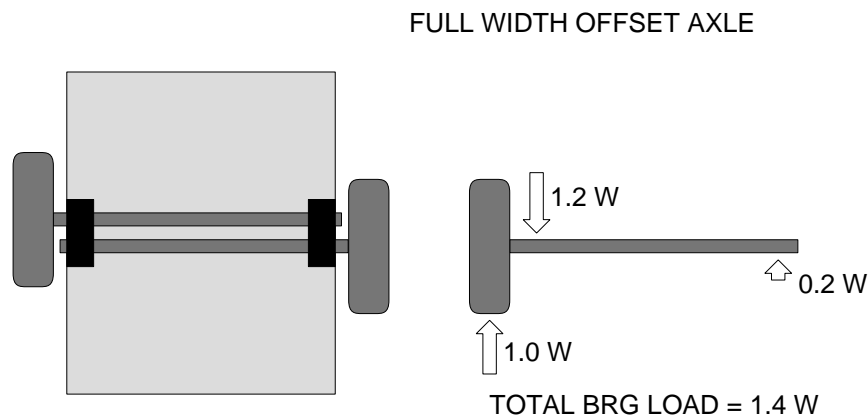


Figure 4: bearing loads in twin offset axles.

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accuracy in manufacture. Figure 3 shows the bearing loads of the usual way of doing it and Figure 4 shows the DTU method. You will see that bearing loads are 30% lower. Surprisingly there is no extra steel required either because there would have to be some steel to support the middle bearings anyway.

## Easy to make design

These axles are designed to be constructed without any special tools and jigs, and without any hard-to-get materials. The only tools which you must have are a simple welder, a hacksaw, and a hammer. You might find that a couple of 4" or a 5" G clamps (or something like it) are useful too. We have deliberately designed the cart so that drilling is not required.

You will see that there are no mitres or complicated angles or joints to cut when making the axles either, so you save time. Also the exact lengths of the components are not very critical -

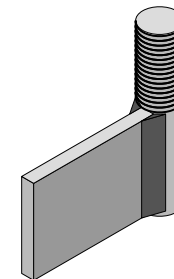
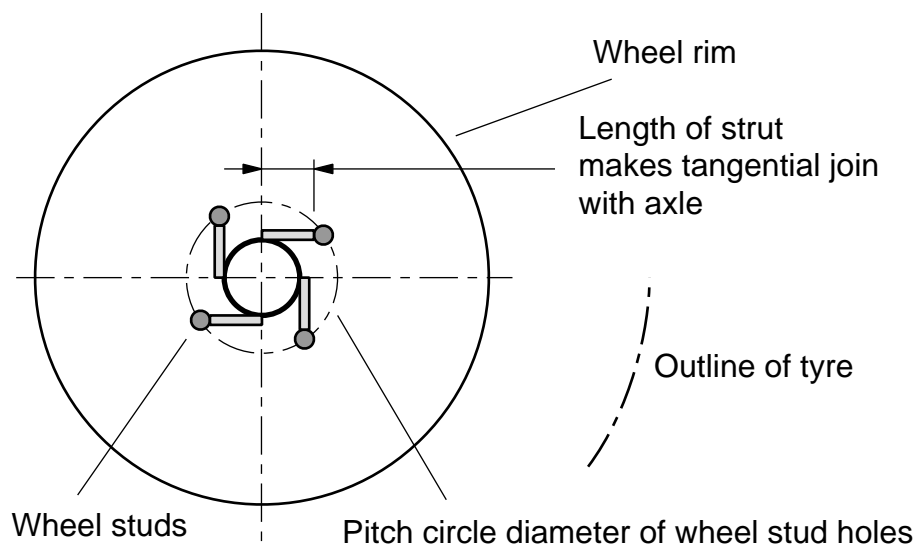


Figure 5: a welded wheel stud and strut fabrication.

again it saves a little time, but you will find that the axles look better if you take a little trouble to get things square and even etc and welding is easier with good square ends. It is much better to use a try square to mark the position of a cut than guess. In the instructions we have described how to mark pipe so you can cut it accurately.

We have tested many of these axles in Kenya and Uganda and we have had only a few failures caused by poor welding or incorrect material ie too thin. We think that they are strong enough, but you can always find someone to break anything. Really to get a reasonable cost you need to experiment a bit to



**Figure 6: length of wheel strut.**

see how the farmers treat their carts and what they expect them to stand.

It is also important to check the plastic sleeve is not worn through and to grease it every few weeks.

### Cutting list and costs

Table 1 shows a cutting list for a complete axle - Recent prices of materials in Kenya are shown converted into £UK.

### Construction step by step

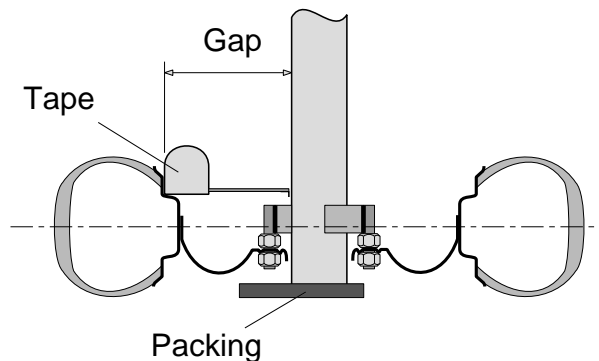
1) The first job, is to get all the material together and clear a

**TABLE 1: 50x50 RHS vestigial donkey cart.**

component	material	# lengths reqd [#xmm]	total material for one axle [mm]	cost [UK£]
wheel studs	50xM12 nuts and bolts	10	10	2.60
wheel stud struts	6 x 40 flat bar	10x65	650.00	0.49
axial thrust rings	10 x 10 square bar	4 x 200	800.00	0.25
pipe clips	50 mm pipe clips	4	4	2.40
axle cross bolts	75xM12 nuts and bolts	4	4	1.04
axles	1-1/2" BSP malleable iron pipe	2 x 1500	3000.00	6.00
hub outer tube	2 BSP malleable iron pipe	2x200	400.00	0.95
plastic bearing sleeves	1 1/2" or 2" PVC plastic pipe	2x300+2x100	800.00	0.53
wheel rims, tyre + tubes				25.00
			<b>TOTAL =</b>	<b>39.25</b>

space to work. Ideally you will be able to work on a flat area of concrete.

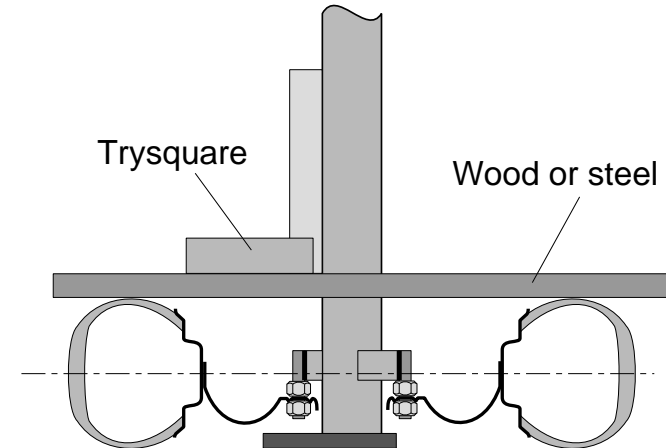
- 2) Start by making the wheel stud struts shown in Figure 5. You need to make one of these struts for every stud hole in the wheels you are going to use. Figure 6 shows how to measure the length of the struts. The struts are made from 6x40 flat bar and M12 bolts 50mm long. The flat bar should be long enough so that it meets the axle tube tangentially as shown in Figure 6.
- 3) Once you have made these struts, screw a nut onto each one until it touches the 40x6 metal. Then put the thread through the hole in the rim and screw another nut onto the thread. Tighten this nut lightly with a spanner. Repeat for all the struts so that they all point the same way round the axle, as in Figure 6, and leave a gap for the axle.



**Figure 7: using tape measure to centre axle in wheel.**

- 4) Now centre the axle in the rim and get it square using a tape measure, a trysquare and a plank or piece of steel resting on the tyre.

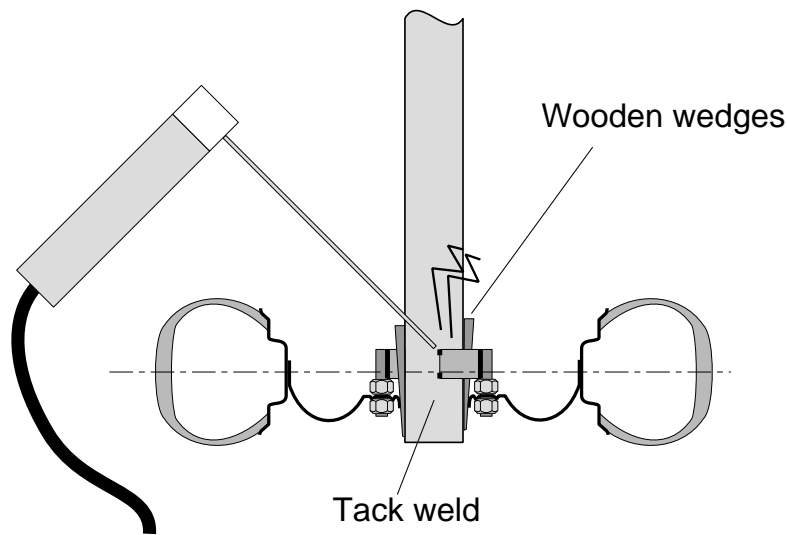
To do this put the wheel rim on the floor and put the axle in place in the middle. You should put something under the end of the pipe to rest it on to get it in the right position as shown in Figure 7. Get an assistant to hold the top end of the pipe and tell him to keep very still! Use your tape to measure from the outside of the pipe to the inside of the rim as Figure 7 shows. Measure in one place and then measure the gap opposite. Move the axle pipe over until it is central. Repeat this for the other direction at right angles.



**Figure 8: using trysquare to get axle square to wheel.**

Now use the try-square and a piece of wood to get the axle square to the rim as shown in Figure 8. You put the wood on the tyre or rim so that it is flat and you put the try-square on the wood. You have to move the axle until it is straight with the try-square and your assistant must hold it without moving. Check it several times - its hard to correct!

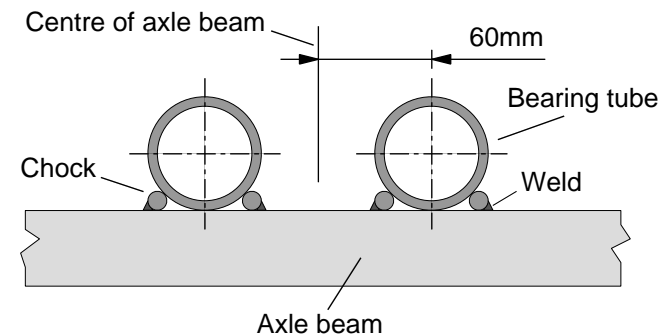
- 5) Once you have it in position, tack weld the ends of the struts to the axle tube as shown in Figure 9, then weld the struts on properly. Do as much welding as you can without



**Figure 9: tyre, wheel and axle tube during tack welding stud support struts**

taking the axle out of the wheel because the metal changes size as it heats and cools and it may move out of place.

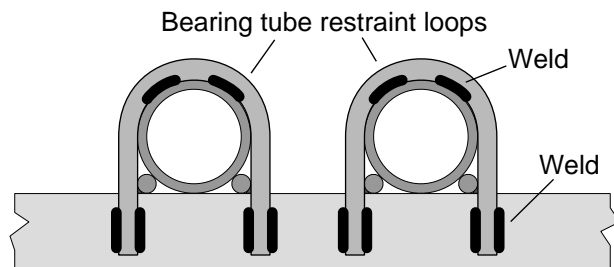
- 6) Next make the bearing tubes from 2" round pipe to the lengths in the cutting list. To mark a line around the pipe to cut it square, wrap a strong piece of paper or thin card around the pipe, get the edge in line and use the edge to guide the felt tip pen or scribe as you mark the line.
- 7) Cut eight 50mm pieces of 8 to 12mm round bar for the bearing tube chocks. Mark the centre of the axle support beam of the cart and put marks on the beam 60mm either side of this. You need to weld the chocks on to the beams so that the bearing tubes just sit nicely in the space between the chocks as shown in Figure 10.
- 8) Fix the axle bearing tubes with loops of 8 to 12mm round bar as shown in Figure 1 and Figure 11. Do not weld the



**Figure 10: position of bearing tubes and chocks.**

bearing tubes directly to the axle support beam. The bearing tubes must be slightly flexible so that they can align themselves with the other bearing on the same axle.

- 9) Make four axial rings of 10 to 12mm square or round bar which just go over the axles. Square bar is better but round will do. You must remember to weld on a tag made of a 15mm length of bar to each ring as shown in the drawings. This makes the rings go round with the axle and stops wear in the wrong places. Put a ring on each axle so the tag goes between two stud support struts.
- 10) Insert an axle into its bearing tubes and push right through until the axial ring touches the bearing tube and then put the second axial ring on.
- 11) Now mark the position of the cross bolt hole. Remember that the nut will have to be turned so do not make the hole too close to the ring - centre about 15mm away is fine. Use



**Figure 11: position of bearing tubes and chocks.**

the welder to blow a hole through for the bolt. Of course a hole will have to be blown through on the other side of the axle too.

- 12) Cut pieces of PVC tube to lengths shown in the cutting list and either cut along their length or cut around like a spring or screw as shown in Figure 12. Remove axles from bearing tubes, apply lots of grease, fit the PVC bearing pipes and the pie clips and refit axles. Use the pipe clips to stop the PVC pipe coming out of the bearing tubes. Tighten the cross bolts.
- 13) You've finished it!

### **Other DTU cart developments**

The DTU has been working on new designs of wheels, hubs and bearings to bring down their costs and make things more locally manufacturable. It has designs for twin axles with wooden bearings and twin axles with scrap or new ball bearings which do not need any machining. And it has two systems of fixed axle: one with PVC bearings and another



**Figure 12: cut PVC bearing tubes like spring to fit axle.**

using needle roller bearings which you make yourself. Again for these needle roller bearings no machining is necessary.

Other hub designs using, for example aluminium castings, have been in production in Nigeria and we are trying to reduce or eliminate the machining in these. Also wheel designs in steel sheet, cast aluminium and timber are under development.

The DTU has also been working on a range of cart body types for use with both donkeys and oxen. It has designs for wooden and steel framed types. The wooden types are cheaper in material terms, but the steel framed ones are easier to make because the joints are more straightforward - nevertheless you can make either type of cart in only a few hours, if you are reasonably set up with tools and materials.

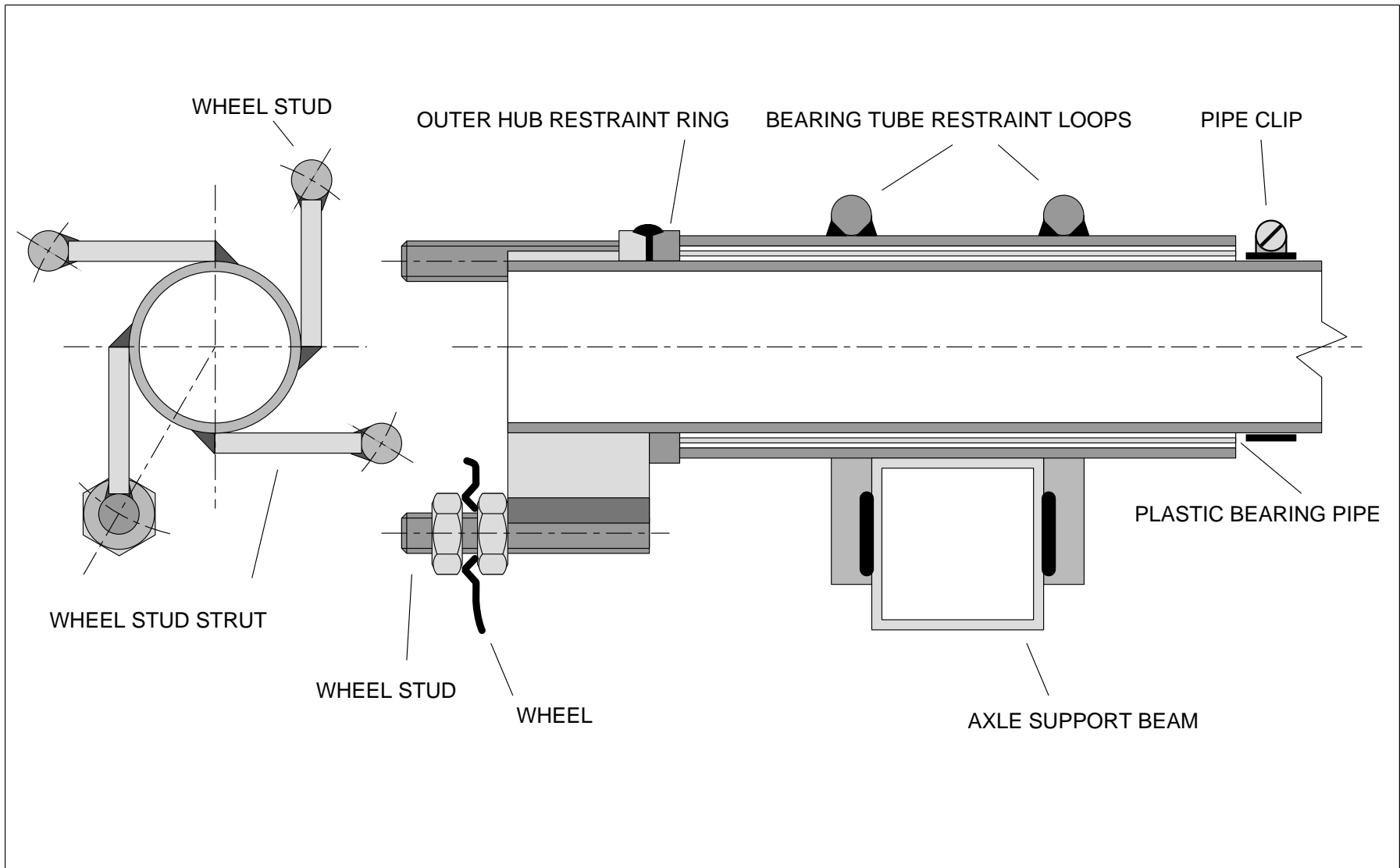
## **Drawings**

You will find four drawings on the next pages, the first two give a general section view of the axle. The third gives a view of the components of the axle itself and the fourth a view of the bearing tube and PVC bearing sleeve.

## **Acknowledgements**

The DTU is grateful to the DFID (British Government) for the financial support necessary to carry out the research and development project under which this product was developed.

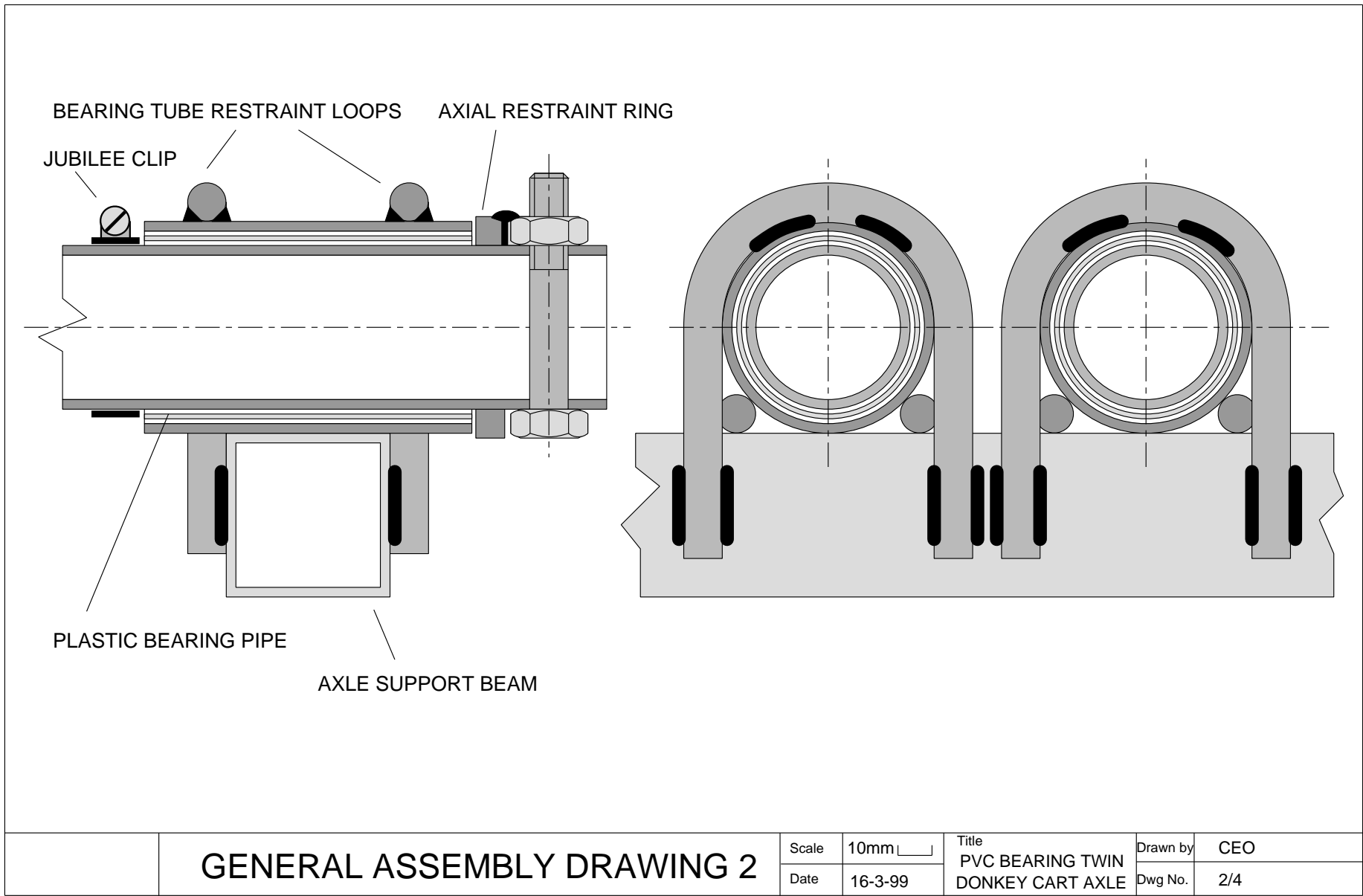
The DTU would also like to thank Dr Pascal Kaumbutho of KENDAT in Kenya and Mr Joseph Mugaga of TOCIDA in Tororo, Uganda for their very considerable help with this project. A large number of other people and organisations have contributed to the success of the project, most notably Mr Anthony Ndungu in Kajiado Kenya, Mr JD Kimani in Kikuyu Kenya and Mr Joseph Gitari in Wanguru Kenya in whose workshops most of the development work of this project was performed. Thanks are due also to Mr Stanley Lameria in Kajiado, Mr Patrick Gitari in Wanguru and Mr Mathew Masai in Machakos for their assistance.

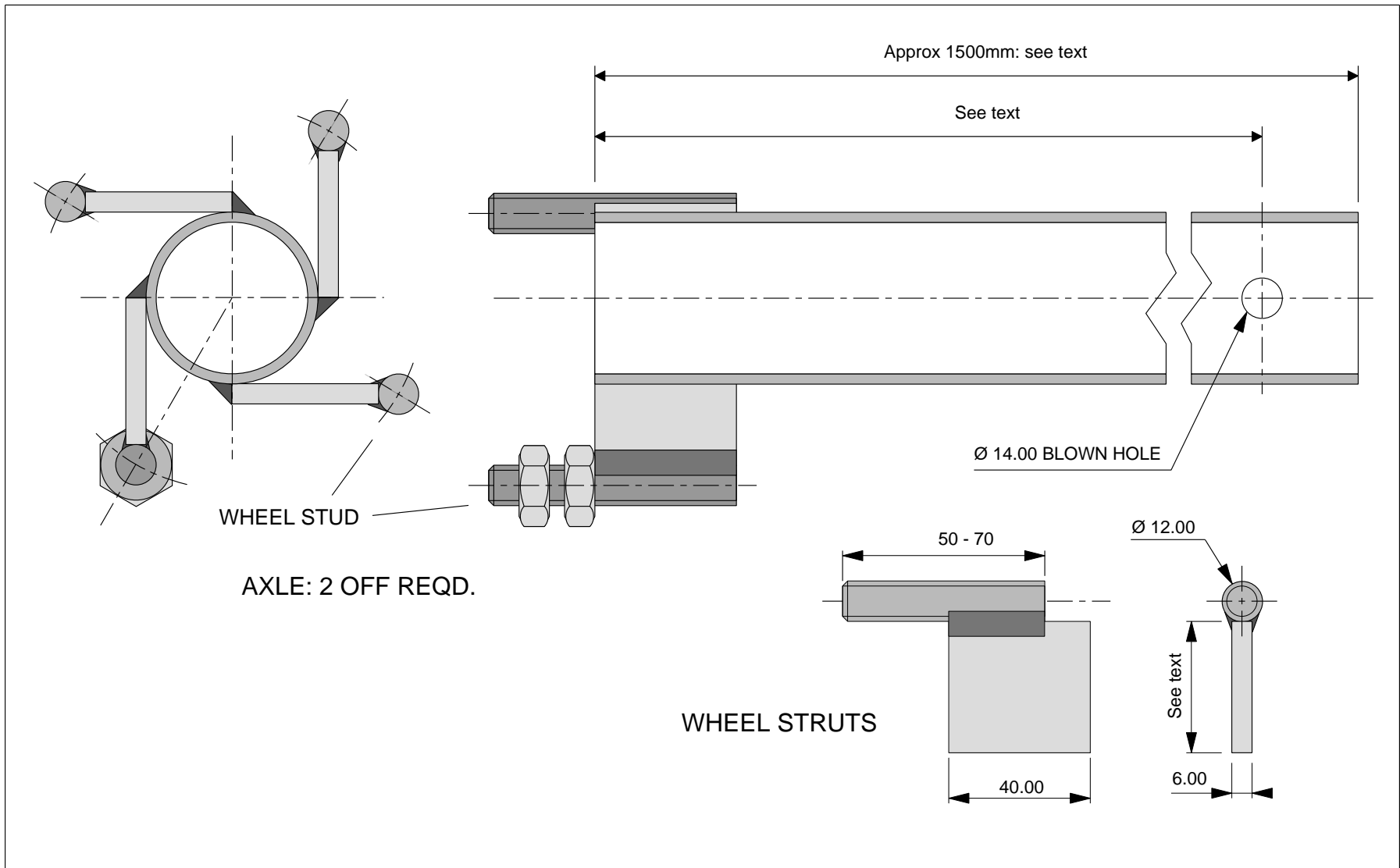


**GENERAL ASSEMBLY DRAWING 1**

Scale	10mm <input type="checkbox"/>	Title PVC BEARING TWIN DONKEY CART AXLE	Drawn by	CEO
Date	16-3-99		Dwg No.	1/4



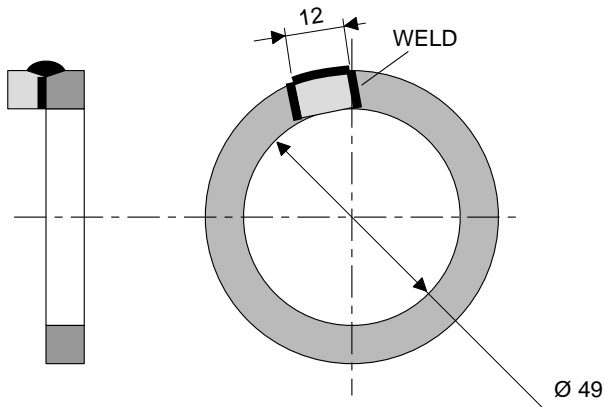
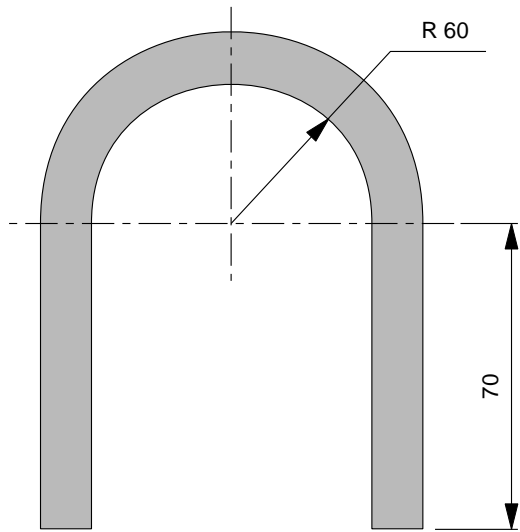




# AXLE COMPONENTS

Scale	10mm [ ]	Title PVC PLAIN BEARING DONKEY CART AXLE	Drawn by	CEO
Date	29-12-96		Dwg No.	3/4

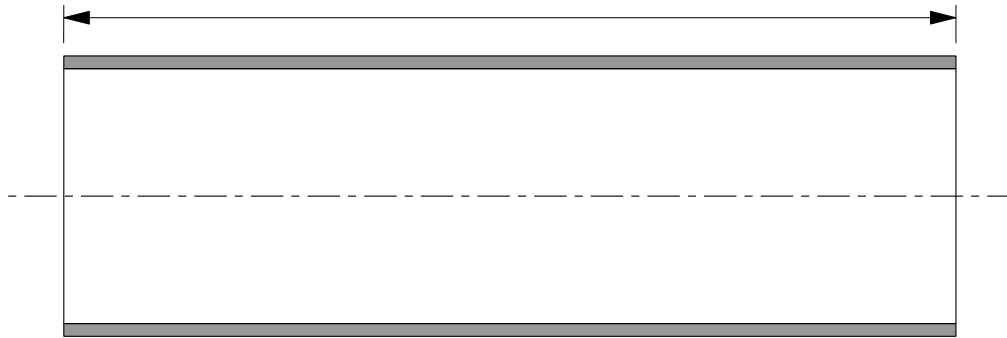
BEARING TUBE SUPPORT LOOPS



AXIAL RESTRAINT RING

HUB TUBE 2" BSP

300: 2 OFF and 100: 2 OFF



PLASTIC BEARING PIPE (SEE TEXT)

300: 2 OFF and 100: 2 OFF



BEARING COMPONENTS

Scale	10mm <input type="checkbox"/>	Title PVC PLAIN BEARING DONKEY CART AXLE	Drawn by	CEO
Date	16-3-99		Dwg No.	4/4

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# **Animal Cart Programme**

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## Making a flatbit for drilling holes in wood

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## Making a Flatbit.

This type of drill bit can be made in a few minutes and will drill holes well in wood and soft metal such as copper and aluminium. If it is hardened it will work in steel as well.

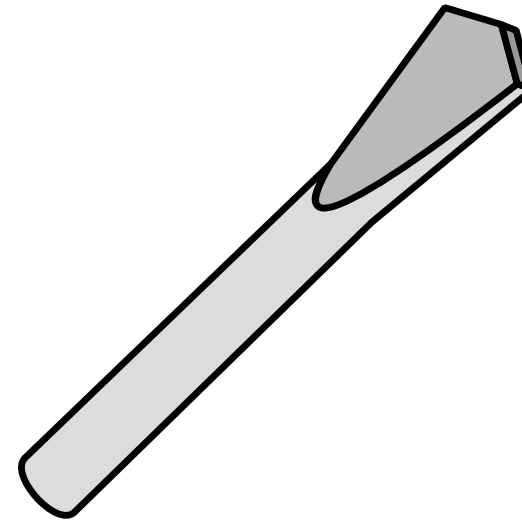


Figure 1: flat bit for drilling holes in wood.

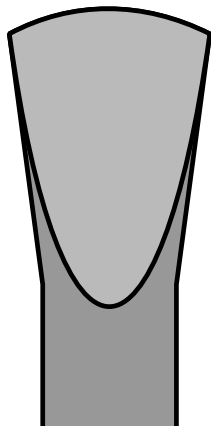


Figure 2: flatten end of rod by hammering.

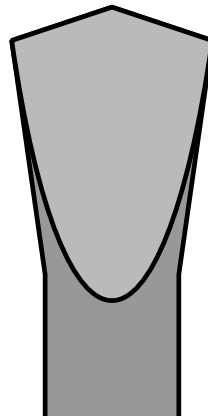
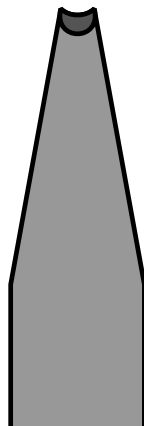


Figure 3: file sharp edges and point.

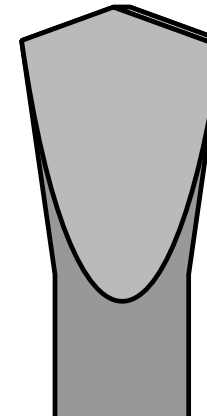
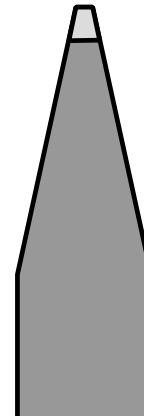
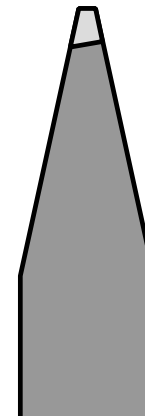


Figure 3: file cutting edges and relief angle.



## Making a flatbit

Flatbits for drilling wood are easy to make and quite useful because you can make them very long and drill holes in quite awkward places. Of course you do need something to turn the bit - like a wheelbrace or a 'drill'. You can use a bent piece of steel like that shown in Figure 2 and weld the flatbit to the end of the rod. To make it comfortable to push you could make a handle from a piece of pipe with an end on it or by cutting it and bending a bit of the pipe over. Another way is by winding a spring of say 6mm round bar around the rod and then bending the end of the wire over as we have shown.

If you can harden the cutting edges of a flatbit you can use it to drill holes in metal too as long as you do not want to drill deep



**Figure 2: using bent steel rod to rotate drill.**

holes - it tends to wander if the depth is more than the diameter.

To get hard cutting edges you will need to use 'silver steel' or spring steel, which you will have to harden and temper if you can. To get it very hard, heat until bright red/ orange hot and plunge into water. It will then be very hard and brittle so if you can you need to reheat slowly at a point two inches from the tip. You will see the steel take on a range of colours and just when the cutting edges look yellow or straw coloured, re-plunge into water. This is a fairly skilled operation but it does give a good result if you get it right.

Another way to get a harder cutting edge is to use a hardfacing welding electrode. This will not be as good as the heat treated steel above but it will be better than mild steel.

Lastly some concrete reinforcing bar called 'high yield' may be a bit harder.

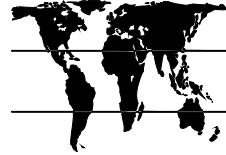
- 1) To make the bit, get some steel bar of the same size as the hole you want to make, or a little bit smaller. Then hammer the end to flatten it a little (a bit like a screwdriver). The drawing shows what we mean.
- 2) Then file the end pointed and finally sharpen the cutting edges.
- 3) That's it!

## **Acknowledgements**

This Technical Release was written as part of a three year animal cart development project in Kenya and Uganda.

The DTU is grateful to the DFID (British Government) for the financial support necessary to carry out the research and development project.

The DTU would also like to thank Dr Pascal Kaumbutho of KENDAT in Kenya and Mr Joseph Mugaga of TOCIDA in Tororo, Uganda for their very considerable help with this project. A large number of other people and organisations have contributed to the success of the project, most notably Mr Anthony Ndungu in Kajaiido Kenya, Mr JD Kimani in Kikuyu Kenya and Mr Joseph Gitari in Wanguru Kenya in whose workshops most of the development work of this project was performed. Thanks are due also to Mr Stanley Lameria in Kajaiido, Mr Patrick Gitari in Wanguru and Mr Mathew Masai in Machakos for their assistance.

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# **Animal Cart Programme**

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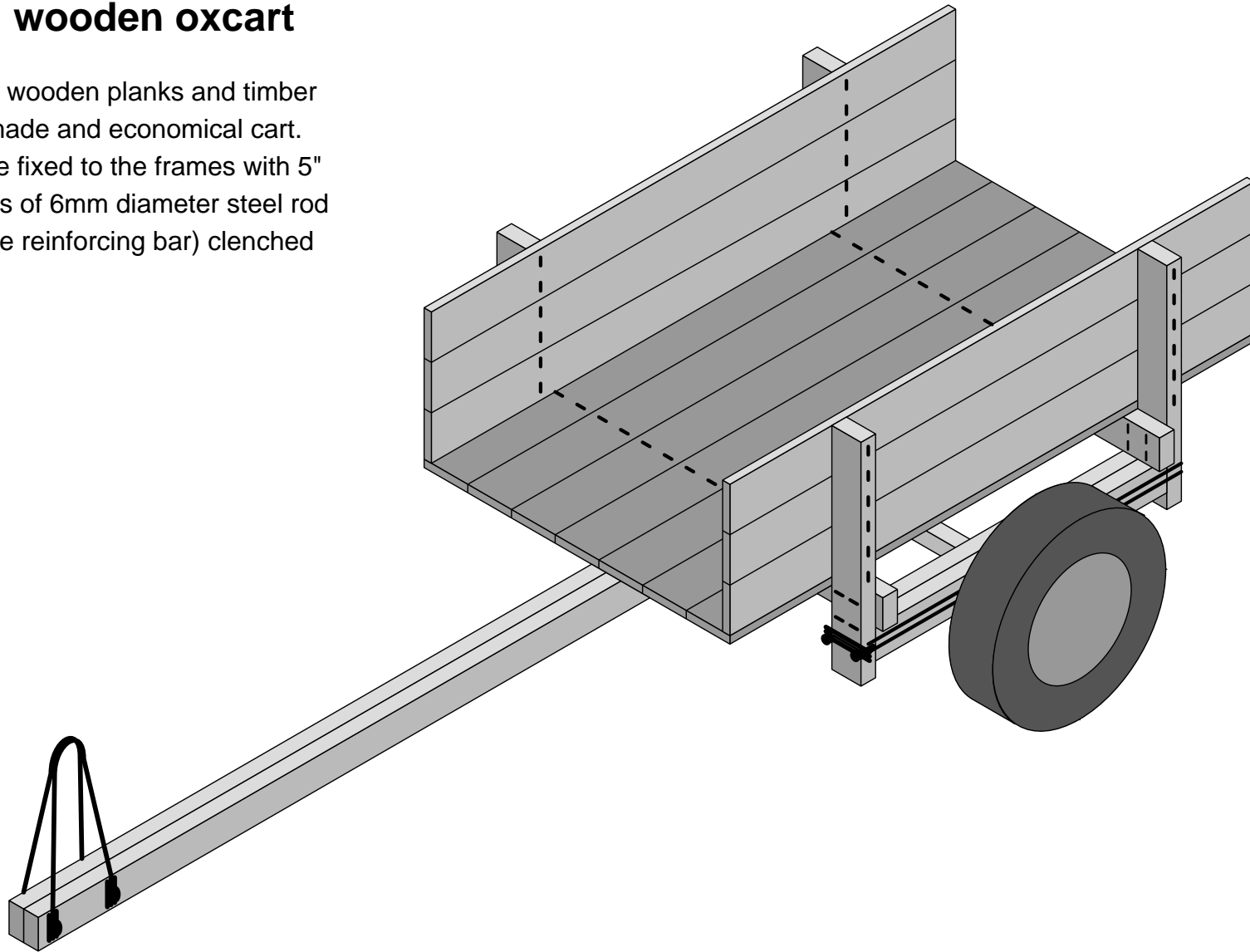
## **VESTIGIAL WOODEN FRAME 2-OX CART**

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## Figure 1: wooden oxcart

This cart uses wooden planks and timber for a quickly made and economical cart. The planks are fixed to the frames with 5" nails or lengths of 6mm diameter steel rod (small concrete reinforcing bar) clenched over.



# Ox Cart Body Made From Timber

## Introduction

This Technical Release tells you how to make a low-cost wooden cart to be pulled by two oxen. It does not cover the construction of the axle. You can use either a scrap axle from a pick-up truck or car or you can make one. We can supply a number of Technical Releases which cover different axle designs.

We have designs for fixed axles with PVC plastic bearings or roller bearings you can make yourself if you are a good welder/fabricator. And we have double axle systems using wooden

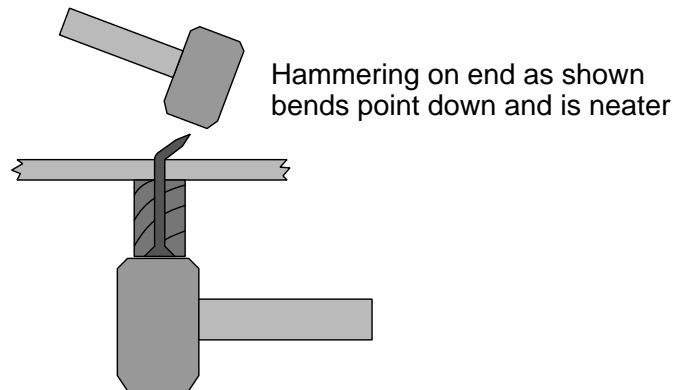


Figure 2: using two hammers to clench nail.

bearings, PVC bearings and ball bearings. These ball bearings can be new or scrap and no machining is needed.

You should find that you can make the cart body for about £ 30 depending on the cost of the materials and labour. Once you get organised, two men can make a cart body in one day. This is quite a lot faster than most carts can be made and it follows from the simplifications which we have made to the design. We've designed it to be easy to make.

## Idea Behind Design

We have designed this cart to be easy to make without lots of special tools and jigs, and without any hard-to-get materials. The only tools which you must have are a woodsaw, a hacksaw or cold chisel and a hammer and for some of the components

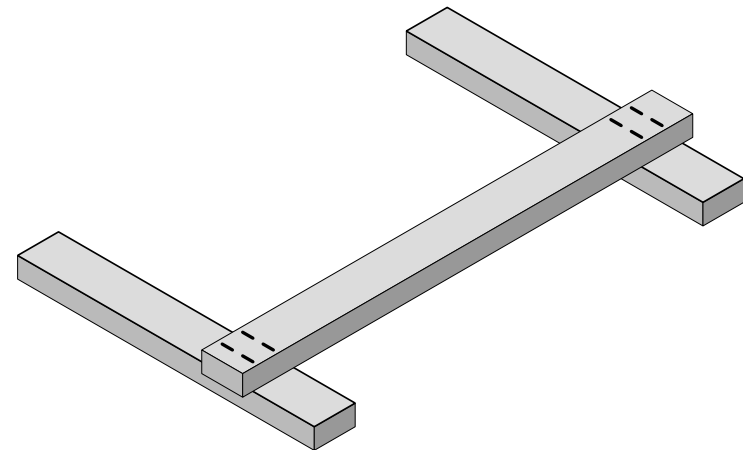
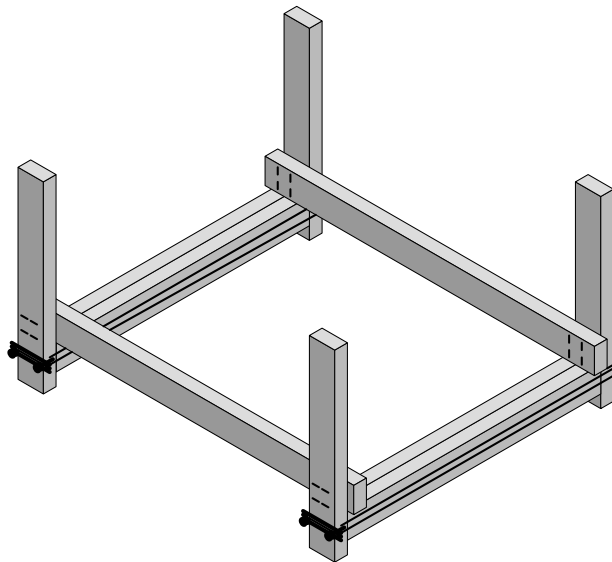


Figure 3: finished U-frame.

shown below you must be able to **weld** - there are alternative ways of making these but they are not as strong. In any case if you make an axle you will have to weld. You might find that a couple of 4" or a 5" G clamps (or something like it) are useful too. For drilling wood we have used flatbits sometimes (Figure 11). We have a Technical Release which describes how to make them.

Most of this cart is joined together using clench nailing which is a bit like riveting. You use nails which are about an inch (25mm) longer than the total thickness of the wood. You probably need to put a piece of scrap timber under the timber



**Figure 4: finished framework before planking.**

you are working on to stop the nails going into the floor. When you have put all the nails in you put a hammer against the head of each nail in turn and then knock the pointed end over as shown in figure 2. Knock the end of the nail into the timber to make it neat.

If you do not have any nails you can use 6 mm round bar. We tell you how to make joints with 6mm bar at the end of this booklet.

You will see that there are no mitres and complicated angles to

TABLE 1: cutting list for wooden oxcart.				
component	material	# lengths & length reqd [#*mm]	total material in cart [mm]	material s cost in Kenya [£]
animal shaft/ boom	100x50 r/s timber or bush pole	2x3400	6800	2.23
body frame bottoms	100x50 roughsawn timber	2x1100	2200	0.72
body frame sides	100x50 roughsawn timber	4x725	2900	0.95
axle beams	100x50 roughsawn timber	4x1000	4000	1.31
axle chocks	100x50 roughsawn timber	4x500	2000	0.66
tray planks	25x150 or similar timber	13x1800	23400	5.76
tray ends planks	25x150 or similar timber	6x1000	6000	1.48
plank fixing nails/ rivets	6" nails/ 8mm dia re-bar	13x4	6.50	3.25
body frame nails/ rivets	6" nails/ 8mm dia re-bar	4x4	2.00	1.00
axle beam ties	8-12mm dia re-bar or similar	4x2400	9600	1.76
axle fixing loops	12mm dia re-bar or similar	2x400	800	0.23
draught pole bolts	M12 bolts	4x50	4	1.04
draught pole bolt extns	12mm dia re-bar or similar	2x520	1040	0.30
draught pole vertical extn	12mm dia re-bar or similar	2x900	1800	0.53
dr. pole vertical extn bolts	M12 bolts	2x75	2	0.52
d. pole vert extn bolt extns	12mm dia re-bar or similar	2x120	240	0.07
TOTAL->				21.81

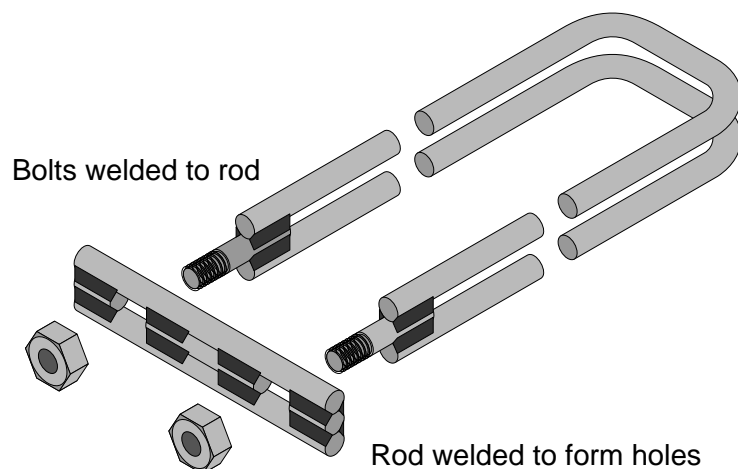
cut in the timber so you save time when making the cart. Also the exact lengths of the components are not very critical - again it saves a little time, but you will find that the carts look better if you take a little trouble to get things square and even etc.

We have tested these carts in Kenya and Uganda and we think that they are strong enough, but we cannot be sure. So treat the cart carefully at first!

### Construction step by step

Table 1 shows a cutting list for a complete cart - Recent prices of materials in Kenya are shown converted into £UK.

- 1) The first job, is to get all the materials together and clear a space to work. Ideally you will be able to work on a flat

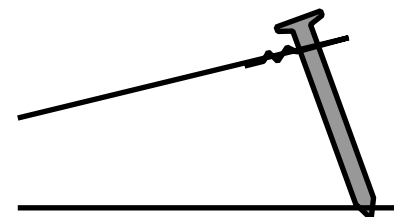


**Figure 5: U-bolts for fixing axle beams to U frames.**

area of concrete. Start by cutting the 100x50 timber into the right lengths, as in the cutting list, and then you can cut the bottom and side planks. Because timber comes in such variable sizes its best not to cut the steel components until you are sure how big they must be.

- 2) Next make up the two U-shaped front and back frames like those shown in figure 3. If you have a G clamp you can use it to hold two pieces of the frame together during nailing and clenching. It's quick and you can tap the bits with a hammer until everything is square and straight.
- 3) Next fit the axle beams in between the two U frames to make the frame shown in figure 4. The best way to join the U frames and the axle beams together strongly is to make up some big U bolts like those shown in Figure 5. These are made from 8 to 12mm round bar and some bolts. You will see from the drawing that they are made by welding rod together, not drilling holes.

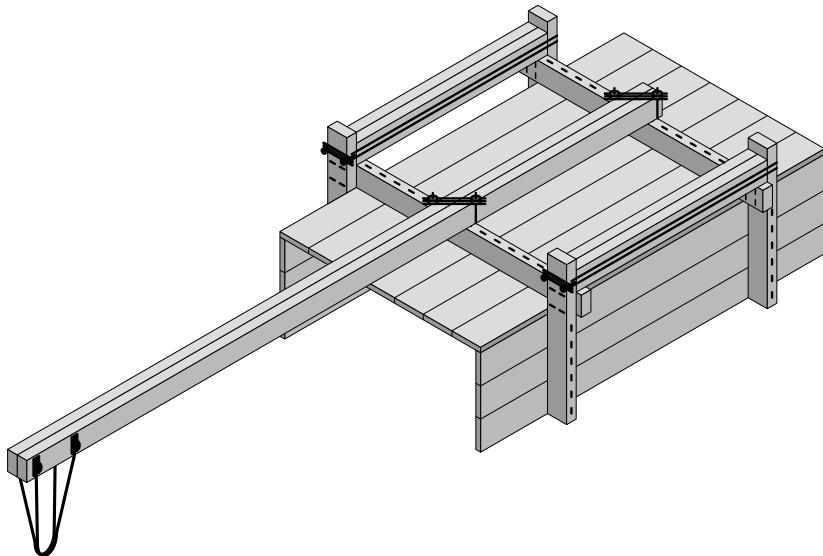
If you cannot get these U-bolts made, use some 6 mm or



**Figure 6: tightening wire by angled nailing.**

8 mm round steel bar to tie the frames and beams together. Be very careful if you twist the ends together because some wire breaks quite easily. You can tighten the wire by nailing at an angle as shown in Figure 6 it. You can also tighten the wire slightly after nailing by kinking it.

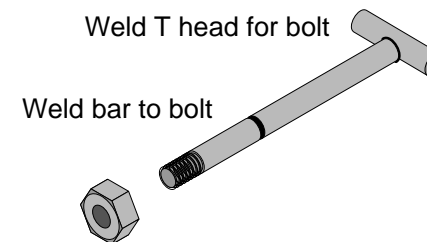
- 4) Next you can fit the side and the bottom planks with more clenched nails.
- 5) Now you need to fix the draught pole. The best way is to use a big U-bolt to fix it to each U-frame. Do not drill holes in the U-frames or the draught pole for these bolts but arrange them as shown in Figure 7. If you cannot get U-



**Figure 7: method of fixing draught pole using U-bolts.**

bolts made up you will need to fix the draught pole with wood clenched nails and wire.

- 6) The draught pole vertical extension is made from 12mm round bar. To fix it you will need to make long bolts as in Figure 8 from round bar and M12 bolts.
- 7) Nearly there! Fix the axle with more U-bolts around the axle and the axle beams as shown in Figure 9. If you are using a scrap vehicle axle you may need to weld extra pieces of steel to it to make it fit properly to the cart axle beams. Whichever axle you use you will find it stronger to nail pieces of wood to the bottom of the axle beams to stop the axle sliding along it.
- 8) Removable ends for the load tray can easily be provided in the way we have shown in Figure 10. The end is tied against the stop with rope or rubber. (Notice that there is a gap between the stop and the load tray so that the tray can be cleaned easily.



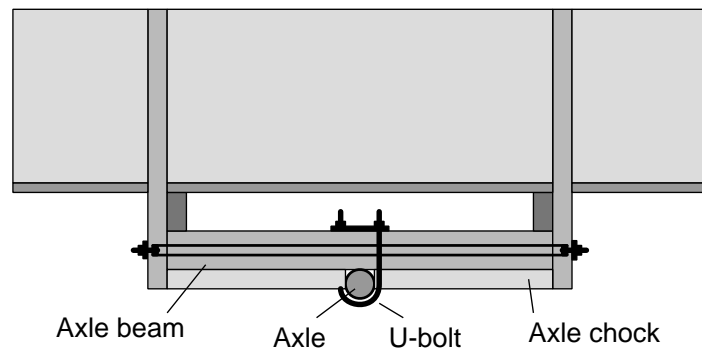
**Figure 8: method of fixing draught pole using U-bolts.**

9) Paint or creosote the cart. You've finished it!

## Modifications

There are many different versions of this cart. You can try longer or shorter carts and you can make them wider or narrower. When you change things check the length and width of the planks of wood that you will use - you do not want to find that you are two inches short of being able to get two runs of plank out of one piece of timber, or that its just too narrow and you have to fiddle about and fit in a narrow strip.

Another modification is to make the cart higher see Figure 11. This lifts the cart body and raises the draught pole reducing the required size of the vertical extension.

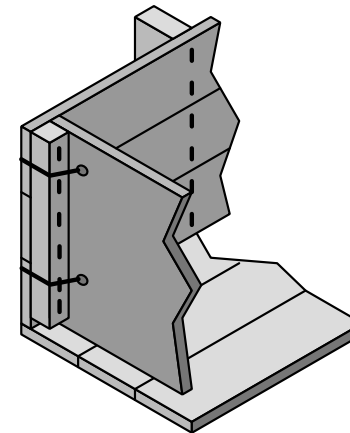


**Figure 9: chocking axle to axle beam.**

## Using 6mm bar instead of nails

You can use 6 mm round bar instead of nails. You will need 16 pieces 150 mm long for the frames and 52 pieces 175 mm long to fix the planks on. You will need to drill a 6mm hole in the wood to use this method. Then put a straight piece of 6mm diameter re-bar (concrete reinforcing bar) right through so it sticks out about 25mm both sides. Then you just knock one end over with a hammer so it lies on the surface of the wood. Next you bend the other end over. Tighten the joint using a second hammer as described above.

You can make the drill yourself if you have to - see our Technical Release on flat bits.

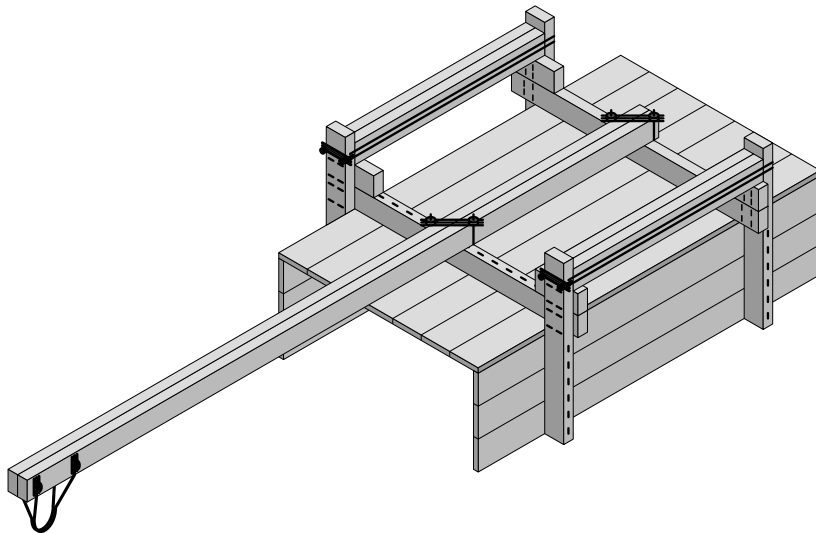


**Figure 10: method of fixing tray ends with rubber or rope**

## Other DTU cart developments

The DTU has been working on a range of cart body types for use with both donkeys and oxen. It has several designs for steel framed types. The wooden types are cheaper in material terms, but the steel framed ones are easier to make because the joints are more straightforward - nevertheless you can make either type of cart in only a day or so if you are reasonably set up with tools and materials.

The DTU has also been working on new designs of wheels, hubs and bearings to bring down their costs and make things more locally manufacturable. It has designs for wooden and



**Figure 11: raised cart**

TR34: 10th March 1999

PVC plain bearings and for using scrap or new ball bearings - without needing machining, It also has a system of needle roller bearings which you can make without machining.

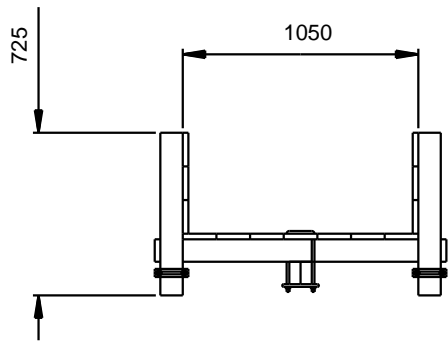
## Cart Drawings

You will find two drawings below, the first one gives a general view of the cart and the second, a view of the main components. As we have said you can vary the size of the cart quite a bit and even make it much longer if you add extra frames. You could even make a four wheeled cart like this!

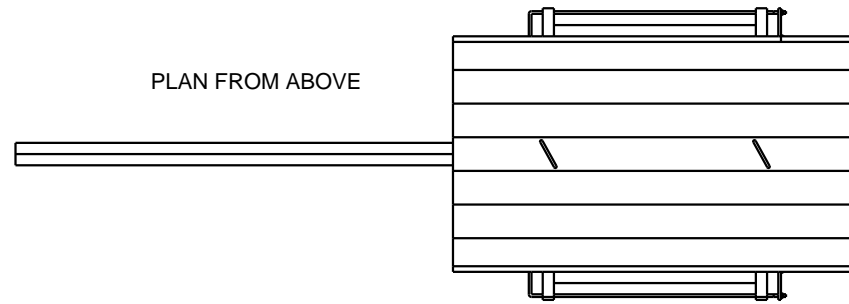
## Acknowledgements

The DTU is grateful to the DFID (British Government) for the financial support necessary to carry out the research and development project under which this product was developed.

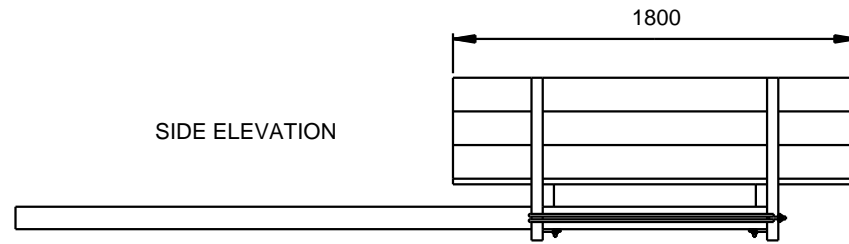
The DTU would also like to thank Dr Pascal Kaumbutho of KENDAT in Kenya and Mr Joseph Mugaga of TOCIDA in Tororo, Uganda for their very considerable help with this project. A large number of other people and organisations have contributed to the success of the project, most notably Mr Anthony Ndungu in Kajjido Kenya, Mr JD Kimani in Kikuyu Kenya and Mr Joseph Gitari in Wanguru Kenya in whose workshops most of the development work of this project was performed. Thanks are due also to Mr Stanley Lameria in Kajjido, Mr Patrick Gitari in Wanguru and Mr Mathew Masai in Machakos for their assistance.



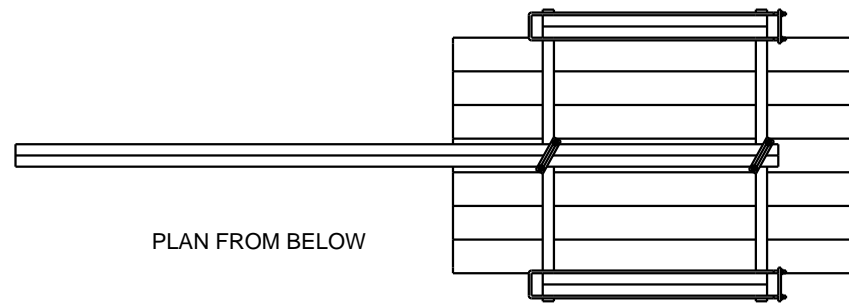
END ELEVATION



PLAN FROM ABOVE



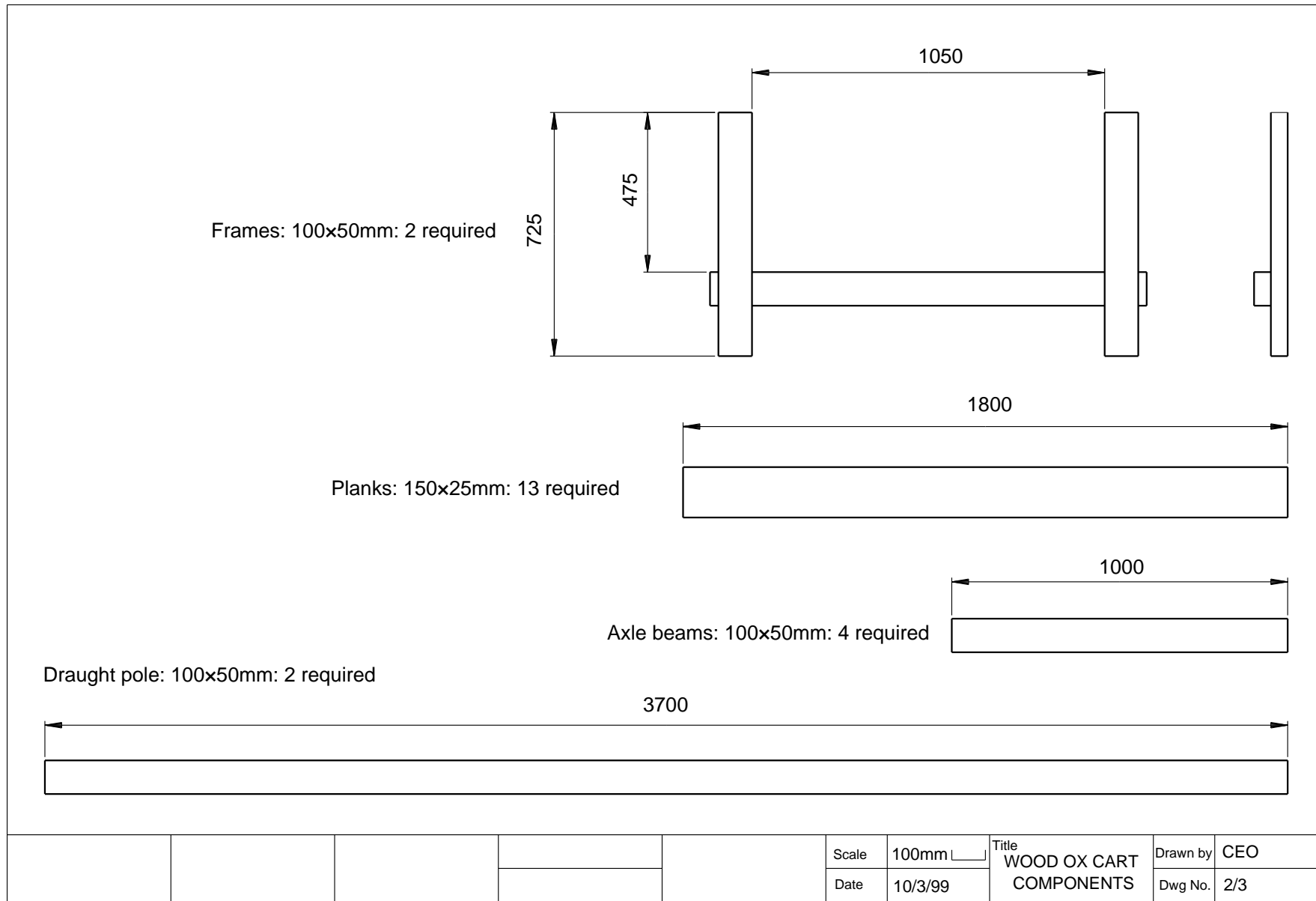
SIDE ELEVATION

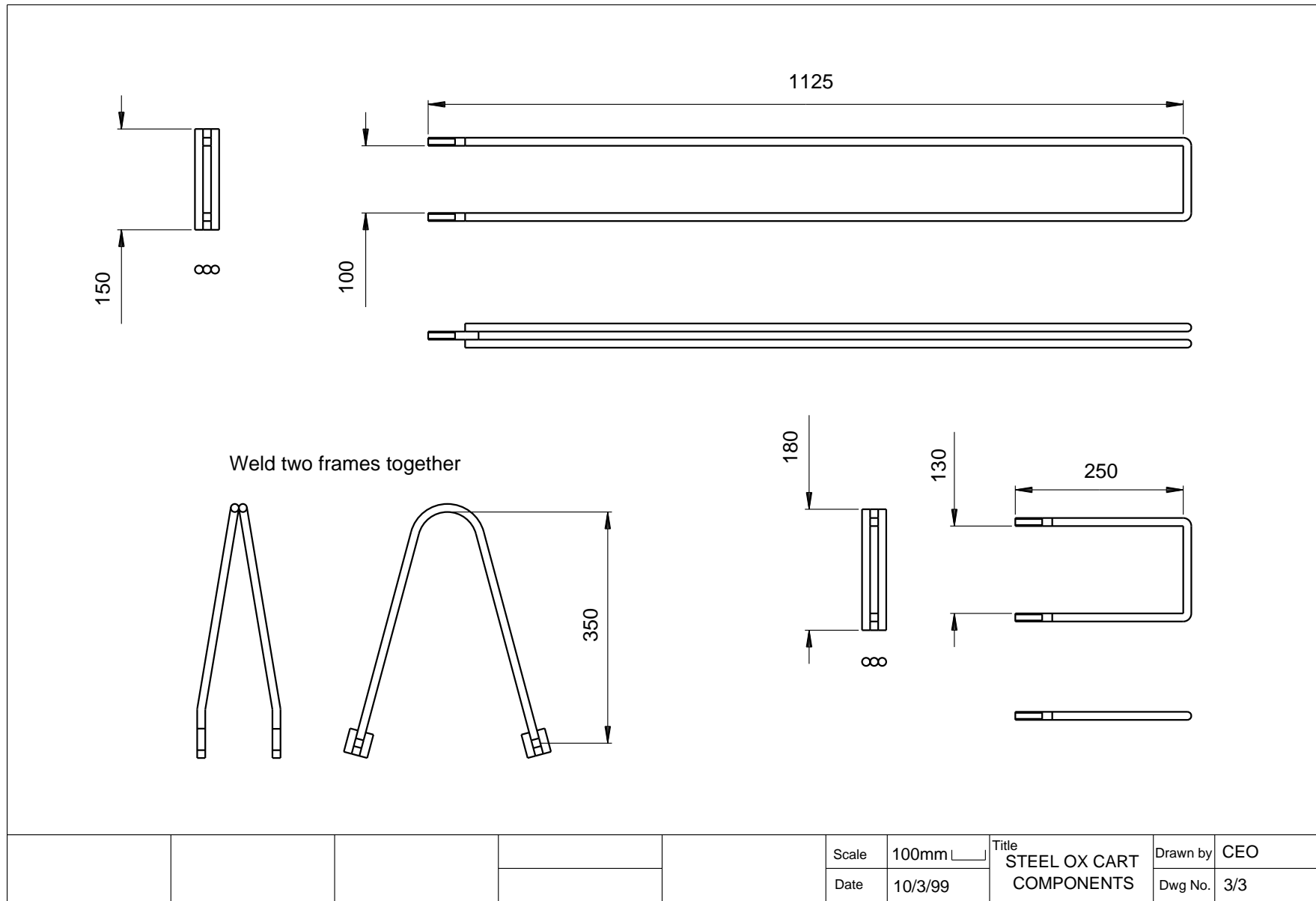


PLAN FROM BELOW

					Scale	200mm <input type="checkbox"/>	Title VESTIGIAL FRAME WOOD OX CART	Drawn by	CEO
					Date	10/3/99		Dwg No.	1/3









# Low-Cost Animal Cart Programme

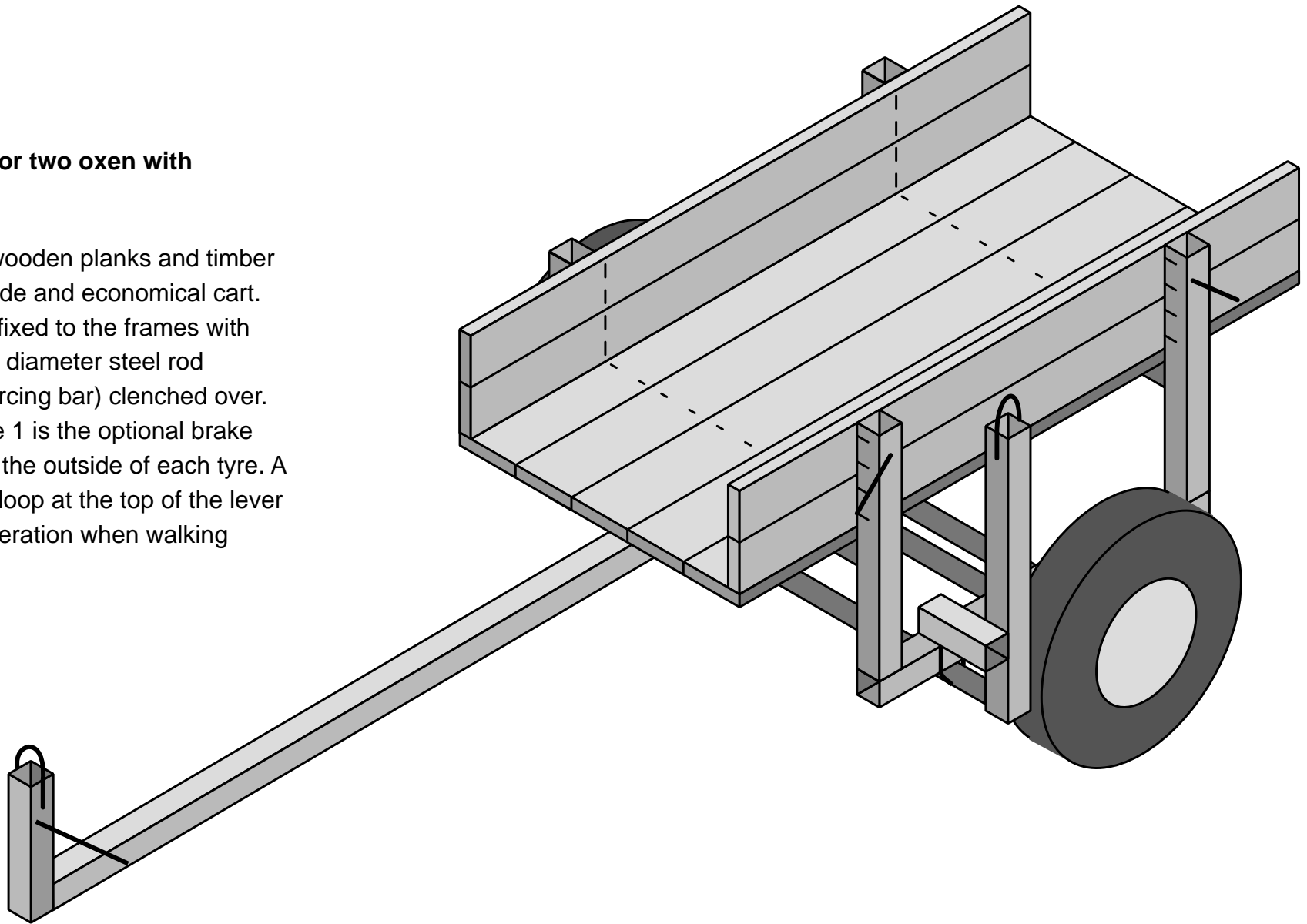
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## Low Cost Vestigial Steel Framed Cart for Two Oxen

TECHNICAL  
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RELEASE

**Figure 1: cart for two oxen with brake.**

This cart uses wooden planks and timber for a quickly made and economical cart. The planks are fixed to the frames with 8 mm or 10 mm diameter steel rod (concrete reinforcing bar) clenched over. Shown in Figure 1 is the optional brake which works on the outside of each tyre. A rope tied to the loop at the top of the lever allows brake operation when walking behind the cart.

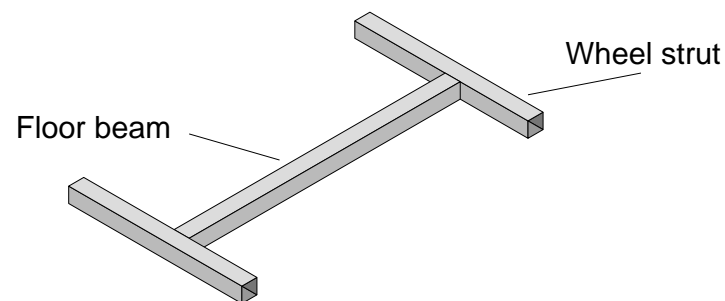


# Steel Box Tubing and Timber Cart for two Oxen.

## Introduction

In this booklet we tell you how to make a simple cart from square steel tube and timber. This Technical Release does not tell you here how to make the axle - you will have to read another Technical Release to for this. We have designs for stub axles with PVC bearings and with needle roller bearings that you can make yourself and we have designs for twin offset axles using PVC, wood and scrap ball bearings. All axles can be made without machine tools - in fact you do not even need a drill!

This Technical Release describes an ox cart made from



**Figure 2: finished H frame.**

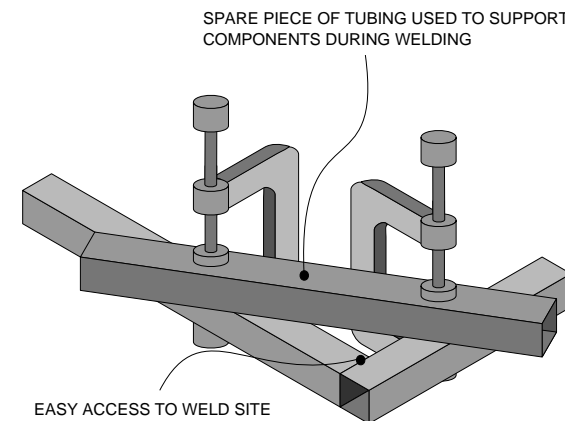
TR33: 5th April 1999

60x60x3 square steel tubing and is suitable for oxen weighing 350 kg to 500 kg. If you have really strong animals then use 75x75x3 tube - its only a little bit more expensive.

You should find that you can make the 60x60x3 cart body for about £ 50 depending on the cost of the materials and labour. An axle plus wheels, tyres and tubes will cost another £ 60 - £ 70. Once you get organised, two men can probably make one cart in a day. We've designed these carts to be easy and quick to make.

## Idea Behind Design

These carts are designed to be constructed without lots of special tools and jigs, and without any hard-to-get materials. The only tools which you must have are a welder, a wood saw,

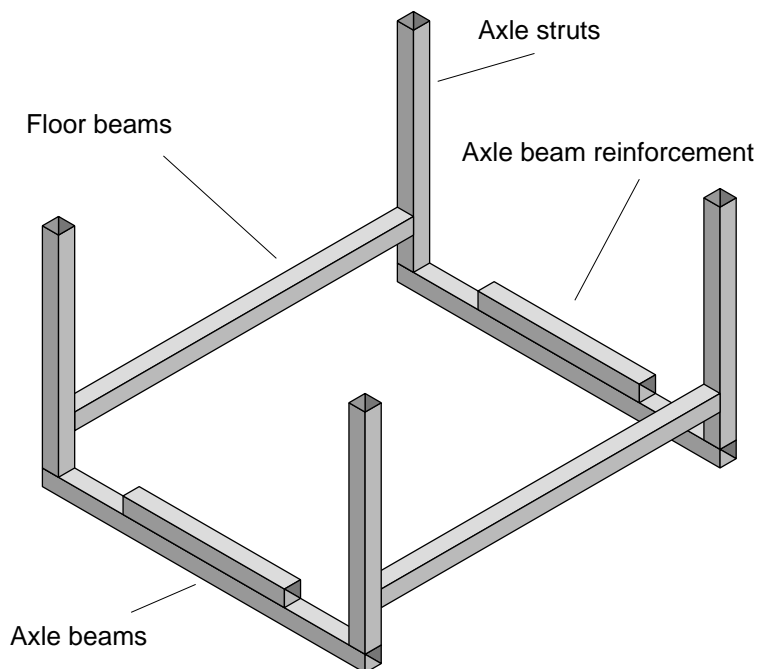


**Figure 3: holding frame components during welding.**

a hacksaw, and a hammer. You might find that a couple of 5" or a 6" G clamps (or something like it) are useful too.

The cart frames are fixed together by welding and the wooden planks are fixed to the frames with clenched steel bar. You weld 8 mm diameter re-bar (concrete reinforcing bar) to the steel box tubing so it sticks out about 20 mm beyond the surface of the planks, and then knock the ends over with a hammer so they lie on the surface of the wood.

You will see that there are no mitres or complicated angles or



**Figure 4: main frame assembly.**

TR33: 5th April 1999

joins to cut when making the cart, so you save time. Also the exact lengths of the components are not very critical - again it saves a little time, but you will find that the carts look better if you take a little trouble to get things square and even etc and welding is easier with good square ends. It is much better to use a try square to mark the position of a cut than guess.

These carts have been tested in Kenya and Uganda and we have had only a few serious failures caused by poor welding or incorrect material. We think that they are strong enough, but we cannot be sure - somebody will always break anything.

**TABLE 1: 60x60 RHS vestigial frame ox cart.**

description	length mm	#	total mm	cost £UK
<b>60x60 RHS:</b>			11520.00	<b>36.67</b>
floor beams 7 x 160 mm (floor planks 160 mm)	1120.00	2	2240.00	
wheel struts 3 x 160 + 25 + 60 + 180	745.00	4	2980.00	
axle beams 1100 mm long	1100.00	2	2200.00	
draw pole	2700.00	1	2700.00	
draw pole upright extn	400.00	1	400.00	
draw pole reinforcement	1000.00	1	1000.00	
<b>R8</b>			5850.00	<b>0.90</b>
plank fixings each plank (13 off) takes 6	75.00	78	5850.00	
<b>R12</b>			1200.00	<b>0.33</b>
yoke loop	400.00	1	400.00	
tie cleats	200.00	4	800.00	
<b>6"x1" timber</b>			23.40	<b>4.99</b>
tray planks 13 off	1.80	13	23.40	
<b>TOTAL =</b>				<b>42.89</b>

## Cutting list and costs

Table 1 shows a cutting list for a complete cart - Recent prices of materials in Kenya are shown converted into £<sub>UK</sub>.

## Construction step by step

- 1) First get all the material together and clear a space to work. Ideally you will be able to work on a flat area of concrete. Start by cutting the 60 × 60 box section steel into the right lengths, as in the cutting list, then cut the bottom and side

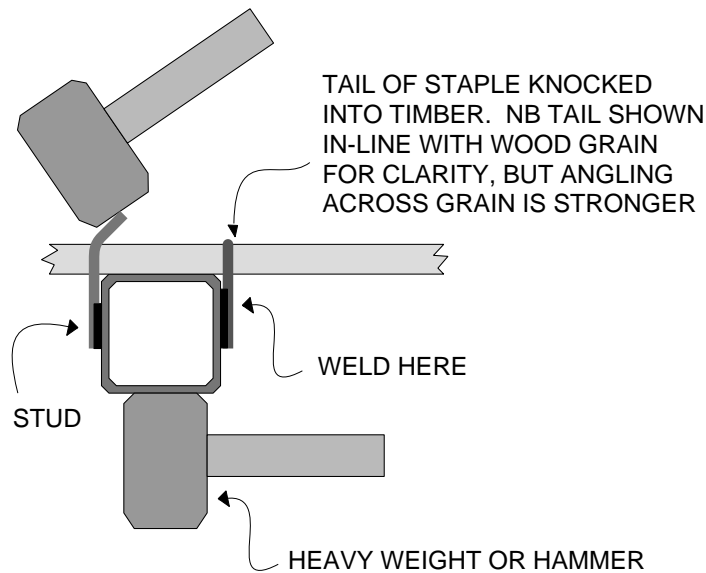


Figure 5: tightening welded stud.

planks. Lastly cut the 8 mm dia or whatever re-bar for the fixings ie the studs.

- 2) Next make up the two H-shaped frames shown in Figure 2. If you have a couple of G clamps you can use them to hold two pieces of the frame together during welding as shown in Figure 3. It's quick and you can tap the parts with a hammer until everything is square and straight and then weld.
- 3) Then stand the two H frames on the axle beams as shown in Figure 4 and weld up the main frame.

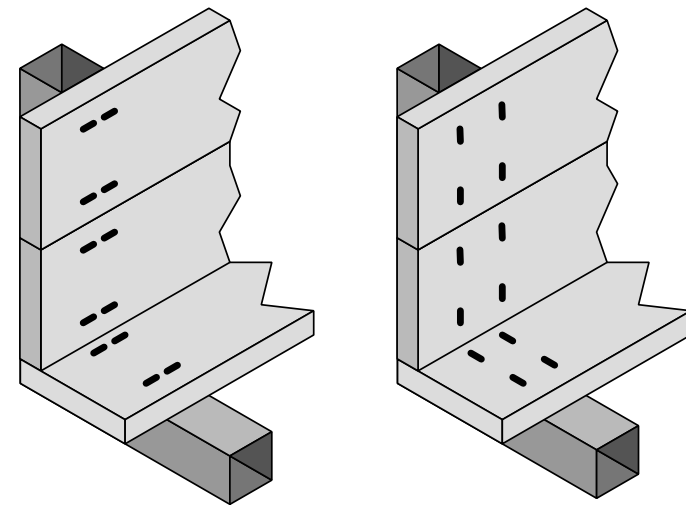
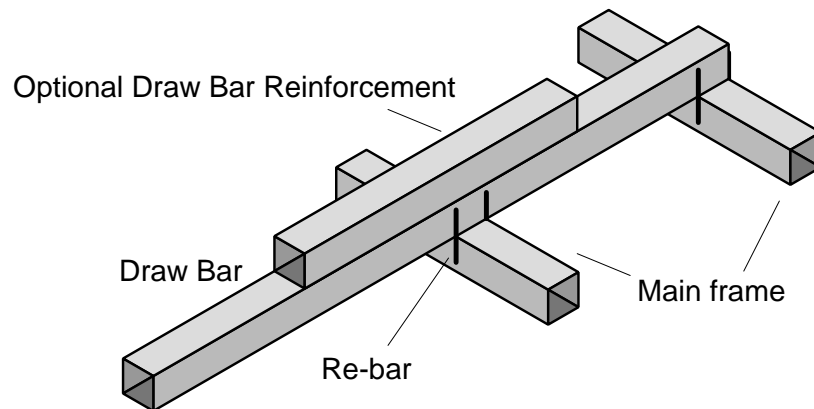


Figure 6: studs or staples bent in line with grain (left) or across it (right).

- 4) Next you can fit the side and the bottom planks to the frames with studs. Studs are just short lengths of round bar welded to the sides of the box section as shown in Figure 5 (which also shows how these studs can be tightened with a hammer and a weight or another hammer).

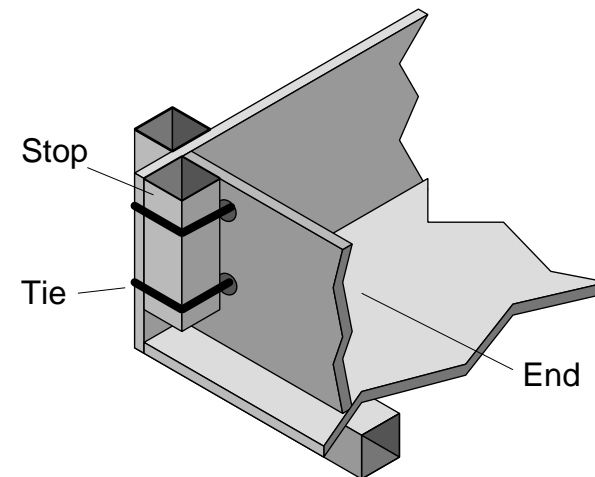
Studs can either be put through holes in the planks or they can just be welded at the edge of each plank and then simply bent over the edge.

When you bend the end of the stud over you can either bend it in line with the grain of the wood or across the grain, as shown in Figure 6. Bending it in line as shown on the left lets it go into the wood nicely and looks neat, but bending it over across the grain gives a stronger joint.



**Figure 7: method of fixing draw bar to body. (View of cart upside down.)**

- 5) Nearly there! Now you need to fix the draw pole. It is best to fix the draw pole to the body so it can be taken off and replaced if it gets damaged. A good way to do this is with short lengths of round bar welded on as shown in Figure 7. It is easy to cut through the re-bar hoops if you need to change the draw bar. You will need to use new re-bar of course when you put the new draw bar on. Also shown in Figure 7 is an easy way to reinforce the boom with an extra piece of steel tube welded to the main tube.
- 6) If you want to make it so that the ends of the load tray can be removed easily you can do so in the way we have shown in Figure 8. This is a good way because it is cheap



**Figure 8: method of fixing tray ends with rubber or rope**



and very easily repairable.

7) Paint or creosote the cart. You've finished it!

## **Modifications**

There are many different versions of this cart. You can try longer or shorter carts and you can make them wider or narrower. When you do this, check the length and width of the planks of wood that you will use - you do not want to find that you are two inches short of being able to get two runs of plank out of one piece of timber, or that its just too narrow and you have to fiddle about and fit in a narrow strip.

## **Other DTU cart developments**

The DTU has been working on a range of carts for use with both donkeys and oxen. It has designs for wooden and steel framed bodies and for a range of wheels and axles. All steel framed carts can be fitted with a simple brake. The DTU also has designs for single and double donkey harness.

## **Cart Drawings**

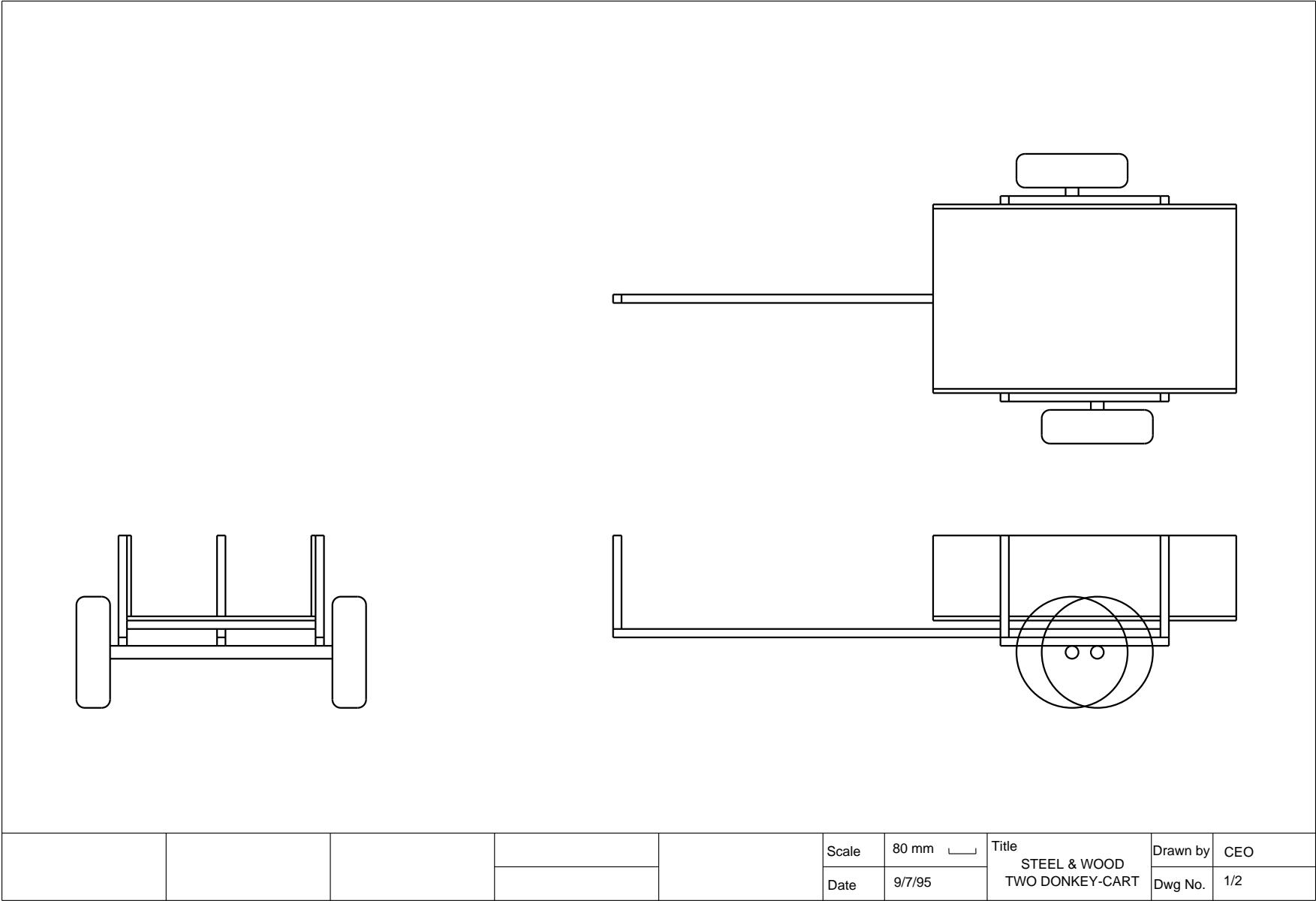
You will find two drawings on the next pages, the first one gives a general view of the cart, and the second gives a view of the main components. As we have said you can vary the size of the cart quite a bit and even make it much longer if you add extra frames. You could even make a four wheeled cart like

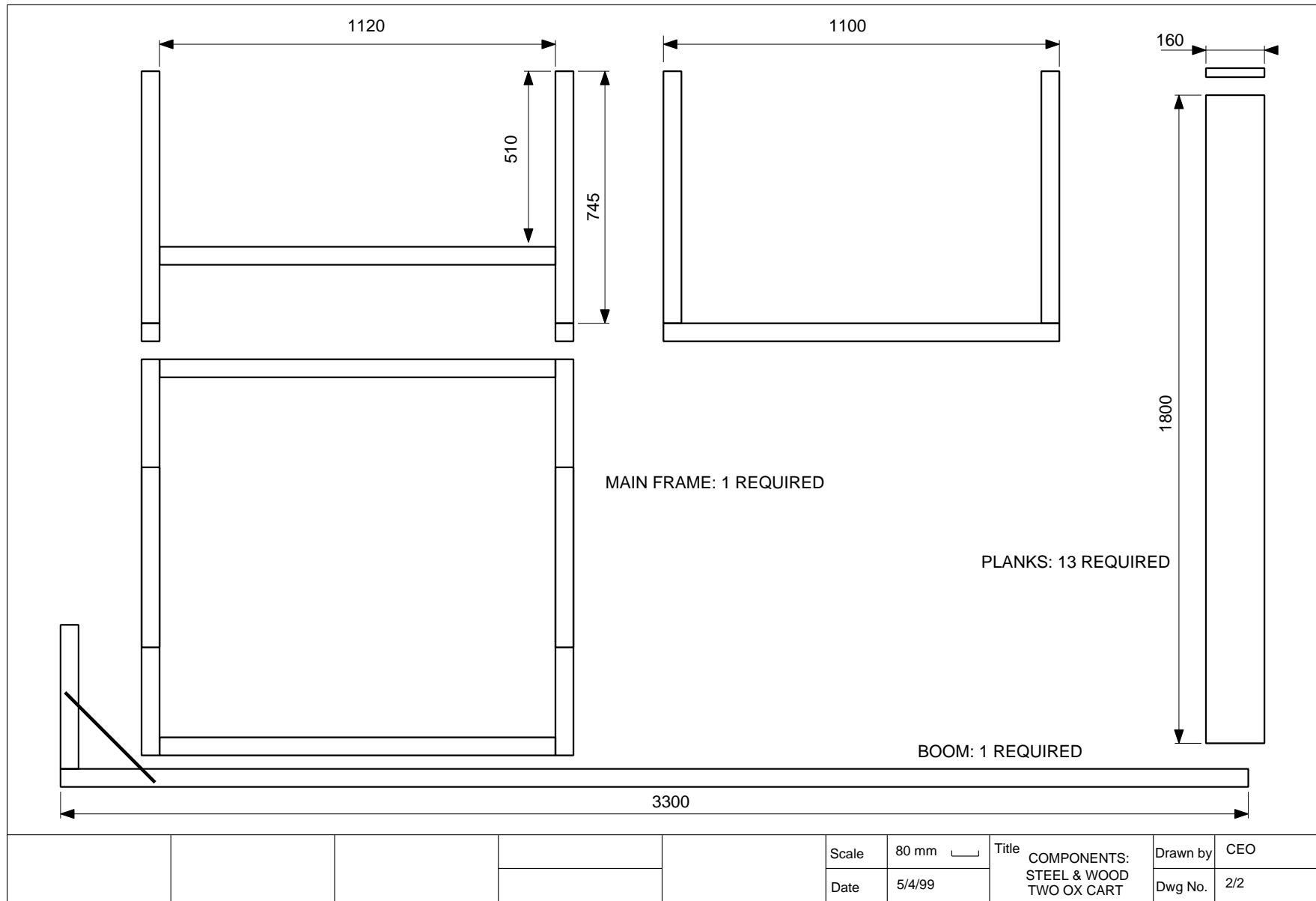
this!



## **Acknowledgements**

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The DTU would also like to thank Dr Pascal Kaumbutho of KENDAT in Kenya and Mr Joseph Mugaga of TOCIDA in Tororo, Uganda for their very considerable help with this project. A large number of other people and organisations have contributed to the success of the project, most notably Mr Anthony Ndungu in Kajiado Kenya, Mr JD Kimani in Kikuyu Kenya and Mr Joseph Gitari in Wanguru Kenya in whose workshops most of the development work of this project was performed. Thanks are due also to Mr Stanley Lameria in Kajaido, Mr Patrick Gitari in Wanguru and Mr Mathew Masai in Machakos for their assistance.





**DTU**   **KENDAT**

# **Animal Cart Programme**

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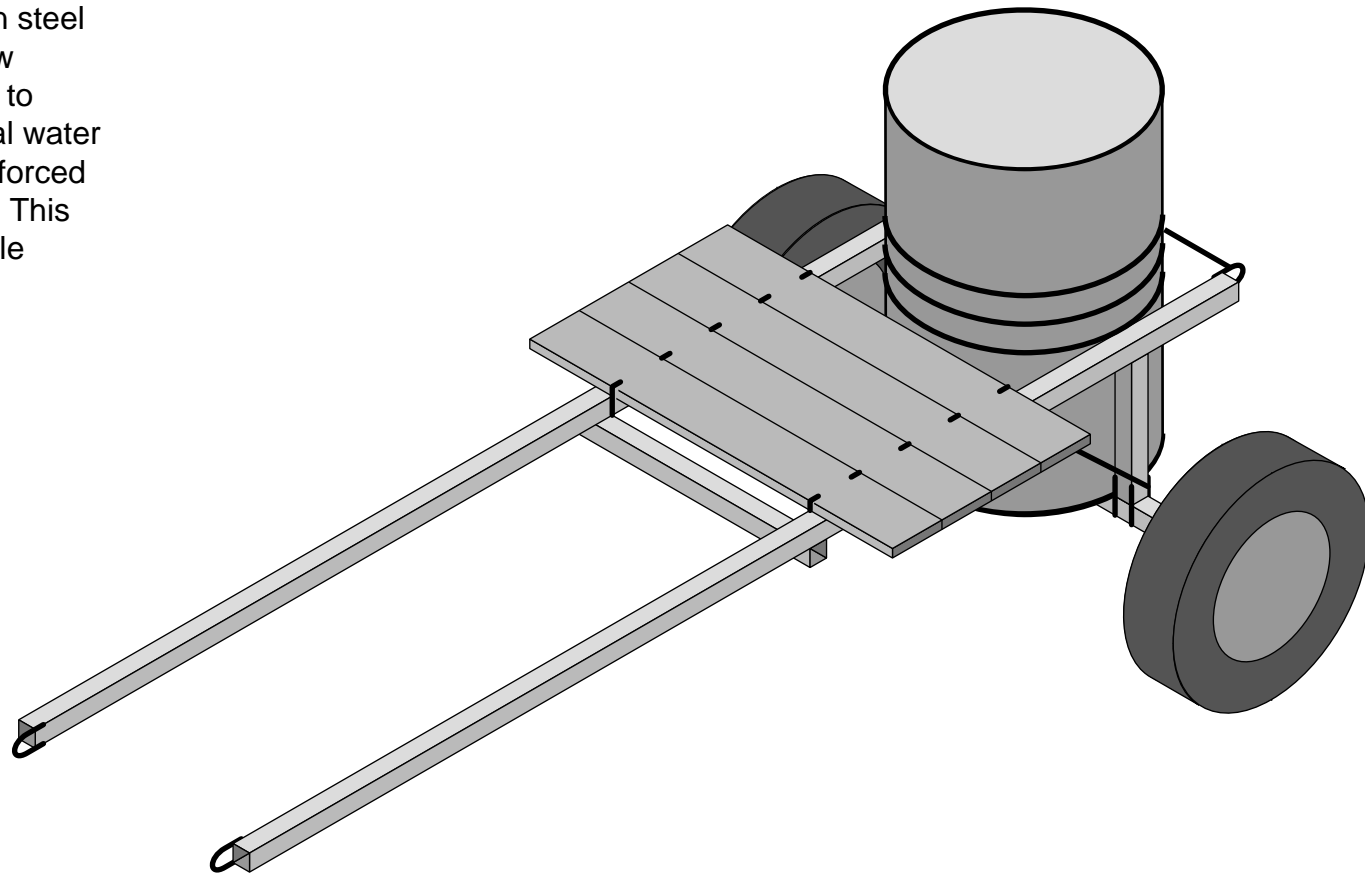
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## **LIGHT SINGLE DRUM WATER CARRIER**

Development Technology Unit, Department of Engineering, University of Warwick, Coventry, CV4 7AL UK, tel: +44 (0)203 523523 extn 2339, fax: +44 (0)203 418922, email: [esceo@eng.warwick.ac.uk](mailto:esceo@eng.warwick.ac.uk)  
KENDAT, PO Box 61441, Nairobi, Kenya, tel/fax: +254 2 766939, email: [kendat@africaonline.co.ke](mailto:kendat@africaonline.co.ke)

**Figure 1: donkey cart made from square box tubing.**

This cart uses square section steel box tubing (RHS rolled hollow section) and a 200 litre drum to make a quick and economical water carrying cart. The cart is reinforced with concrete reinforcing bar. This cart has two shafts for a single donkey.



# Lightweight water carrier cart for one donkey.

## Introduction

In many towns and villages in Africa water is delivered commercially. You buy water from people selling it from carts. This cart design was developed in Kenya where water is widely sold like this and the cart is as simple and cheap as we can design it from new materials there.

This booklet tells you how to construct a water carrier cart - you will need to use another booklet Technical Release 28 to tell you how to make the axle. You should be able to make the cart

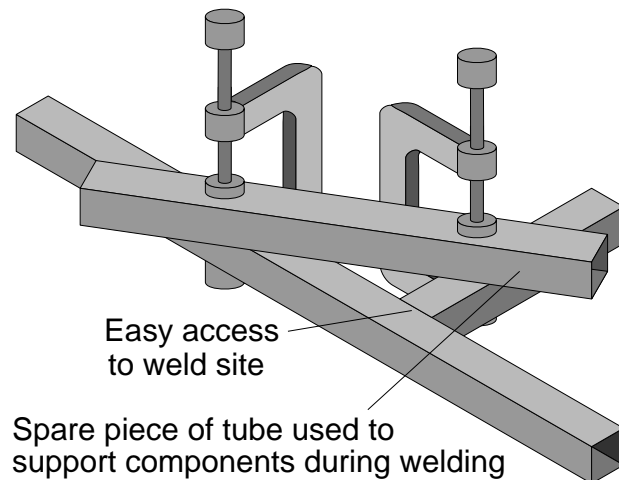


Figure 2: supporting components during welding.

make one cart including the axle per day.

In other booklets in this series we tell you how you can make other simple low-cost carts and axles

## Idea Behind Design

The idea behind the designs in these booklets is to allow construction without lots of special tools and jigs, and without any hard-to-get materials. The only tools which you must have are a welder and a hacksaw. You might also find that a couple of 4" or a 5" G clamps (or something like it) are useful too. A wheelbrace or carpenters brace is also useful - you can make the drill bit yourself.

You will see that there are no mitres and unusual angles to cut in the square tubing so you save time when making the cart. Also the exact lengths of the components are not very fussy. But you will find that the carts look better if you take trouble to

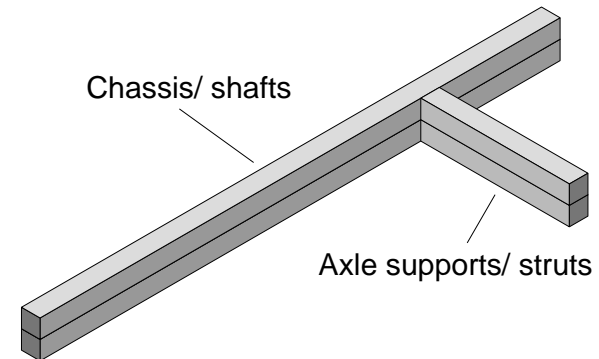


Figure 3: welding animal shaft and axle support strut assemblies.

get things square and straight.

Carts like these have been tested in Kenya. We have not had problems with them but if you find that the square tube breaks too easily you can reinforce it by welding on some round bar or concrete reinforcing bar 8mm, 10mm or 12mm. If you used tubing with a wall thickness of 2.0 mm or more you probably would not need to put these strengtheners on.

## Cutting list and costs

Table 1 shows a cutting list for a complete cart. Recent prices of materials in Kenya are shown converted to £ UK. The

**Table 1: materials and costs.**

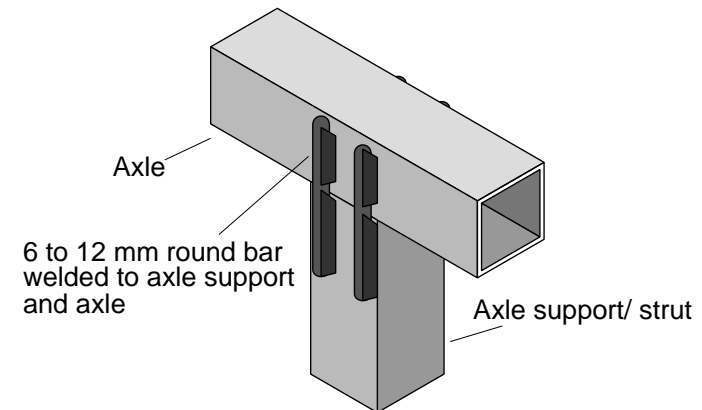
TABLE 1: cutting list.				
component	material	# lengths & length reqd [#*mm]	total material in cart	materials cost in Kenya [£uk]
animal shafts	50x50 RHS	2x3000	6000	14.37
body cross pieces	50x50 RHS	2x700	1400	3.35
axle struts	50x50 RHS	2x375	750	1.80
shaft strengtheners	8mm to 12mm round bar <sup>1</sup>	4x600	2400	0.66
axle strut braces	8mm to 12mm round bar <sup>1</sup>	2x600	1200	0.33
axle fixing bars	8mm to 12mm round bar <sup>1</sup>	8x70	560	0.15
hitch/ drum tie loops	8mm to 12mm round bar <sup>1</sup>	2x250	500	0.14
TOTAL =				20.67

<sup>1</sup> The round bar can be anything actually - it doesn't even have to be round, so deformed or high-yield re-bar is fine. You could even use flat strip as long as its more than say 8mm thick.

method shown in Figure 2 is probably the easiest way to support the components during welding the first shaft and support. It's quick and if you do not tighten the clamps too tight to start with, you can tap the parts with a hammer until everything is square and straight. Then tighten the clamps before you weld.

Repeat the process using the first shaft and support as a pattern for the second as shown in Figure 3. Make sure you do not weld the two assemblies together!

- 3) Now you can weld the cross pieces under the animal shafts after you have checked for squareness etc.
- 4) Next weld the axle on using the method shown in Figure 4. Here small pieces of round bar eg 12 mm are welded across the join. If you do it like this you can easily remove the axle just by cutting the rod. This is much easier than grinding welds away. Alternatively you can bolt the axle on



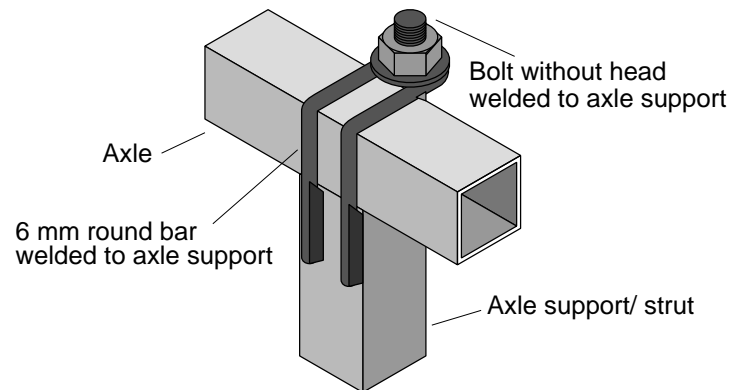
**Figure 4: method of fixing axle to axle supports.**

as shown in Figure 5.

- 5) Next you need to weld on the axle support strut braces to the square tube. Figure 5 shows the frame nearly ready.
- 6) Now fix the planks on using clenched over 8 mm re-bar as shown in Figure 6
- 7) Paint the cart. You've finished it!

## Getting water out

Users usually cut a hole in the top of the drum or cut the whole top off to make it easy to pour water in quickly. To get water out some users in Kenya fix some 3 inch layflat hose onto a piece of pipe fixed to the larger threaded hole in one end of the drum. Tying the end up stops water coming out and letting it down squirts water out very quickly.



**Figure 5: fixing planks to frame with clenched studs.**

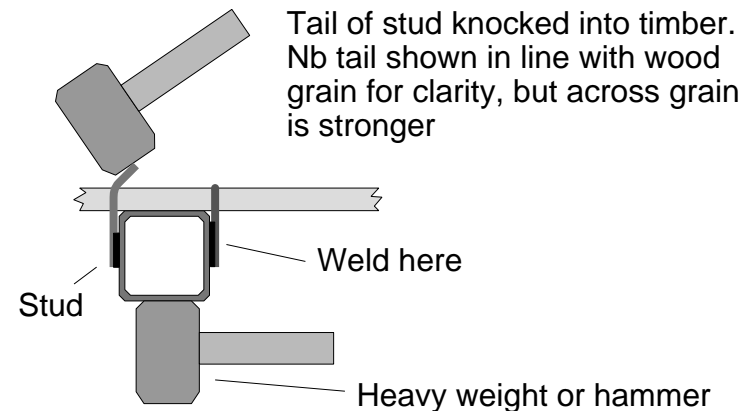
## Modifications

This cart could be used as a flatbed cart by removing the drum and putting more planks on top of the shafts.

## Other DTU cart developments

The DTU has been working on a range of cart body types for use with both donkeys and oxen. It has designs for both wooden and steel framed types. The wooden types are cheaper in material terms, but the steel framed ones are easier to make because the joints are more straightforward - but you can make either type of cart in only a day or two.

The DTU has also been working on new designs of wheels, hubs and bearings to bring down their costs and make things



**Figure 6: fixing planks to frame with clenched studs.**



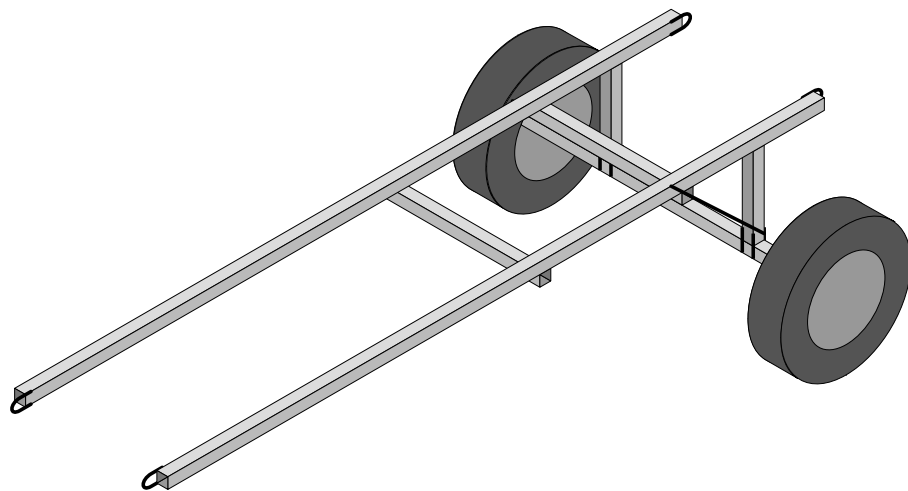
more locally manufacturable. We have developed easily made wooden bearings, bearings from PVC pipe, axles using old ball races and axles where you make your own roller bearings. Technical releases for all these are available.

## Cart Drawings

The drawing for the cart is shown on the following page and the list of materials has been shown on a previous page.

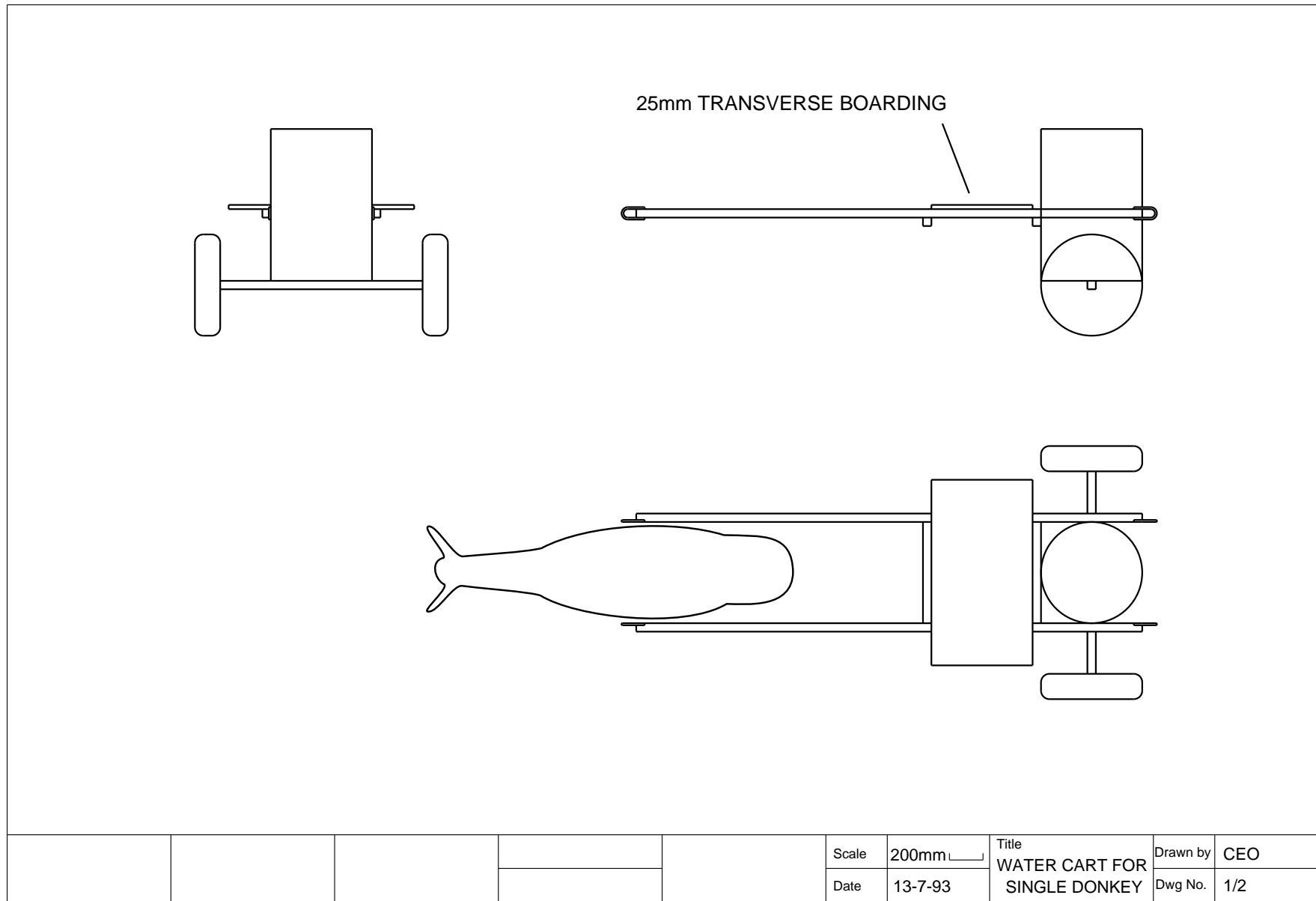
## Acknowledgements

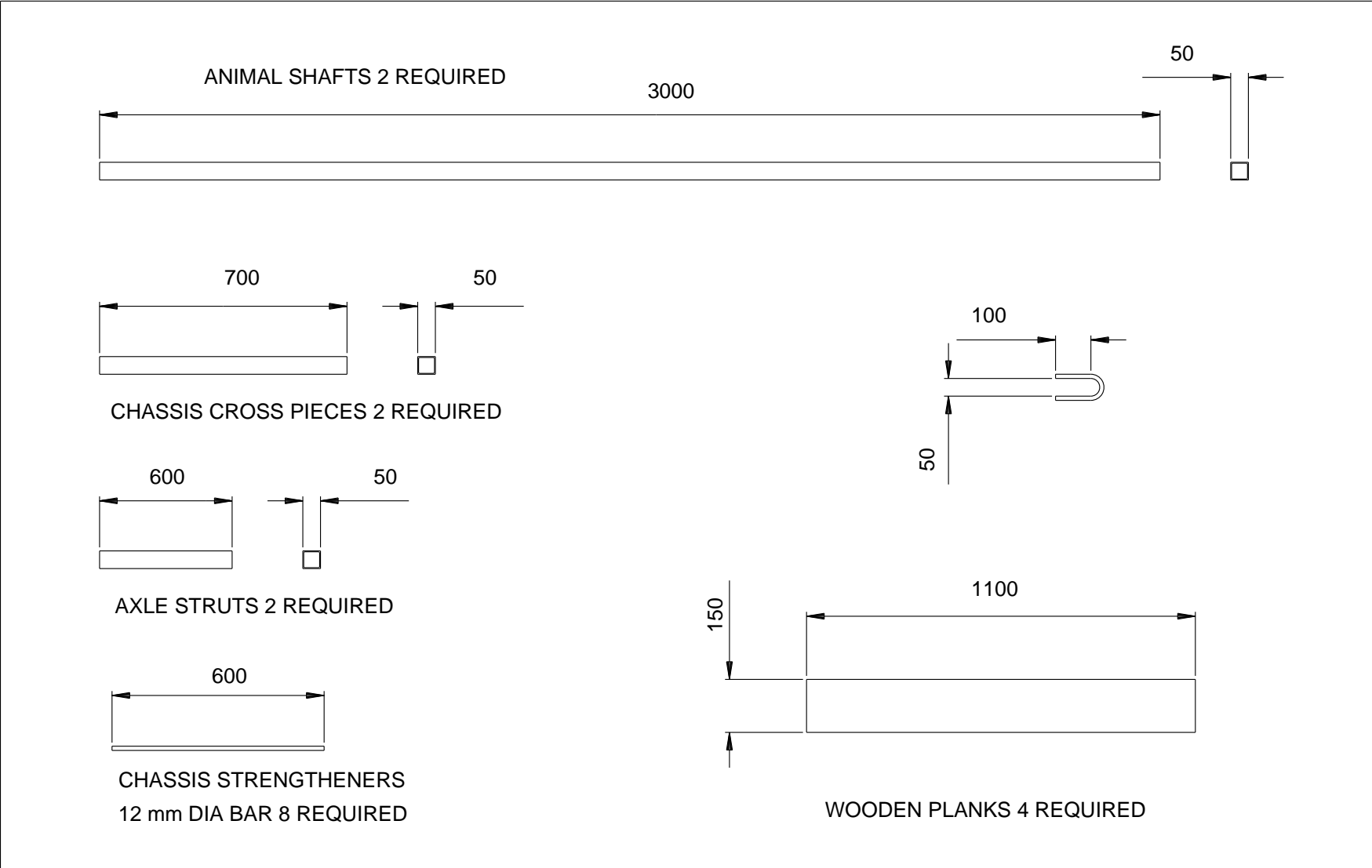
The DTU is grateful to the DFID (British Government) for the financial support necessary to carry out the research and development project under which this product was developed.



**Figure 7: cart frame without drum and planks.**

The DTU would also like to thank Dr Pascal Kaumbutho of KENDAT in Kenya and Mr Joseph Mugaga of TOCIDA in Tororo, Uganda for their very considerable help with this project. A large number of other people and organisations have contributed to the success of the project, most notably Mr Anthony Ndungu in Kajiado Kenya, Mr JD Kimani in Kikuyu Kenya and Mr Joseph Gitari in Wanguru Kenya in whose workshops most of the development work of this project was performed. Thanks are due also to Mr Stanley Lameria in Kajaido, Mr Patrick Gitari in Wanguru and Mr Mathew Masai in Machakos for their assistance.





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TECHNICAL  
**29**  
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# Low-Cost Animal Cart Programme

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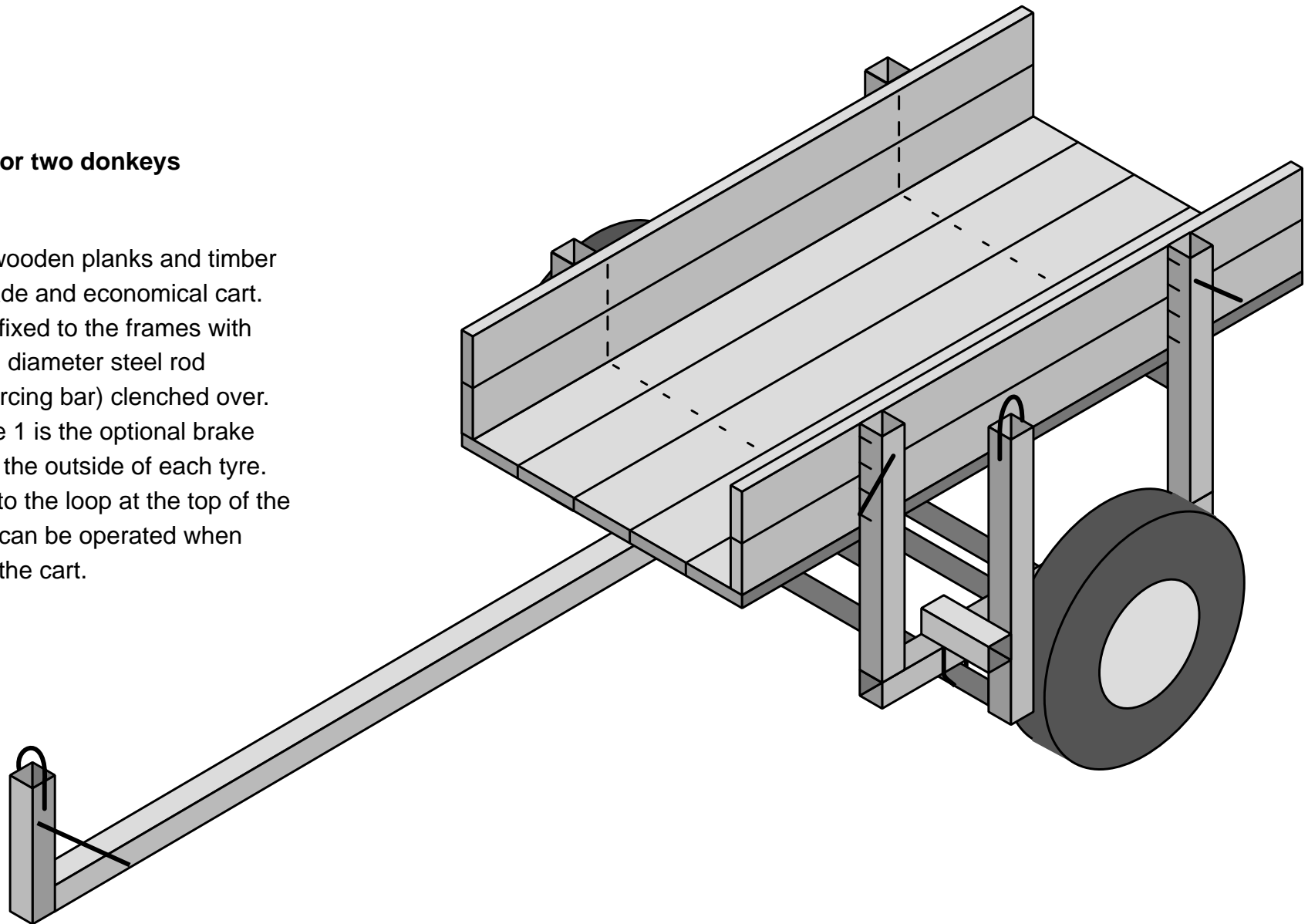
## Low Cost Steel Framed Cart for Two Donkeys

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**Figure 1: cart for two donkeys with brake.**

This cart uses wooden planks and timber for a quickly made and economical cart. The planks are fixed to the frames with 8 mm or 10 mm diameter steel rod (concrete reinforcing bar) clenched over. Shown in Figure 1 is the optional brake which works on the outside of each tyre. If a rope is tied to the loop at the top of the lever the brake can be operated when walking behind the cart.

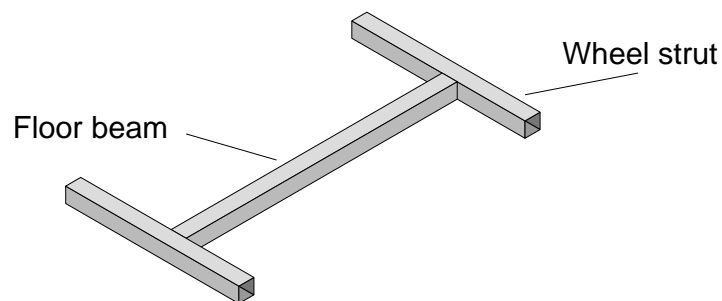


# Two Donkey Cart made from Steel Box Tubing and Timber.

## Introduction

In this booklet we tell you how to make a simple cart from square steel tube and timber. This Technical Release does not tell you here how to make the axle - you will have to read another Technical Release to for this. We have designs for stub axles with PVC bearings and with needle roller bearings that you can make yourself and we have designs for twin offset axles using PVC, wood and scrap ball bearings. All axles can be made without machine tools - in fact you do not even need a drill!

You should find that you can make the cart itself for about £ 40



**Figure 2: finished H frame.**

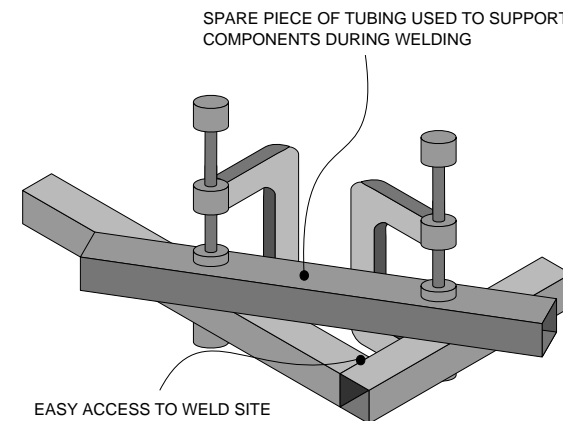
TR29: 4th April 1999

depending on the cost of the materials and labour. An axle plus wheels, tyres and tubes will cost another £ 50 - £ 60. Once you get organised, two men can probably make one cart in a day. We've designed these carts to be easy and quick to make.

## Idea Behind Design

These carts are designed to be constructed without lots of special tools and jigs, and without any hard-to-get materials. The only tools which you must have are a welder, a wood saw, a hacksaw, and a hammer. You might find that a couple of 4" or a 5" G clamps (or something like it) are useful too.

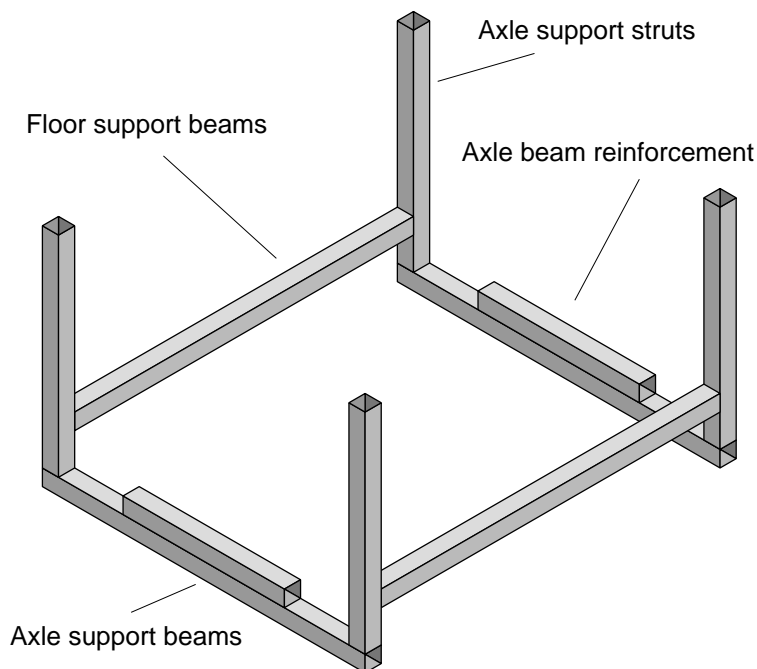
The cart frames are fixed together by welding and the wooden planks are fixed to the frames with clenched steel bar. You weld 8 mm diameter re-bar (concrete reinforcing bar) to the steel box



**Figure 3: holding frame components during welding.**

tubing so it sticks out about 20 mm beyond the surface of the planks, and then knock the ends over with a hammer so they lie on the surface of the wood.

You will see that there are no mitres or complicated angles or joints to cut when making the cart, so you save time. Also the exact lengths of the components are not very critical - again it saves a little time, but you will find that the carts look better if you take a little trouble to get things square and even etc and welding is easier with good square ends. It is much better to



**Figure 4: main frame assembly.**

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use a try square to mark the position of a cut than guess.

These carts have been tested in Nigeria, Kenya and Uganda and we have had only a few serious failures caused by poor welding or incorrect material. We think that they are strong enough, but we cannot be sure - somebody will always break anything.

### Cutting list and costs

Table 1 shows a cutting list for a complete cart - Recent prices of materials in Kenya are shown converted into £<sub>UK</sub>.

**TABLE 1: 50x50 RHS vestigial frame donkey cart.**

description	length m	#	total m	cost £ <sub>UK</sub>
<b>50x50 RHS:</b>			<b>11560.00</b>	27.71
floor beams 7 x 160 mm (planks 160 mm)	1120.00	2	2240.00	
wheel struts 3 x 160 + 25 + 60 + 240	805.00	4	3220.00	
axle support beams 1000 mm long	1000.00	2	2000.00	
draw pole	2700.00	1	2700.00	
draw pole upright extn	400.00	1	400.00	
draw pole reinforcement	1000.00	1	1000.00	
<b>R8</b>			<b>3900.00</b>	6.01
plank fixings each plank (13 off) takes 6	75.00	52		
<b>R12</b>			<b>1200.00</b>	0.33
yoke loop	400.00	1	400.00	
tie cleats for rope	200.00	4	800.00	
<b>6"x1" timber</b>			23.40	4.99
tray planks 13 off	1.80	13	23.40	
TOTAL COST =				39.04

## Construction step by step

- 1) First get all the material together and clear a space to work. Ideally you will be able to work on a flat area of concrete. Start by cutting the 50 × 50 box section steel into the right lengths, as in the cutting list, then cut the bottom and side planks. Lastly cut the 8 mm dia or whatever re-bar for the fixings ie the studs.
- 2) Next make up the two H-shaped frames shown in Figure 2. If you have a couple of G clamps you can use them to hold

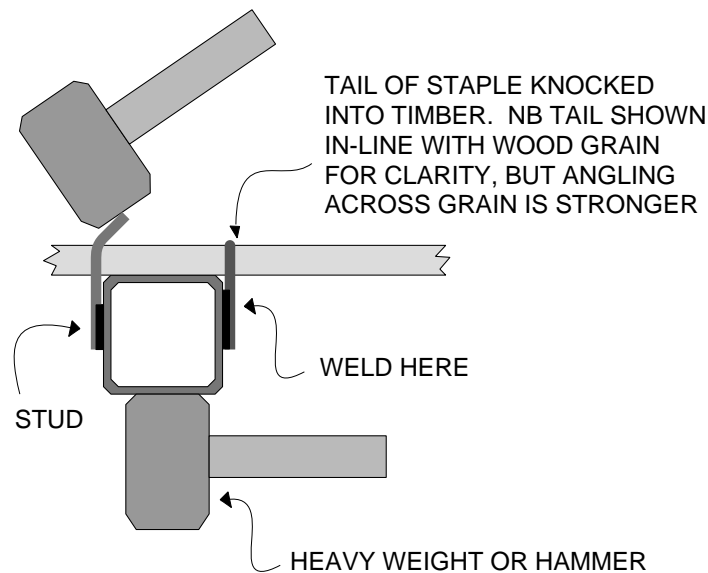


Figure 5: tightening welded stud.

two pieces of the frame together during welding as shown in Figure 3. It's quick and you can tap the parts with a hammer until everything is square and straight and then weld.

- 3) Then stand the two H frames on the axle support beams as shown in Figure 4 and weld up the main frame. If you are using our PVC bearing system then weld on some axle beam reinforcement as shown in the figures but with the ball bearing and wooden bearing types you do not need this.
- 4) Next you can fit the side and the bottom planks to the

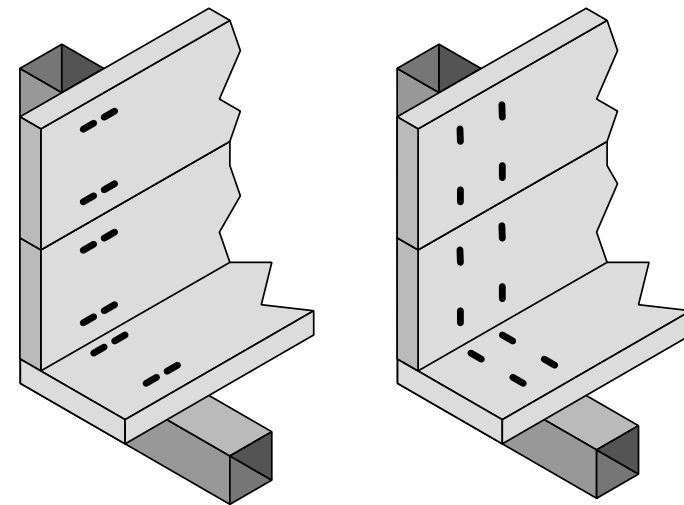


Figure 6: studs or staples bent in line with grain (left) or across it (right).

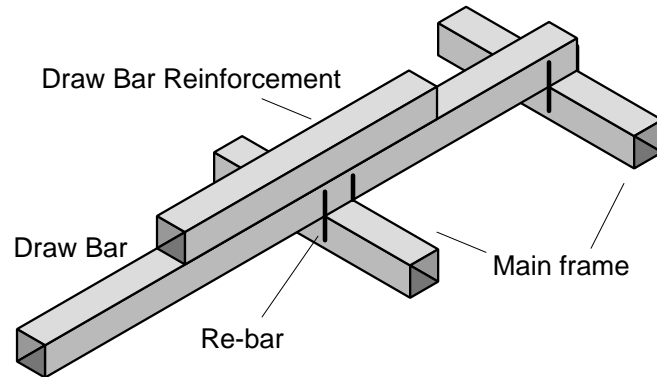


frames with studs. Studs are just short lengths of round bar welded to the sides of the box section as shown in Figure 5 (which also shows how these studs can be tightened with a hammer and a weight or another hammer).

Studs can either be put through holes in the planks or they can just be welded at the edge of each plank and then simply bent over the edge.

When you bend the end of the stud over you can either bend it in line with the grain of the wood or across the grain, as shown in Figure 6. Bending it in line as shown on the left lets it go into the wood nicely and looks neat, but bending it over across the grain gives a stronger joint.

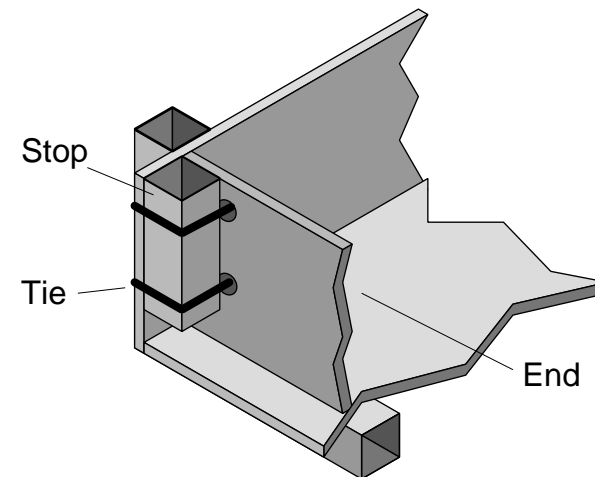
5) Nearly there! Now you need to fix the draw pole. It is best



**Figure 7: method of fixing draw bar to body. (View of cart upside down.)**

to fix the draw pole to the body so it can be taken off and replaced if it gets damaged. A good way to do this is with short lengths of round bar welded on as shown in Figure 7. It is easy to cut through the re-bar hoops if you need to change the draw bar. You will need to use new re-bar of course when you put the new draw bar on. Also shown in Figure 7 is an easy way to reinforce the boom with an extra piece of steel tube welded to the main tube.

6) If you want to make it so that the ends of the load tray can be removed easily you can do so in the way we have shown in Figure 8. This is a good way because it is cheap and very easily repairable.



**Figure 8: method of fixing tray ends with rubber or rope**

7) Paint or creosote the cart. You've finished it!

## **Modifications**

There are many different versions of this cart. You can try longer or shorter carts and you can make them wider or narrower. When you do this, check the length and width of the planks of wood that you will use - you do not want to find that you are two inches short of being able to get two runs of plank out of one piece of timber, or that its just too narrow and you have to fiddle about and fit in a narrow strip.

## **Other DTU cart developments**

The DTU has been working on a range of carts for use with both donkeys and oxen. It has designs for wooden and steel framed bodies and for a range of wheels and axles. All steel framed carts can be fitted with a simple brake. The DTU also has designs for single and double donkey harness.

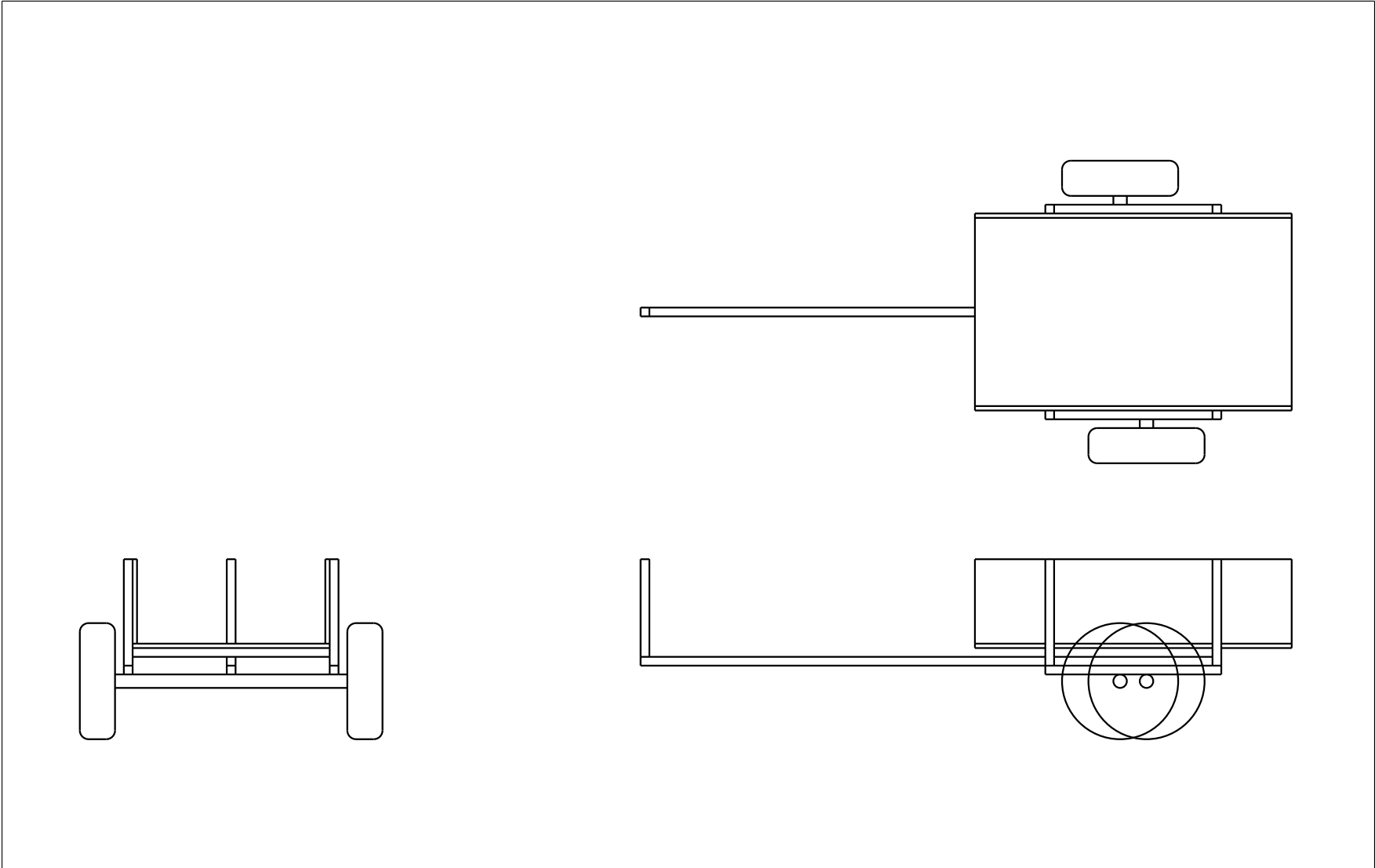
## **Cart Drawings**

You will find two drawings on the next pages, the first one gives a general view of the cart, and the second gives a view of the main components. As we have said you can vary the size of the cart quite a bit and even make it much longer if you add extra frames. You could even make a four wheeled cart like this!

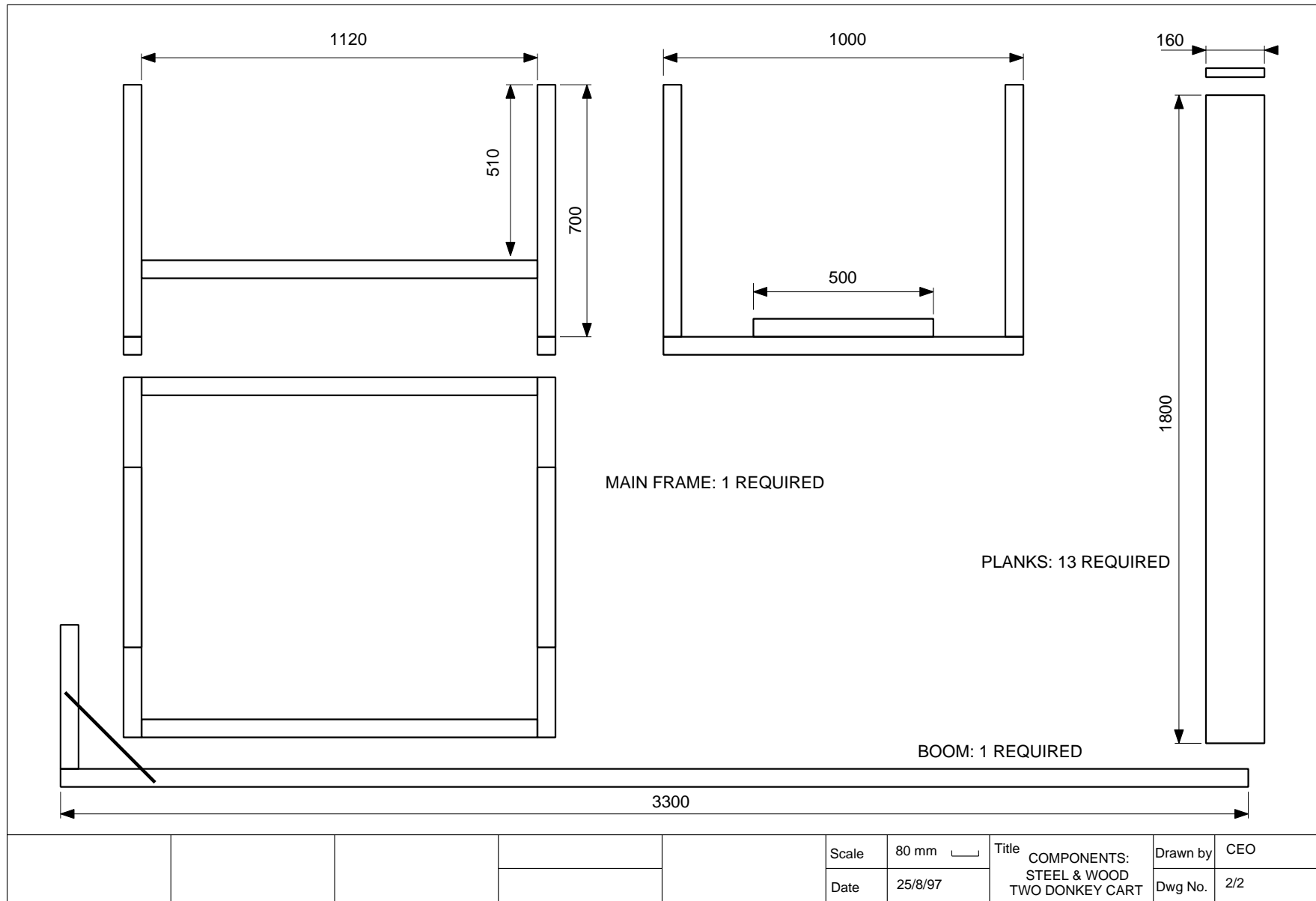
## **Acknowledgements**

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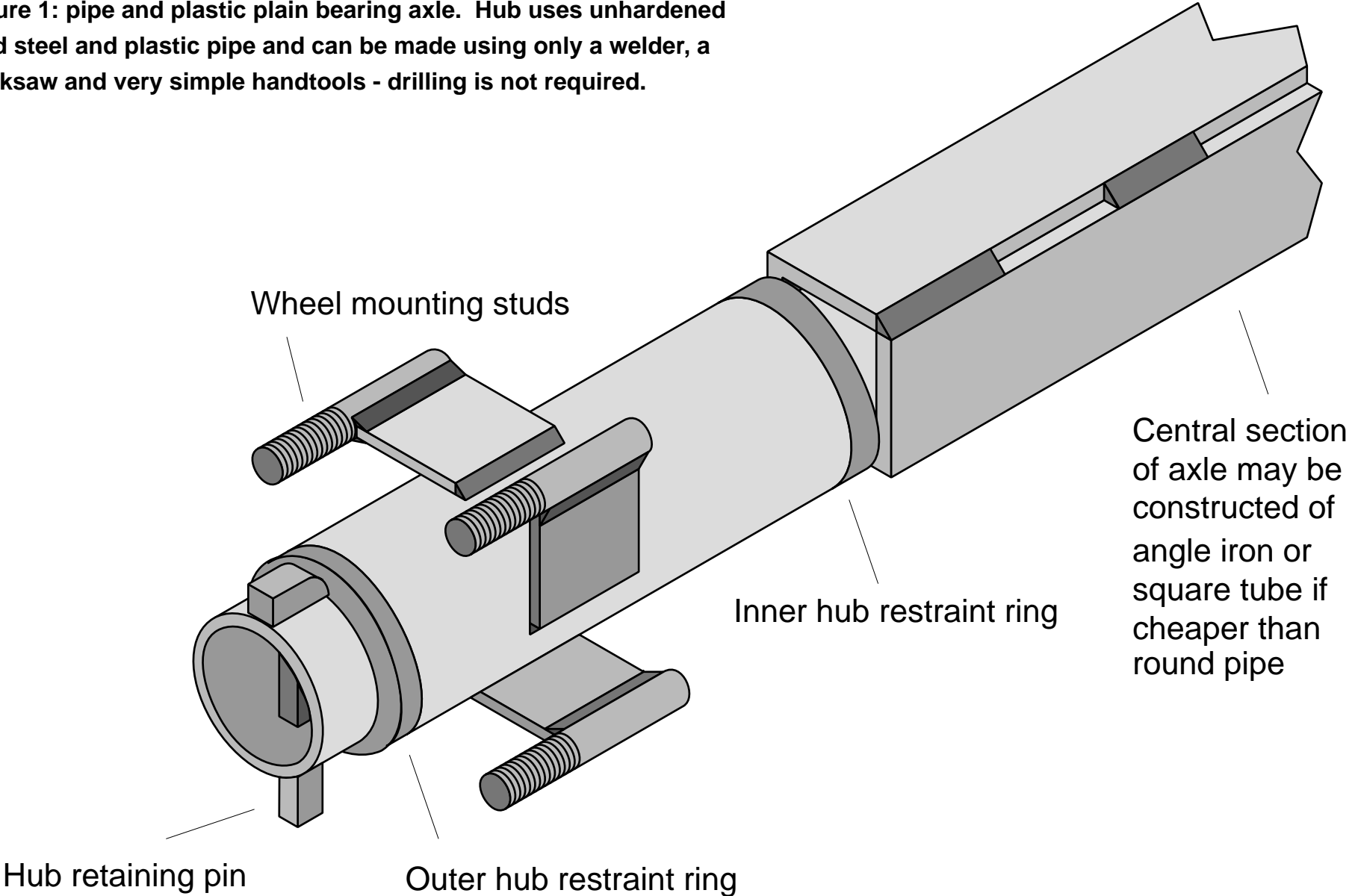
# Animal Cart Programme

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## PIPE PLAIN BEARING DONKEY CART AXLE

**Figure 1: pipe and plastic plain bearing axle. Hub uses unhardened mild steel and plastic pipe and can be made using only a welder, a hacksaw and very simple handtools - drilling is not required.**



# Pipe Plain Bearing Donkey-Cart Axle

## Introduction

Not enough farmers in Africa have animal carts. Those who have carts can take their produce to places where they can get the best prices. They can also get into town and buy fertilizer and better seeds and move things around their farm easier. The trouble is that carts are too expensive for many farmers. The question is what can be done about it?

Carts are made in many different places. Some carts are made in factories in industrial countries and some are made in factories in Africa, but most are made by local blacksmiths or carpenters using scrap car and 4WD axles. In many countries these people cannot get enough axles to meet the demand so the price is high. Another problem is that the axles are often so worn that they do not last long. Lots of farmers take the (differential) unit out of the axle too, which makes the axle break sooner and lets the dirt in.

What you need is an axle which blacksmiths and fabricators can make with fairly simple tools - without having to get parts machined. There are usually blacksmiths and fabricators in the

small market towns used by the farmers. Experts think that having the cart maker close to the farmer is a good thing because they can talk to each other easily and sort out any problems. And of course if the cart is made locally, it can be repaired locally, so there will not be problems with spare parts.

## Idea behind design

The idea behind the design of axle described in this technical release is to allow construction without the use of machine tools (drills, lathes and milling machines), and to use materials which should be readily available. The materials can be used 'as bought' - no hardening of any of the components is needed. The only tools which you must have are a welder and a hacksaw, but a file and a vice are also very handy. Of course if you do have power tools - especially a power hacksaw or anglegrinder with cutoff wheel - things can be made much faster. This axle is suitable for a wide range of production methods so that if you have to make many of them you can make special tools to make it quicker.

The hubs in this design use 2"BSP pipe on 1 $\frac{1}{2}$ " BSP axles so that they have a small diameter and will fit most scrap car wheels. Most wheels have a hole in the middle for the axle.

This hole is usually about 60mm diameter, or a bit bigger. Sometimes they are smaller and the wheel will not fit, but you can sometimes saw or file the hole bigger if you have to. Another way of avoiding the hole in the wheel problem is to use live axles as described in Technical Release 29.

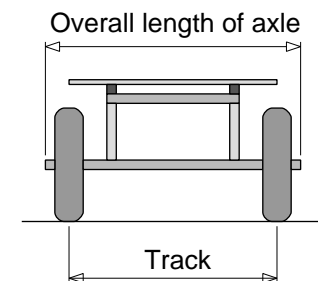
The best way to make these axles is to use a piece of plastic pipe between the axle and the hub tube to make a bearing. The best plastic is probably polythene, but this is hard to get in short lengths so we have used PVC in Kenya. Search around the stores in your area to see what is available. If the only steel pipes you can find for the axle and hub tube do not have enough gap between them for a plastic bearing then you can still get good performance without it, but the axle will wear a bit faster and the cart will be a little harder to pull. Alternatively you can enlarge the hub tube a little see the **modifications** section.

You will see from Figure 1 that the wheels are fixed to the axles by struts rather than by thick metal discs as on most axles. Putting the fixing studs on struts like this is much easier and cheaper. It also means that you might be able to fit a slightly different wheel by bending the struts a bit to fit. Or if that does not work you can even cut nearly through the welds and then weld them in the right place. You could even cut the struts right

off and weld on a different number if your wheels have a different number of holes.

## Performance

We have not yet properly tested axles like these, but many farmers and water carriers in Kenya have used them on their carts for three years or more without even a plastic bearing. Of course you need to clean the axle and hubs out and regrease them every year at least and if you use them heavily you should grease them every day. Actually this is easy because all you need to do is remove the hub restraint pin through the end of the axle, take the wheel and hub off, put some grease on the axle and replace everything. It should only take a few seconds.



**Figure 2: track width of cart.**



## Length of axle

You need to decide how long to make your axle. Of course you can make the axle any length you like to suit your cart, but most carts will need an overall axle length of between 1400 to 1600 mm. In the **cutting list and cost** section you will see that you can make the axle with a central section of some other material than the 1½" BSP if this is very expensive. We have assumed that you will use square box tubing but you could use angle iron. To calculate how long to make the axle decide how big you want the **track** to be (see Figure 2) and add 280 mm. This distance will now be the **overall length of the axle** (see Figure 2 for this also). If you are going to use square box tubing or angle iron for the central section of the axle then you should subtract 240 mm from the **track** and make the central section this long.

## Cutting list and costs

The table shows a cutting list for a complete axle - two wheel hubs with stub axles joined by a square tube section in the middle. We have shown this way because round pipe is very expensive in some countries. But if pipe is reasonably cheap where you are then make the whole axle out of one piece of

pipe. Recent prices of materials in Kenya for the axle are shown in \$<sub>US</sub>. The 2" BSP (British Standard Pipe) is about 61mm outside diameter, or a bit less, with a wall thickness of about 3.6mm. The 1½" BSP is about 49mm outside diameter, with a wall thickness of about 3.2mm.

component	material	number & length reqd [no.x mm]	total material in axle [mm]	materials cost in Kenya [\$US]
central axle	2" square box tubing	1x1200	1200	3.20
hub stub axles	1½" BSP malleable iron pipe	2x350	700	2.60
hub outer tube	2" BSP malleable iron pipe	2x200	400	1.80
optional plastic brg	1½" or 2" plastic pipe	2x200	400	0.47
hub retaining rings	6mm or 8mm square bar	4x154	616	0.12
hub restraint pegs	6mm or 8mm square bar	90x2	180	0.04
wheel studs	50 x 12mm bolts	8x50	na	2.40
wheel stud struts	6x40 black or bright steel strip	8x37	296	0.60
TOTAL COST =				11.23

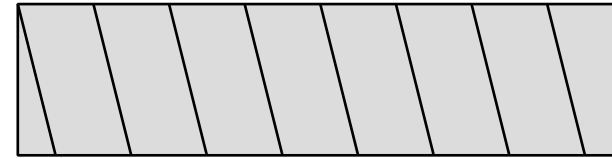
## Construction step by step

1. The first and probably most difficult job, is to get some suitable pipes. Obviously the axle has to be strong enough to carry the cart, so it should be made from pipe bigger than about 40mm outside diameter. You must also make sure that the pipe has a wall thickness of more than about 2.5 mm.

The hub pipe also must have a wall thickness of 2.5mm or more. And it must have a bore (or inside diameter), which goes easily over the axle with enough room for the plastic bearing and some grease. There can be quite a lot of clearance (slackness or looseness) between the hub and the axle (say up to 3mm) - it does not have to be tight. If you cannot get steel pipes with enough clearance for a plastic pipe bearing then the axle will work quite well without it, but you should grease it more often.

These instructions deal with making an axle to the design shown in the drawings. If you find that you cannot get the right sizes of material you might still be able to make an axle with other sizes. See the **Modifications** section later in this booklet.

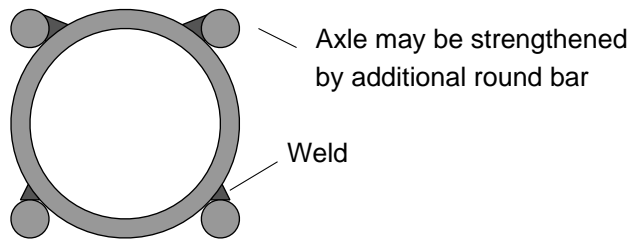
2. You will probably find that no plastic pipe fits properly between the axle pipe and the hub tube but all you need to do is slit a piece along its length and open it up a bit or close it down until it fits. A better way is to make a helical saw cut in the plastic pipe so it is like a spring. Then it will open up or close down to the size easily and it will not tend to wear the area around the slit.



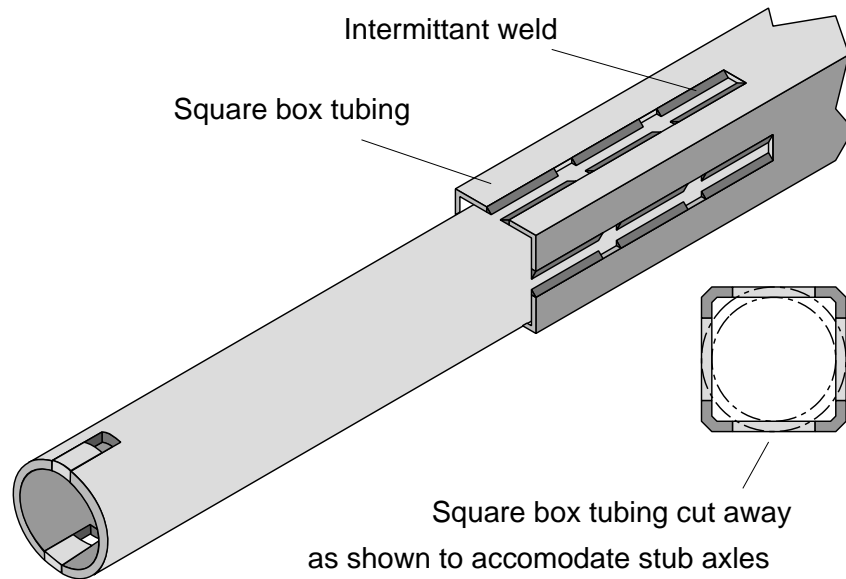
**Figure 3: helical sawn cut in plastic pipe bearing sleeve.**

3. When you have got the right pipe sizes, you can cut the two hub pipes each 200 mm long and the axle pipe about 1500 mm or 1600 mm long or if you are going to do it with a central section in square pipe or angle iron you need to cut the central section about 1200 mm long plus the two stub axles each about 350mm long. If you need to support a simple one piece pipe axle an easy way is to weld short pieces of round bar onto it as shown in Figure 4. If you make these about 300 mm long they will strengthen the axle quite a lot as well.

Figure 5 shows how you can weld the stub axle tube into the square box tubing. You will need to cut slots in the sides of the square tube so that it can bend in or out to accept the stub-axles. When you are welding the stub axles in, make sure you tack weld them in first and check that they are straight before you do the final weld.

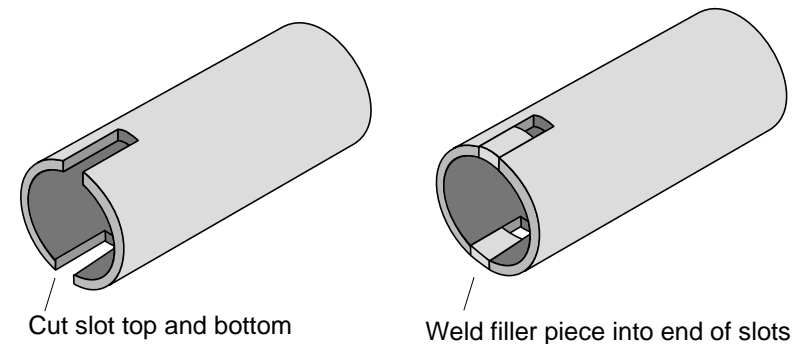


**Figure 4: method of adding round bar to support pipe axle and strengthen it if needed.**



**Figure 5: method of welding stub axles into square tube.**

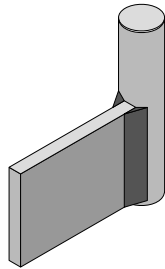
- Next you need to make a hole near each end of the axle pipe for the hub restraint pin. To do this without using a drill cut a slot in each side of each end of the axle. Make the slots about 30 mm long to start with and about 10 mm wide. You want the slots just the right length so that with the hub restraint pins in place the hub tubes are not pinched tight. It does not matter if they are a bit loose.



**Figure 6: method of making hole for hub restraint pin without drilling.**

- The next step is to weld the stud bolts or bits of threaded rod onto the struts. If you have a vice it makes welding the bits together easier because you can clamp the pieces together while you tack weld them. You need to make one strut for each wheel stud unless you are using five or six

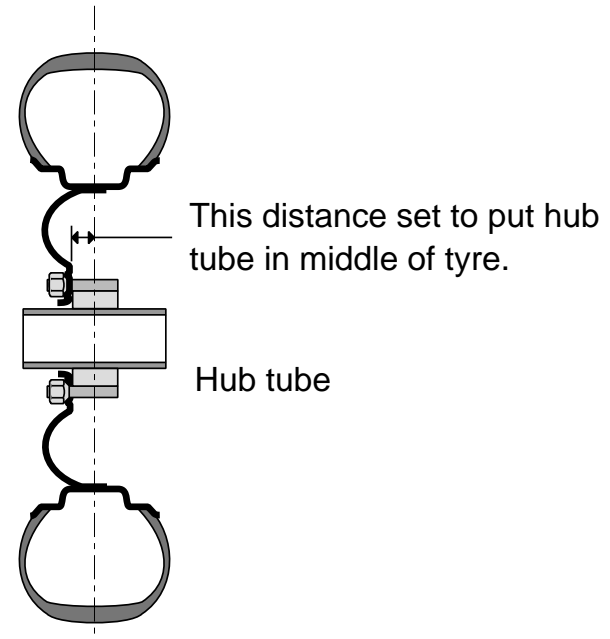
stud wheels on a single donkey cart. If so you could use only three studs per wheel if the cart user wants only light use from the cart.



**Figure 7: stud welded to the wheel struts.**

We have used this method of fixing wheels successfully with the old VW wheels which have very large holes in the middle.

When you've made up the struts you can put a nut on each stud and then put the studs through the wheels, and put a second nut on each stud. Then get everything even and straight with the hub pipe in place as well in preparation for welding the struts to the hub tube. You want to get the middle of hub pipe level with the middle of the tyre, as is shown in Figure 7. Most car wheels need the studs to be about 40mm offset and this is what is on the drawings.

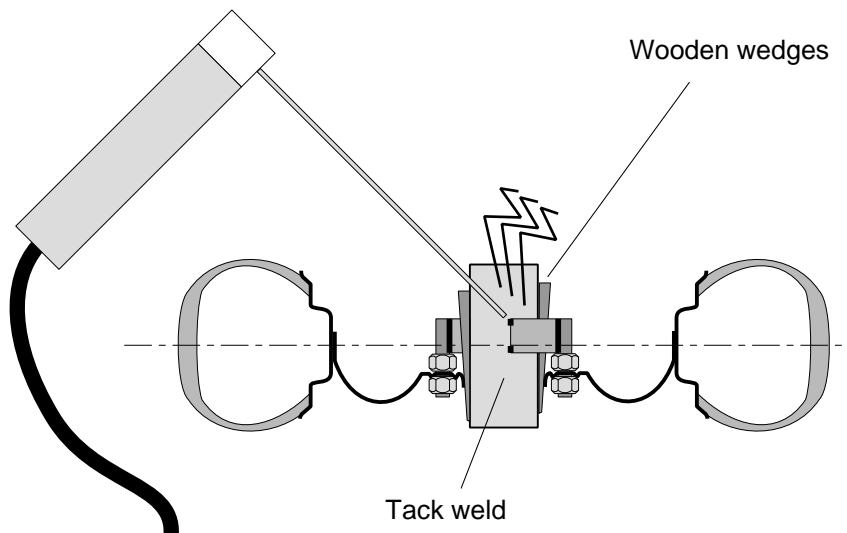


**Figure 8: cross section of tyre wheel and hub tube showing centering of hub tube in wheel**

Getting the hub in the middle of the wheel and tyre means that the bearings in the hub are evenly loaded. You might find that holding the hub tube in the wheel with some wedges as shown in Figure 8 is a good way to do it.

When you are happy, tack weld the struts to the hub pipe. Then remove the wheel and wedges so you've got room and finish the welding of the struts to the hub tube. Repeat

this for the other hub. If you are going to make several axles you can make up a simple jig, rather than the wedges, to hold everything for welding. We have used a piece of plywood with a central hole to fit snugly over the hub tube and four holes for the studs. In other words its a bit like a dummy wheel.



**Figure 9: cross section of tyre wheel and hub tube during tack welding of stud support struts**

It is best to check that the hubs, and stub-axles still go together when you've finished welding because sometimes

weld contraction can pull it all out of shape and make it all too tight. You might need to file off some high spots inside the hub. If you can get it together without a hammer you'll be ok because it will wear to the right shape.

6. Nearly there! Now take the wheels off the hubs and make up four rings (called hub restraint rings on the drawing) from 6 mm or 8 mm square steel bar (or round bar if you cannot find square). One ring must be welded about 230 mm from each end of the axle pipe or from the ends of the stub axles to stop the hubs going too near the centre of the axle.
7. Now put it together! Smear some grease onto the plastic bearing pipe (if you are using one) and onto the axle and put the hub tube and plastic bearing onto the axle. Then put the outer hub restraint ring on and secure it with the hub restraint pin. Do the same for the other hub.
8. Paint everything!
9. You've done it!

## Modifications

Pipes can be made slightly bigger (up to 1mm bigger) by forcing a short piece of round bar of the right diameter through them with a press. Another way to do it is to saw the pipe along its length and open it up to the right size and then weld it. You can also make it a bit smaller like this by cutting a wider slot and squashing the pipe down. Try to clean the weld back flush with the tube using a file if you can as this will give longer life. It does not matter if

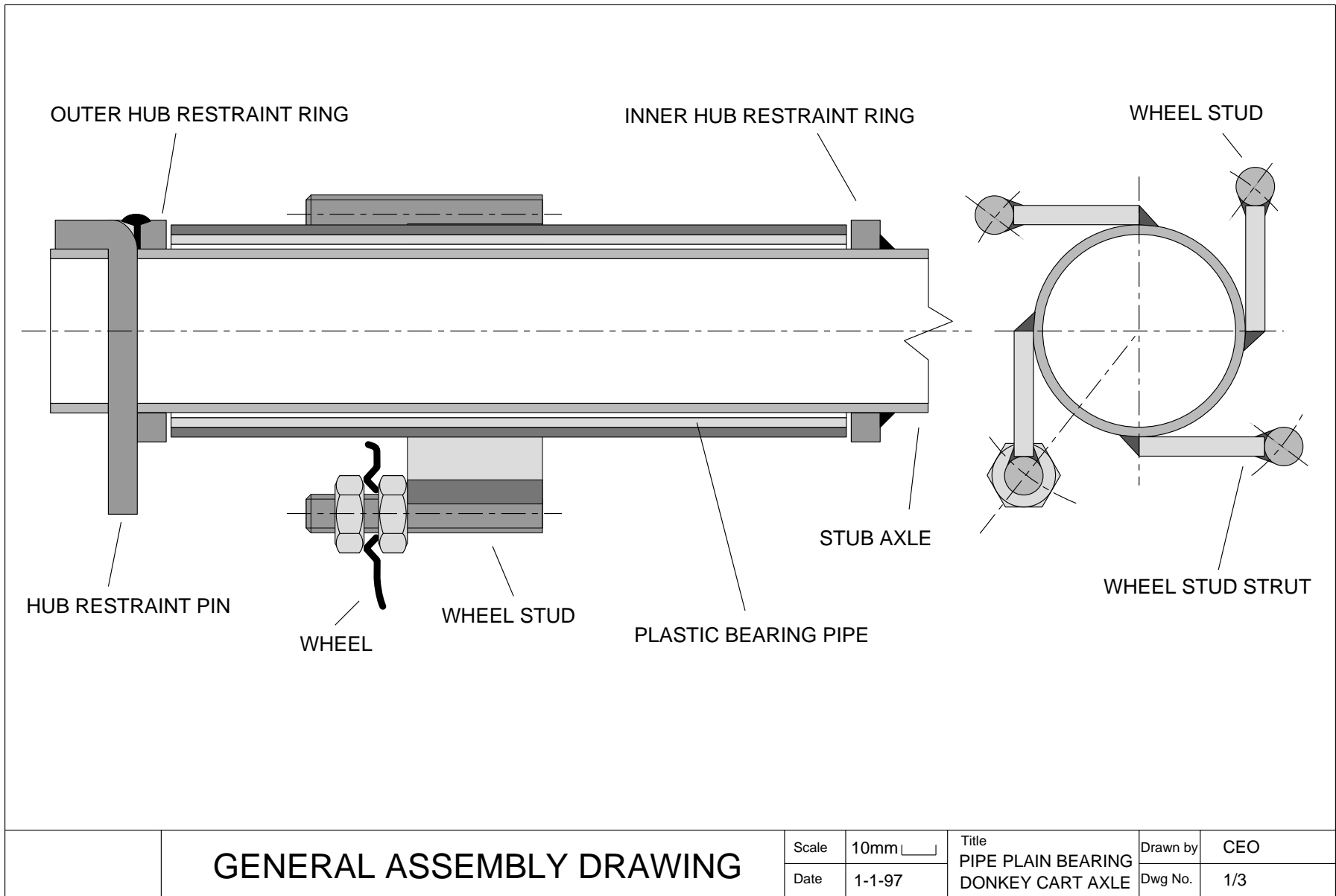
If you find that you cannot get anything like the materials talked about in the cutting list then maybe you can adapt the design a bit. If the hole in the middle of the wheels is big then you stand a better chance of finding a combination of pipes and rollers that will fit. You can often cut a bit out of the middle of the wheel to make the hole bigger. The hole in Land Rover wheels is big and you can get 4" pipe into them. Of course the shaft does not have to be a pipe - it could be solid and then it could be a bit smaller, say 30mm diameter if the steel is high quality.

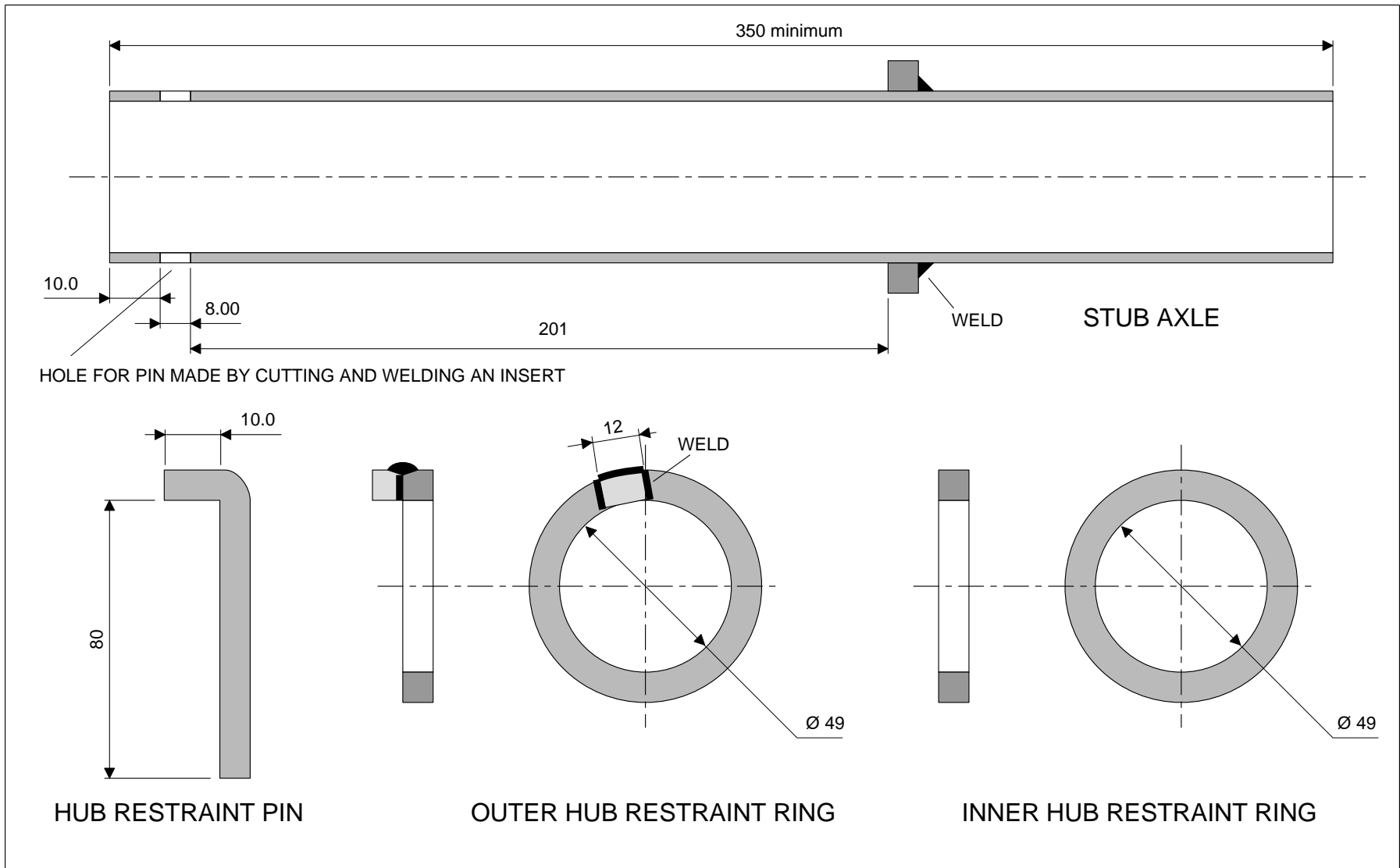
Another idea that we have tried is to use a hardwood as the hub and even the wheel. If you think about it, the wear on something which is rolling must be less than when something is sliding over it, so a wooden bearing should be better than a

sliding one. Some bearings we have tried have had a steel ring fitted inside so that the rollers roll on this steel. We have also tried making these rings from round bar like wire so that it's like the rollers roll on the inside of a spring. This seemed to work quite well.

## Other DTU cart developments

Other methods of hub design using aluminium castings, for example, which might need no machining, are under development at Warwick and wheel designs in steel sheet, cast aluminium and timber are also in manufacture or under development. A range of designs for donkey and ox carts made of steel and wood, is also available, some of which are in production in Kenya and Nigeria.

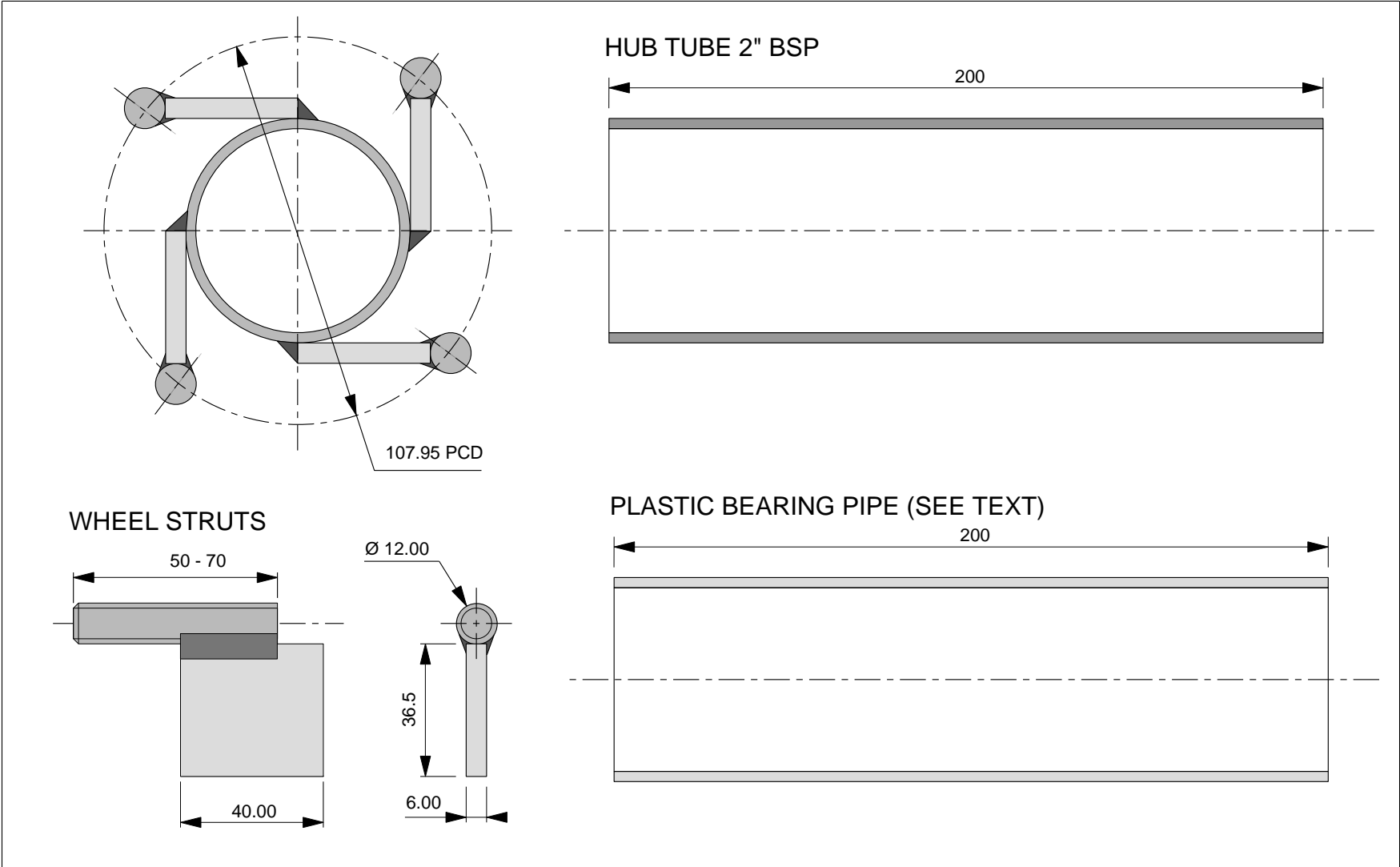




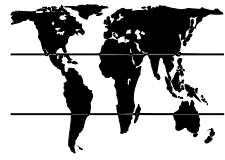

# HUB AND AXLE COMPONENTS

Scale	10mm [ ]	Title	PIPE PLAIN BEARING	Drawn by	CEO
Date	29-12-96	Title	DONKEY CART AXLE	Dwg No.	2/3





<b>HUB TUBE, PLASTIC BEARING &amp; WHEEL STUDS</b>	Scale	10mm <input type="checkbox"/>	Title PIPE AND PLAIN BEARING DONKEY CART AXLE	Drawn by	CEO
	Date	1-1-97		Dwg No.	3/3

**DTU**   **KENDAT**

# **Animal Cart Programme**

TECHNICAL  
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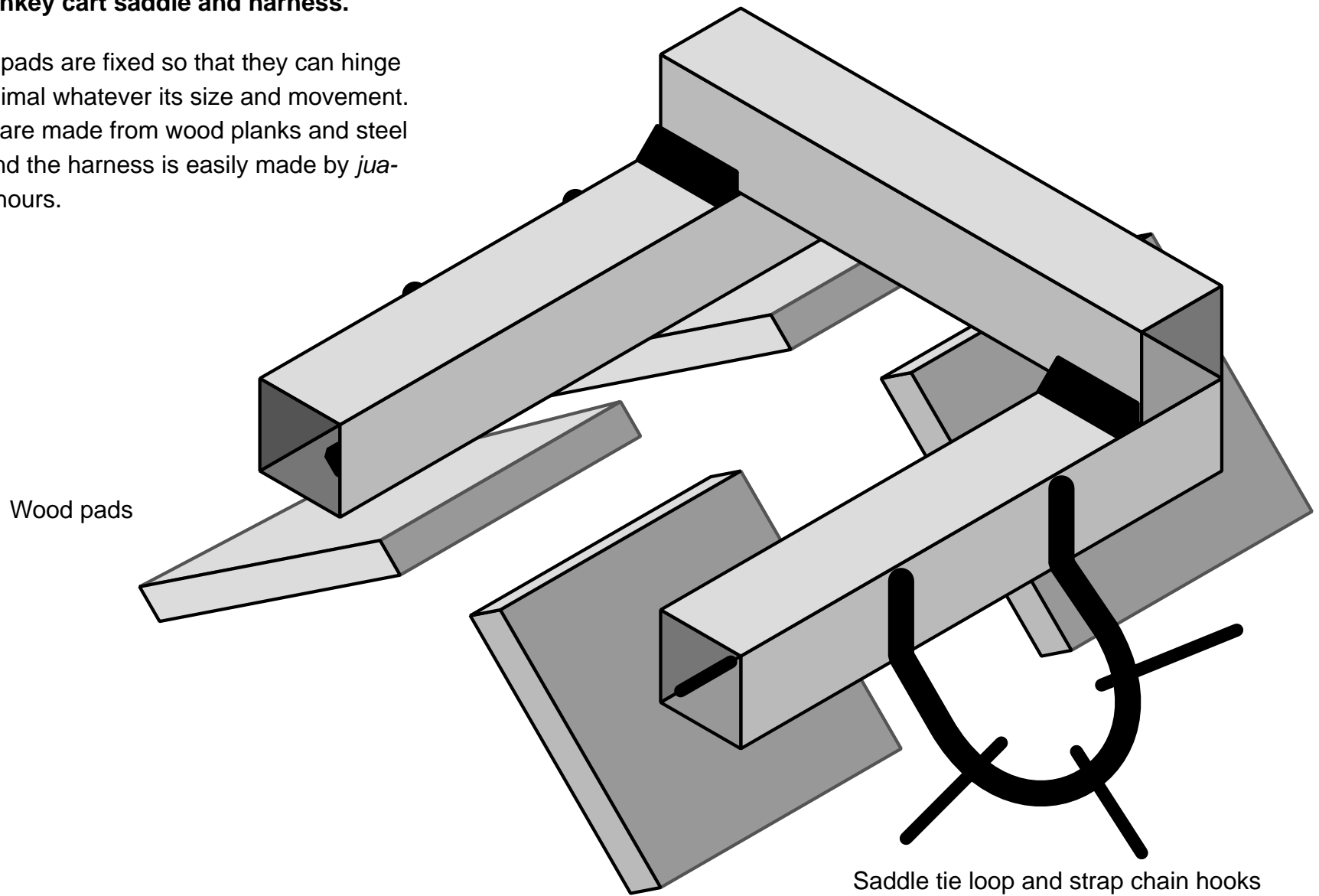
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## Single Donkey Harness for Cart Pulling

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**Figure 1: donkey cart saddle and harness.**

The wooden pads are fixed so that they can hinge and fit the animal whatever its size and movement. The saddles are made from wood planks and steel box tubing and the harness is easily made by *jua-kali* in a few hours.



# Donkey Harness for Carts Made From Steel Box Tubing, Timber and Canvas/Sacking

## Introduction

This Technical release tells you how to make a saddle and harness system for one donkey to pull a cart with two shafts. Another Technical Release tells you how to make a saddle and yoke harness for two donkeys and a cart with a single draw pole.

You should find that you can make the whole harness for less than £<sub>UK</sub>5, depending on the cost of the materials and labour. Once you get organised, two men can probably make a complete harness in two hours - we have designed this harness to be easy to make.

Other booklets in this series tell you how to make simple low-cost axles and carts: we have designs for steel framed and wooden framed carts and for many different kinds of axle. All carts and axles can be made without special tools - even drilling metal is not required.

## Idea Behind Design

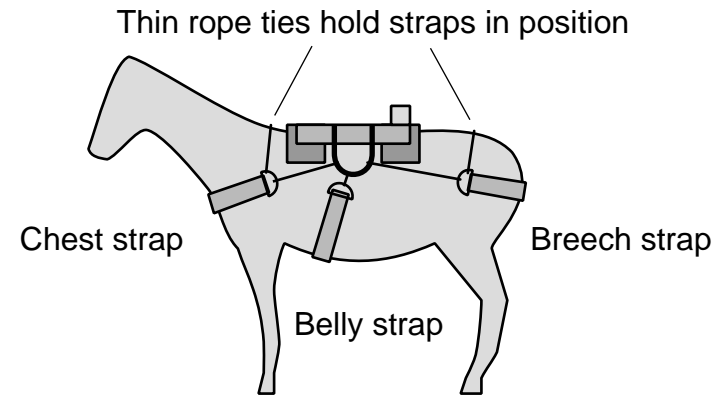
Saddles are used in many countries to hitch animals to carts. Our saddles use a system of hinged pads which swivel to fit

any animal in any reasonable condition. As the animal moves and changes condition the saddle still fits. Using this harnessing method carts can be pulled, steered and braked, and stabilised if the load is too far back on the cart body.

These harness has been tested in Kenya and work well - we have even had donkeys jump over a hedge pulling a cart with this harness! But we would like to test them for a year or two more to see how the animals react.

Special tools and jigs and hard-to-get materials are not required to make the harness. The only tools which you must have are a simple welder, a woodsaw, a hacksaw and a hammer.

The saddle frame is welded and the wooden pads are fixed to the frames with nails which are put through holes in the steel



**Figure 2: saddle secured to donkey with straps.**

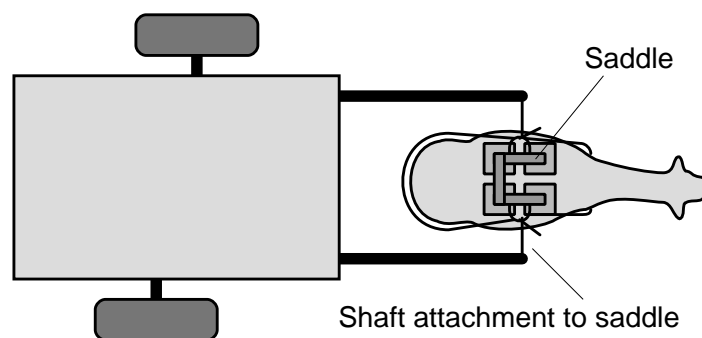
frame and welded so that they are loose and allow the pads to follow the shape of the animal.

## Cutting list and costs

Table 1 shows a cutting list for a complete harness - recent prices of materials in Kenya are shown converted into £<sub>UK</sub>.

## Construction step by step

- 1) The first job, is to get all the material together and clear a space to work. Ideally you will be able to work on a flat area of concrete.
- 2) Make up the U-shaped frame as shown in Figure 4. If you have a G clamp you can use it to hold two pieces of the frame together during welding.



**Figure 3: donkey harnessed to cart.**

- 3) Then weld the tie loops and the yoke attachment stub and loop onto the U frames so that the frame looks as shown in Figure 5.

- 4) Next cut the wooden load pads and round off all the edges so that there are no sharp corners to stick into the donkey.

Hammer two nails through each of the pads in the positions shown in the drawings. With some timbers you may need to drill holes for the nails to avoid splitting or burn the holes with a hot nail. Then cut the nails so that about 30 mm projects from the timber as shown in Figure 9.

- 5) Now mark the position of the holes required to accommodate the pad nails in the steel tubing. These holes

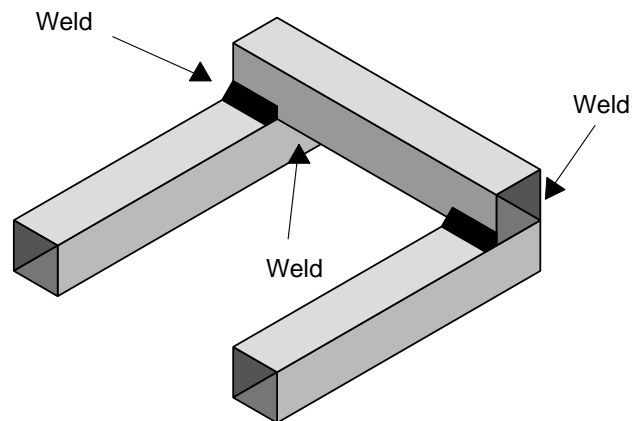
**TABLE 1: harness materials cutting list.**

component	material	# components	total mat [mm]	mat cost [£ <sub>UK</sub> ]
main frames	50x50 box tubing	3x325	1800.00	1.06
strap loops	12 mm re-bar	2x300	1200.00	0.19
load pad pivots	12 mm re-bar	4x20	160.00	0.03
load pads	25x150 timber	4x150	1200.00	0.14
pad fix nails	nail or 6mm re bar	8x50	800.00	0.04
strap rings	6mm re bar	6x180	2160.00	0.11
strap clencher	6mm re bar	6x120	1440.00	0.07
strap hooks	6mm re bar	6x150	1800.00	0.09
straps	CC5 canvas	3x4x65	1560.00	1.97
strap chains	dog chain	3x300	900.00	0.70
			<b>TOTAL =</b>	<b>4.40</b>

should be 15 mm and 65 mm from the ends of the square tube as shown in Figure 7. Blow the holes through with the welder at maximum current setting or use an angle grinder or file or hacksaw.

- 6) Next you can weld on the pad pivots blocks as shown in Figure 7.
- 7) Now put the nails through the blown holes and weld a piece of nail across the ends of the nails as shown in Figure 10. Welding down inside the tube looks difficult but skilled workers can weld the pads in about one minute.

An alternative way of doing it is to cut slots 70 mm long along the corners where the holes would be as shown in Figure 8. The slots should be 8 mm wide so that the nails

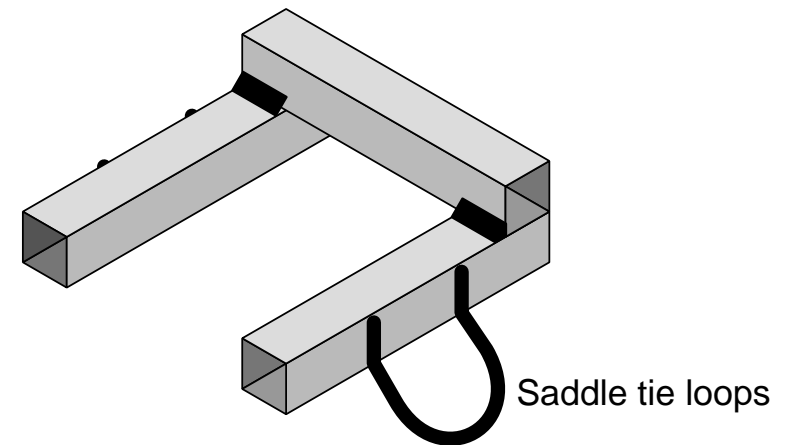


**Figure 4: welding of frame cross piece.**

are very loose in them. Make up the pads as shown in Figure 9, put the nail loop into the slot in the right place and weld the pad pivot blocks into place across the slot so that they are in the same place as in Figure 7.

- 8) Next you need to make up the six straps to hold the saddles onto the donkeys. The D rings at the end of the straps can be made from 6 mm diameter concrete reinforcing bar as shown in Figure 11. A separate piece of the re-bar is clenched over the strapping using hammer blows to fix the D rings to the ends of the straps as shown.

The straps themselves can be made from heavy canvas or hessian sacking. You should use three or four thicknesses



**Figure 5: tie loop welded to U-frame.**

of material for them to make them strong enough and soft enough not to hurt the donkey.

- 9) Make the strap chain hooks from more 6 mm re-bar as shown in Figure 12 and fit the fixed ends to the saddle tie loops.
- 10) Paint and creosote the saddle. You've finished it!

### Method of harness use

- 1) First put a blanket or two folded hessian or jute sacks (not plastic) onto the donkey's back to protect it.

Remember that protecting the donkey will save money because it can work harder if it is comfortable and will not

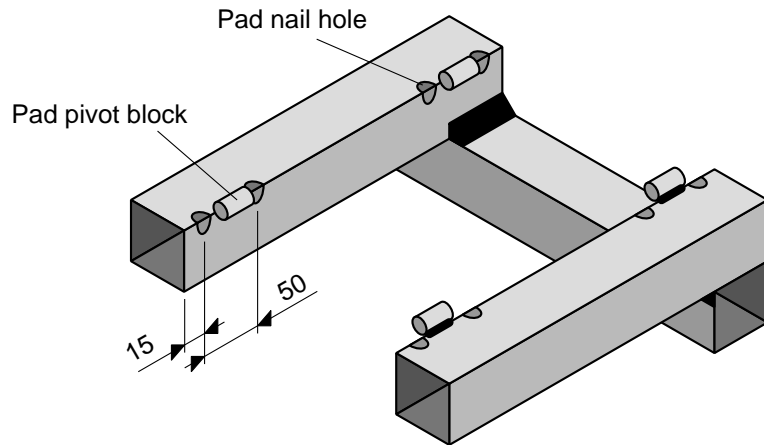


Figure 6: pad nail hole positions and pad pivots.

get sick from skin wounds.

- 2) Put the saddle on so that the cross beam is towards the animal's rear. Position the fronts of the wood pads about 100 mm behind the animal's shoulder blades. This means that the saddle should never come near parts of the animal's back which move.
- 3) Next hook the breaching strap to the loops hanging from the side of the saddle. It should be tight enough to tend to pull the saddle a little rearwards. Make sure that the breaching strap is pulled up high so that it does not rub the backs of the legs. But it should not be so high that the animal cannot defecate. Tie a piece of thin rope across the animal's back between the rings of the strap to hold the

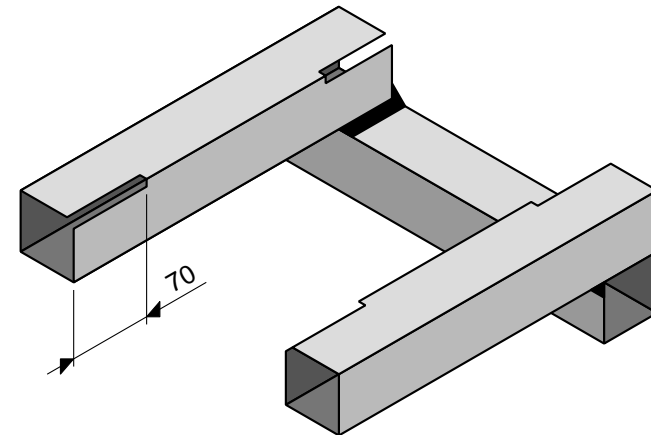
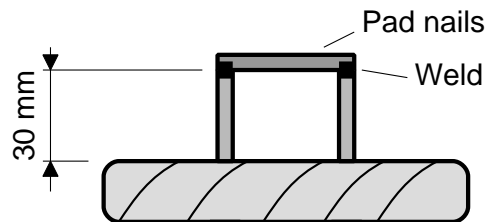


Figure 7: pad nail slots.

strap up.

- 4) Now hook the chains for the belly strap onto the hooks fixed to the saddle tie loops. The strap should be 50 mm or 100 mm behind the front legs - check that the legs do not rub on the strap when the animal walks. Tighten the strap so that you can just get a couple of fingers under it between the strap and the animal. This will be much tighter than the other straps.
- 5) Hook the chest strap to the loop and adjust the tension so that it is a little loose. Use another short piece of rope to hold the chest strap up so that it is just below the windpipe. The strap goes tight when the animal pulls really hard. We have noticed that the belly strap and breaching strap are nearly enough without the chest strap and so we leave the chest strap a bit loose.
- 6) You are ready to go! You should be able to saddle an



**Figure 8: welded pad nails.**

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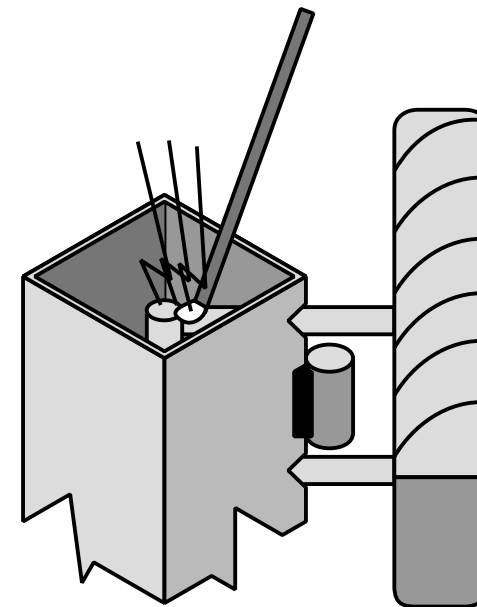
animal in only a few seconds when you get practised.

## Saddle Drawing

You will find drawings of the saddle and yoke on the last pages of this Technical Release.

## Other DTU cart developments

The DTU has been working on a range of cart designs for use with both donkeys and oxen. It has designs for wooden and



**Figure 9: welding re-bar to frames for wooden load pads.**



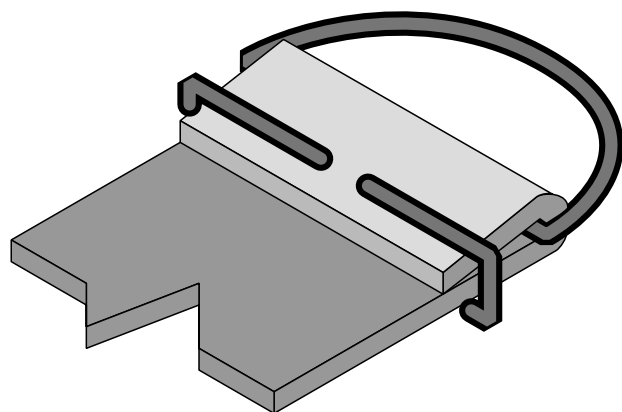
steel framed types. You can make either type of cart in only a few hours, if you are reasonably set up with tools and materials.

The DTU has also been working on new designs of wheels, hubs and bearings to bring down their costs and make things more locally manufacturable. It has a system of axles with bearings made from PVC pipe, another with wooden bearings and a third using scrap ball bearings. None of these axles need machining and they only take two men a day to make.

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## Acknowledgements

The DTU is grateful to the DFID (British Government) for the financial support necessary to carry out the research and

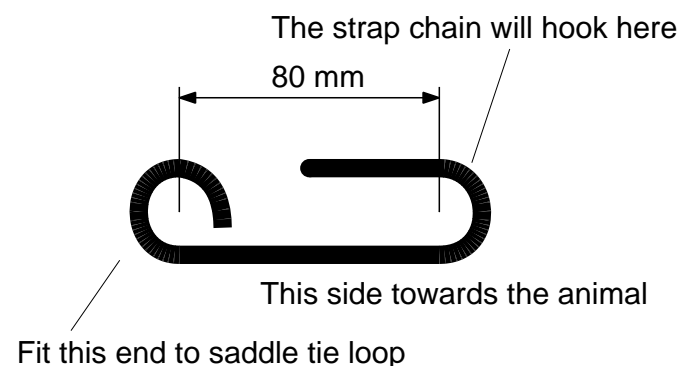


**Figure 10: D rings for straps made from re-bar.**

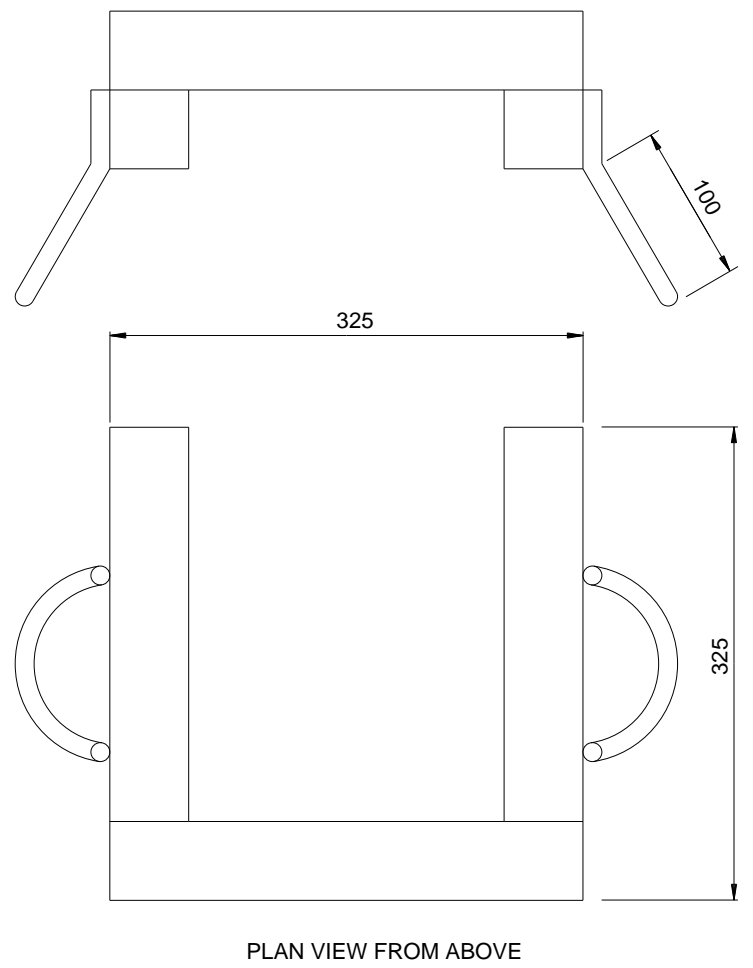
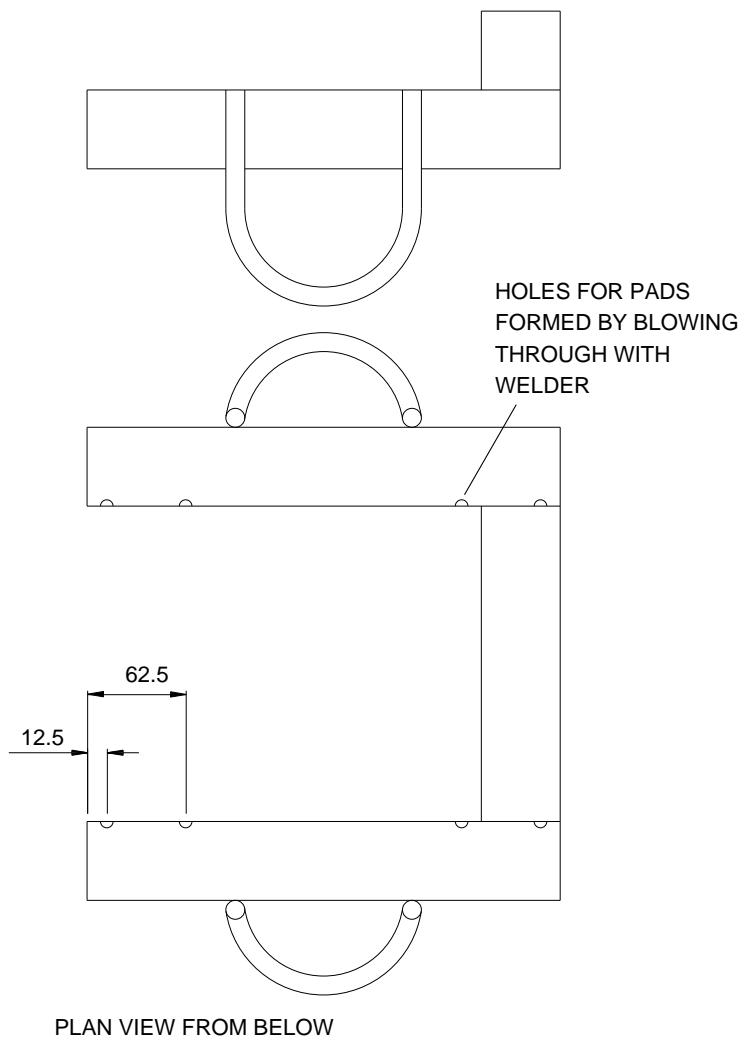
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development project under which this product was developed.

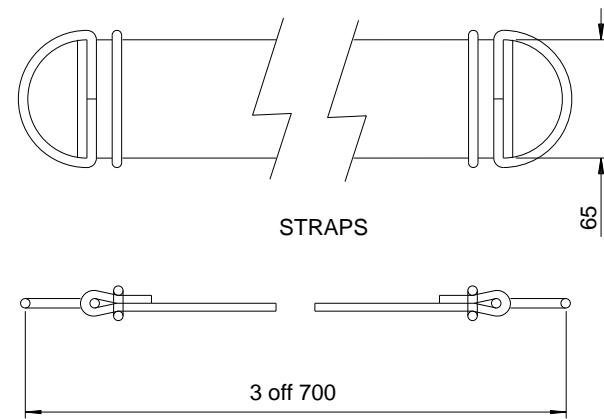
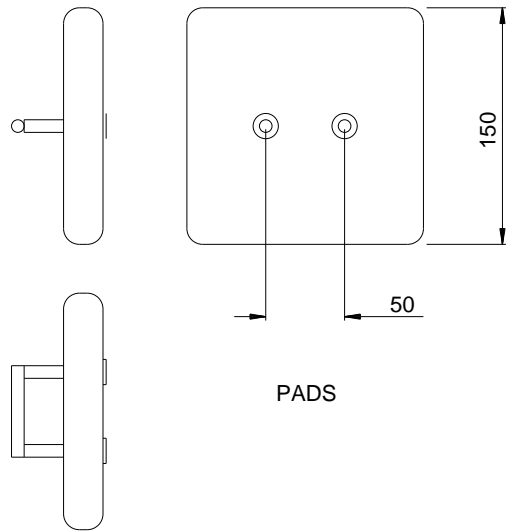
The DTU would also like to thank Dr Pascal Kaumbutho of KENDAT in Kenya and Mr Joseph Mugaga of TOCIDA in Tororo, Uganda for their very considerable help with this project. A large number of other people and organisations have contributed to the success of the project, most notably Mr Anthony Ndungu in Kajiado Kenya, Mr JD Kimani in Kikuyu Kenya and Mr Joseph Gitari in Wanguru Kenya in whose workshops most of the development work of this project was performed. Thanks are due also to Mr Stanley Lameria in Kajiado, Mr Patrick Gitari in Wanguru and Mr Mathew Masai in Machakos for their assistance.



**Figure 11: chain hooks for straps.**



Scale	50 mm	Title	Saddle for	Drawn	CEO
Date	15/4/99		donkey carts - frame	Dwg #	1/2



					Scale	<u>50 mm</u>	Title	Drawn	CEO
					Date	15/4/99	Saddle pads & straps	Dwg #	2/2



# Animal Cart Programme

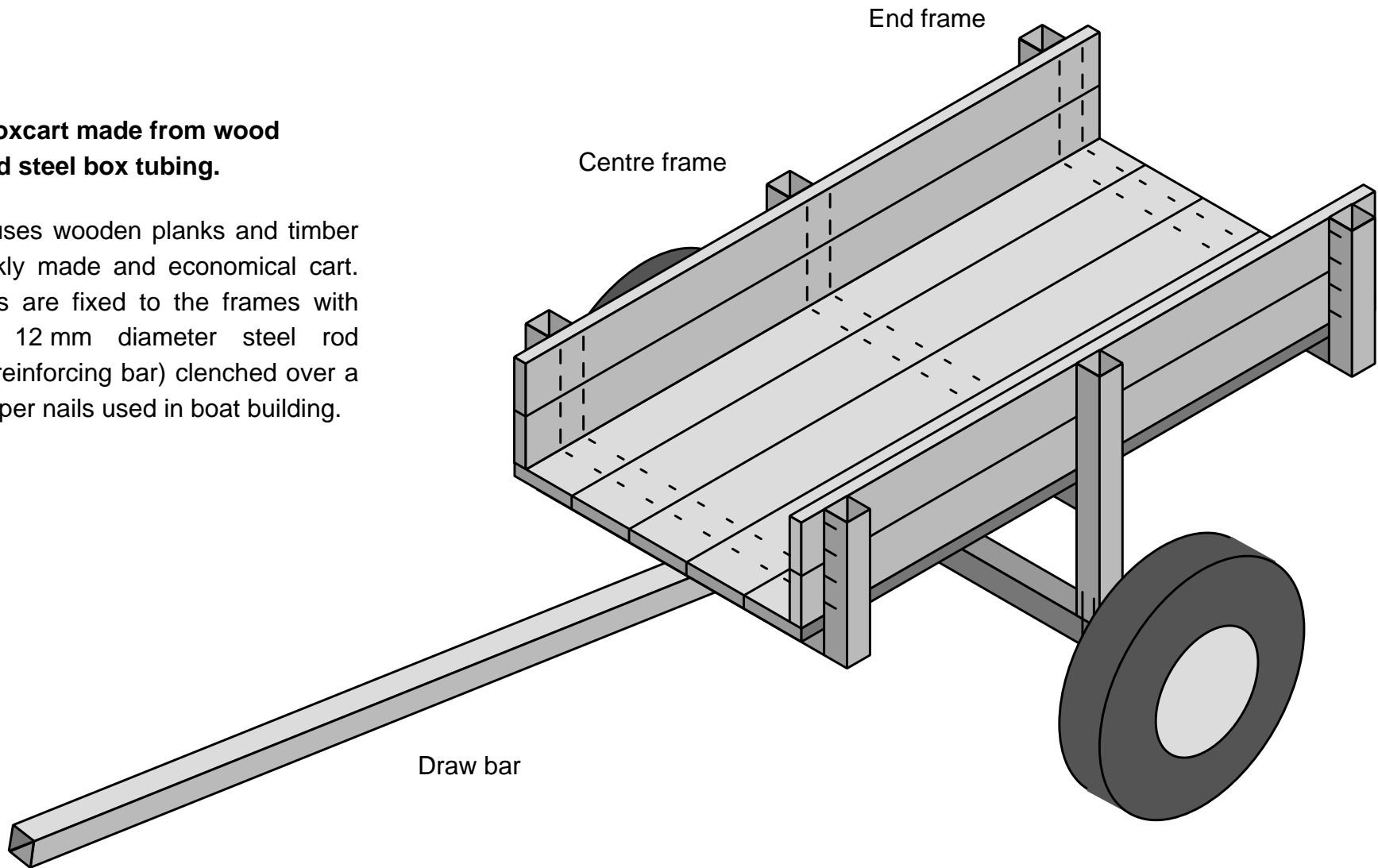
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## LOW-COST STEEL & WOOD OX CART

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**Figure 1: oxcart made from wood planks and steel box tubing.**

This cart uses wooden planks and timber for a quickly made and economical cart. The planks are fixed to the frames with 6 mm to 12 mm diameter steel rod (concrete reinforcing bar) clenched over a bit like copper nails used in boat building.



# Ox Cart Body Made From Steel Box Tubing and Timber

## Introduction

Not enough farmers in Africa have animal carts. Those who have carts can take their produce to places where they can get the best prices. They can also get into town and buy fertilizer and better seeds and move things around their farm easier. The trouble is that carts are too expensive for many farmers. The question is what can be done about it?

What you need is a body which fabricators and carpenters can make quickly with simple tools. These cart makers will probably be in the small market towns used by the farmers. Experts think that having the cart maker close to the farmer is a good thing because they can talk to each other easily and sort out any problems. And of course if the cart is made locally, it can be repaired locally, so there should not be any problems with spare parts.

Carts are made in many different places. Some carts are made in factories in industrial countries and some are made in factories in Africa, but most are made by local blacksmiths or carpenters using scrap car and Land-Rover axles. These

people cannot get enough axles to meet the demand so the carts are expensive. Even if they do have the axles, they still end up building heavy bodies that take ages to make. In another booklet in this series we have told you how you can make simple low-cost axles; in this booklet we tell you about a simple steel and timber body. You should find that you can make the body for about \$<sub>US</sub>60, depending on the cost of the materials and labour. Once you get organised, two men can probably make one body in a day. This is quite a lot faster than most carts can be made and it follows from the simplifications which we have made to the design. We've designed these carts to be easy to make.

## Idea Behind Design

The idea behind the design of oxcart described in this technical release is to allow construction without lots of special tools and jigs, and without any hard-to-get materials. The only tools which you must have are a simple welder, a woodsaw, a hacksaw, a hammer and a drill able to make a 10 mm or 12 mm hole in wood. (In fact you can make the drillbit yourself if you have to - read our booklet **Making a flatbit** - it's not too difficult.) You might find that a couple of 4" or a 5" G clamps (or something like it) are useful too. (The symbol " means inches so 4" means about 100mm because there are about 25mm in an inch.)

The cart frames are fixed together by welding and the wooden planks are fixed to the frames with clenched steel bar. This is a bit like the way small boats used to be fixed together. It's called clenching. What you do is make a holes through the wood to be fixed, put a giant staple made from 6 mm, 8 mm or 10 mm diameter re-bar (concrete reinforcing bar) over the steel box tubing and through the wood so it sticks out about 50 mm, and then knock the ends over with a hammer so they lie on the surface of the wood. You can tighten the joint more by putting a big hammer or something hard and heavy under the staple as shown in Figure 5 and then hitting the ends harder. If you put some washers (or something like them made from sheet steel) on the re-bar before you bend it over it will make the joint a bit stronger still. It does not make a very rigid joint, but you will find that the flexibility gives the cart some resilience so that it takes knocks better.

You will see that there are no mitres or complicated angles or joints to cut so you save time when making the cart. Also the exact lengths of the components are not very critical - again it saves a little time, but you will find that the carts look better if you take a little trouble to get things square and even etc and welding is easier with good square ends.

These carts have been tested a bit in Nigeria, but we have not tested them enough. We think that they are strong enough, but we cannot be sure. Really to get a reasonable price you need

to experiment a bit to see how the farmers treat their carts and what they expect their carts to stand. It's no good saying it must be strong enough so that they cannot ever break it - somebody will always break anything. It is very expensive to make something unbreakable. At least you can repair these carts easily and cheaply.

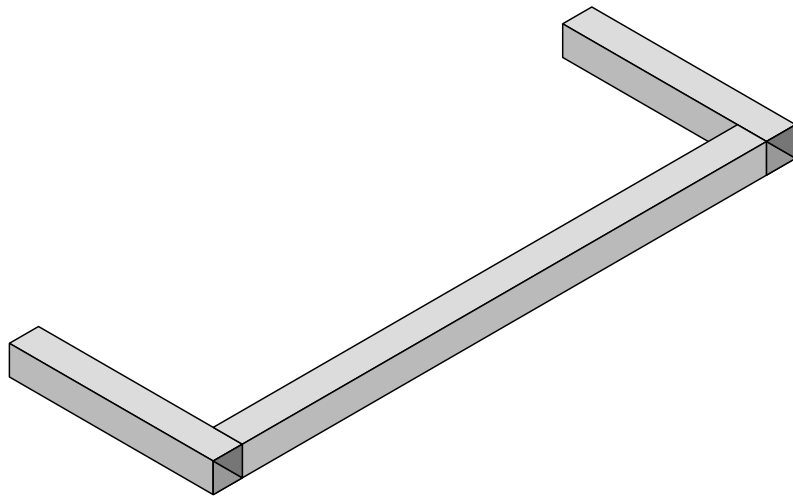
## Cutting list and costs

Table 1 shows a cutting list for a complete cart - Recent prices of materials in Nigeria are shown converted into \$<sub>US</sub>.

component	material	number of lengths & length required [No.xmm]	total material in cart [mm]	materials cost in Nigeria [\$us]
animal draw bar	80x80 box tubing	1 x 3 600	3 600	12.77
frame bottoms	80x80 box tubing	3 x 1 000	3 000	10.64
end frame sides	80x80 box tubing	4 x 415	1 660	5.89
centre frame sides	80x80 box tubing	2 x 750	1 500	5.32
tray bottom planks	30 x 150 or similar timber	6 x 2 000	12 000	3.87
tray side planks	30 x 150 or similar timber	4 x 2 000	8 000	2.58
tray ends	30 x 150 or similar timber	2 x 1 000	4 000	1.29
plank fixing staples	8 mm dia re-bar or similar	60 x 400	24 000	2.55
axle fixing studs	M12 threaded rod or bolts	4 x 150	600	2.55
axle fixing loops	8 mm dia re-bar or similar	4 x 550	2 200	0.23
TOTAL->				47.69

## Construction step by step

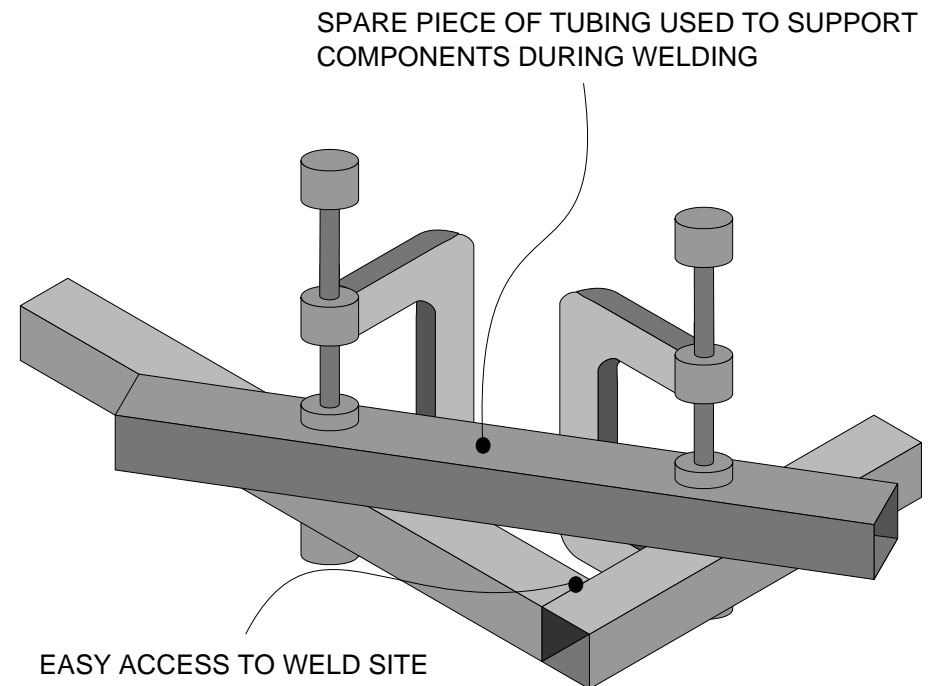
- 1) The first job, is to get all the material together and clear a space to work. Ideally you will be able to work on a flat area of concrete. Start by cutting the 80 x 80 box section steel into the right lengths, as in the cutting list, then cut the bottom and side planks. Lastly cut the 6 mm or 10 mm dia or whatever re-bar for the fixings (the staples etc).



**Figure 2: finished end frame.**

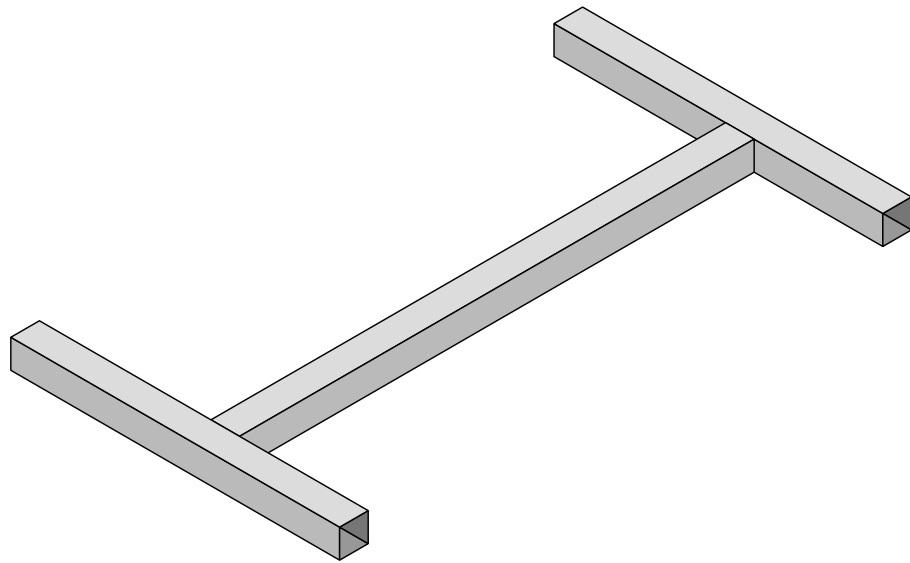
- 2) Next make up the two U-shaped front and back frames (endframes). If you have a couple of G clamps you can

use them to hold two pieces of the frame together during welding as shown in Figure 3. It's quick and you can tap the parts with a hammer until everything is square and straight and then weld.



**Figure 3: holding frame components during welding.**

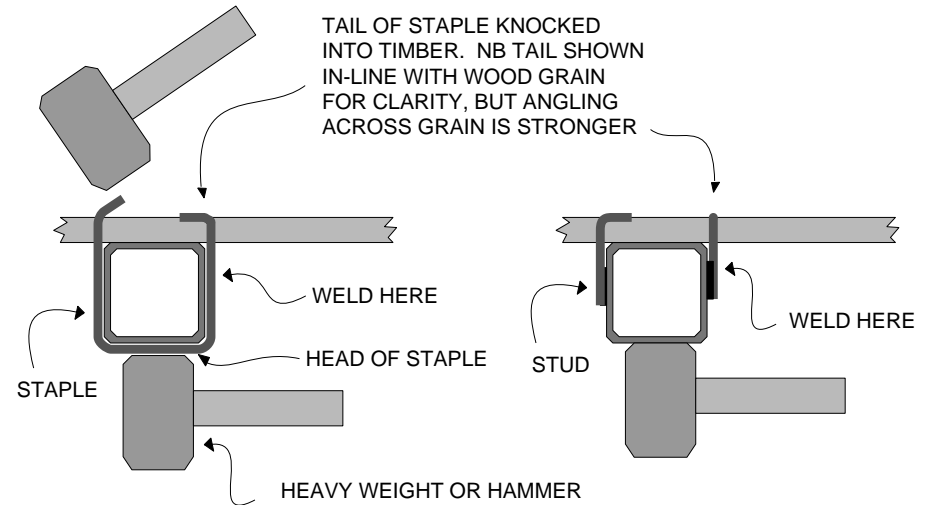




**Figure 4: a finished centre frame.**

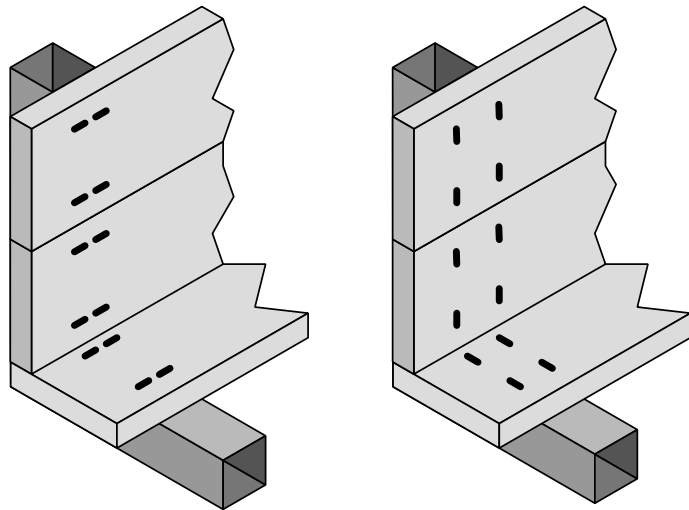
- 3) Then make up the frame that goes in the middle (as shown in Figure 4) - the one which supports the axle.
- 4) Next you can fit the side and the bottom planks to the end frames and then the middle frame with staples or studs. Figure 5 shows how these staples and studs can be tightened with a hammer and a weight or another hammer. You need to fix the staples in the right place with a small weld. Studs are another way of fixing the planks. Studs are just short lengths of round bar welded to the sides of

the box section as shown in the right of Figure 5. This saves round bar but means more welding.



**Figure 5: tightening staple or welded stud.**

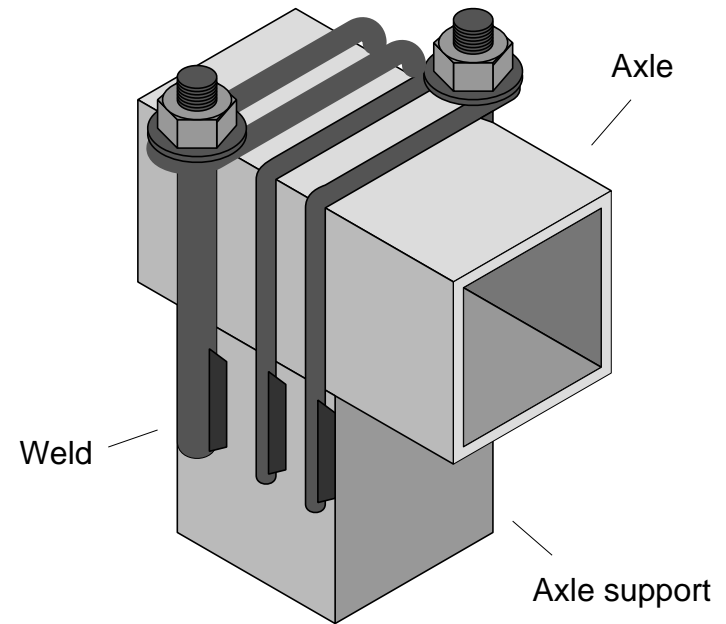
When you bend the end of the stud or staple over you can either bend it in line with the grain of the wood or across the grain, as shown in Figure 6. Bending it in line as shown on the left lets it go into the wood nicely and looks neat, but bending it over across the grain gives a stronger joint.



**Figure 6: studs or staples bent in line with grain (left) or across it (right).**

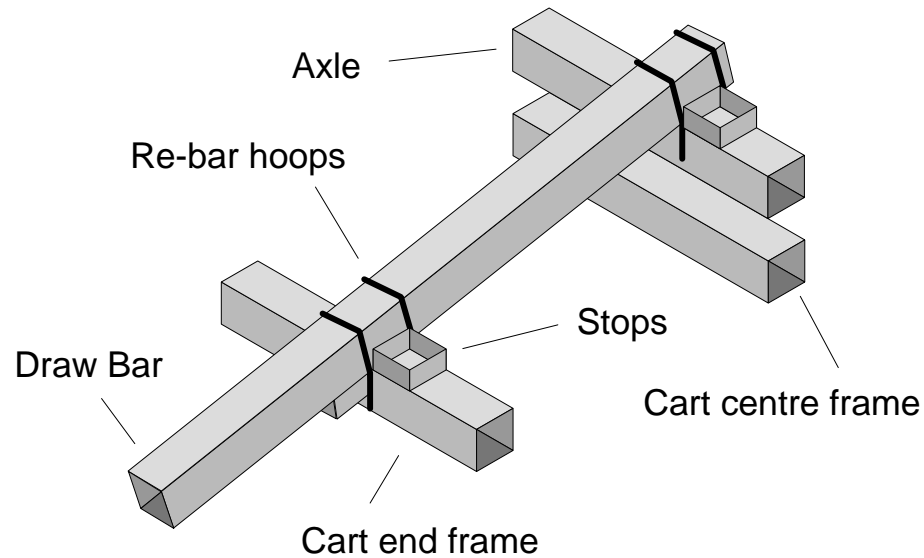
One thing we have not tried is bending the staple or fixing over the edge of a plank instead of putting it through a hole.

- 5) Next fix the axle with a one or two loops of round bar and some threaded rod and nuts and washers as shown in Figure 7. If you can get big threaded rod (say 16 mm and some 10 mm plain rod, you can fix the axle with one loop and threaded rod, but if you have only 12 mm then you must use two loops as shown.



**Figure 7: method of fixing axle to axle supports.**

- 6) Nearly there! Now you need to fix the draw bar (or pole or dissel boom - there are so many names for this!). It is best to fix the draw bar to the body so it can be taken off and replaced if it gets damaged. A good way to do this is with stops made of short lengths of box tubing, and round bar welded on as shown in Figure 8. The stops carry the main loads and it is easy to cut through the re-bar hoops if you need to change the draw bar. You will need to put new hoops on of course when you put the new draw bar on.

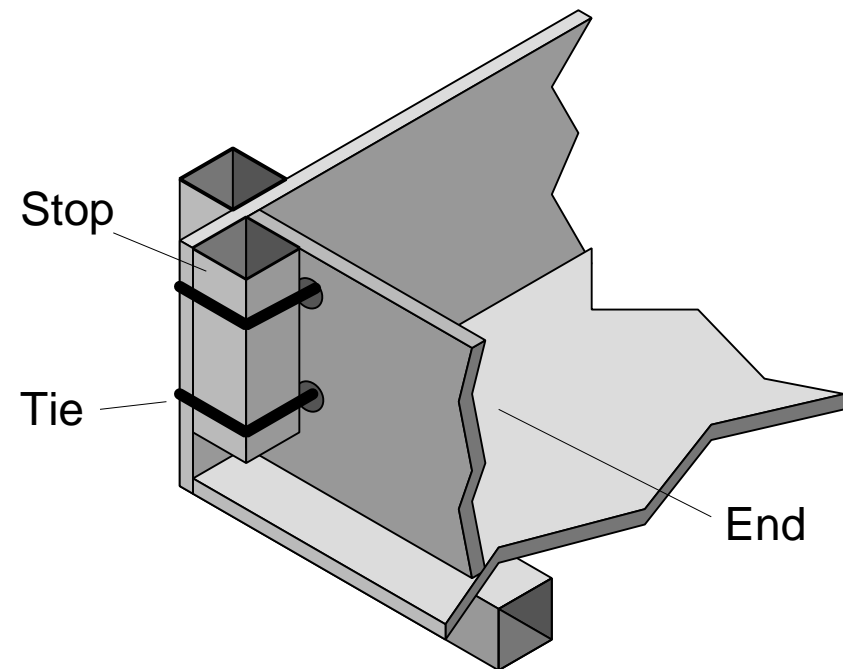


**Figure 8: method of fixing draw bar to body. (View of cart upside down.)**

7) If you want to make it so that the ends of the load tray can be removed easily you can do so in the way we have shown in Figure 9. Here a piece of the box section steel is fixed to the side planks by clench bars or bolts and stops the end being able to fall out. It is better if box does not touch the bottom planks because then it is easier to clean the corners. The end can be tied to these end stops with

rope or inner tube rubber. This is a good way because it is cheap and very easily repairable, but the farmers may want some flashy looking thing which will be very expensive to make. You will probably find that things like latches take longer to make than the rest of the cart. Explain to the farmers that they will cost extra too!

8) Paint or creosote the cart. You've finished it!



**Figure 9: method of fixing ends with rubber or rope**

## **Modifications**

There are many different versions of this cart. You can try longer or shorter carts and you can make them wider or narrower. When you do this, check the length and width of the planks of wood that you will use - you do not want to find that you are two inches short of being able to get two runs of plank out of one piece of timber, or that its just too narrow and you have to fiddle about and fit in a narrow strip.

## **Other DTU cart developments**

The DTU has been working on a range of cart body types for use with both donkeys and oxen. It has designs for wooden and steel framed types. The wooden types are cheaper in material terms, but the steel framed ones are easier to make because the joints are more straightforward - nevertheless you can make either type of cart in only a few hours, if you are reasonably set up with tools and materials.

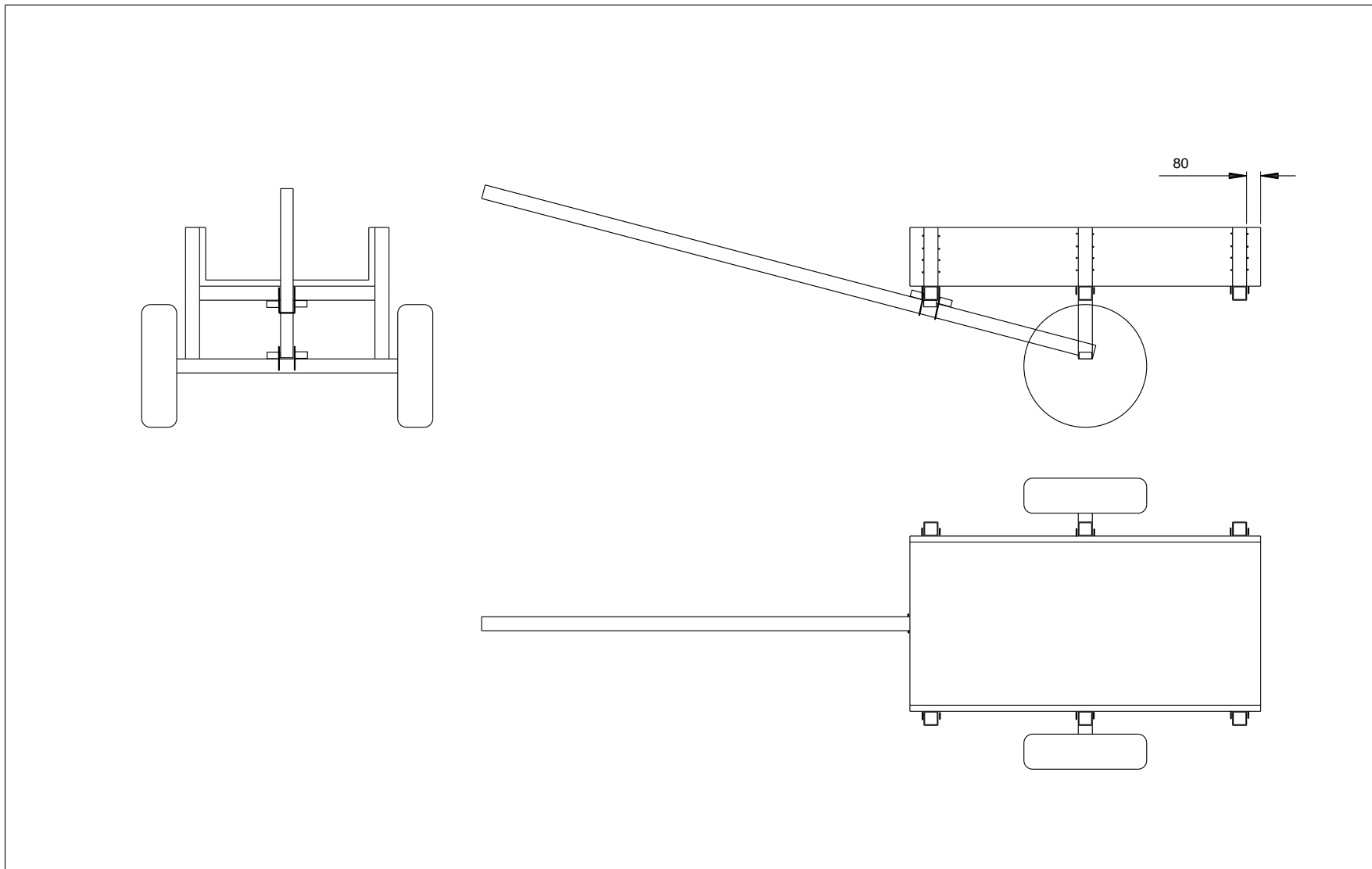
The DTU has also been working on new designs of wheels, hubs and bearings to bring down their costs and make things more locally manufacturable. For example it has pioneered a system of hubs using steel pipe such as water pipe which do not need machining to make a roller bearing hub. Obviously friction is low with these hubs and they usually give good

milage before being worn out too - we usually get 15 000 km before they are very badly worn, but they may need cleaning and relubrication several times before they get this far. Still they are reasonably cheap - we can make them in Nigeria for about \$<sub>US</sub>40, they only take one man a day, and they do not need any special tools.

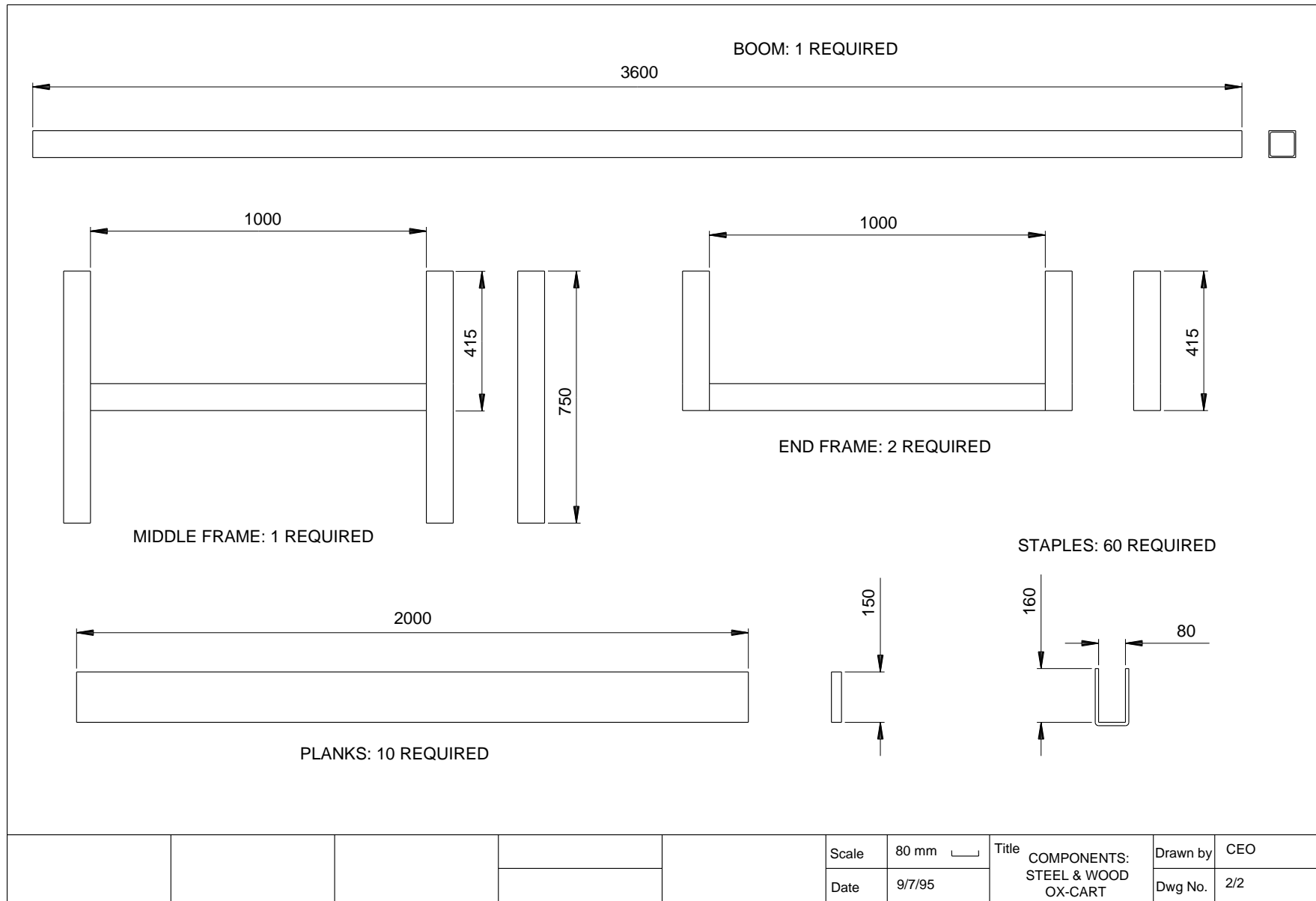
Other hub designs using, for example aluminium castings, are in production in Nigeria and we are trying to reduce or eliminate the machining in these. Also wheel designs in steel sheet, cast aluminium and timber are in manufacture or under development.

## **Cart Drawings**

You will find two drawings on the next pages, the first one gives a general view of the cart, and the second gives a view of the main components. As we have said you can vary the size of the cart quite a bit and even make it much longer if you add extra frames. You could even make a four wheeled cart like this!



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					Date	9/7/95		Dwg No.	1/2





# Animal Cart Programme

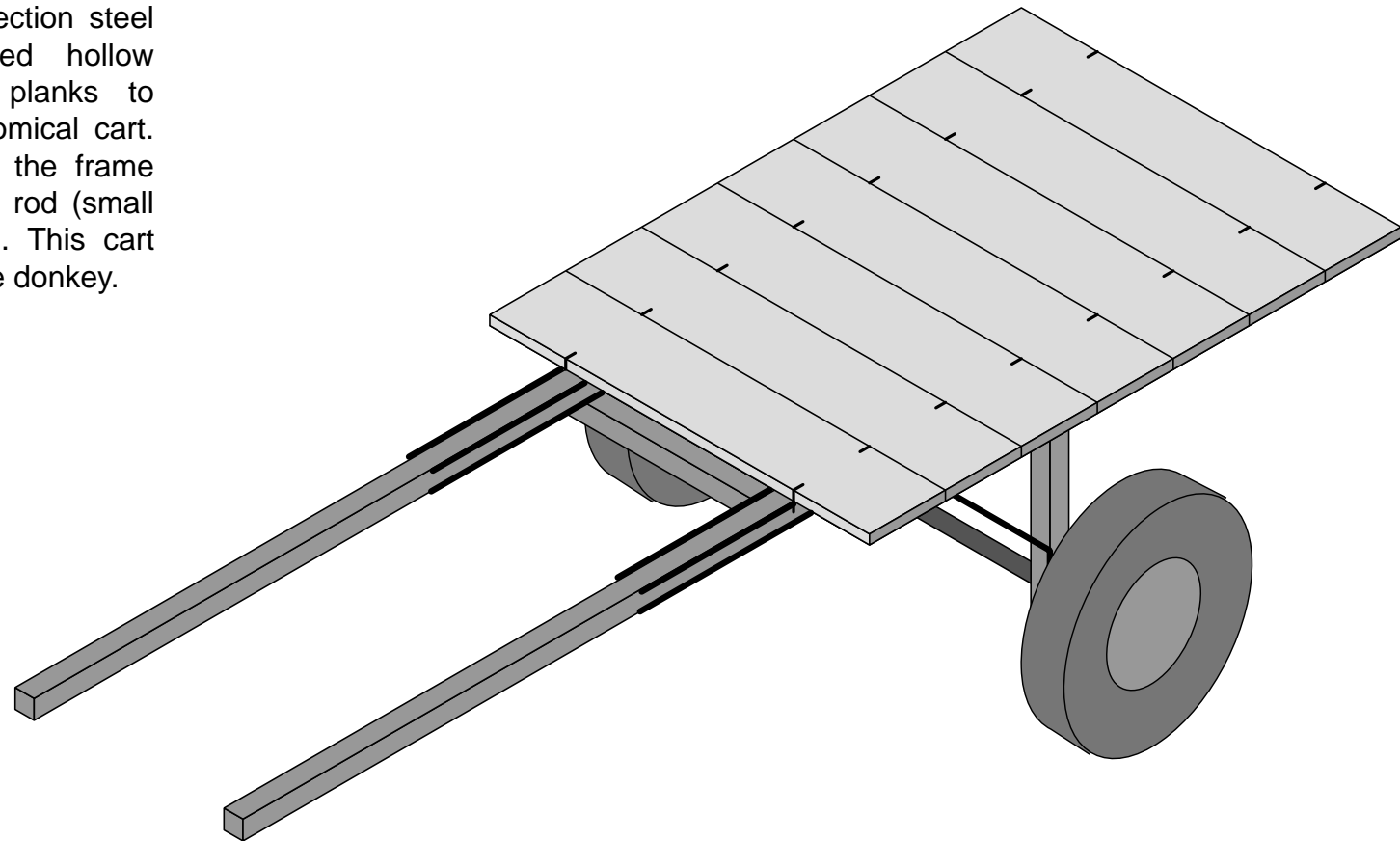
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## LIGHT STEEL AND WOOD DONKEY CART

**Figure 1: donkey cart made from square box tubing and wooden planking.**

This cart uses square section steel box tubing (RHS rolled hollow section) plus wooden planks to make a quick and economical cart. The planks are fixed to the frame with 6mm diameter steel rod (small concrete reinforcing bar). This cart has two shafts for a single donkey.





## TECHNICAL RELEASE 25

# Lightweight Donkey Cart Body Made From Square Box Tubing and Timber Planks

### Introduction

Not enough farmers in developing countries have animal carts. Those who have carts can take their produce to places where they can get good prices. They can also get into town and buy fertilizer and better seeds and move things around their farm easier. The trouble is that carts are too expensive for many farmers. What can be done?

Carts are made in many different places. Some carts are made in factories in industrial countries and some are made in African factories, but most are made by local blacksmiths or carpenters using scrap car and Land-Rover axles. These people cannot get enough axles to meet the demand, so the price is high. Even if they did have the axle, they still end up building heavy bodies that take ages to make. In another booklet in this series we have told you how you can make simple low-cost axles; in this booklet we tell you about a simple steel and timber body. You should be able to make the body for about \$<sub>US</sub> 30 depending on the cost of the materials and labour. Once you get organised, two men can probably make two bodies per day.

What you need is a cart body which carpenters and fabricators can make with their simple tools. These people will probably be in the small market towns used by the farmers and they will have an electric welder and some basic handtools like a hacksaw. Experts think that having the cart maker close to the farmer is a good thing because they can talk to each other easily and sort out any problems. Also if the cart is made locally, it can be repaired locally, so there should not be any problems with spare parts.

### Idea Behind Design

The idea behind the design of donkey cart described in this technical release is to allow construction without lots of special tools and jigs, and without any hard-to-get materials. The only tools which you must have are a welder and a hacksaw. You might also find that a couple of 4" or a 5" G clamps (or something like it) are useful too. (The symbol " means inches here, so that 4" is about 100mm since there are about 25mm in an inch.) A wheelbrace or carpenters brace is also useful - you can make the drill bit yourself.

You will see that there are no mitres and unusual angles to cut in the square tubing so you save time when making the cart. Also the exact lengths of the components are not very fussy. But you will find that the carts look better if you take trouble to get things square and straight.

These carts have been tested in Nigeria, but we would like to

test them more. The only problems which we have found so far have been breaking of the animal shafts and we have fixed this by welding some strengtheners (bits of 8mm, 10mm or 12mm round bar or re-bar) to the top and bottom of the chassis. (Re-bar means concrete reinforcing bar). The construction tends to be a bit light in Nigeria, because they sell square tubing with very thin walls (much less than 1mm thickness). If you used tubing with a wall thickness of 2.5mm or more you probably would not need to put these strengtheners on. But really to get a cart at a reasonable cost you need to experiment a bit to see how the farmers treat their carts and what they expect them to stand. It's no good saying it must be strong enough so that they cannot ever break it - somebody will always break anything - and it will be very expensive to make it nearly unbreakable. At least with this design you can repair it easily and cheaply.

## Cutting list and costs

Table 1 shows a cutting list for a complete cart. Recent prices of materials in Nigeria are shown converted to \$<sub>US</sub>. The square box tube (sometimes called rolled hollow section or RHS) is about 2" or 50mm on one side. You can often buy it in a variety of wall thicknesses. It's best with a wall thickness of 2.5mm (12 gauge) or more, but we have used wall thicknesses down to 1.6mm (16 gauge) as we mentioned earlier.

## Construction step by step

- 1) The first job, is to get all the material together and clear a space to work. Ideally you will be able to work on a flat area of concrete. Start by cutting the square box tube into the right lengths, as in the cutting list shown in Table 1. Then cut the various bits of re-bar or whatever you are going to use. You could cut the timber also at this stage, but it might be easiest to leave it till last.

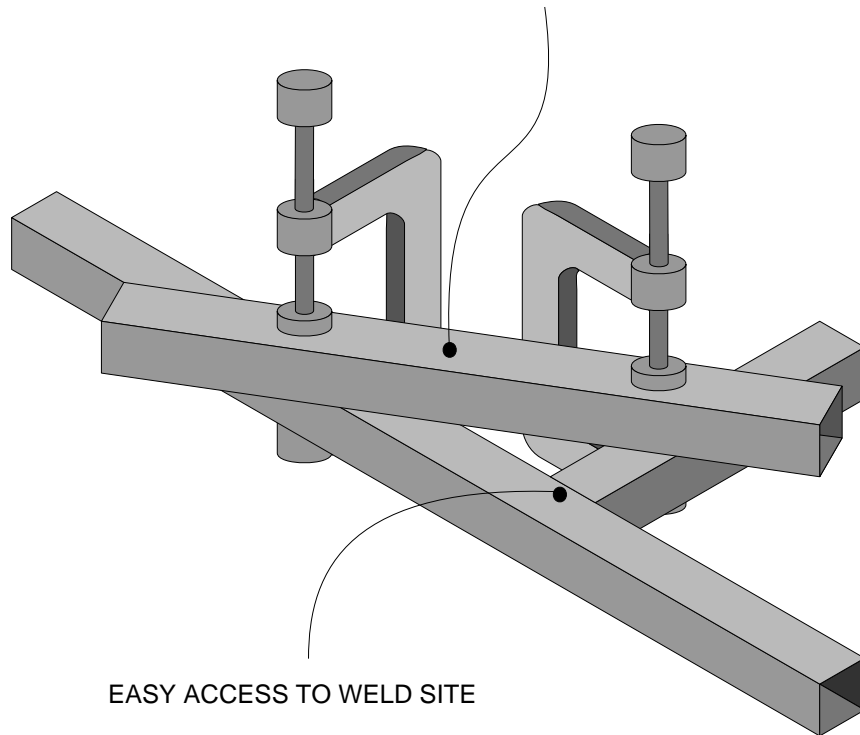
component	material	# lengths & length reqd	total material in cart	materials cost in Nigeria
[#*mm]				
animal shafts	50x50 RHS	2x3150	6300	8.94
body cross pieces	50x50 RHS	3x700	2100	2.98
axle struts	50x50 RHS	2x600	2400	3.40
shaft strengtheners	8mm to 12mm round bar <sup>1</sup>	8x600	4800	1.02
axle strut braces	8mm to 12mm round bar	3x850	2550	0.54
axle fixing studs	M12 threaded rod or bolts	2x125	250	0.85
axle fixing loops	6mm dia re-bar or similar	2x330	660	0.07
plank fixing studs	6mm dia re-bar or similar	14x75	1050	0.11
tray planks	1"x12" or similar timber	6x1100	6600	3.90
TOTAL =				21.82

<sup>1</sup> The round bar can be anything actually - it doesn't even have to be round, so deformed or high-yield re-bar is fine. You could even use flat strip as long as its more than say 8mm thick.

- 2) Next weld the axle supports to the animal shafts. The method shown in Figure 2 is probably the easiest way to support the components during welding the first shaft and support. It's quick and if you do not tighten the clamps too

tight to start with, you can tap the parts with a hammer until everything is square and straight. Then tighten the clamps before you weld.

SPARE PIECE OF TUBING USED TO SUPPORT COMPONENTS DURING WELDING

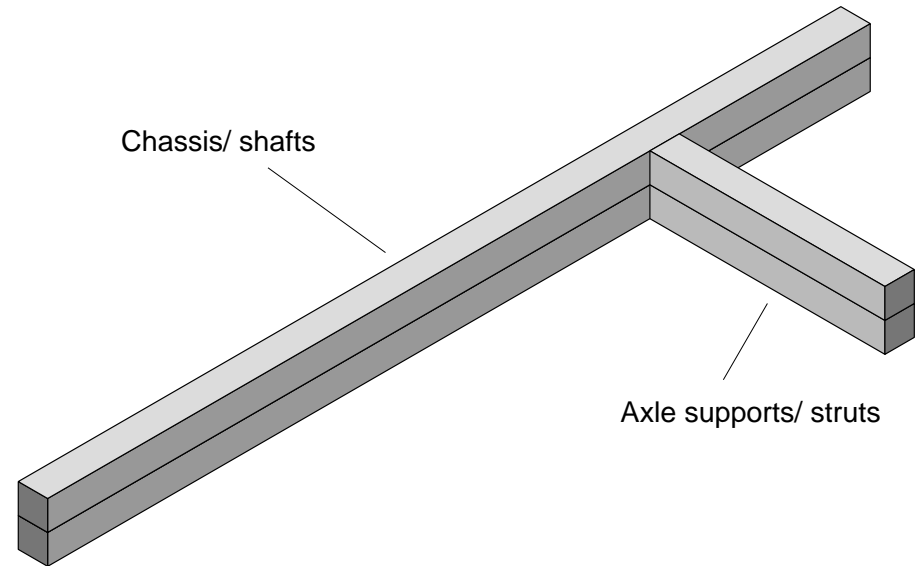


EASY ACCESS TO WELD SITE

**Figure 2: supporting components during welding.**

Repeat the process using the first shaft and support as a pattern for the second as shown in Figure 3. Make sure you do not weld the two assemblies together!

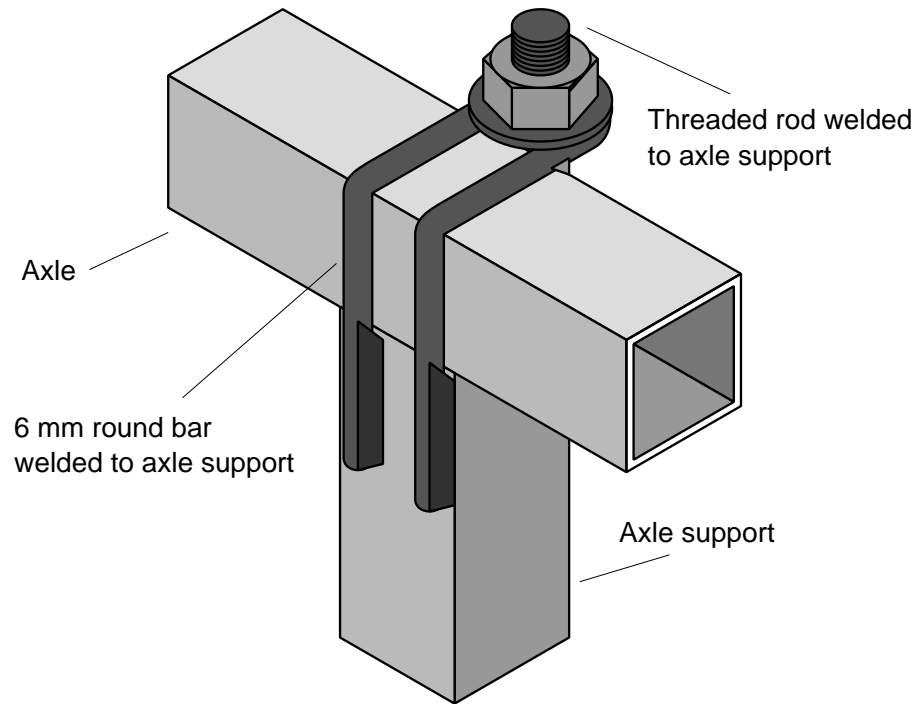
- 3) It may be easiest to fix the axle retaining bolts and loops on at this stage so that you can use them in the next stage. Figure 4 shows a good way to fix a square axle on.



**Figure 3: welding animal shaft and axle support strut assemblies.**

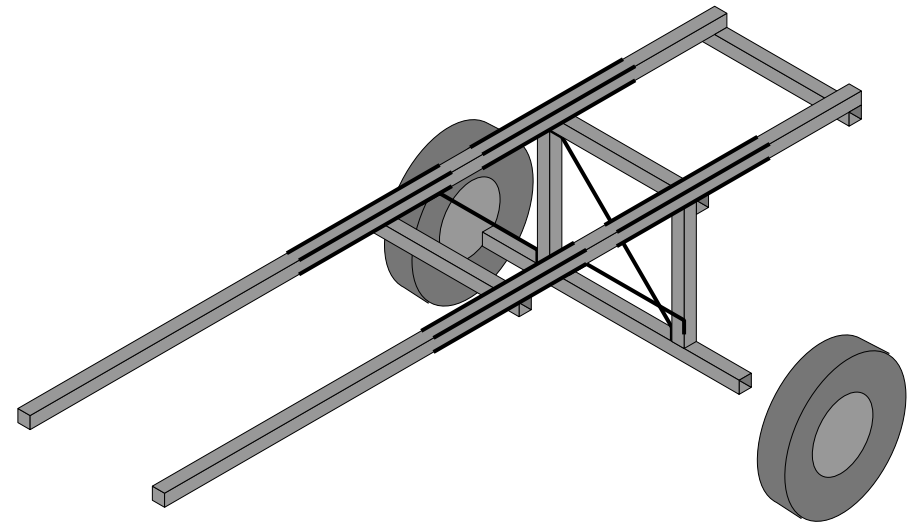
- 4) Now you can weld the three cross pieces under the animal shafts after you have checked for squareness etc.
- 5) Next you need to weld on the various reinforcements to the square tube. These are the axle braces and the pieces where the shafts might get broken - over the axle supports and at the front of the load tray/ wooden planking. Figure 5

shows the frame nearly ready for fixing the planking.



**Figure 4: method of fixing axle to axle supports.**

- 6) Nearly there! Now you need to fix the wood onto the square tube. You can do this with staples or studs. Staples use more steel but studs need more welding. Figure 6 shows the choices - staples are like big U s, and studs are just pieces of 6 mm wire sticking up which you bend over the wood.

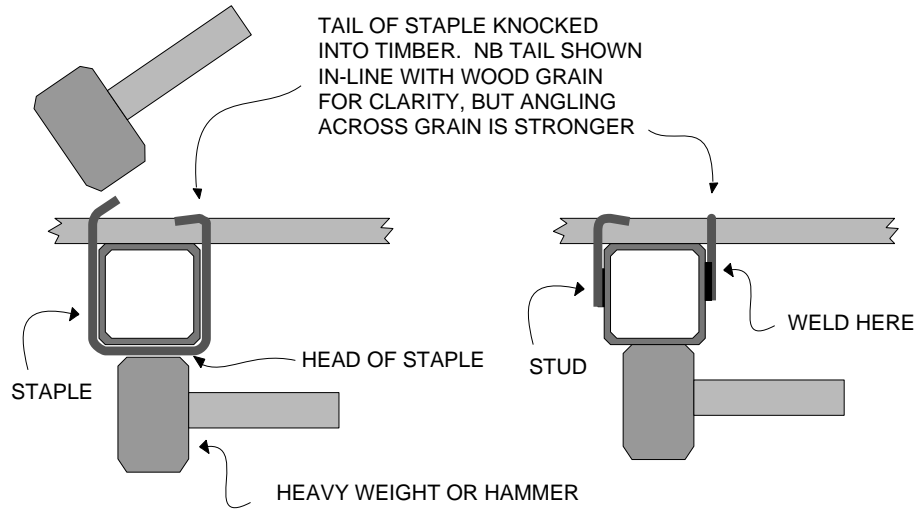


**Figure 5: cart frame before planking.**

To make staples you can make a jig from some bolts in a piece of wood or you can just bend the staples in a vice. They do not have to be very accurate, but as usual the more accurate the better.

To fit the staples, drill a hole in the plank both sides of the tubing and push both legs of the U through the wood using a hammer if necessary. When it's through, hold another hammer or something heavy against the bottom of the U whilst you knock the protruding legs over with another hammer. You might find this easier with someone to help you. Then clench the legs by knocking them into the surface of the wood to leave the surface flush. Once you

are happy that all is in the right place, weld the staple to the square tubing as shown in Figure 6. Then put the rest of the staples in in the same way.



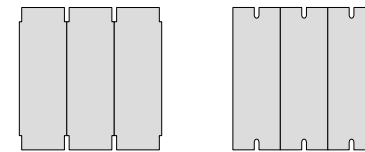
**Figure 6: fixing wood with staples or studs.**

If you want to use studs, weld them on to the side of the square tube as shown in Figure 6. You can either drill holes for them as described earlier for staples, or you can bring them up past the edge of the planks, which saves drilling holes.

7) Paint the cart. You've finished it!

## Modifications

There are many different versions of this cart. The one shown in this document has no sides, because it is for one donkey and is as light as possible. It is good for everything except loose materials such as sand, but you can always put this into sacks. To fix ropes for tying firewood or sorghum stoba etc, you can cut slots or notches in the ends of the planks as shown in Figure 7, which shows two ways of doing it.



**Figure 7: notched ends in planks to tie rope to.**

You could put side planks on a cart like this using the same 6mm wire/ round bar/ re-bar to tie them on. This would be cheap and very easily repairable.

A danger with building carts is that the farmers will want something flashy looking which will be very expensive to make. You would probably find that things like hinges and latches take as much time to make as the basic parts of the cart.

If you want a cart with permanent sides you could build our medium weight donkey cart.

You can try longer and shorter carts and you can make them

wider or narrower. When you do this, check the length and width of the planks of wood that you will use - you do not want to find that you are two inches short of being able to get two runs of plank out of one piece of timber, or that its just too narrow and you have to fiddle about and waste time filling the gap with an extra little strip.

Another thing is the height of the cart. No-one seems to know why some carts are made high and others low. Its better for the animals if the load tray is low particularly if the carts will be operated over rough ground. But you may find that farmers want a high load tray to keep loads dry if they are fording rivers a lot, or it may be a status thing (if you are wealthy enough to own a cart, your eye level must be above a pedestrian's). Or it may be that it's too tiring to load a low cart - if, for example, you have to bend your back twice for each bundle - once to pick it up off the ground and again to put it down onto a low load tray. We have also found that farmers usually want the body to come out over the wheels so they can load on lots of straw or light materials.

## **Other DTU cart developments**

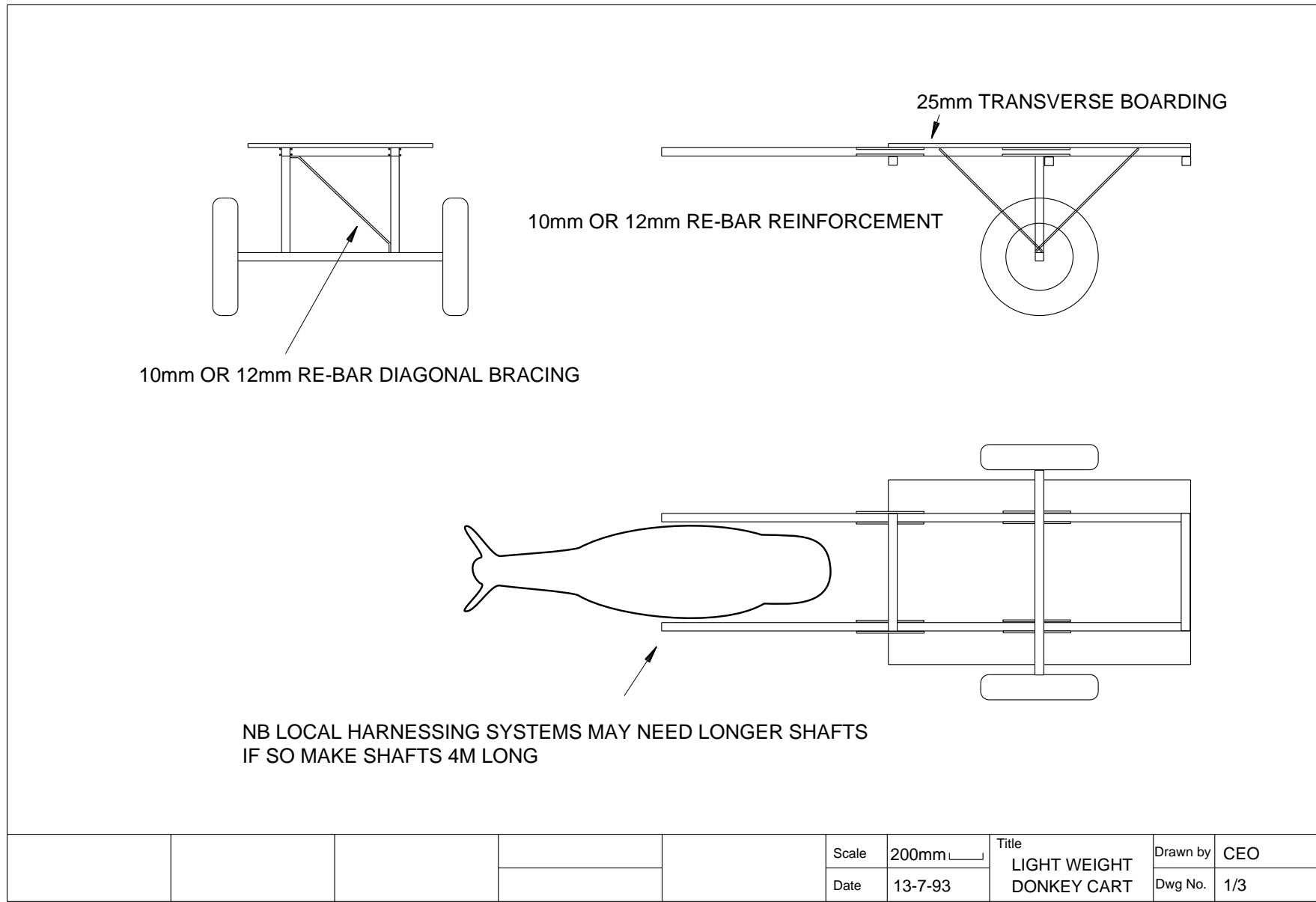
The DTU has been working on a range of cart body types for use with both donkeys and oxen. It has designs for both wooden and steel framed types. The wooden types are cheaper in material terms, but the steel framed ones are easier to make because the joints are more straightforward - but you can make either type of cart in only a few hours, if you have all the tools and materials you need before you start.

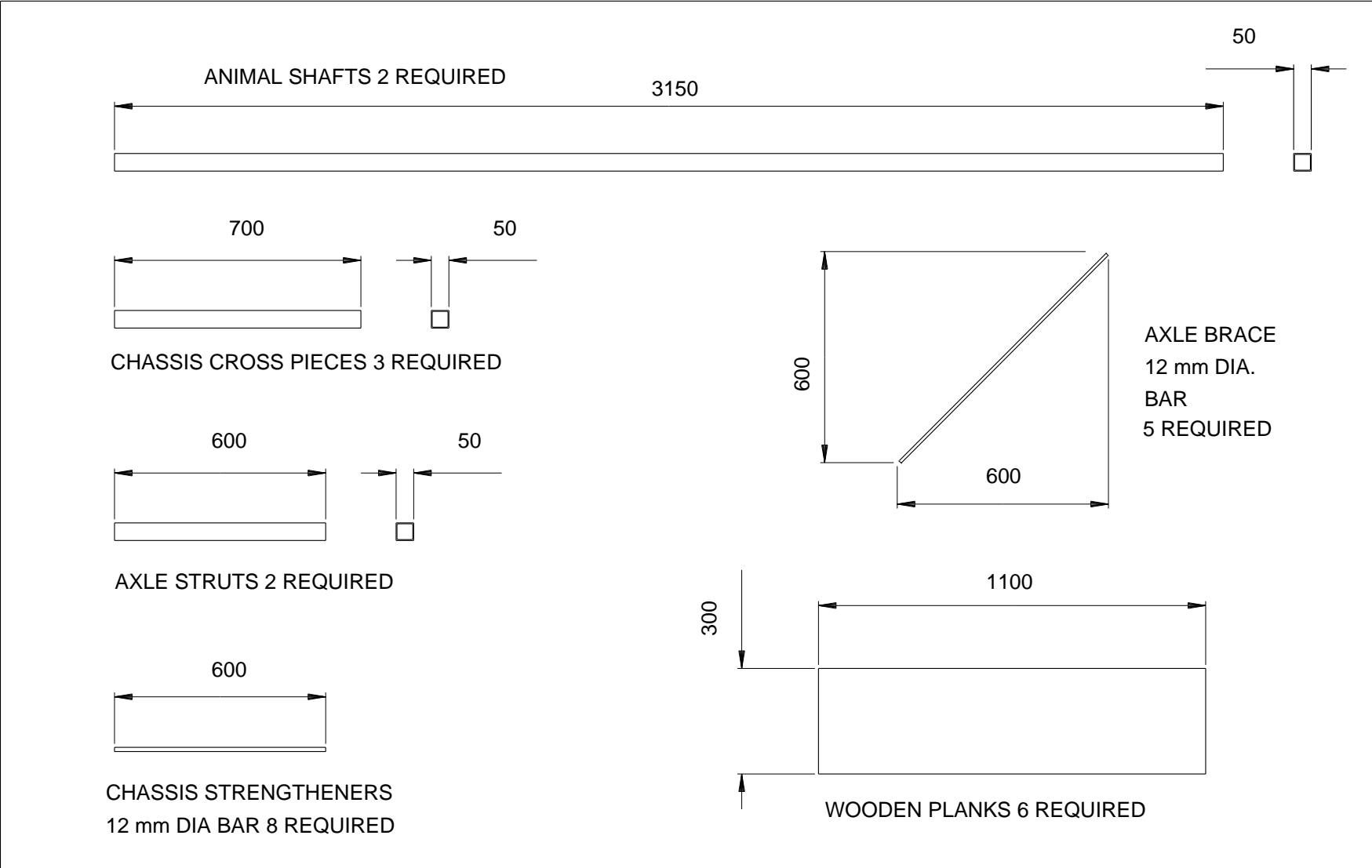
The DTU has also been working on new designs of wheels, hubs and bearings to bring down their costs and make things more locally manufacturable. For example it has worked on a system of hubs using water pipe which do not need machining to make a roller bearing hub. Friction is low with these hubs and they usually give good milage before being worn out too - we usually get 15 000 km before they are very badly worn, but they may need cleaning and relubrication several times before they get this far. But they are reasonably cheap - we can make them in Nigeria for about \$<sub>US</sub>20. They only take one man a day to make and they do not need any special tools.

Other hub designs using, for example aluminium castings, are in production in Nigeria and we are trying to reduce or eliminate the machining in these. Also wheel designs in steel sheet, cast aluminium and timber are in manufacture or under development.

## **Cart Drawings**

The drawing for the cart is shown on the following page and the list of materials has been shown on a previous page.

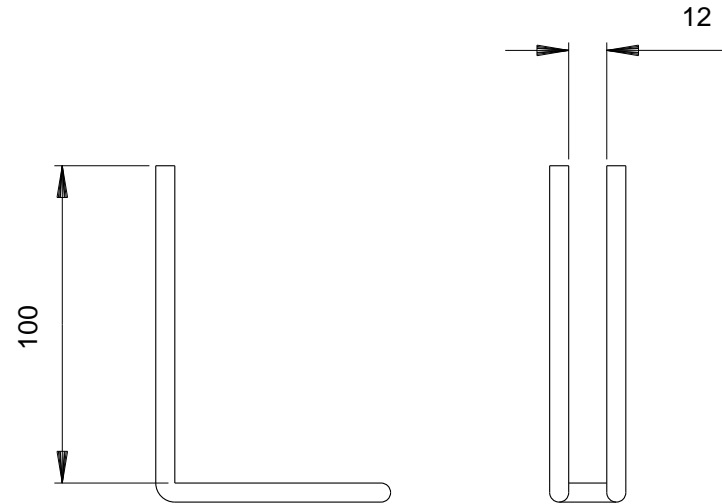
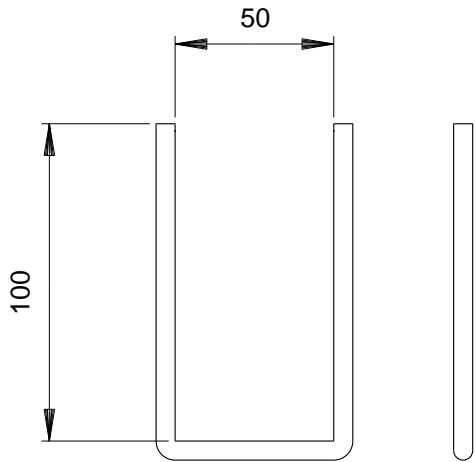




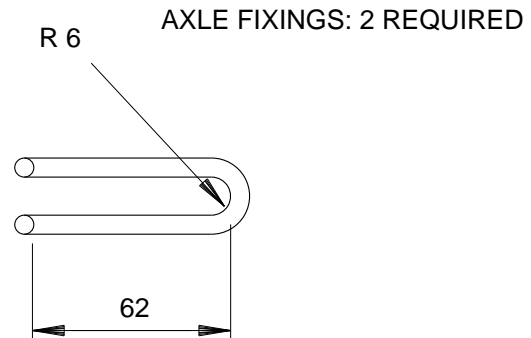
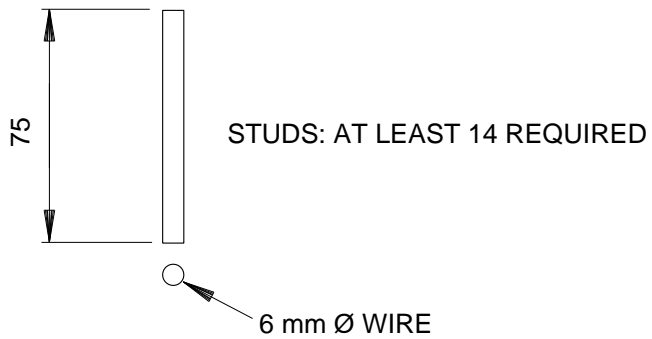
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STAPLES: AT LEAST 14 REQUIRED



NB STUDS AND STAPLES ARE ALTERNATIVES



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# Animal Cart Programme

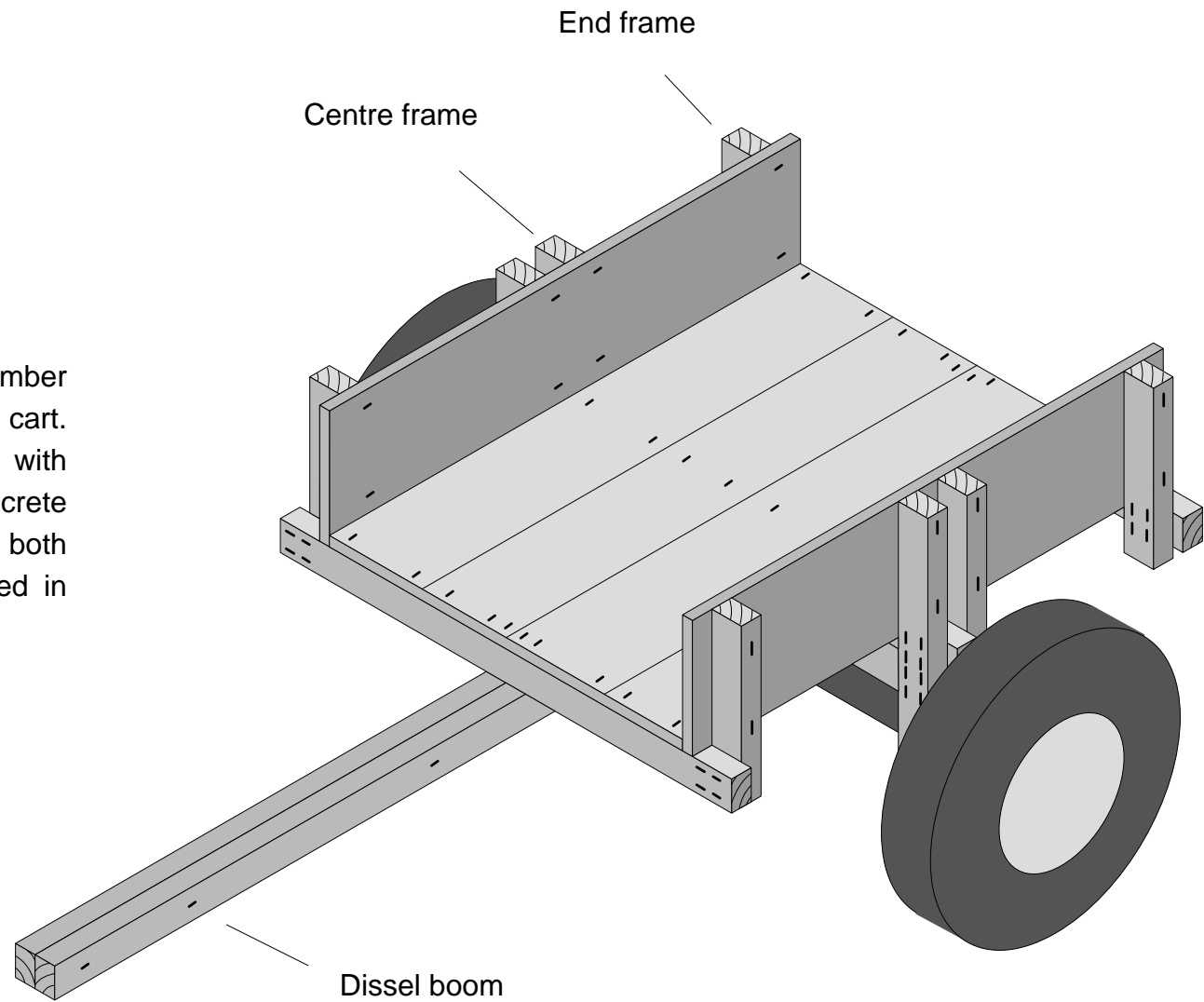
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## SIMPLE LOW-COST WOODEN OX CART



**Figure 1: wooden oxcart**

This cart uses wooden planks and timber for a quickly made and economical cart. The planks are fixed to the frames with 6mm diameter steel rod (small concrete reinforcing bar) clenched over at both ends a bit like copper nails are used in boat building.



# Ox Cart Body Made From Timber

## Introduction

Not enough farmers in Africa have animal carts. Those who have carts can take their produce to places where they can get the best prices. They can also get into town and buy fertilizer and better seeds and move things around their farm easier. The trouble is that carts are too expensive for many farmers. The question is what can be done about it?

What you need is a body which carpenters can make quickly with their simple tools. These people will probably be in the small market towns used by the farmers. Experts think that having the cart maker close to the farmer is a good thing because they can talk to each other easily and sort out any problems. And of course if the cart is made locally, it can be repaired locally, so there should not be any problems with spare parts.

Carts are made in many different places. Some carts are made in factories in industrial countries and some are made in factories in Africa, but most are made by local blacksmiths or carpenters using scrap car and Land-Rover axles. These people cannot get enough axles to meet the demand so the carts are expensive. Even if they did have the axles, they still

end up building heavy bodies that take ages to make. In another booklet in this series we have told you how you can make simple low-cost axles; in this booklet we tell you about a simple timber body. You should find that you can make the body for about \$<sub>US</sub>20, depending on the cost of the materials and labour. Once you get organised, two men can probably make two bodies per day. This is quite a lot faster than most carts can be made and it follows from the simplifications which we have made to the design. We've designed it to be easy to make.

## Idea Behind Design

The idea behind the design of oxcart described in this technical release is to allow construction without lots of special tools and jigs, and without any hard-to-get materials. The only tools which you must have are a woodsaw, a hacksaw or cold chisel, a hammer and a drill able to make a 6mm hole in wood. In fact you can make the drill yourself if you have to. If you need to make a drill read the section **Making a flatbit** below - it's not too difficult, and its quite handy sometimes to be able to make very long drills. You might find that a couple of 4" or a 5" G clamps (or something like it) are useful too. (The symbol " means inches so 4" means about 100mm because there are about 25mm in an inch.)

The way that all the parts of this cart are joined together is like the one that used to be used to fix small boats together. It's called clenched nailing and is a bit like riveting. What you do is make a hole right through the wood to be joined, and then put a straight piece of 6mm diameter re-bar (concrete reinforcing bar) right through so it sticks out about 25mm both sides. Then you just knock one end over with a hammer so it lies on the surface of the wood. Next you bend the other end over. Then you put a big hammer or something hard and heavy like a piece of steel against one of the ends and then hit the other with another hammer. What happens is that you tighten the two bits of wood together and you get quite a strong joint. If you put some washers or something like them made from sheet steel on the re-bar before you bend it over it will make the joint a bit stronger still. It does not make a very rigid joint, but you might find that the flexibility gives the cart some resilience so that it takes knocks better.

You will see that there are no mitres and complicated angles to cut in the timber so you save time when making the cart. Also the exact lengths of the components are not very critical - again it saves a little time, but you will find that the carts look better if you take a little trouble to get things square and even etc.

These carts have been tested a bit in Nigeria, but we have not tested them enough. We think that they are strong enough, but we cannot be sure. Really to get a reasonable price you need

to experiment a bit to see how the farmers treat their carts and what they expect their carts to stand. It's no good saying it must be strong enough so that they cannot ever break it - somebody will always break anything - and it will very expensive to make it nearly unbreakable. At least you can repair these carts easily and cheaply.

## Cutting list and costs

Table 1 shows a cutting list for a complete cart - Recent prices of materials in Nigeria are shown converted into \$<sub>US</sub>.

TABLE 1: cutting list for wooden oxcart.				
component	material	number of lengths & length required [No.xmm]	total material in cart [mm]	materials cost in Nigeria [\$us]
animal shaft/ boom	75x50 or bush pole	2x3700	7400	2.39
body frame bottoms	75x50 roughsawn timber	3x1100	3300	1.06
body frame sides	75x50 roughsawn timber	6x300	1800	0.58
axle struts	75x50 roughsawn timber	4x600	2400	0.77
tray bottom planks	25x300 or similar timber	4x1800	7200	4.64
tray side planks	25x300 or similar timber	2x1800	3600	2.32
tray ends	25x300 or similar timber	2x1100	2200	1.42
plank fixing staples	6mm dia re-bar or similar	30x250	7500	0.80
body frame staples	6mm dia re-bar or similar	12x150	1800	0.19
axle fixing studs	M12 threaded rod or bolts	2x100	200	0.64
axle fixing loops	6mm dia re-bar or similar	2x200	400	0.04
TOTAL->				14.86

## Construction step by step

- 1) The first job, is to get all the material together and clear a space to work. Ideally you will be able to work on a flat area of concrete. Start by cutting the 75x50 timber into the right lengths, as in the cutting list, and then you can cut the bottom and side planks. Then cut the 6mm dia re-bar for

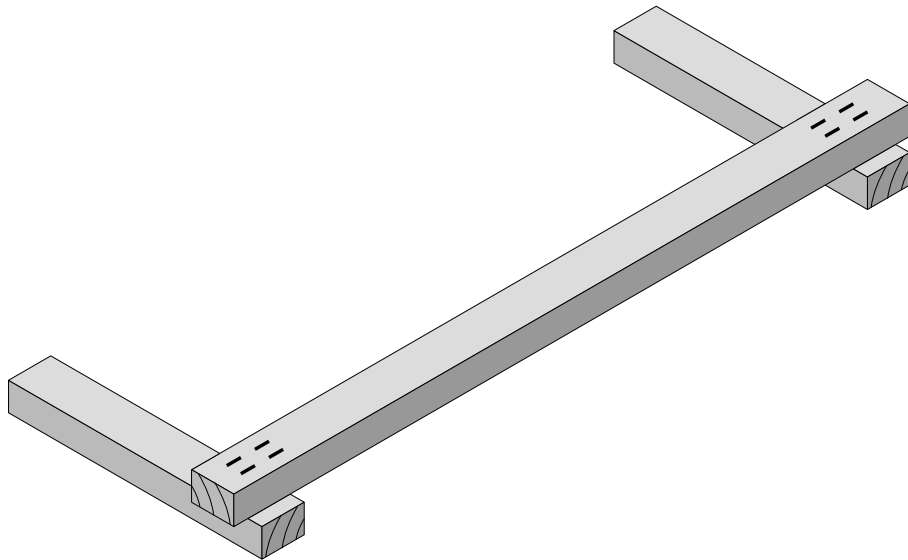


Figure 2: a finished end frame.

the fixings.

- 2) Next make up the two U-shaped front and back frames (endframes). If you have a G clamp you can use it to hold two pieces of the frame together during drilling and clenching. It's quick and you can tap the bits with a hammer until everything is square and straight and then drill the holes. You might also find that leaving the G clamp on makes it easier to get the re-bar fixings through.

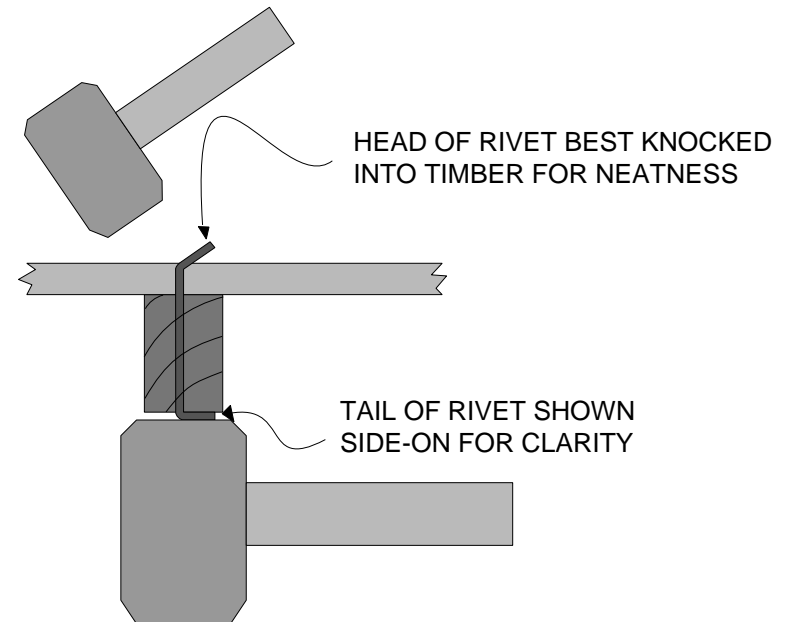


Figure 3: Using two hammers to clench rivet.

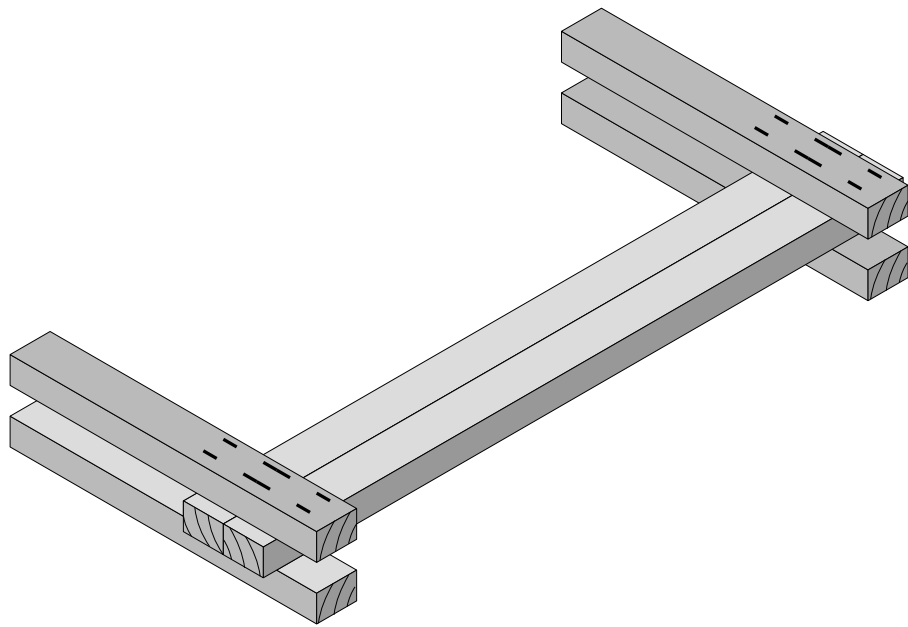


Figure 4: a finished midframe/ axle support frame including spacer.

- 3) Then you can make up the frames that go in the middle - the ones that support the axle. You can start with the frame bottom and then fix the uprights to it either side with four rivets. When you've done both ends you will end up with an H shaped assembly.
- 4) Next you can fit the side and the bottom planks to the end frames and then the middle frame with more rivets.

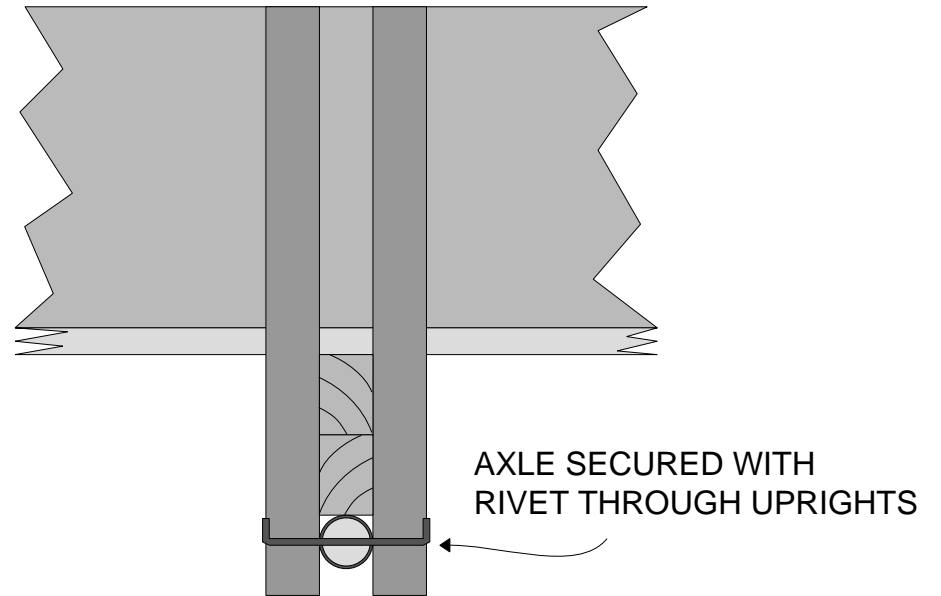


Figure 5: method of fixing axle to axle supports.

- 5) Nearly there! Fix the axle with a rivet right through the middle of it where it goes between uprights of the middle frame - obviously you need to drill through the axle to do this. Another way is to bolt the axle in with a bolt right underneath the axle, but you need a long bolt to do this.
- 6) If you want to make it so that the ends of the load tray can be removed easily you can do in the way we have shown in

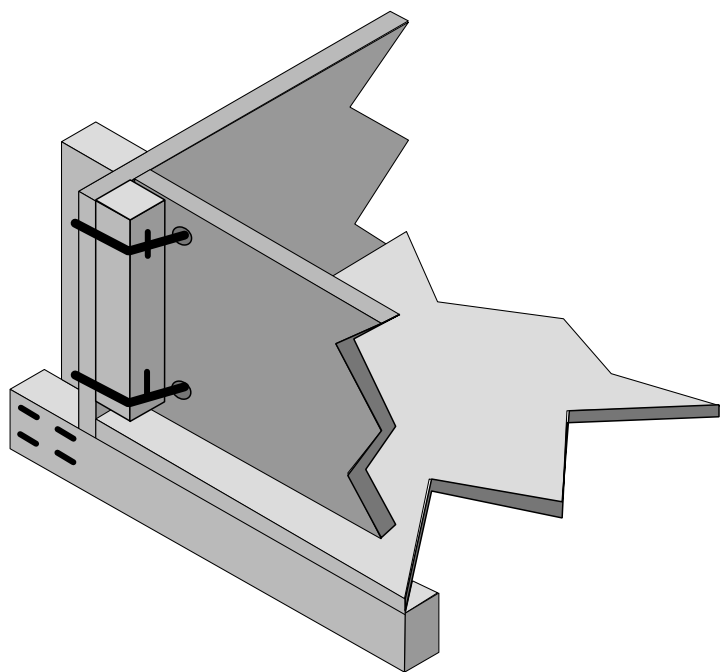


Figure 6: method of fixing tray ends with rubber or rope

7) Paint or creosote the cart. You've finished it!

## Modifications

There are many different versions of this cart. You can try longer or shorter carts and you can make them wider or

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narrower. When you do this, check the length and width of the planks of wood that you will use - you do not want to find that you are two inches short of being able to get two runs of plank out of one piece of timber, or that its just too narrow and you have to fiddle about and fit in a narrow strip.

This cart design does not have ends to the load tray, but if your farmers really want ends you can make them from some more plank. A good way to fix the end planks might be to fix them to the inside of these with bits of truck inner tube as giant bungees or elastic bands. This is an appropriate way because it is cheap and very easily repairable, but the farmers may want some flashy looking thing which will be very expensive to make. You will probably find that things like latches take longer to make than the rest of the cart. Explain to the farmers that they will cost extra too!

## Other DTU cart developments

The DTU has been working on a range of cart body types for use with both donkeys and oxen. It has designs for wooden and steel framed types. The wooden types are cheaper in material terms, but the steel framed ones are easier to make because the joints are more straightforward - nevertheless you can make either type of cart in only a few hours, if you are reasonably set up with tools and materials.



The DTU has also been working on new designs of wheels, hubs and bearings to bring down their costs and make things more locally manufacturable. For example it has pioneered a system of hubs using steel pipe such as water pipe which do not need machining to make a roller bearing hub. Obviously friction is low with these hubs and they usually give good milage before being worn out too - we usually get 15 000 km before they are very badly worn, but they may need cleaning and relubrication several times before they get this far. Still they are reasonably cheap - we can make them in Nigeria for about \$<sub>US</sub>20, they only take one man a day, and they do not need any special tools.

Other hub designs using, for example aluminium castings, are in production in Nigeria and we are trying to reduce or eliminate the machining in these. Also wheel designs in steel sheet, cast aluminium and timber are in manufacture or under development.

### **Making a flatbit**

Flatbits for drilling wood are easy to make and quite useful because you can make them very long and drill holes in quite awkward places.

To make the bit, get some round steel bar of the same size as the hole you want to make, or a little bit smaller. Then hammer the end to flatten it a little (a bit like a screwdriver). The drawing shows what we mean. In fact if you can harden the cutting edges you can use the flat bit to drill holes in metal too as long as you do not want to drill deep holes. To get hard cutting edges you will need to use either 'silver steel' or say spring steel or even to case harden the edges - though you will lose the hardness as soon as you re-sharpen the drill if it's just case hardened.

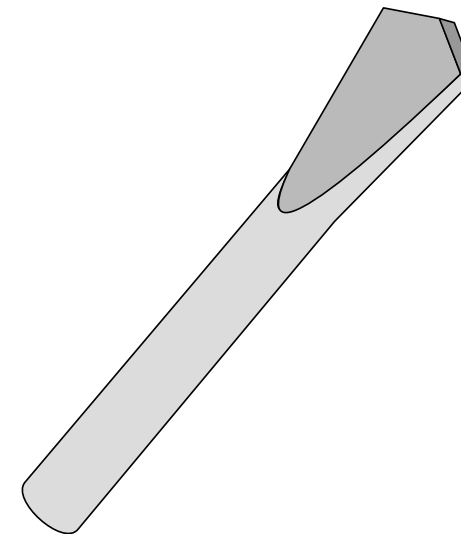


Figure 7: flat bit for drilling holes

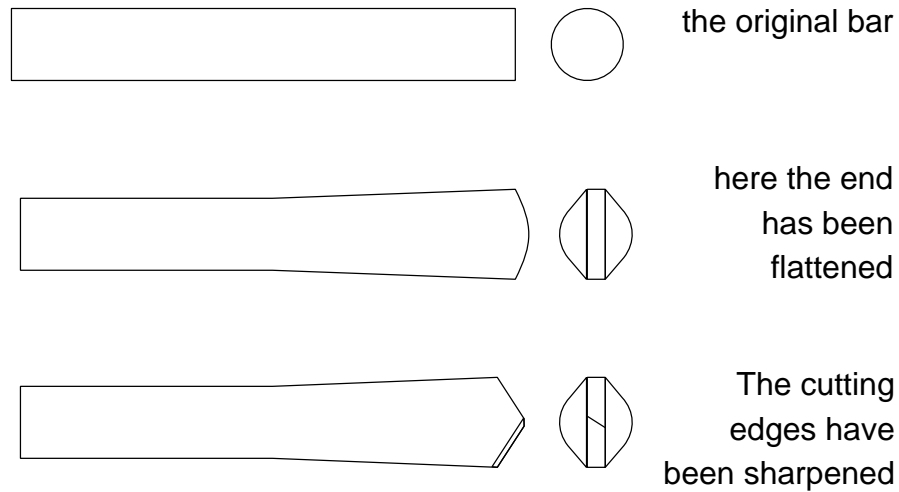
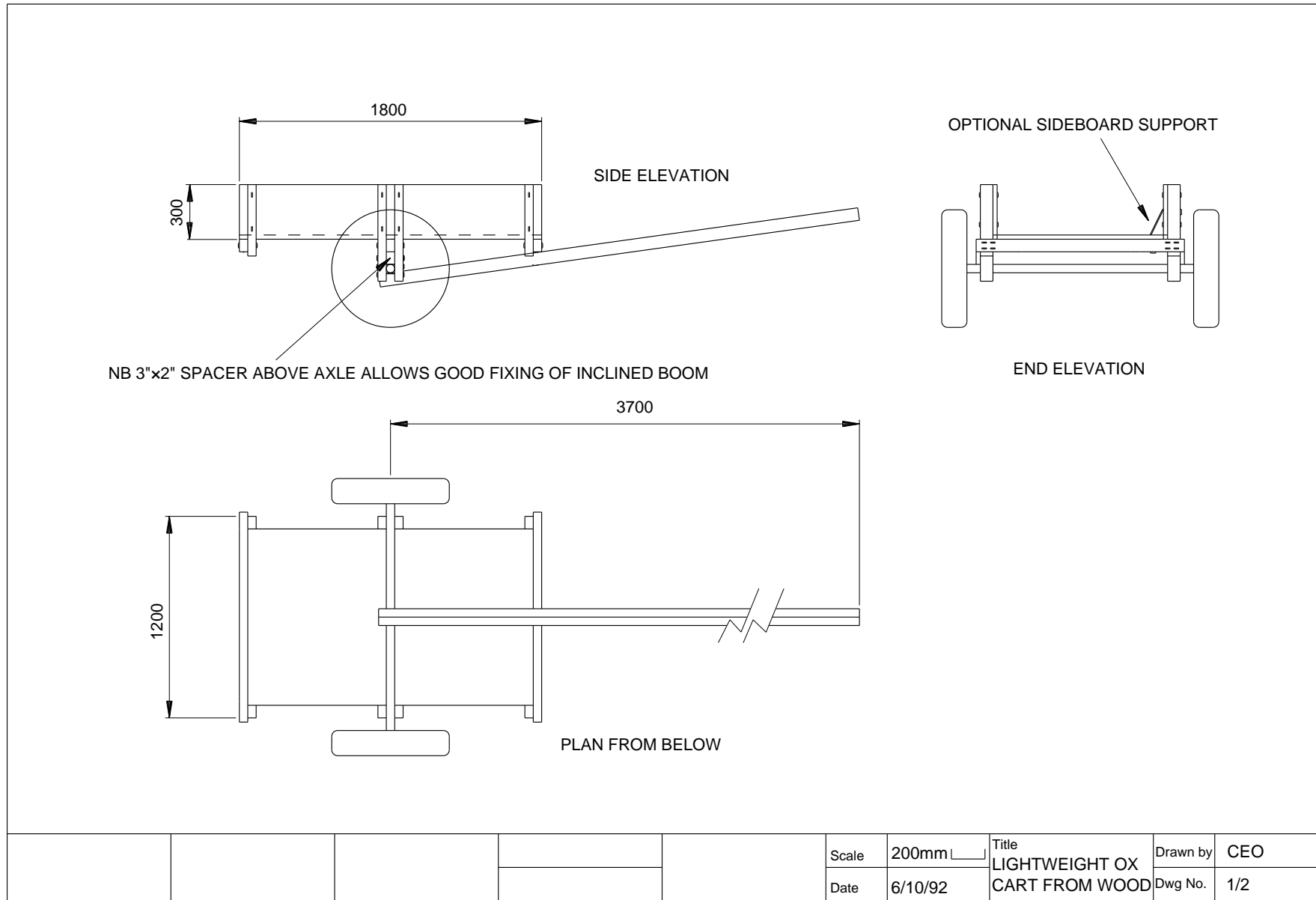
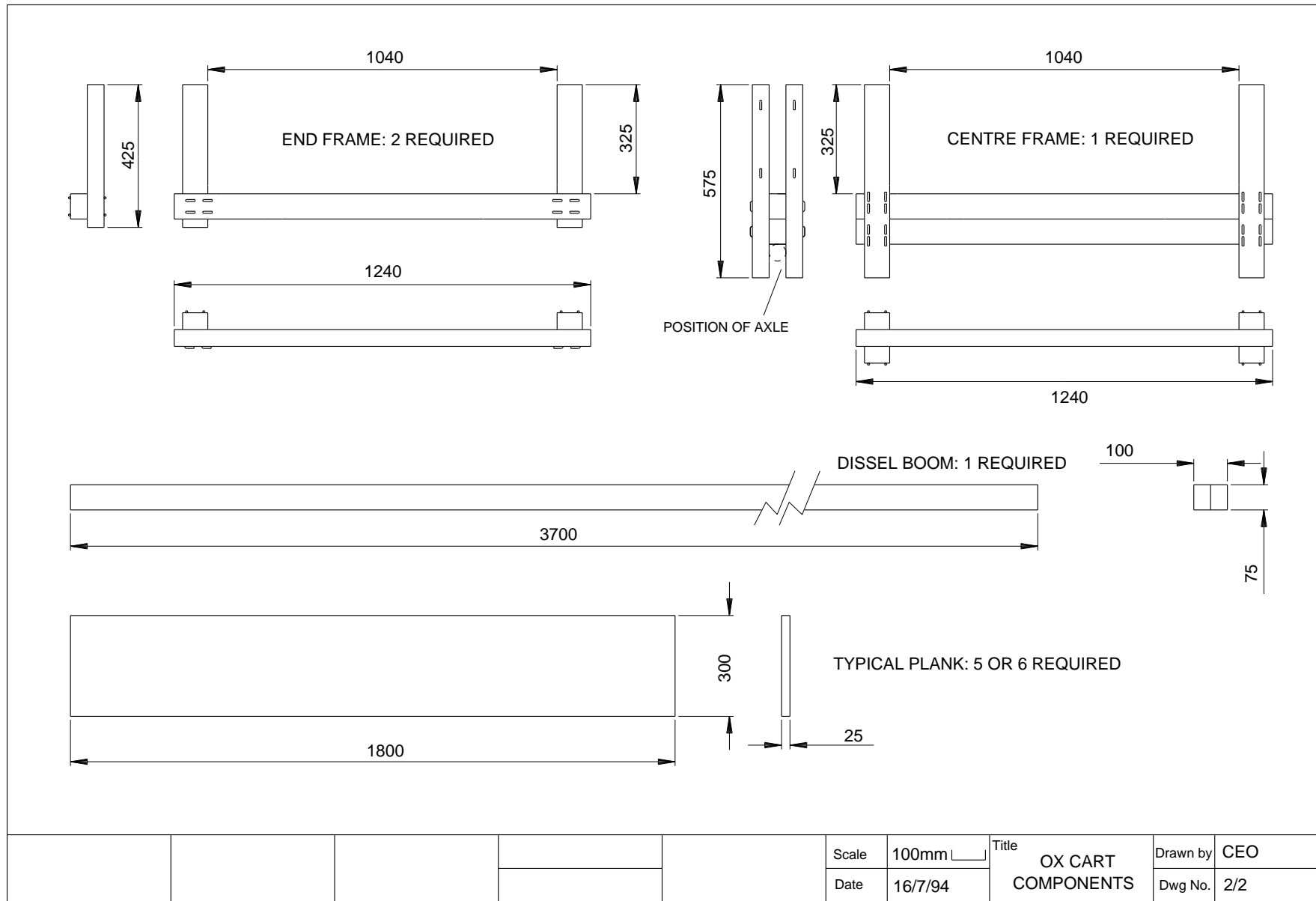


Figure 8: stages in the making of a flat bit for drilling holes.

## Cart Drawings

You will find two drawings below, the first one gives a general view of the cart and the second, a view of the main components. As we have said you can vary the size of the cart quite a bit and even make it much longer if you add extra frames. You could even make a four wheeled cart like this!







# Animal Cart Programme

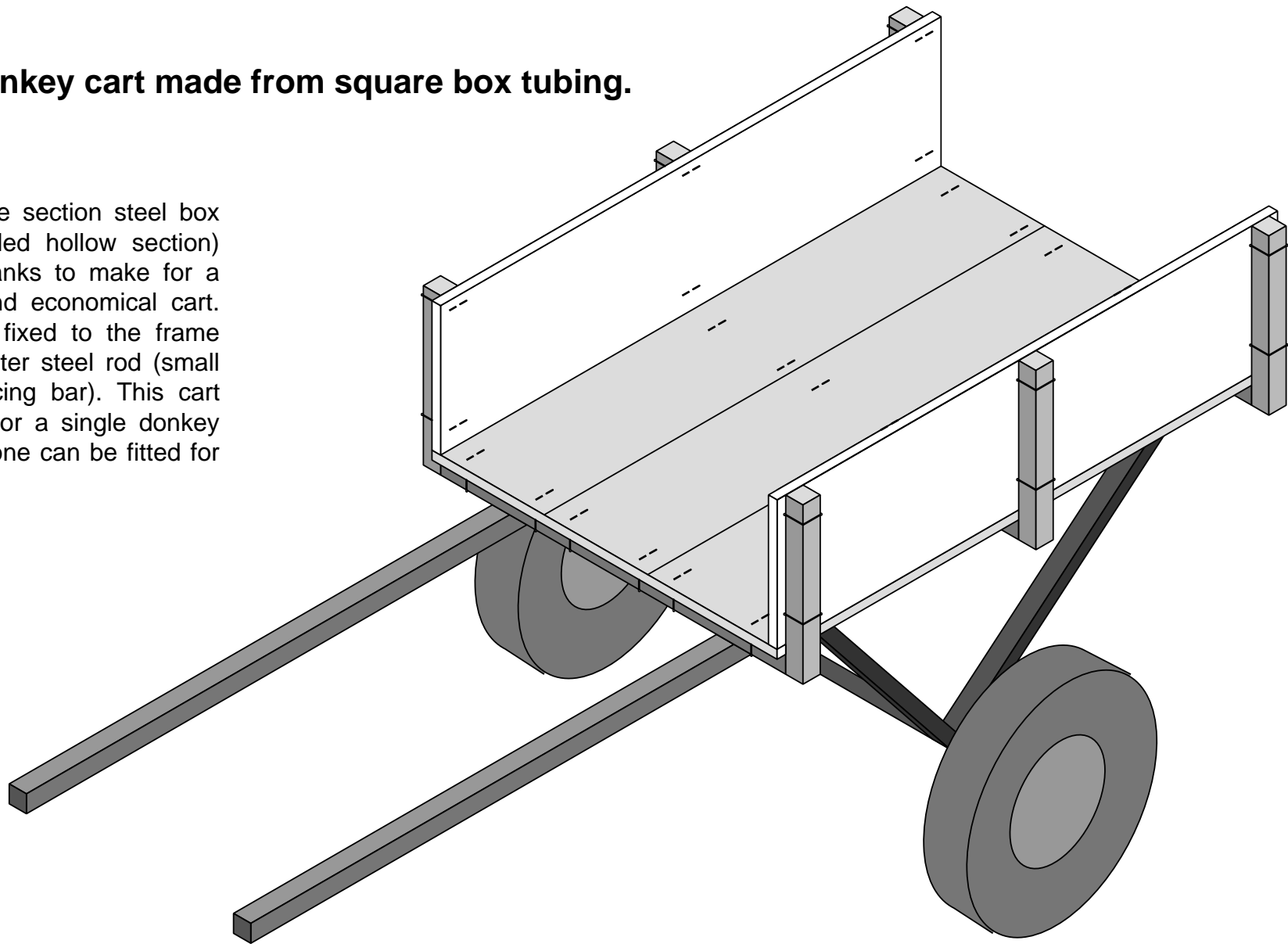
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## STEEL FRAME AND WOOD DONKEY CART

**Figure 1: donkey cart made from square box tubing.**

Cart uses square section steel box tubing (RHS rolled hollow section) plus wooden planks to make for a quickly made and economical cart. The planks are fixed to the frame with 6mm diameter steel rod (small concrete reinforcing bar). This cart has two shafts for a single donkey but one central one can be fitted for two animals.



# Donkey Cart Body Made From Square Box Tubing and Timber Planks

## Introduction

Not enough farmers in Africa have animal carts. Those who have carts can take their produce to places where they can get the best prices. They can also get into town and buy fertilizer and better seeds and move stuff around their farm easier. The trouble is that carts are too expensive for many farmers. The question is what can be done?

Carts are made in many different places. Some carts are made in factories in industrial countries and some are made in African factories, but most are made by local blacksmiths or carpenters using scrap car and Land-Rover axles. These people cannot get enough axles to meet the demand so the price is high. Even if they did have the axle, they still end up building heavy bodies that take ages to make. In another booklet in this series we have told you how you can make simple low-cost axles; in this booklet we tell you about a simple steel and timber body. You should find that you can make the body for about \$<sub>US</sub> 35 depending on the cost of the materials and labour. Once you get organised, two men can probably make two bodies per day.

What you need is a body which carpenters and fabricators can make with their simple tools. These people will probably be in the small market towns used by the farmers and they will have an electric welder and some basic handtools like a hacksaw.

Experts think that having the cart maker close to the farmer is a good thing because they can talk to each other easily and sort out any problems. And of course if the cart is made locally, it can be repaired locally, so there should not be any problems with spare parts.

## Idea Behind Design

The idea behind the design of donkey cart described in this technical release is to allow construction without lots of special tools and jigs, and without any hard-to-get materials. The only tools which you must have are a welder, a hacksaw, and a drill able to make a 6mm hole in wood. In fact you can make the drill yourself. You might find that a couple of 4" or a 5" G clamps (or something like it) are useful too. (The symbol " means inches here, so that 4" is about 100mm since there are about 25mm in an inch.)

You will see that there are no mitres and funny angles to cut in the square tubing so you save time when making the cart. Also the exact lengths of the components are not very fussy - again it saves a little time. But you will find that the carts look better if you take trouble to get things square and even etc.

These carts have been tested a bit in Nigeria, but we have not tested them enough. The only problems which we have found so far have been breaking of the animal shafts and we have cured this by welding some strengtheners (bits of 8mm, 10mm or 12mm round bar or re-bar) to the top and bottom of these shafts. (Re-bar means concrete reinforcing bar). The

construction tends to be a bit light in Nigeria, because they sell very thin wall square tubing (much less than 1mm thickness) there. If you used tubing with a wall thickness of 2.5mm or more you probably would not need to put these strengtheners on. Really to get a cart at a reasonable cost you need to experiment a bit to see how the farmers treat their carts and what they expect them to stand. It's no good saying it must be strong enough so that they cannot ever break it - somebody will always break anything - and it will be very expensive to make it nearly unbreakable. At least like this you can repair it easily and cheaply.

## Cutting list and costs

Table 1 shows a cutting list for a complete cart. Recent prices of materials in Nigeria are shown converted to \$<sub>US</sub>. The square box tube (sometimes called rolled hollow section or RHS) is nominally 2" or 50mm on one side. You can often buy it in a variety of wall thicknesses. It's best with a with a wall thickness of 2.5mm (12 gauge) or more, but we have used wall thicknesses down to 1.6mm (16 gauge) as we mentioned earlier.

## Construction step by step

1) The first job, is to get all the material together and clear a space to work. Ideally you will be able to work on a flat area of concrete. Start by cutting the square box tube into the right lengths, as in the cutting list above. Then cut the

various bits of re-bar or whatever you are going to use. You could cut the timber also at this stage, but it might be easiest to leave it till last.

2) Next weld the three U-shaped frames together. You might find the method shown in Figure 2 the easiest way to support the components during welding. It's quick and if you do not tighten the clamps too tight to start with, you can tap the bits with a hammer until everything is square and

component	material	number of lengths and length required [no.xmm]	total material in cart [mm]	materials' cost in Nigeria [\$us]
animal shafts	50x50 RHS	2x3150	6300	8.94
body frame bottoms	50x50 RHS	3x1100	3300	4.68
body frame sides	50x50 RHS	6x300	1800	2.55
axle struts	50x50 RHS	4x600	2400	3.40
shaft strengtheners	8mm to 12mm round bar <sup>1</sup>	8x600	4800	1.02
axle strut braces	8mm to 12mm round bar	2x850	1700	0.36
axle fixing studs	M12 threaded rod or bolts	2x100	200	0.64
axle fixing loops	6mm dia re-bar or similar	2x200	400	0.04
plank fixing staples	6mm dia re-bar or similar	30x250	7500	0.80
tray bottom planks	1"x12" or similar timber	4x1800	7200	4.26
tray side planks	1"x12" or similar timber	2x1800	3600	2.13
tray ends	1"x12" or similar timber	2x1100	2200	1.30
TOTAL->				30.12

<sup>1</sup> The round bar can be anything actually - it doesn't even have to be round, so deformed or high-yield re-bar is fine. You could even use flat strip as long as its more than say 8mm thick.



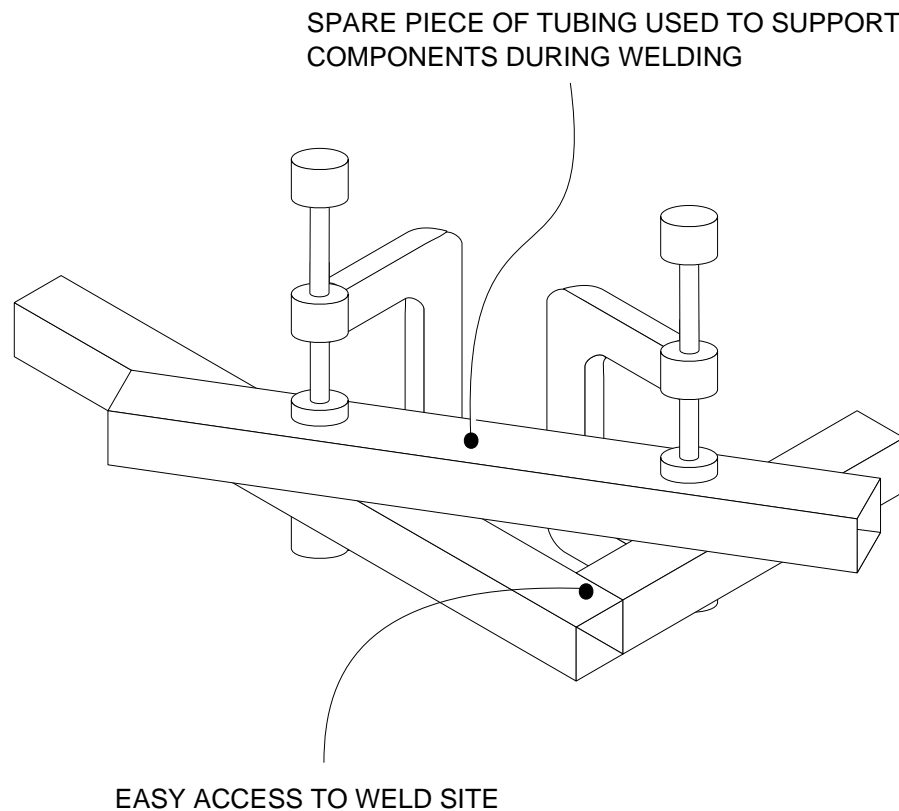


Figure 2: supporting components during welding.

straight. Then tighten the clamps before you weld.

- 3) Then take two axle support strut pieces and weld them together to make an L shape. When you do this you need to weld only two edges together to leave a space for the axle as Figure 3 shows. You can then weld this L piece to

an animal shaft.

Repeat the process using the first sub assembly as a pattern for the second, but remember that the second assembly must be a mirror image of the second. In other words you will need to put the first assembly upside down on the ground and assemble the second one on top of it, as shown in Figure 4. make sure you do not weld the two assemblies together!

- 4) It may be easiest to fix the axle retaining bolts and loops on at this stage so that you can use them in the next stage.
- 5) Now you can weld the three U-frames on top of the animal shafts after you have checked for squareness etc.
- 6) Nearly there! Now you need to bend the staples to hold the wood onto the square tube. You could make up a jig for this with some bolts in a piece of wood or you can just bend them in a vice. They do not have to be very accurate, but as usual the more accurate the better. To fit them, drill a hole both sides of the tubing and push both legs of the U through the wood using a hammer if necessary. When it's through, hold a hammer against the bottom of the U whilst you knock the protruding legs over with another hammer. You might find this easier with someone to help you. Then clench the legs by knocking them into the surface of the wood to leave the surface flush. Once you are happy that

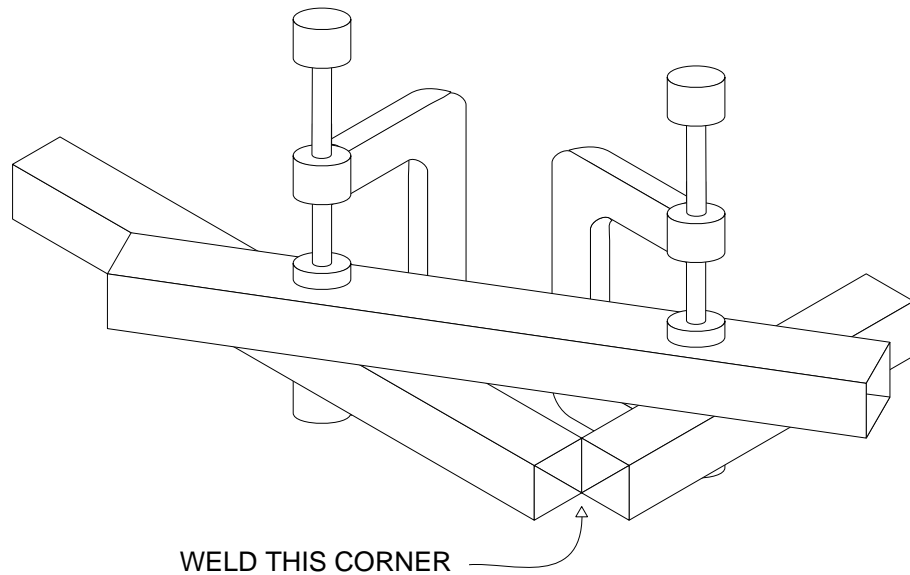


Figure 3: welding axle supports.

all is in the right place, weld the staple to the square tubing with a couple of substantial tack welds, as shown in Figure 5. Then put the rest of the staples in in the same way.

7) Paint the cart. You've finished it!

## Modifications

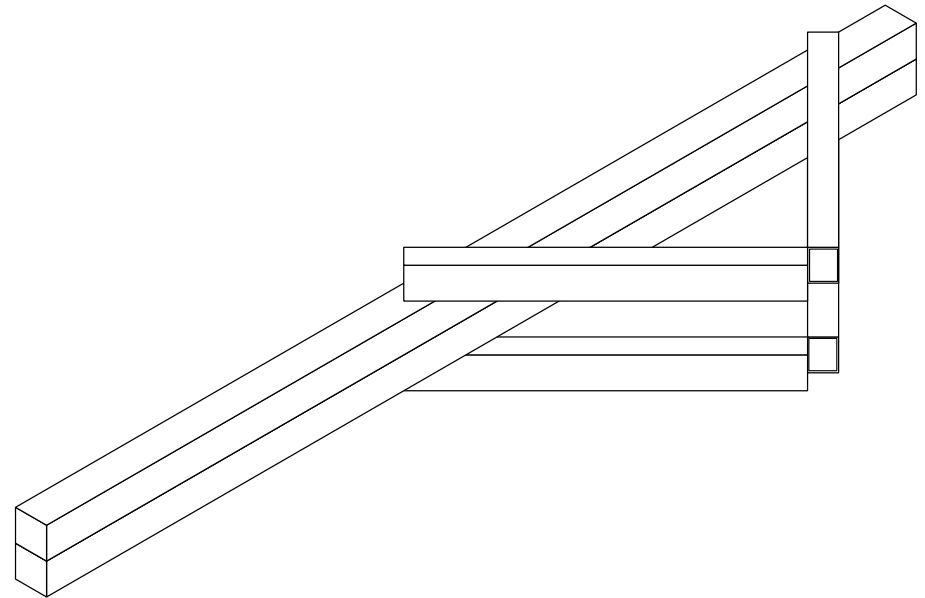


Figure 4: welding animal shaft and axle support struts assemblies.

There are many different versions of this cart. This one has sides, for example, but you could make these removable by not using staples to fix the sides. A good way to fix the side planks might be to leave the steel uprights in place and tie the planks to the inside of these with bits of truck inner tube as giant bungees or elastic bands. This is an appropriate way because it is cheap and very easily repairable, but the farmers may want some flashy looking thing which will be very expensive to make. You will probably find that things like latches take as much time as the basic parts of the cart.

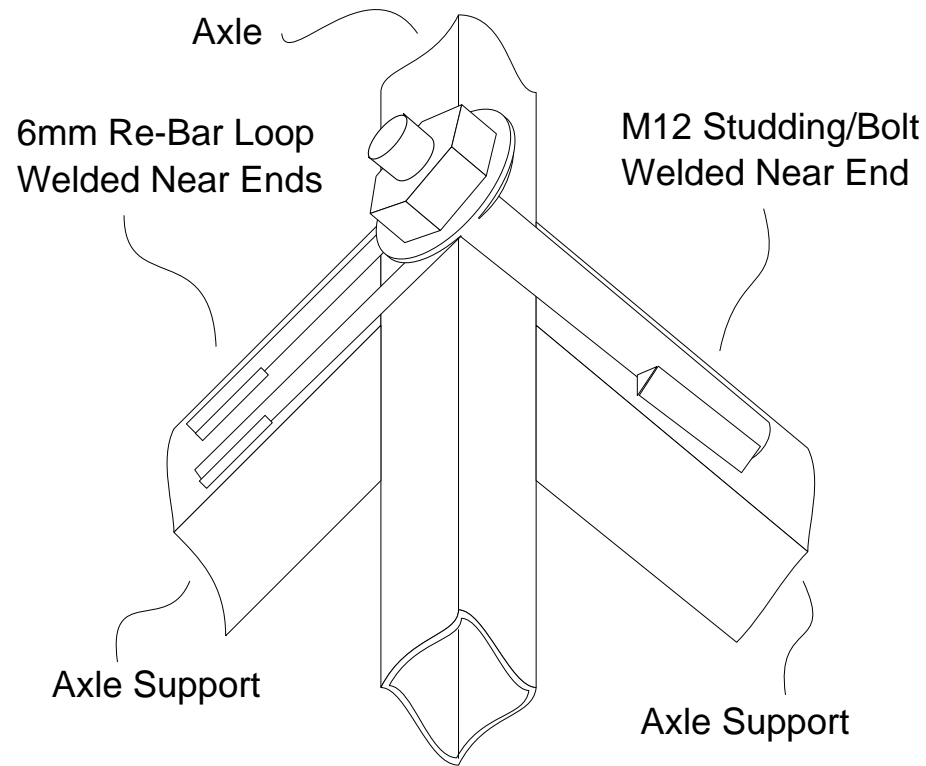


Figure 5: method of fixing axle to axle supports.

You can try longer and shorter carts and you can make them wider or narrower. When you do this, check the length and width of the planks of wood that you will use - you do not want to find that you are two inches short of being able to get two

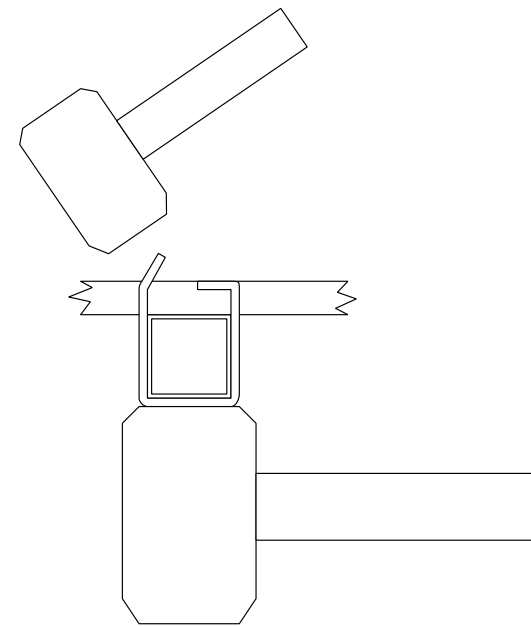


Figure 6: Using two hammers to clench wood fixing staple.

runs of plank out of one piece of timber, or that its just too narrow and you have to fiddle about and waste time filling the gap with an extra little strip.

Another thing is the height of the cart. No-one seems to know why some carts are made high and others low. Its better for the animals if the load tray is low particularly if the carts will be operated a lot over rough ground. But you may find that farmers want a high load tray to keep loads dry if they are fording rivers a lot, or it may be a status thing (if you are

wealthy enough to own a cart, your eye level must be above a pedestrian's). Or it may be that it's too tiring to load a low cart - if, for example, you have to bend your back twice for each bundle - once to pick it up off the ground and again to put it down onto a low load tray. We have found that farmers usually want the body to come out over the wheels so they can load on lots of straw or light materials.

## **Other DTU cart developments**

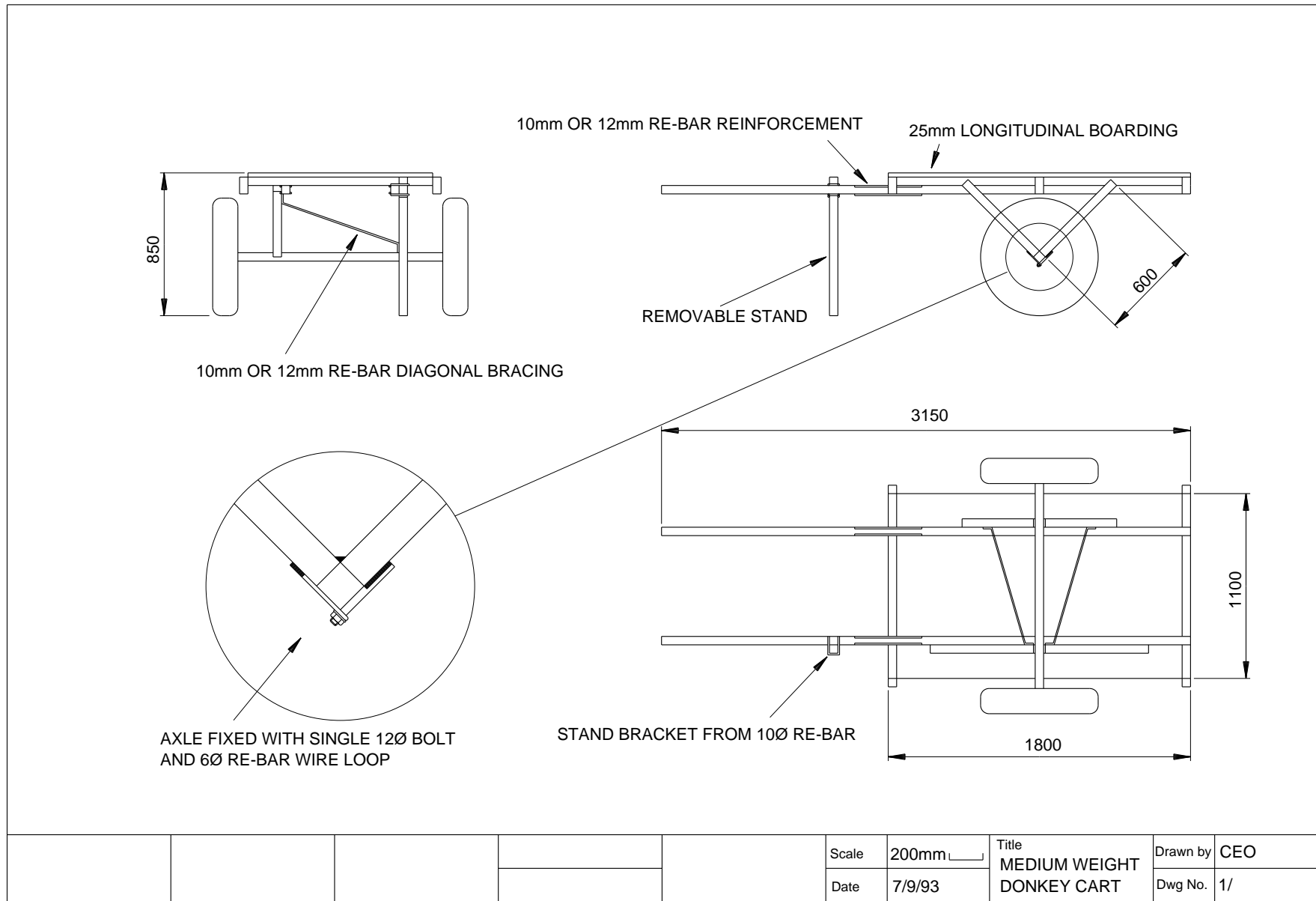
The DTU has been working on a range of cart body types for use with both donkeys and oxen. It has designs for both wooden and steel framed types. The wooden types are cheaper in material terms, but the steel framed ones are easier to make because the joints are more straightforward - nevertheless you can make either type of cart in only a few hours, if you are reasonably set up with tools and materials.

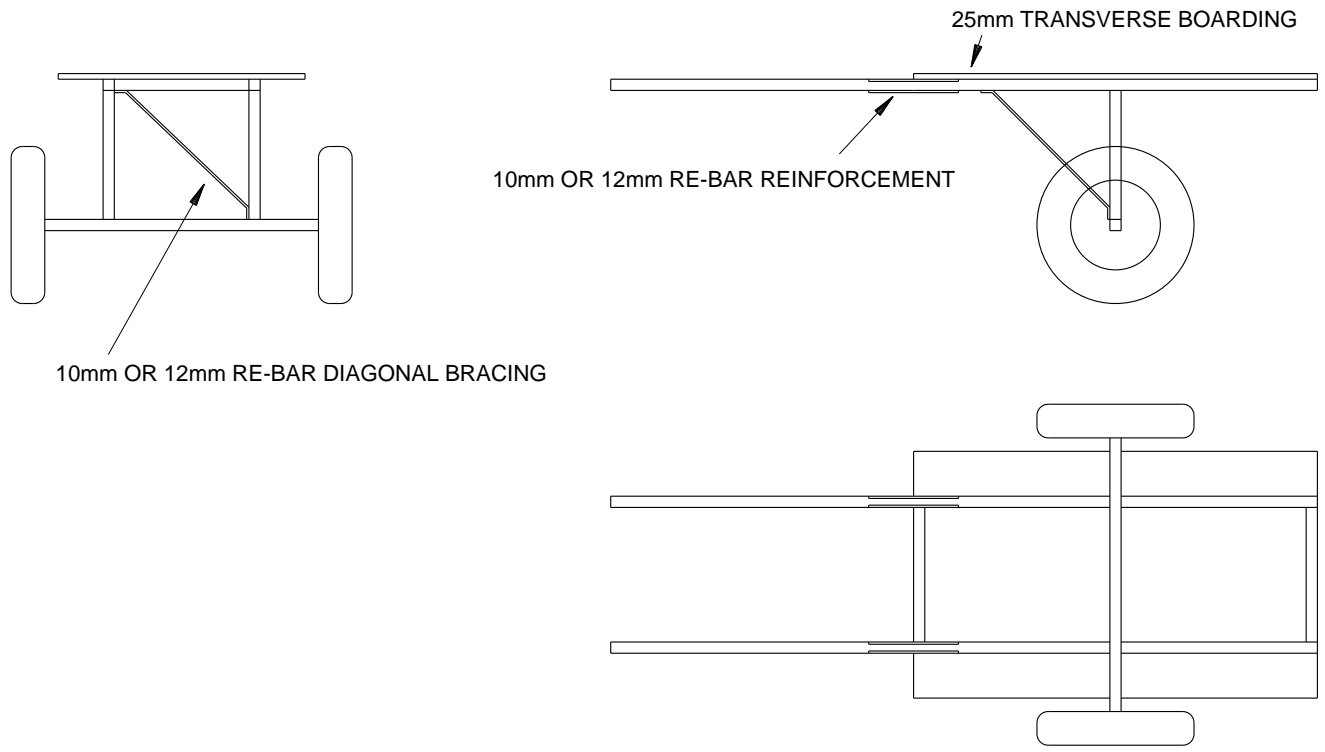
The DTU has also been working on new designs of wheels, hubs and bearings to bring down their costs and make things more locally manufacturable. For example it has pioneered a system of hubs using water pipe which do not need machining to make a roller bearing hub. Obviously friction is very low with these hubs and they usually give good milage before being worn out too - we usually get 15 000 km before they are very badly worn, but they may need cleaning and relubrication several times before they get this far. Still they are reasonably cheap - we can make them in Nigeria for about \$<sub>US</sub>20, they only take one man a day to make, and they do not need any special tools.

Other hub designs using, for example aluminium castings, are in production in Nigeria and we are trying to reduce or eliminate the machining in these. Also wheel designs in steel sheet, cast aluminium and timber are in manufacture or under development.

## **Cart Drawings**

Two drawings of carts are shown in the following pages. The first one is simple, but quite strong and easy to make, and is the one for which we have shown the list of materials. The second cart is lighter and even easier to make. You can use this cart with small donkeys.





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# Animal Cart Programme

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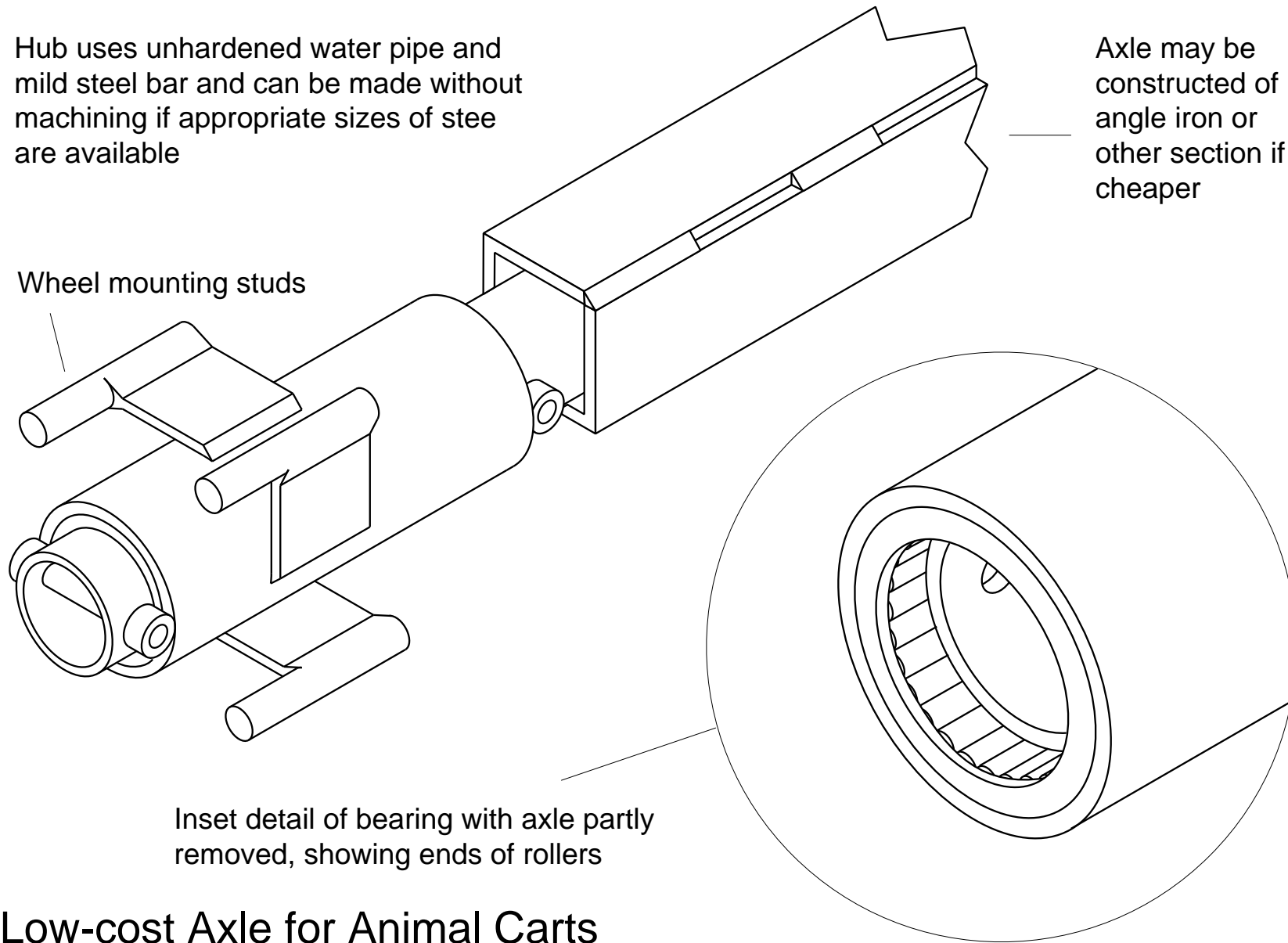
## PIPE AND ROLLER AXLE FOR OX CARTS



Hub uses unhardened water pipe and mild steel bar and can be made without machining if appropriate sizes of steel are available

Axle may be constructed of angle iron or other section if cheaper

Wheel mounting studs



Inset detail of bearing with axle partly removed, showing ends of rollers

## Low-cost Axle for Animal Carts



# Pipe and Roller Ox-Cart Wheel Hubs

## Introduction

Not enough farmers in Africa have animal carts. Those who have carts can take their produce to places where they can get the best prices. They can also get into town and buy fertilizer and better seeds and move stuff around their farm easier. The trouble is that carts are too expensive for many farmers. The question is what can be done about it?

Carts are made in many different places. Some carts are made in factories in industrial countries and some are made in factories in Africa, but most are made by local blacksmiths or carpenters using scrap car and Land-Rover axles. These people cannot get enough axles to meet the demand, so the price is high. Another problem is that the axles are often so worn that they do not last long. Lots of farmers take the differential unit out of the axle too, which makes it break sooner and lets the dirt in.

What you need is an axle which blacksmiths and fabricators can make with fairly simple tools - without having to get parts machined. There are usually blacksmiths and fabricators in the small market towns used by the farmers. Experts think that having the cart maker close to the farmer is a good thing

because they can talk to each other easily and sort out any problems. And of course if the cart is made locally, it can be repaired locally, so there won't be problems with spare parts.

## Idea behind design

The idea behind the design of axle described in this technical release is to allow axle construction without the use of machine tools (lathes and milling machines), and using materials which should be readily available. The materials can be used 'as bought' - no hardening of any of the components is needed, and you do not need to be super accurate - good hand working is good enough. The only tools which you must have are a hacksaw, a file and a drill able to drill a 13mm hole in steel. Having a vice is also very handy!

Of course if you do have power tools - especially a power hacksaw or cutoff wheel - things can be made much faster. This axle is suitable for a wide range of production methods - you could even tool up for manufacture with some specially made tools!

The long thin needle rollers in this design have been used so that the hubs will usually fit scrap Land-Rover and Japanese four-wheel-drive vehicle wheels. These wheels have a hole in the middle for the axle which is 115mm diameter (ie 4½") on a

Land-Rover wheel, but is smaller on the Japanese vehicles. If the wheel won't fit you can sometimes saw or file the hole bigger. Putting the fixing studs on struts like you see in the drawings means that you might be able to bend the struts a bit to fit a different wheel. Or if that doesn't work you can even cut nearly through the welds and then weld them in the right place. You could even cut the struts right off and weld on a different number, if your wheels have a different number of holes.

## Performance

We have tested smaller versions of axles like these for more than 10 000km in the laboratory and some axles have been ok for 30 000km. With the smaller axles we usually set the load at 200kg per wheel, but we have used them at 400kg for thousands of km. With these big axles we expect double the load capacity - say up to 800kg on each wheel. You will probably find that the axles need to be cleaned and regreased every six months or year depending on how much they are used. The materials that you use do not have to be perfect - some of the axles we have tested have not been very round at all - one was more than 1mm out, but they have still worked. We have tried rollers made out of 6" nails with the heads cut off on the small version of the hub. They still worked even though they were slightly bent. Another material which might work for small rollers is welding electrode with the flux knocked off. Of

course none of these axles are as good as axles with proper bearings in them, but they are a lot cheaper and easier to make and they should still last many years.

## Cutting list and costs

Table 1 shows a cutting list for a complete axle - two wheel hubs and stub axles joined by an angle iron section in the middle. We did this because angle iron was much cheaper than pipe. But if it isn't where you are, then make the whole axle out of one piece of pipe. Recent prices of materials in Nigeria are shown converted to \$<sub>US</sub>. The 3"BSP (British Standard Pipe) is about 89mm outside diameter with a wall thickness of up to 5mm. The 2"BSP is about 61mm outside diameter with a wall thickness of about 4.5mm.

## Construction step by step

These instructions deal with making an axle to the design shown in the drawings. If you find that you can't get the right sizes you might still be able to make an axle with other sizes. See the Modifications section on page 6.

1. The first and probably most difficult job, is to get some

Table 1 Cutting list and costs for pipe and roller ox cart axle				
component	material	number & length required [no.xmm]	total material in axle [mm]	materials cost in Nigeria [\$us]
central axle	75mm (3") angle iron <sup>1</sup>	2x1200	2400	2.98
hub stub axles	2" BSP malleable iron pipe	2x500	1000	5.67
hub outer race	3" BSP malleable pipe	2x250	500	1.24
rollers	10 mm or 3/8" dia BMS <sup>2</sup>	40x228	9576	26.49
roller retaining rings	10 mm or 3/8" dia BMS	4x219	880	2.43
axial thrust rollers	25 mm dia BMS <sup>3</sup>	4x12	48	0.41
hub restraint bolts	M12 bolts x100mm	4x100	400	1.28
wheel studs	12mm studding	8x70	560	2.55
wheel stud struts	6x40 black steel strip	5x62	310	0.47
stud washers	3x40 BMS strip 4	5x40	200	0.14
TOTAL COST =				43.66
1 Axle could be one piece of pipe with the stub axles - see text.				
2 BMS = bright mild steel bar.				
3 Thrust rollers can be made from a stack of washers. They are not essential but give better performance in dusty environments.				
4 Backing washers, placed on the stud before the wheel, make the wheel more secure if it has large stud holes.				

suitable pipes and roller material. Obviously the axle has to be strong enough to carry the cart, so you must make sure that the pipe has a wall thickness of more than say 3.5 mm.

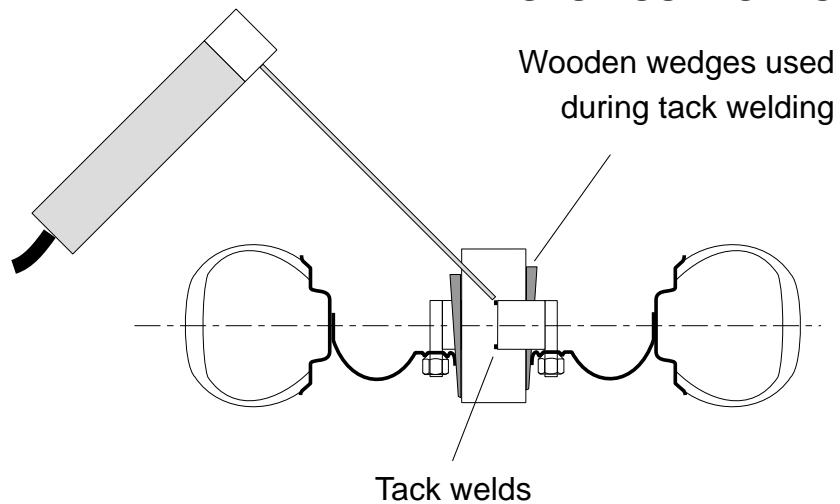
The hub pipe must also have a wall thickness of 3.5mm or more. It must also have a bore (or inside diameter), which goes over the axle with enough room for rollers all the way

around between it and the axle. Rollers must be 9mm, 3/8" or 10mm diameter (if they will go in). There can be quite a lot of play (looseness, space or clearance) between the rollers and the axle (say 1mm) - it does not have to be tight like an ordinary ball race.

- When you have worked out how to get the right pipe and roller sizes, then you can cut the two hub pipes 250mm long and the two stub axles 450mm or so long. You also have to cut enough rollers to fill up between the stub axle and the hub pipes. You will probably need about 20 or 21 for each hub and the rollers must be about 228mm long. Do not try to squeeze the hub full of rollers - the best way to find out how many you need is to put as many in as you can and then take one or two out. You should clean up the ends of the rollers with a file after you have sawn them.
- The next step is to weld the stud bolts or bits of threaded rod onto the struts. When you've done this you can put the studs into the wheels, put the nuts on, and get everything even and straight with the hub pipe in as well. You might find that holding the hub tube in the wheel with some wedges, as shown in Figure 2 makes things easier. Also don't forget that you want to get the middle of hub pipe level with the middle of the tyre, as is shown in Figure 3. Most wheels need the studs to be about 40mm offset and this is what is on the drawings. When you are happy, tack weld

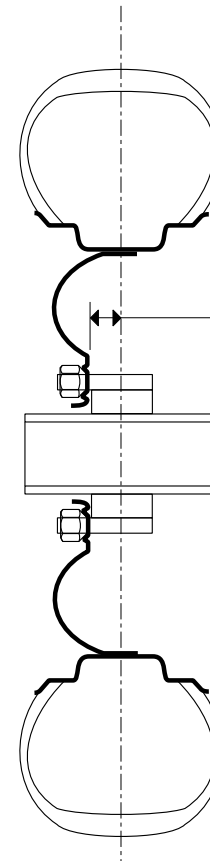
the struts to the hub tube, take the wheel off so you get at the tube easily and weld the stud support struts to the hub tube. Repeat this for the other hub. If you are going to make several axles you can make up a simple jig to hold everything for welding. We have used a piece of 18mm plywood with a central hole that fits the hub tube tightly and has a hole for each of the studs. Really this is like a dummy wheel. After welding its best to check that the hubs, rollers and stub-axles still go together - sometimes weld contraction can pull it all out of shape and make it all

**Figure 2: CROSS SECTION OF TYRE WHEEL AND HUB TUBE DURING TACK WELDING OF STUD SUPPORTS**



too tight. You might need to file off some high spots inside the hub or you may even have to use smaller rollers. If you

**Figure 3: CROSS SECTION OF TYRE WHEEL AND HUB TUBE SHOWING CENTERING OF HUB TUBE**



This distance must be set to get the hub tube in the middle of the tyre.

Hub tube

Getting the hub in the middle of the wheel and tyre means that the bearings in the hub are evenly loaded.

can get it together without a hammer you'll be ok because it will wear to the right shape.

4. Now take the wheels off the hubs and make up four rings (called roller restraint rings on the drawing) from the same material as you used for the rollers. Bend them in a vice if you have it, and cut the rod so that there is say a 4mm gap between the ends when they are the right diameter. Then you can push them into the end of the hub tube and weld the ends together. It's best to remove them then from the tube and clean up the weld with a file. The rings have to be welded just inside the ends of hub pipes to stop the rollers falling out so do this next. When they're welded in you need to use a half round file to open the hole in the middle where the axle pipe will go so that it's got plenty of room - you don't want it rubbing on the axle.
5. Next drill the two holes in each stub axle for the cross bolts. Put the end ones about 20mm from the end of the stub axles. You need to make the holes for the other two bolts just far enough away from the end of the hub so that you can just get the thrust rollers on. Probably the best way to do it is to assemble the hubs on the axles after you've drilled the first holes, offer up the other roller and mark the position. It doesn't matter if the hubs are a bit loose on the axles.
6. Nearly there! Now you need to cut two bits of angle iron and weld them together to make the center axle to join the stub axles. You must put the stub-axles in position when

you weld - the contraction of the angle iron when the weld cools down clamps everything (if you are lucky). Otherwise just put a few tack welds on to hold it in place.

7. Now put it all together! Put some grease into the hub and put the right number of rollers in so that they are in place against the inside of the hub tube. You can hold them in place with a bit of rag or a plastic bag if the grease does not stick them. Alternatively you can put the hub a little way onto the shaft and then just ease the rollers into place one by one. Then just slide the whole thing onto the stub axles and fit the cross bolts. (If a plastic bag or rag was used to hold the rollers it should be pushed out by the axle.)
8. You've done it!

## Modifications

If you cannot get suitable sizes of pipe and round bar, then pipes can be made slightly bigger (up to 1mm bigger) by forcing a short piece of round bar of the right diameter through them with a press. Another way to do it is to saw the pipe along its length and open to the right size and then weld it. You can also make it a bit smaller like this by cutting a wider slot and squashing the pipe down. Don't worry too much about the rollers rolling over a groove, but you will need to clean any flash

or weld bead off from the bore.

If you find that you cannot get anything like the materials talked about in the cutting list then maybe you can adapt the design a bit. If the hole in the middle of the wheels is big then you stand a better chance of finding a combination of pipes and rollers that will fit. You can often cut a bit out of the middle of the wheel to make the hole bigger. The hole in Land Rover wheels is big and you can just get 4" pipe into them. You may find that you can even use small pipe say 1/2" BSP pipe to make the rollers for example, but you must make sure that it has a thick wall. Of course the shaft does not have to be a pipe - it could be solid and then it could be a bit smaller, say 38mm diameter or bigger if the steel is high quality.

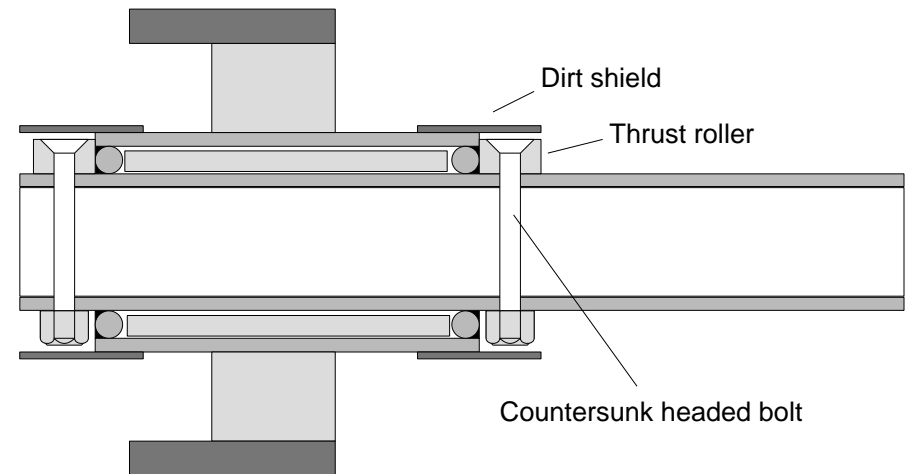
Another idea that we have tried is to use a hardwood as the hub and even the wheel. If you think about it, the wear on something which is rolling must be less than when something is sliding over it, so a wooden bearing should be better than a sliding one. Some bearings we have tried have had a steel ring fitted inside so that the rollers roll on this steel. We have also tried making these rings from round bar like wire so that it's like the rollers roll on the inside of a spring. This seemed to work quite well.

The main thing to remember with these bearings is that the rollers must be long compared to the diameter of the axle. In

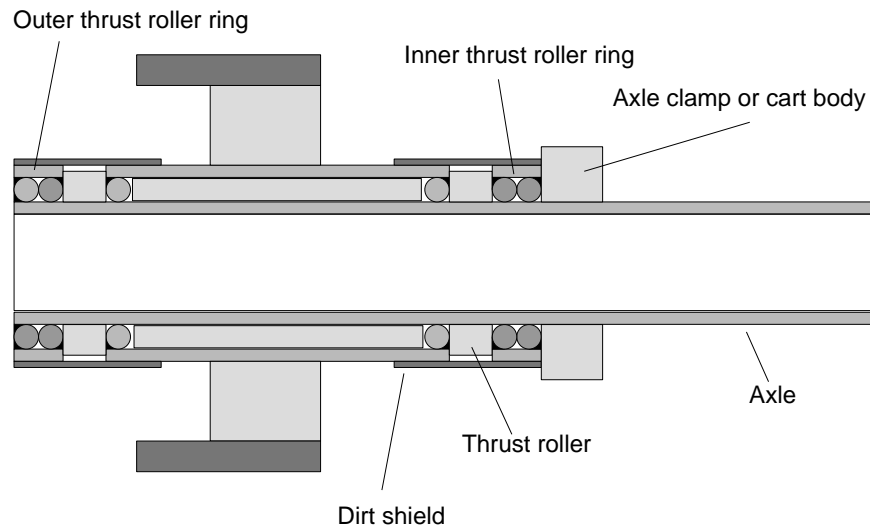
the axle and hub shown in this technical release the rollers are about four times as long (228mm) as the diameter of the axle (about 60mm). Another rule is that bigger diameter rollers work better.

## Other thrust bearing arrangements

We have tried some other ways of making the thrust rollers at the ends. You can have just one roller on each cross bolt and this one can have a countersunk hole in its end so that the



**Figure 6: axial restraint rollers on countersunk head cross bolts.**



**Figure 7: axial restraint rollers held inside dirt/ oil shields.**

cross bolt head (if it is countersunk) can fit in and not stick out. This makes it easier to put dust shields on. You can see this arrangement in Figure 6.

Another way that we have used rollers is to put them inside the dirt shields without any bolts. You can see this in Figure 7. The rollers have no holes - they are just plain pieces of rod. You need to use big rod so that its diameter is a bit bigger than its

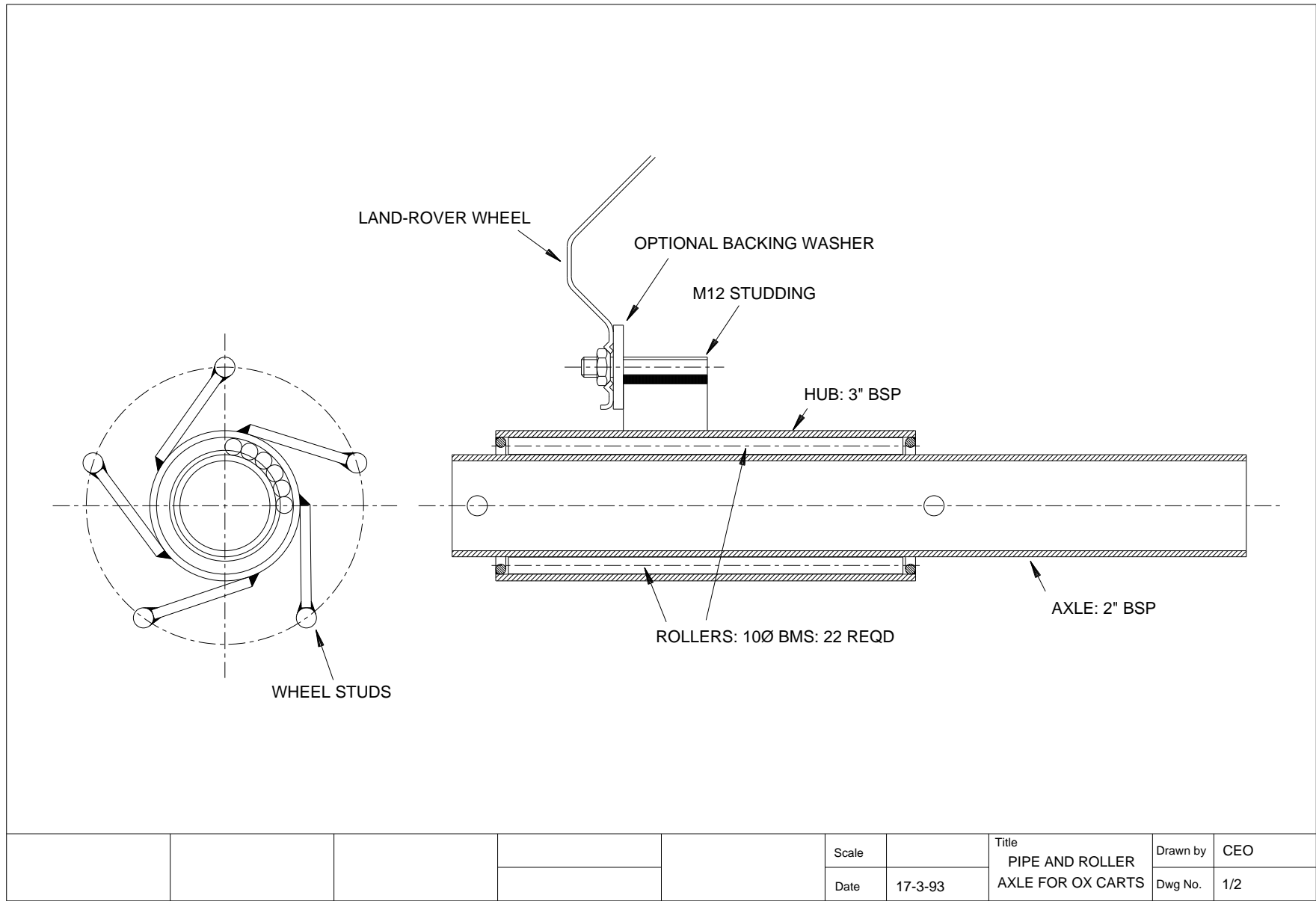
length. If you do not do this the rollers can turn over and jam. You should clean up the ends of the rollers with a file and round off the corners a bit so that they can slide inside the dirt shield and not catch on anything. The rollers roll against thrust roller rings made of the same pipe as the hub tube is made from and the same rod as the rollers. The outer thrust roller ring should be welded to the axle. The inner one is held on by the cart body or the clamps which hold the axle to the body. You can put one or more thrust rollers in.

One more advantage of this method of axle construction is that you do not need to drill any holes.

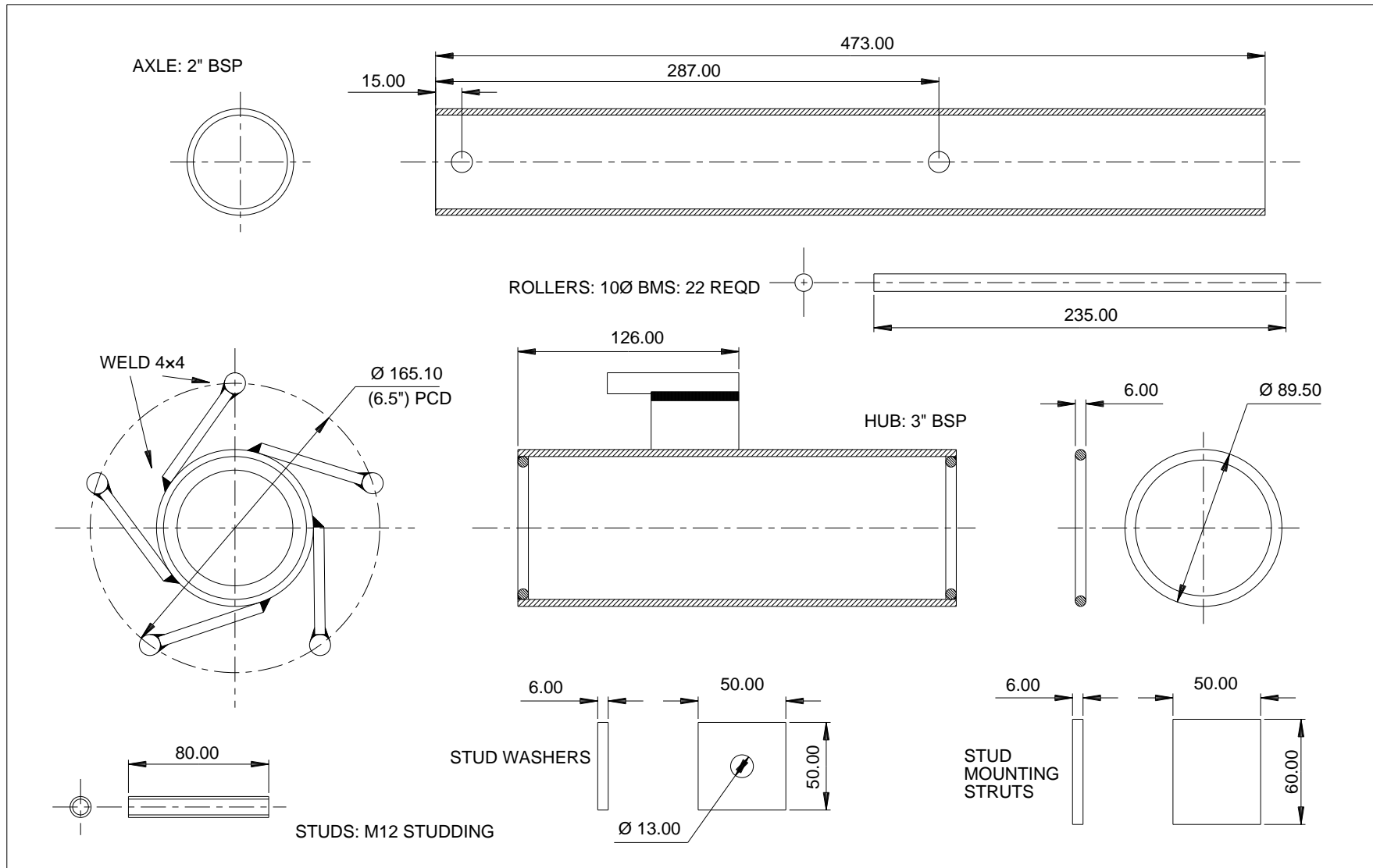
### Other DTU cart developments

Other methods of hub design using aluminium castings, for example, which might need no machining, and others which need only limited machining are under development at Warwick and wheel designs in steel sheet, cast aluminium and timber are also in manufacture or under development. We have also been working on a variety of other bearing types including pressed cup-and-cone ball bearings. A range of designs for donkey and ox carts made of steel and wood, is also available, some of which are in production in Nigeria.

If you are interested we can send you more information.







# PIPE AND ROLLER AXLE FOR OX-CARTS

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# Animal Cart Programme

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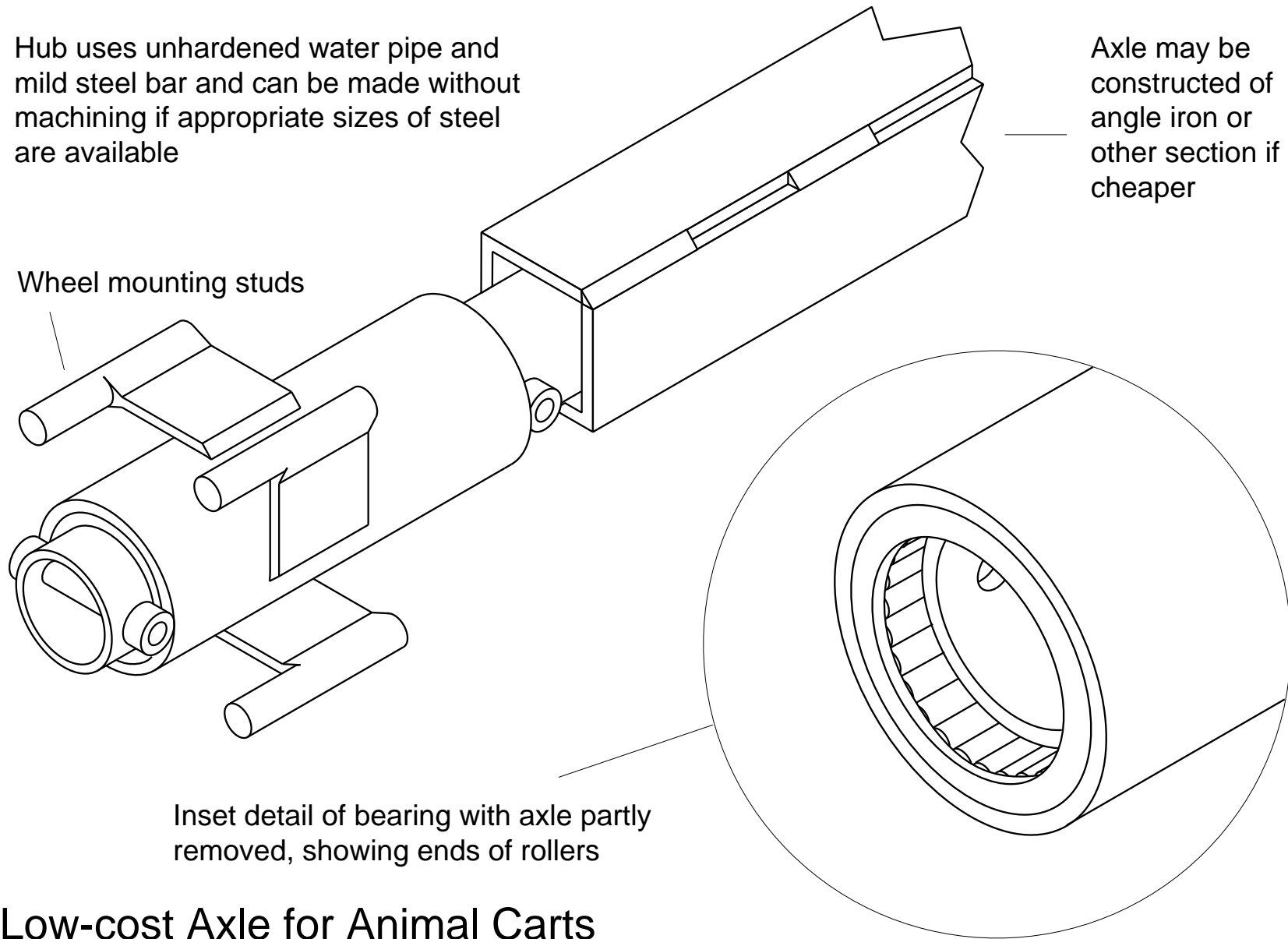
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## PIPE AND ROLLER DONKEY CART AXLES

Hub uses unhardened water pipe and mild steel bar and can be made without machining if appropriate sizes of steel are available

Axle may be constructed of angle iron or other section if cheaper

Wheel mounting studs



Inset detail of bearing with axle partly removed, showing ends of rollers

## Low-cost Axle for Animal Carts

# Pipe and Roller Donkey-Cart Axles

## Introduction

Not enough farmers in Africa have animal carts. Those who have carts can take their produce to places where they can get the best prices. They can also get into town and buy fertilizer and better seeds and move stuff around their farm easier. The trouble is that carts are too expensive for many farmers. The question is what can be done about it?

Carts are made in many different places. Some carts are made in factories in industrial countries and some are made in factories in Africa, but most are made by local blacksmiths or carpenters using scrap car and Land-Rover axles. These people cannot get enough axles to meet the demand so the price is high. Another problem is that the axles are often so worn that they do not last long. Lots of farmers take the diff (differential) unit out of the axle too, which makes it break sooner and lets the dirt in.

What you need is an axle which blacksmiths and fabricators can make with fairly simple tools - without having to get parts machined. There are usually blacksmiths and fabricators in the

small market towns used by the farmers. Experts think that having the cart maker close to the farmer is a good thing because they can talk to each other easily and sort out any problems. And of course if the cart is made locally, it can be repaired locally, so there will not be problems with spare parts.

## Idea behind design

The idea behind the design of axle described in this technical release is to allow construction without the use of machine tools (lathes and milling machines), and using materials which should be readily available. The materials can be used 'as bought' - no hardening of any of the components is needed. The only tools which you must have are a hacksaw, a file and a drill able to drill a 13mm hole in steel. Having a vice is also very handy.

Of course if you do have power tools - especially a power hacksaw or cutoff wheel - things can be made much faster. This axle is suitable for a wide range of production methods.

The long thin needle rollers in this design have been used so that the hubs will usually fit scrap car wheels. Most wheels have a hole in the middle for the axle. This hole is usually

about 60mm diameter, or a bit bigger. Sometimes they are smaller and the wheel will not fit. You can sometimes saw or file the hole bigger. Putting the fixing studs on struts like you see in the drawings means that you might be able to bend the struts a bit to fit a different wheel. Or if that does not work you can even cut nearly through the welds and then weld them in the right place. You could even cut the struts right off and weld on a different number if your wheels have a different number of holes.

## Performance

We have tested axles like these for more than 10 000km in the laboratory and some axles have been ok for 30 000km. Usually we set the load at 200kgf per wheel, but we have used them at 400kgf for thousands of km. Sometimes you need to clean them out and regrease them. Some of the axles we have tested have not been very round at all - one was more than 1mm out, but they have still worked. We have tried rollers made out of 6" nails with the heads cut off. They still worked even though they were slightly bent. (The symbol " means inches so 6" means about 150mm since there are 25mm in one inch.)

component	material	number & length required [no.xmm]	total material in axle [mm]	materials cost in Nigeria [US\$]
central axle	2" angle iron <sup>1</sup>	2x1200	2400	3.94
hub stub axles	1¼" BSP malleable iron pipe	2x350	700	4.71
hub tube	2" BSP malleable pipe	2x164	328	1.47
rollers	5 mm or 3/16" dia BMS <sup>2</sup>	60x152	9120	2.49
roller retaining rings	5mm or 3/16" dia BMS	4x167	668	0.20
axial thrust rollers	16 mm dia BMS <sup>3</sup>	4x8	32	not used
hub restraint bolts	M8 or M10 bolts x70mm	70x4	280	1.28
wheel studs	12mm studding	8x70	560	2.55
wheel stud struts	6x40 black steel strip	4x37	148	0.68
stud washers	3x40 BMS strip 4	4x40	160	not used
TOTAL COST =				17.32

1 Axle could be one piece of pipe with the stub axles - see text.

2 BMS = bright mild steel round bar.

3 Thrust rollers can be made from a stack of washers. They are not essential but give better performance.

4 Backing washers, placed on the stud before the wheel, make the wheel more secure if it has large stud holes.

## Cutting list and costs

The table shows a cutting list for a complete axle - two wheel hubs and stub axles joined by an angle iron section in the middle. We did this because angle iron was much cheaper than pipe. But if it is not where you are then make the whole axle out of one piece of pipe. Recent prices of materials in Nigeria are shown in \$<sub>US</sub>. The 2" BSP (British Standard Pipe)

is about 60.8mm outside diameter, or a bit less, with a wall thickness of about 3.6mm. The 1¼" BSP is about 42.9mm outside diameter, with a wall thickness of about 3.2mm.

## Construction step by step

These instructions deal with making an axle to the design shown in the drawings. If you find that you cannot get the right sizes you might still be able to make an axle with other sizes. See the **Modifications** section on page 6.

1. The first and probably most difficult job, is to get some suitable pipes and roller material. Obviously the axle has to be strong enough to carry the cart, so it should **not** be made from pipe smaller than about 40mm outside diameter. You must make sure that the pipe has a wall thickness of more than 2.5 mm.

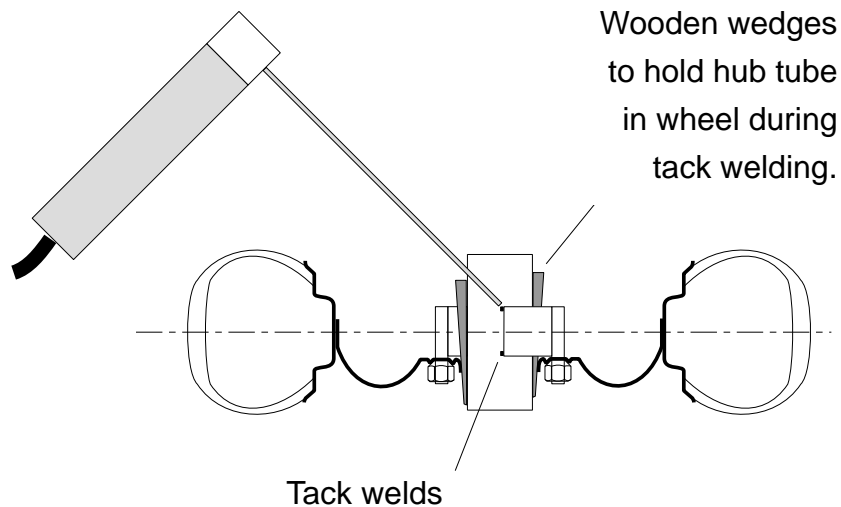
The hub pipe must also have a wall thickness of 2.5mm or more. And it must have a bore (or inside diameter), which goes over the axle with enough room for rollers all the way around between it and the axle. Rollers must be 4.5mm, 3/16" or 5mm diameter (if they will go in). There can be quite a lot of play (slackness, looseness or clearance) between the rollers and the axle (say 1mm) - it does not

have to be tight like an ordinary ball race.

2. When you have worked out how to get the right pipe and roller sizes, then you can cut the two hub pipes 164mm long and the two stub axles 300mm long. You also have to cut enough rollers to fill up between the stub axle and the hub pipes. You will probably need about 25 or 27 for each hub and the rollers must be about 152mm long. Do not try to squeeze the hub full of rollers - the best way to find out how many you need is to put as many in as you can and then take one or two out. You should clean up the ends of the rollers with a file after you have sawn them.
3. The next step is to weld the stud bolts or bits of threaded rod onto the struts. When you've done this you can put the studs into the wheels, put the nuts on, and get everything even and straight with the hub pipe in as well. You might find that holding the hub tube in with some wedges as shown in Figure 4 is a good way to do it. You also want to get the middle of hub pipe level with the middle of the tyre, as is shown in Figure 5. Most car wheels need the studs to be about 40mm offset and this is what is on the drawings. When you are happy, tack weld the struts to the hub pipe, remove the wheel and wedges so you've got room and weld the stud supports to the hub tube. Repeat this for the

other hub. If you are going to make several axles you can make up a simple jig, rather than the wedges, to hold everything for welding. We have used a piece of plywood with a central hole to fit snugly over the hub tube and four holes for the studs. In other words its a bit like a dummy wheel. Its best to check that the hubs, rollers and stub-axles still go together when you've finished welding -

**Figure 5: CROSS SECTION OF TYRE WHEEL AND HUB TUBE DURING TACK WELDING OF STUD SUPPORT STRUTS**



sometimes weld contraction can pull it all out of shape and make it all too tight. You might need to file off some high spots inside the hub. If you can get it together without a hammer you'll be ok because it will wear to the right shape.

4. Now take the wheels off the hubs and make up four rings (called roller restraint rings on the drawing) from the same material as you used for the rollers. The rings have to be welded just inside the ends of hub pipes to stop the rollers falling out. When they're welded in you need to use a half round file to open the hole in the middle where the axle pipe will go so that it's got plenty of room - you do not want it rubbing on the axle.
5. Next drill the four holes for the cross bolts. Put the end ones about 15mm from the end of the axles. At the other end you need to make them just far enough away from the end of the hub so that you can turn the nuts to get them on. Again about 15mm seems to do the trick. It does not matter if they are a bit loose.
6. Nearly there! Now you need to cut two bits of angle iron and weld them together to make the center axle to join the stub axles. You must put the stub-axles in position when you weld - the contraction of the angle iron when the weld cools down clamps everything (if you are lucky). Otherwise

just put a few tack welds on to hold it in place.

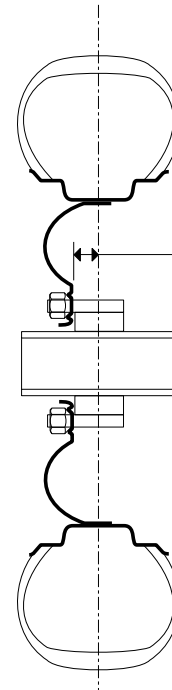
7. Now put it together! Put some grease into the hub and put the right number of rollers in so that they are in place against the inside of the hub tube. You can hold them in with a bit of rag or a plastic bag if the grease does not stick them. Then just slide them onto the stub axles and fit the cross bolts. (If a plastic bag or rag was used to hold the rollers it should be pushed out by the axle.)

8. You've done it!

## Modifications

If you cannot get suitable sizes of pipe and round bar, then pipes can be made slightly bigger (up to 1mm bigger) by forcing a short piece of round bar of the right diameter through them with a press. Another way to do it is to saw the pipe along its length and open to the right size and then weld it. You can also make it a bit smaller like this by cutting a wider slot and squashing the pipe down. Do not worry about the rollers rolling over the groove - as long as you clean the weld back flush with the tube it will be ok.

If you find that you cannot get anything like the materials talked



**Figure 5: CROSS SECTION OF TYRE WHEEL AND HUB TUBE SHOWING CENTERING OF HUB TUBE IN WHEEL**

This distance must be set to get the hub tube in the middle of the tyre.

Hub tube.

Getting the hub in the middle of the wheel and tyre means that the bearings in the hub are evenly loaded.

about in the cutting list then maybe you can adapt the design a bit. If the hole in the middle of the wheels is big then you stand a better chance of finding a combination of pipes and rollers that will fit. You can often cut a bit out of the middle of the wheel to make the hole bigger. The hole in Land Rover wheels is big and you can get 4" pipe into them. You may find that you can use small pipe say 1/2" pipe to make the rollers for example. Of course the shaft does not have to be a pipe - it could be solid and then it could be a bit smaller, say 30mm diameter if the steel is high quality.

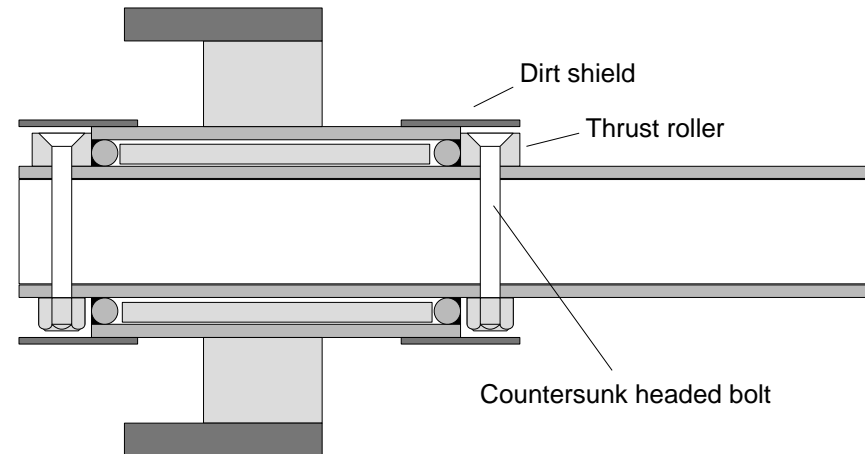


Another idea that we have tried is to use a hardwood as the hub and even the wheel. If you think about it, the wear on something which is rolling must be less than when something is sliding over it, so a wooden bearing should be better than a sliding one. Some bearings we have tried have had a steel ring fitted inside so that the rollers roll on this steel. We have also tried making these rings from round bar like wire so that it's like the rollers roll on the inside of a spring. This seemed to work quite well.

The main thing to remember with these bearings is that the rollers must be long compared to the diameter of the axle. In the axle and hub shown in this technical release the rollers are about four times as long (150mm) as the diameter of the axle (43mm). Also bigger rollers work better. In our design for Land-Rover wheels on bullock carts we use 3/8" or 10mm diameter rollers and we have successfully used rollers over 20mm diameter in some experiments.

### Other ways of making the thrust bearings

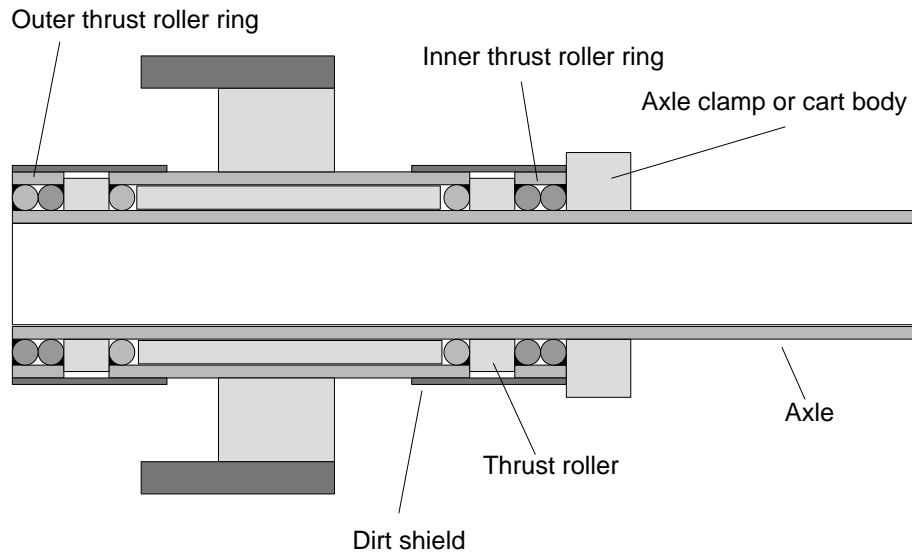
We have tried some other ways of making the thrust rollers at the ends. You can have just one roller on each cross bolt and this one can have a countersunk hole in its end so that the



**Figure 6: axial restraint rollers on countersunk head cross bolts.**

cross bolt head (if its countersunk) can fit in and not stick out. This makes it easier to put dust shields on. You can see this arrangement in Figure 6.

Another way that we have used rollers is to put them inside the dirt shields without any bolts. You can see this in Figure 7. The rollers have no holes - they are just plain pieces of rod. You need to use big rod so that its diameter is a bit bigger than its length. If you do not do this the rollers can turn over and jam.



**Figure 7: axial restraint rollers held inside dirt/ oil shields.**

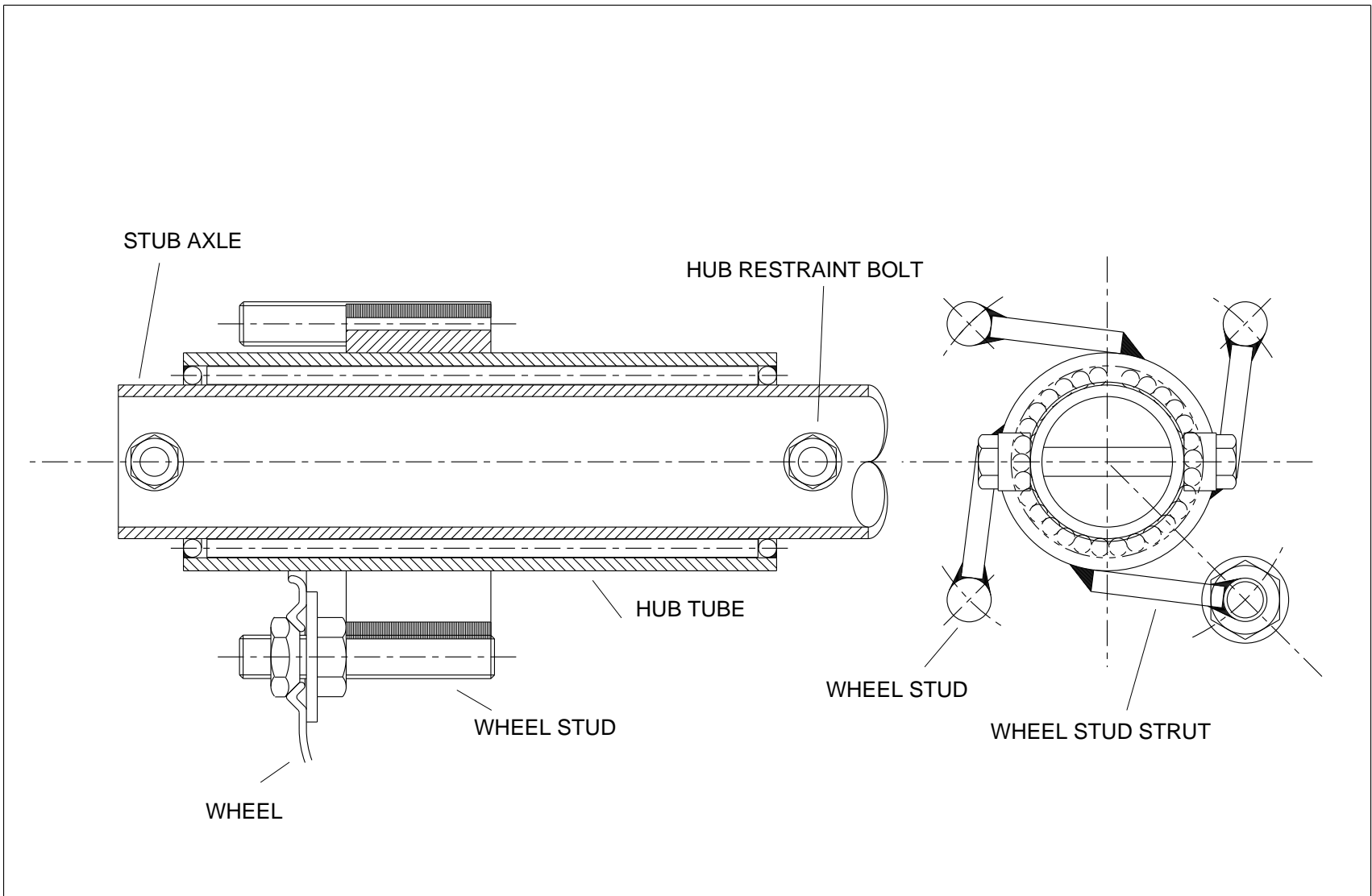
You must clean up the ends of the rollers with a file and round off the corners a bit so that they can slide inside the dirt shield and not catch on anything. The rollers roll against thrust roller rings made of the same pipe as the hub tube is made from and the same rod as the rollers. The outer thrust roller ring should be welded to the axle. The inner one is held on by the cart body or the clamps which hold the axle to the body. You can

put one or more thrust rollers in.

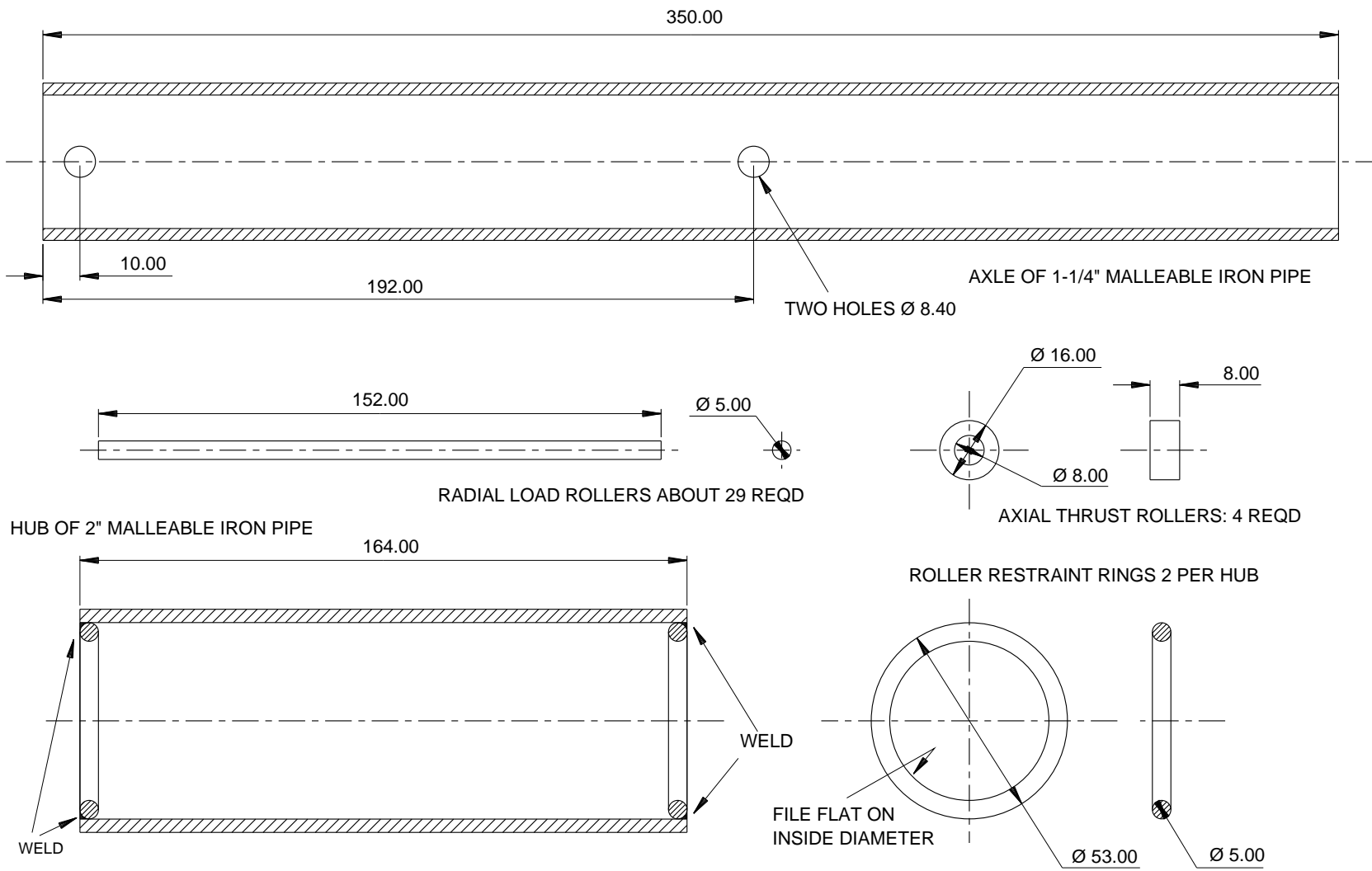
One more advantage of this method of axle construction is that you do not need to drill any holes.

### Other DTU cart developments

Other methods of hub design using aluminium castings, for example, which might need no machining, are under development at Warwick and wheel designs in steel sheet, cast aluminium and timber are also in manufacture or under development. A range of designs for donkey and ox carts made of steel and wood, is also available, some of which are in production in Nigeria.

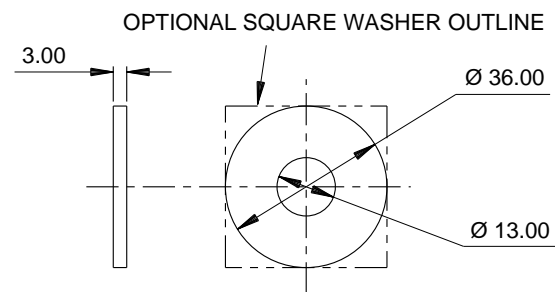
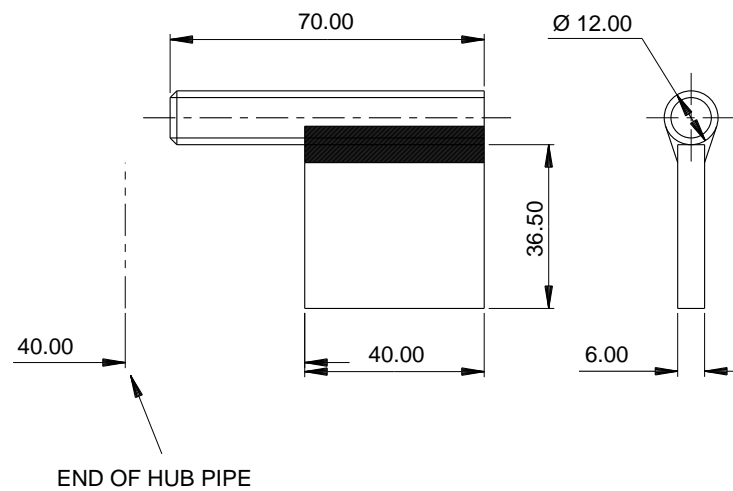
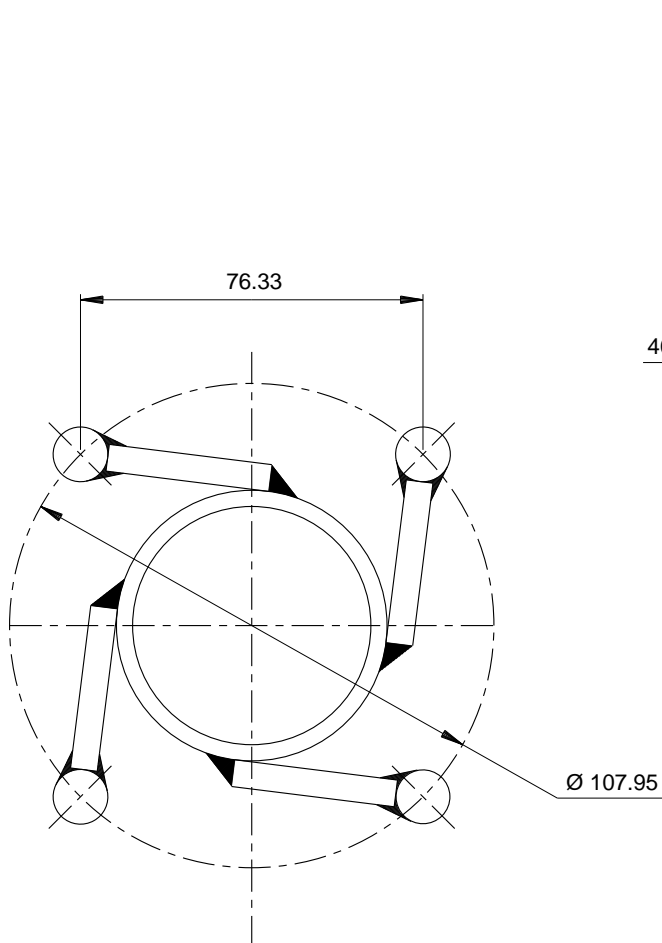


<b>GENERAL ASSEMBY DRAWING</b>	Scale	10mm <input type="checkbox"/>	Title PIPE AND ROLLER DONKEY CART AXLE	Drawn by	CEO
	Date	11-2-93		Dwg No.	1/3



# HUB AND AXLE COMPONENTS

Scale	10mm	Title	Drawn by	CEO
Date	11-2-93	PIPE AND ROLLER DONKEY CART AXLE	Dwg No.	2/3



# WHEEL MOUNTING COMPONENTS

Scale 10mm

Date 11-2-93

Title  
PIPE AND ROLLER  
DONKEY CART AXLE

Drawn by CEO

Dwg No. 3/3