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MANUFACTURE AND DIFFUSION OF LOW-COST TRANSPORT DEVICES IN ZIMBABWE

PHASE 2: FINAL REPORT

PROJECT NUMBER:	DP\ZIM\89\003
PROJECT DURATION:	36 MONTHS
PHASE 2 PERIOD:	24 MONTHS
STARTING DATE:	01-06-92

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DATE: DECEMBER 1994

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EXECUTIVE SUMMARY

The project involves the dissemination of a wheel manufacturing technology to overcome a constraint on the production of ox-carts by small to medium size workshops. The anticipated output is that these workshops will be able to increase the supply of ox-carts to rural communities and also diversify their activities into production of other low-cost transport devices such as wheelbarrows and handcarts. The objective of the project is to improve the access of rural households to these low-cost means of transport, thereby providing significant benefits to small-scale farmers, low-income households and particularly women.

Phase 2 of the project, which encompases the training and technical programme together with associated monitoring and evaluation activities, has been completed and the objectives satisfactorily achieved. Fifty workshops have been trained in the use of the wheel manufacturing technology and about half of these are currently implementing the technology in producing wheels and axles for ox-carts and other transport devices. The technology has proven appropriate for and acceptable to the workshops and there have been no technical problems in transferring it. A local infrastructure has been established with the capability to continue training in and support for the technology. There is a growing demand for ox-carts produced by trained workshops and this is expected to continue as more carts are put into service and rural households become more aware of the quality and reliability of the axle assemblies. It is therefore confidently concluded that the project has established a sustainable technology which is having a significant impact on the supply of ox-carts and which has a high potential for further expansion.

The selling price of carts produced by trained workshops is intermediate between that of the larger producers and that of informal sector artisans. However, it is considered that the reliability and reparability of these carts provides good value to users in terms of high availability and low operating costs over the life of the cart. The volume of sales indicates there is a good demand for the carts but at present it is not clear which rural groups are benefiting from the increased supply of carts. Therefore in an attempt to more clearly direct benefits to specific target groups of the project, poorer households and women, a number of lower-cost transport devices, which use wheels produced with the technology, have been developed. These comprise a wheelbarrow, a waterbarrow and a low-cost, light donkey cart/handcart. Because the production of good quality axle assemblies has overcome a constraint on the supply of ox-carts from small and medium sized workshops there has been a good take-up of the technology and this part of the project has been successful. However, the introduction of lower-cost transport devices involves much more work with target groups to promote and disseminate the devices and this is likely to be a more difficult and time consuming process. Phase 3 of the project will concentrate on this process but it is probable that dissemination will need to continue beyond the end of the project.

Phase 2 has involved a number of activities. The outcomes of these activities are briefly summarised below:

Manufacture of production tools: the production tools comprise a hand-operated bending device to form the wheel rims and an assembly jig to ensure accurate welding up of the wheel. Manufacture of these tools has been established with medium-size commercial workshops as it was felt that this would give the best chance of sustainability and continued availability of good quality tools in the future. It is known that two of the suppliers are advertising and marketing the tools outside the project. Some problems were initially experienced with consistent quality of tools and IAE may need to monitor this from time to time in the future.

Training programme: 50 workshops have been trained in the use of the wheel manufacturing technology, covering most rural areas of the country. The training has been effective - trained workshops have had few problems in implementing the technology and non have indicated that they have not taken it up because of difficulties in using the technology. Almost all workshops commented that the training course was relevant and useful to them. An effective network of training centres has been established to provide on-going training and support. It is confidently anticipated that this will provide a sustainable base for the technology and a means for on-going dissemination.

Follow-up of trained workshops: about half of the trained workshops are so far implementing the technology. Reasons for non take-up of the training range over lack of demand for ox-carts, concentration on other products and continued access to scrap-axles (mainly around Harare). Workshops initially reported some resistance from rural communities to carts incorporating the new wheel technology, but this now appears to be breaking down, particular for the more capable workshops producing good quality carts, some with guarantee, which report a growing demand for their carts. The main advantages of the technology to the workshops are that it overcomes the constraint on production of carts imposed by the limited supply of scrap axles and enables workshops to produce carts of better quality and reliability than those with scrap-axles. This gives them a competitive advantage. The benefit to rural communities is an increase in supply of better quality and more reliable carts. Although the selling price of these carts is in the medium bracket it is considered that they will provide better value and lower overall costs over the life of the carts. A few workshops have taken up parts of the training to make hubs or rims for scrap axles which is increasing the supply of lower-cost carts.

Co-ordination of inputs for trained workshops: The main input problem for trained workshops has been the supply of wheel bearings. Rolling element (ball or roller) bearings are widely preferred for cart wheels but these are generally expensive. Scrap bearings may be used but these tend to be unreliable and if used in any quantity soon become scarce and more costly. The project has been able to identify and establish a supply of low-cost ball bearings from China which should overcome this problem.

Because of their small requirements and limited cash flow, smaller workshops generally face considerable disadvantages in gaining access to materials and in being able to purchase them at competitive rates. Since material costs usually constitute 70 to 80% of selling price this is a major constraint on being able to produce goods at a lower cost. An example is the cost of the wheelbarrow developed in the project, in which the cost of materials is only slightly less than the price at which an industrially produced wheelbarrow can be purchased from a hardware shop.

Development and testing programme: Facilities and skills have been developed at IAE for testing and evaluating designs of cart components and other transport devices to ensure that they are adequately robust and reliable for their intended use. Field tests have been carried out to measure the impact loads applied to the wheels for different types of tyres on earth tracks. This information has been used to develop an improved design of cart wheel which is now being produced by trained workshops.

A need identified in the project is for a puncture-resistant tyre for ox-carts which has some of the cushioning properties of a pneumatic tyre. Discussions with trained workshops and cart users indicate substantial interest in and potential for a tyre of this type. Considerable progress has already been made in developing a tyre in collaboration with local rubber companies and this work will continue at IAE with support from I.T. Zimbabwe and I.T. Transport.

Development of low-cost transport devices: This activity has concentrated mainly on developing lower-cost devices which may be more appropriate for particular target groups of the project, women and poorer households. Devices developed are a wheelbarrow, waterbarrow and handcart. The latter has also been adapted as a light donkey cart. A number of wheelbarrows and waterbarrows have already been produced and sold by trained workshops. Dissemination of the waterbarrow and handcart/donkey cart is continuing in collaboration with organisations working with the target groups as part of Phase 3 of the project.

Institution building at IAE: Training and support for the wheel manufacturing technology have been fully integrated into the activities of the Rural Technology Training Centre at IAE. The staff are very capable of and committed to continuing the activities needed to support and disseminate the technology.

Socio-economic monitoring and evaluation: Surveys carried out in Phase 1 of the project indicated the benefits of ownership of ox-carts and this has been confirmed by the willingness of rural households to invest relatively large sums in the purchase of carts produced in the programme. Surveys of trained workshops in Phase 2 have shown that the project has removed the main constraint on their production of carts and has increased their supply of carts. However, it was not clear that the project was benefiting specific target groups and it was decided to concentrate socio-economic inputs on activities to improve the impact of the project on these groups. This work, which is continuing in Phase 3, is mainly aimed at developing a more effective dissemination strategy, particular for lower-cost transport devices which are considered to be appropriate for women and poorer households.

A survey of owners of broken down carts confirmed that there is a strong demand for the repair of carts and that one of the main constraints on repair work is the very limited availability of wheel and axle components. The project can therefore have a substantial impact on the rehabilitation of broken down carts which is a relatively low-cost option for getting more carts into use. So far, over 100 axles have been sold by trained workshops, but it is considered that there is opportunity for increased impact of the project in this area.

1. INTRODUCTION

The key feature of this project is a national programme of training and dissemination to introduce a wheel manufacturing technology developed by ITDG into small workshops to help them overcome a bottleneck in the production of animal-drawn carts (ox-carts). The anticipated output is that these workshops will be able to increase the supply of carts to rural communities and also to diversify their activities into production of other low-cost vehicles such as wheelbarrows and handcarts. The overall objective of the project is to improve the access of rural households to these low-cost means of transport, thereby providing significant benefits to small-scale farmers, low-income households and particularly women.

The three-year project is being implemented by the Institute of Agricultural Engineering (IAE), Zimbabwe. The Intermediate Technology Development Group (ITDG) is the contractor for the project, providing technical assistance to and supervision of the project. ITDG will also carry out socio-economic monitoring and evaluation of the project.

This report covers activities carried out in Phase 2 of the project which has run for two years from June 1992 to June 1994. Two progress reports have been prepared during this period:

Progress Report No. 1 -	September 1993, covering period June 1992 to June 1993
Progress Report No. 2 -	December 1993, covering period July 1993 to November 1993

This final report covers all of Phase 2, but in some cases summarises the outcome of activities which have already been described in detail in the progress reports.

The main activities carried out in Phase 2 have been:

- organisation of supply of production tools;
- a national training programme for workshops covering the use of the wheel manufacturing technology;
- follow-up monitoring of trained workshops to determine the extent of implementation of training, problems experienced and outputs resulting from the training programme;
- co-ordinating inputs to workshops where problems have arisen with the supply of materials or components needed to implement the technology;
- development and testing of wheel and axle components;
- development of low-cost transport devices to suit the needs of specific target groups and to extend the range of outputs of the project;
- socio-economic activities covering monitoring of users of devices produced in the project and a dissemination programme to maximise the impact of the project.

2. MANUFACTURE OF PRODUCTION TOOLS

Workshops require two production tools to implement the wheel manufacturing technology introduced by the project:

- a hand-operating bending machine for producing the wheel rims;
- an assembly jig for setting up the parts of the wheel for welding to ensure accurate and consistent construction.

Basic metalworking tools are also needed, such as a welding set, drill for hole sizes up to 11mm diameter, tools for cutting steel sections (hand tools are adequate but a power-saw saves time and effort) and a hand-grinder (preferably an angle-grinder).

The adaptation of the production tools to suit manufacturing facilities in Zimbabwe is described in the Phase I Report, Appendix 3.3. Drawings of the equipment and the list of materials needed are reproduced in Annex 1. Steel prices have increased by almost 50% since April 1992 (the reference date for the material costs) so that the estimated material costs of the production tools are now Z$270 for the rim-bender and Z$225 for the assembly jig.

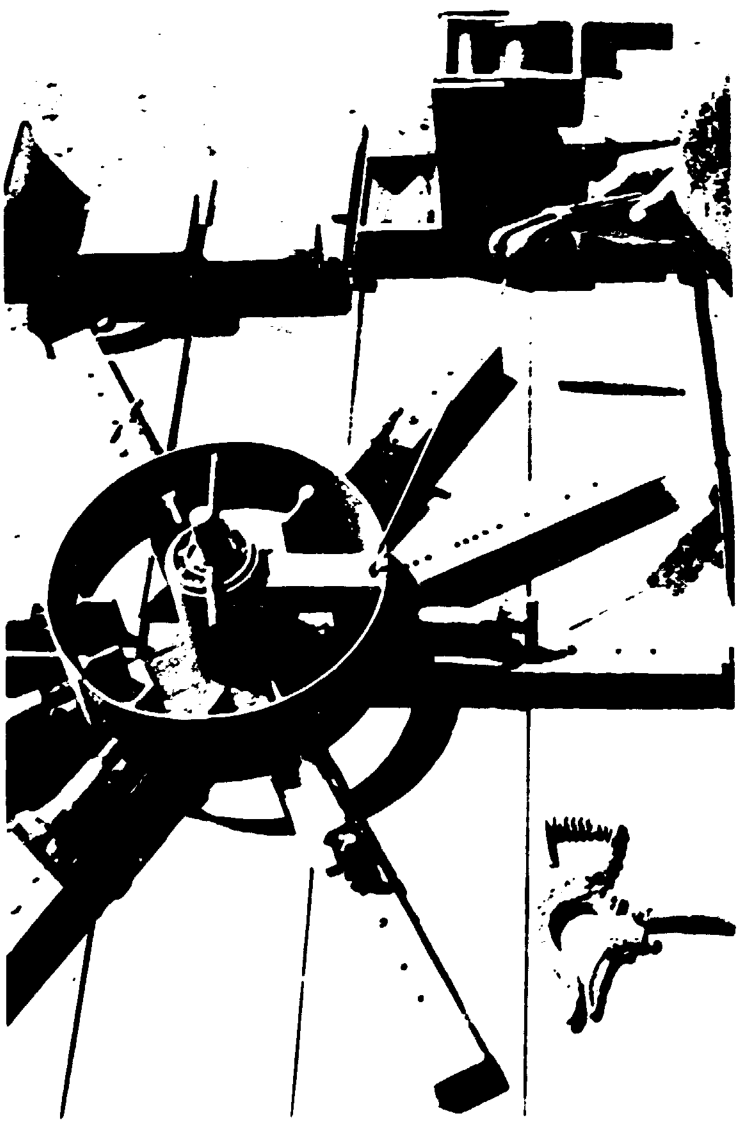
Figure 2.1 shows the production tools in use. Although the rim-bending machine can be readily used by one person, it is easier for two people to use it, one guiding the section being bent and the other operating the machine. The equipment is simple to operate and monitoring of trained workshops has not shown up any problems in the use of the production tools.

Sixty (60) sets of equipment have so far been produced for the project. Fifty (50) have been supplied to trained workshops, three have been donated to Hlekweni Technical Training Centre, three are in use at IAE and four spare sets are held at IAE.

The first ten sets were produced in the IAE workshop and a further six were manufactured by the Driefontein Mission Training Workshop. All other sets have been manufactured by commercial producers as it was felt that this would be the most sustainable and accessible form of supply in the long-term.

Contracting out the manufacture of equipment to commercial producers has involved considerable effort in identifying suitable workshops and in policing quality control. The main problem has been to achieve a consistent level of quality of manufacture. This appears to be a problem of the attitudes of workshops rather than capabilities. For instance, two workshops which initially supplied good quality sets of tools, subsequently supplied poor quality tools in follow-up orders. it seems that these workshops were attempting to increase profit margins by cutting production costs, for example by using trainee technicians. This appears to be a fairly common problem, and quotations of production costs which seem low need to be treated with suspicion. The third workshop tried has maintained a consistent level of quality and is the supplier of production tools currently recommenoed by IAE.

A set of tools purchased from the current supplier costs Z$1,600 (about US$200). The estimated material costs are around Z$500 and costs of labour and consumable materials Z$250 to 300 so that the mark-up to cover overheads and profit margin is about 100%. The cost of materials and consumables is quite high for smaller workshops and might necessitate a deposit with placement of an order to cover the purchase of these items. It



(Above)
Bender being used to form the rim for an ox-cart wheel.

(Left)
Rim and hub mounted in assembly jig and spokes being welded into position.

Figure 2.1: **PRODUCTION TOOLS IN USE**

was, therefore, considered better to organise production of tools by medium-sized workshops which have an adequate cash flow to be able to stock sets of equipment for demonstration to potential customers and to be able to readily produce additional sets to order. These workshops are also likely to be more market orientated with a better approach to promotion and customer satisfaction. However, this needs to be balanced against the higher overheads and therefore higher prices charged by larger workshops.

It is known that at least two of the workshops contracted to supply production tools for the project are attempting to market them independently. One is advertising in a national newspaper and the current supplier has demonstrated the tools at agricultural field days. This is a promising development in terms of broadening the dissemination of the technology but at the same time causes some concern regarding the quality of wheels and axles produced by workshops which have not been properly trained and the effect that this might have on the marketing of the technology by workshops trained in the project. However, it is felt with some confidence, that this will be offset by the good reputation being developed by some of the better workshops trained in the project and the guarantees they are providing on the quality of the devices they are producing. The possibility of licensing the spread of the technology does not seem very feasible.

3. TRAINING PROGRAMME

The main aim of the programme was to train workshops in the use of the wheel manufacturing equipment to produce wheels and axles for ox-carts. In order to increase the utility of the equipment the courses also covered the construction of other types of wheels and one or two simple vehicles to which the wheels could be fitted.

3.1 Details of Training Programme

Each course ran for ten days and generally covered the construction of the following items:

- a wheel and axle assembly for an ox-cart;
- a strengthened bicycle-type wheel to take a standard bicycle tyre. This wheel is suitable for use on cycle trailers and light handcarts;
- a wheel with solid-rubber tyre for use on heavy-duty handcarts;
- a wheelbarrow wheel with solid-rubber tyre;
- a wheelbarrow and a handcart.

Trainees were encouraged to put forward their own ideas on devices they would like to construct during the course and, after completing the wheel and axle for an ox-cart some flexibility was allowed in modifying the content to match the wishes of the trainees.

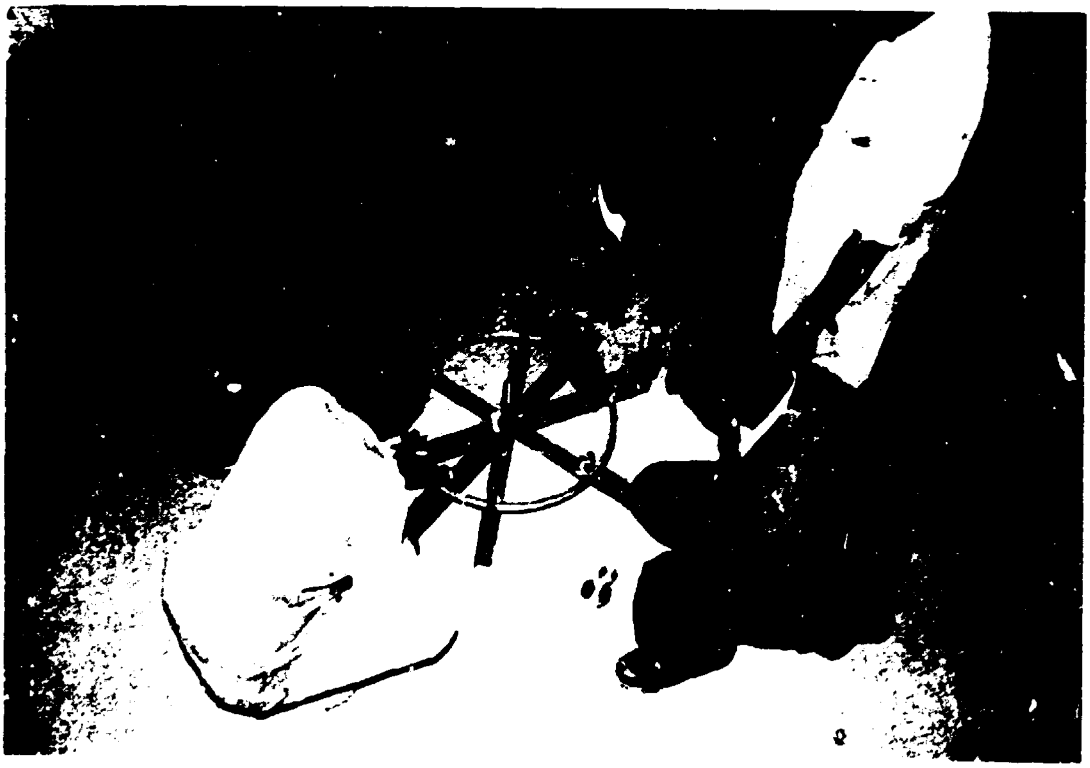
A typical programme for a training course is included in Annex 2. Illustration of typical activities are shown in Figure 3.1.

Eight training courses have been held in six different regions of Zimbabwe. As far as possible venues were chosen as the towns where workshops in the region would generally travel to obtain their materials. Prior to each course, a survey was made of workshops in the region to demonstrate the wheel-making equipment and to identify workshops which were both interested in and could benefit from attending a training course. The main criteria used to select workshops for a course were:

- the workshop was already involved in the production of ox-carts and was experiencing problems with the supply of wheels and axles;
- the workshop had access to the materials, tools and skills needed to make use of the course.

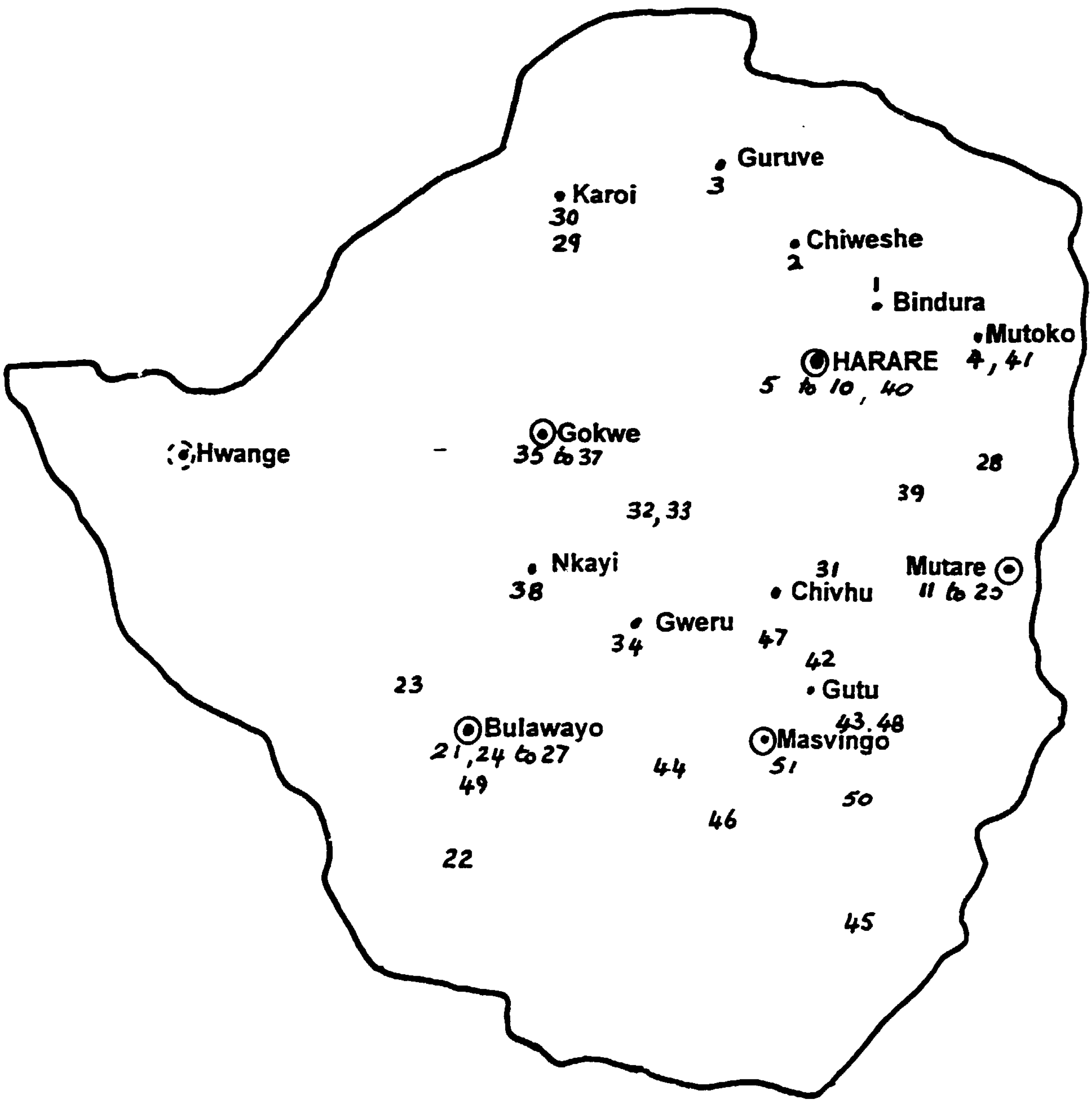
Details of the training courses and the number of participants are listed in Table 3.1. A complete list of the workshops trained is included in Annex 3 and their distribution over the country is shown in the map of Figure 3.2. The map shows that the training programme has effectively covered the country apart from the North-West region. This region is sparsely populated and there are few workshops. A survey has been carried out around Hwange at which four workshops were identified that could benefit from training. IAE are intending to carry out a training course in Hwange in January 1995.

Bending a rim from angle-section



Setting the rim up in the assembly jig

Figure 3.1: TRAINING COURSE ACTIVITIES



o locations of training courses

Numbers refer to list of trained workshops in Annex 3.

Figure 3.2: MAP SHOWING LOCATIONS OF TRAINING COURSES AND TRAINED WORKSHOPS

Table 3.1: DETAILS OF TRAINING COURSES

Course No.	Date	Venue	Number of Workshops Trained
1	July 1992	IAE Harare	5
2	November 1992	IAE Harare	5
3	January 1993	Mutare	10
4	February 1993	Bulawayo	7
5	May 1993	IAE Harare	4
6	September 1993	Gokwe	7
7	November 1993	IAE Harare	3 new and 4 retrained
8	March 1994	Masvingo	9
			TOTAL 50

The training programme has included a number of technical training centres as follows:

- Driefontein Mission Training School - Gutu, Midlands — trained prior to programme and retrained during programme
- Silvera House - Harare
- Chinhoyi Rural Trade School - Chinhoyi
- Hlekweni Training Centre - Bulawayo
- Masvingo Technical College - Masvingo

Driefontein Mission, Silvera House and Chinhoyi Rural Trade School are already including wheel-making in their courses, whilst Hlekweni Training Centre and Masvingo Technical College are planning to introduce courses in 1995. It is known that in addition to the fifty workshops trained in the IAE programme at least another ten have so far been trained by either Driefontein Mission or Silvera House.

A good network of training centres has therefore been established to provide ongoing training of new workshops and support to those already trained. IAE will also continue to provide training and support as required. Contact with workshops will be maintained through the Agritex extension network and also through the monitoring activities of the IAE Rural Technology Training Centre in connection with this project and their blacksmith training programme.

3.2 Effectiveness of Training

The training was very much "hands-on" so that the trainees learnt effectively by making wheels and other devices for themselves. A training manual (see Annex 4) was also provided so that trainees would have a reference source to look up if they ran into difficulties when implementing the technology in their own workshops. All trainees were able to cope quite adequately with the course and there was general agreement that the course was very relevant and useful. Follow-up monitoring showed that trainees had few difficulties in using the technology in their own workshops and where workshops have not taken up the technology it has generally been due to reasons related to their activities and attitudes, rather than any difficulties with the technology.

3.3 Conclusions

- the project has achieved its aim of training 40 to 50 workshops in the use of the wheel-making technology. The training has covered rural areas throughout most of the country. The one major area not yet covered has a fairly low level of activity in cart-making, but will be covered by a course in January 1995;

- the training has been effective. Trainees have had few problems in taking up the technology in their own workshops and there have been no reports of workshops not adopting the technology because of difficulties in using it. Almost all trainees commented that the training course was relevant and useful to them;

- an effective network of training centres has been established to provide on-going training and support. It may confidently be anticipated that this will provide a sustainable base for the technology and a means for on-going dissemination.

4. FOLLOW-UP TO TRAINING PROGRAMME

4.1 Implementation of the Technology

Regular follow-up visits have been made to trained workshops at roughly four-monthly intervals. These have shown that approximately half of the trained workshops are actually using the technology. Various reasons were put forward, or surmised, why the other half had not taken up the technology. For instance:

- the low demand for ox-carts resulting mainly from the depressed state of the economy. Many small farmers have not fully recovered from the effects of the severe drought in 1991/92 and do not have the cash needed to purchase a cart - they also have limited access to credit. The other main source of funds used to purchase carts, returned funds from migrant workers, appears to have been cut by effects of the structural adjustment programme;

- some workshops are continuing to use up stocks of scrap axles that they have accumulated over a number of years. It is likely that some of these workshops will adopt the technology as these stocks run out;

- some workshops, particularly those near to the larger urban centres such as Harare, are still able to find scrap axles for their carts. Fitting a scrap axle to a cart involves less time and effort than manufacturing an axle assembly, but the quality and reliability of the cart may not be as good. The wheel-making technology therefore tends to be more beneficial to rural workshops since scrap axles are usually much more difficult to find in these areas and consequently also more costly;

- although no workshops mentioned difficulties in using the technology, it seems likely that some did not have the commitment to or capability of manufacturing items such as wheel/axle assemblies which for small, informal workshops, particularly those with no training in metalwork, are relatively complex.

The workshops that are using the technology are producing wheel/axle assemblies of varying quality. Again this appears to be a matter of attitude and capability rather than of any difficulty with using the technology. Some workshops are cutting corners and sacrificing quality to increase profit margins and/or reduce costs. This tends to be more common around Harare where there is greater competition from low-cost carts with scrap axles produced by the informal sector. Other workshops appear to have little business sense and understanding of the need for quality control and customer satisfaction.

Approximately a quarter of the trained workshops are producing good quality work and it is mainly these that will be responsible for developing the reputation of and demand for good quality carts with wheel/axle assemblies produced with the technology. Short profiles of two typical workshops are presented in Figures 4.1 and 4.2.

Establishing acceptability of the carts and building up demand is a gradual process which will accelerate as more carts are put into the field and people become more aware of their quality and reliability. It appears that this process is beginning to gain some momentum. Workshops initially reported customer resistance to carts incorporating an unfamiliar technology but more recently some workshops have received orders and enquiries from up to 100km away for these specific types of carts.

There has been some concern that the poor quality carts produced by some trained workshops might have a negative effect on the reputation and dissemination of the technology. To combat this, a number of the better workshops are offering a one year guarantee for their carts. This also appears to be breaking down customer resistance and increasing demand for the carts.

4.2 Details of Production by Trained Workshops

The numbers of devices produced by trained workshops up to February 1994 incorporating technology acquired through the training programme is as follows:

- 328 ox-carts;
- 112 wheel/axle assemblies for ox-carts;
- 67 wheelbarrows and water barrows;
- 15 handcarts.

In addition, a few workshops are using only parts of the technology. For example, one workshop is using the bending device to make wheel rims which are attached to scrap hubs, whilst another is fabricating hubs for fitting to scrap rims. The training programme is therefore having flow-on benefits to help workshops overcome specific constraints on axle manufacture, and in this way is contributing to an increase in the supply of carts at the lower end of the price range. For instance, the workshop fabricating hubs for scrap rims is selling carts at around Z$1,400.

The main buying period for farmers is from August to October when they receive payments from the grain marketing board. The production figures will therefore cover mainly the 1992 and 1993 seasons. The market was very depressed in 1992 because of the drought while 1993 showed a partial recovery. It is therefore considered that the production figures to date are quite promising considering the newness of the technology and the depressed state of the market. The project impact assessment in early 1995 will include the 1994 sales season which is expected to have been slightly better than 1993 and therefore should show a significant increase on the above production figures. However, poorer communities are suffering significant economic hardships as a result of the structural adjustment programme and this will restrict the demand for items such as ox-carts.

4.3 Details of Products

The major item covered in the training programme and produced by trained workshops is a wheel/axle assembly for ox-carts. An axle-assembly and a cart fitted with one of these axles are shown in Figure 4.3. Details of the designs and the materials needed are presented in Annex 5.

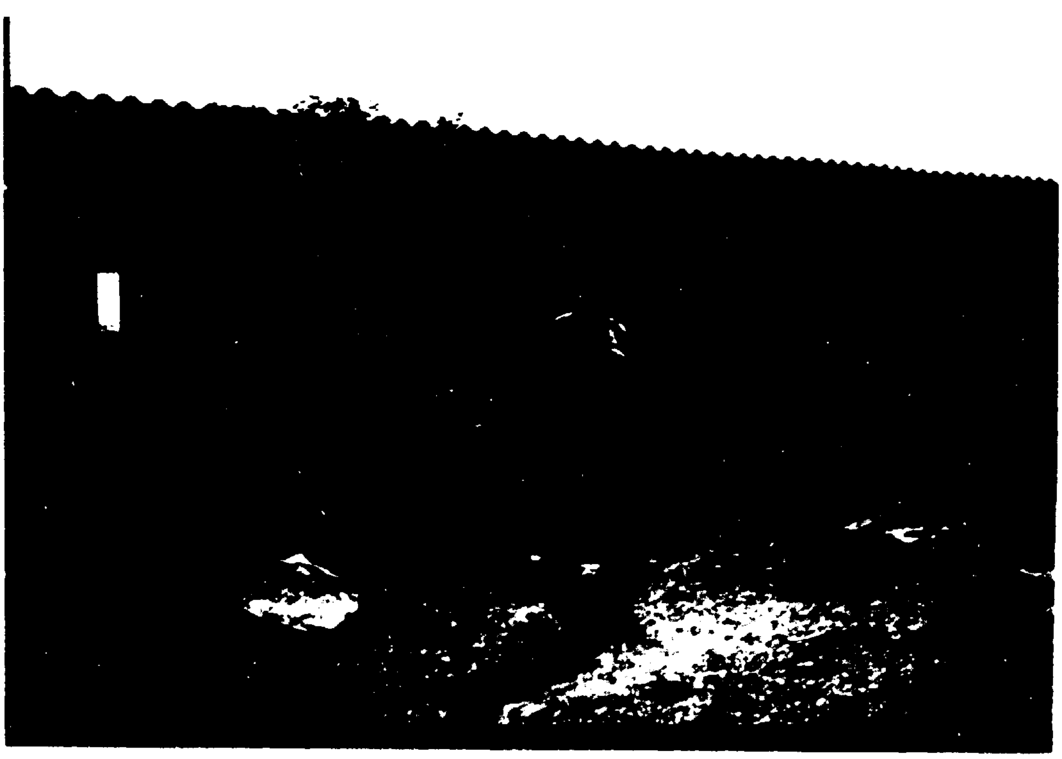
The cost breakdown for an axle-assembly is shown in Table 4.1 and for a complete cart in Table 4.2. It can be seen that the cost of the axle assembly has a large influence on the cost of the cart, making up roughly 50% of the total cost. The other main cost item is the sheet steel used for the body of the cart.

The main cost items for the axle assembly are tyres and tubes. New agricultural tyres are cheaper than motor-vehicle tyres but are still relatively costly. Scrap tyres are much cheaper but they are very variable in quality and, because treads are often badly worn, are very prone to puncturing. There is therefore considerable potential for and user interest in a low-cost, puncture resistant tyre (see development programme in Section 6).

Figure 4.1: PROFILE OF A TRAINED WORKSHOP

Workshop:	Sams' Welders, Bindura
Owner:	Samual Muuduri
Facilities:	Backyard workshop with small store and office building. Facilities shared with vehicle repair workshop
Tools and Equipment:	Basic metalworking tools, including welding equipment - no machine tools
Employees:	Help from vehicle repair technician but otherwise mainly family members on a casual basis
When Trained:	July 1992, IAE, Harare
Production of Carts:	49 sold to date
Type of Cart:	Good quality cart with steel sheet welded onto a support frame. Wheels fitted with scrap tyres - not always possible to match tyres
Selling Price:	Z$2,800 - includes delivery and 1 year guarantee
Other Products:	Mainly cart and axle production
Comments of Owner:	Almost went out of business because of difficulties of finding scrap axles. With introduction of wheel manufacturing technology the business is flourishing to extent that a business loan has been taken out to build new workshop premises. Increased sales of carts has also funded purchase of pick-up vehicle which is very important in collecting materials and delivering carts to buyers. Only advertising has been display of carts at agricultural field days - main sales are through word of mouth, once one cart is sold in a village, four or five others may follow. Main problems are availability and cost of materials and high cost of loan to set up new premises.

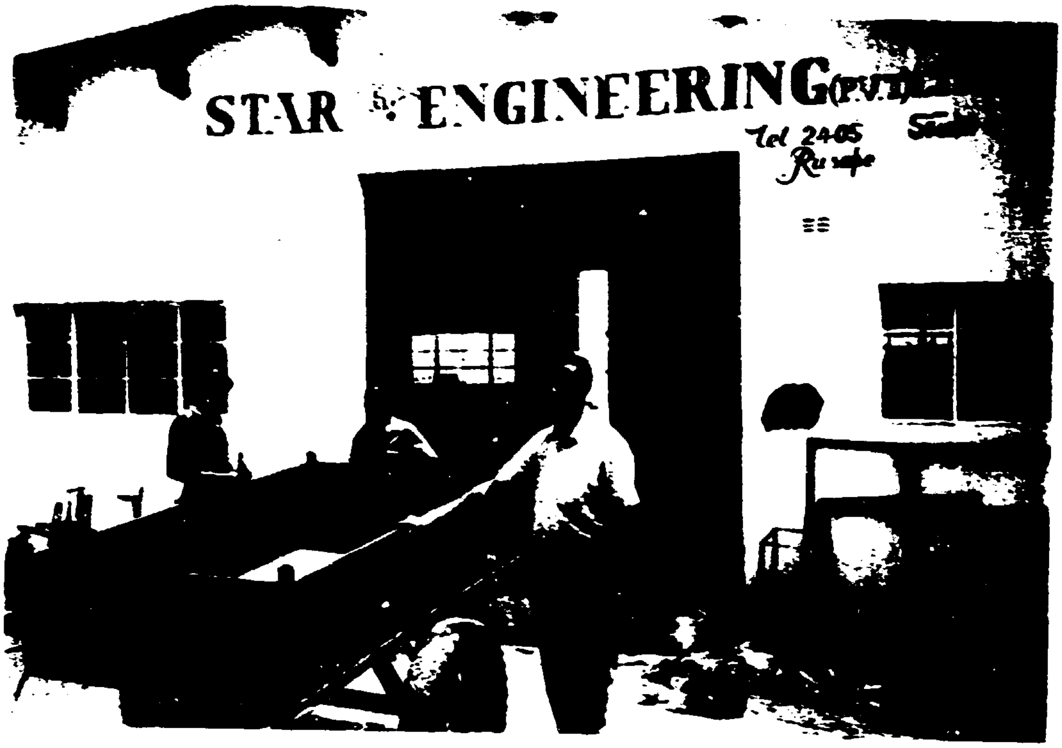
Existing Workshop of Sam's Welders



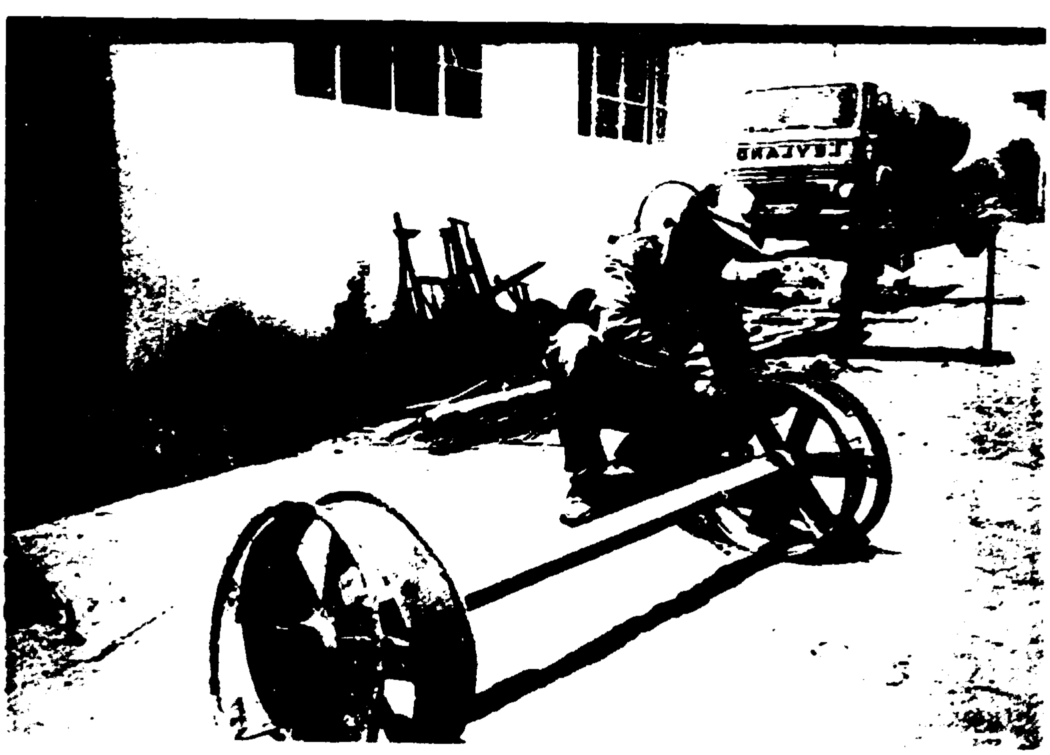
Samual Muuduri in front of his new workshop premises

Figure 4.2: PROFILE OF A TRAINED WORKSHOP

Workshop:	Star Engineering, Rusappe
Owner:	Mr. Pswari
Facilities:	Relatively large concrete workshop and yard with small separate office
Tools and Equipment:	Basic metal-working tools, including welding equipment - no machine tools
Employees:	Skilled foreman, 3 self-trained craftsmen, 2 semi-skilled handymen and 2 general hands
When Trained:	November 1993 at IAE, Harare
Production of Carts:	12 made and sold
Type of Cart:	Good quality cart with sheet metal body welded onto a support frame; wheels fitted with new agricultural tyres and tubes
Selling Price:	Z$3,000 - includes delivery and 1 year guarantee
Other Products:	Steel structures and frames, mainly for buildings
Comments of Owner:	Training course was impetus to-go into cart production, giving the opportunity to produce good quality carts. Intends to make cart production main activity, possibly accounting for 75% of business. Cart put on display in local garage has attracted enquiries from up to 100km away. Feels there is good demand for better quality carts. Main problems are variable availability of materials, continual increase in steel prices and high interest costs on loan to purchase premises.

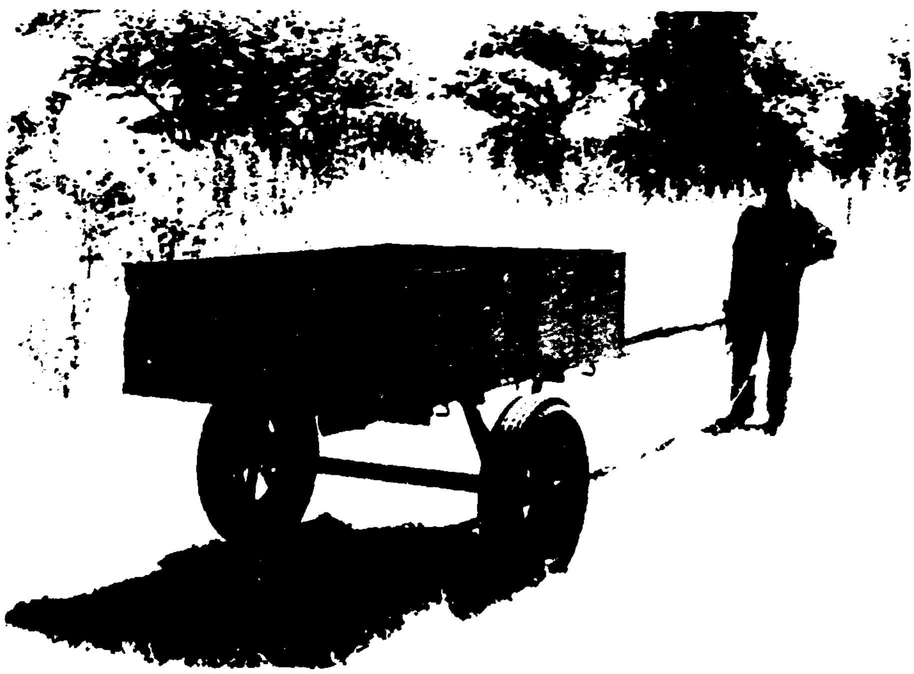


Mr. Pswari with an ox-cart manufactured in his workshop



Axle produced by Star Engineering

Ox-cart axle with detachable-bead wheels and agricultural type tyres



Ox-cart of typical design produced by trained workshops

Figure 4.3: MAIN ITEM COVERED IN TRAINING PROGRAMME
A WHEEL/AXLE ASSEMBLY FOR AN OX-CART

Table 4.1: COST BREAKDOWN FOR A WHEEL/AXLE ASSEMBLY

Item	Material Specification	Quantity Required	Unit Cost (Z$)	Total Cost (Z$)
Wheel:				
Rim	100 x 6 flat bar	1.23m	28.00/m	34.44
Beads	16mm round bar	3.2m	7.80/m	24.96
Clamps	50 x 5 flat bar	0.3m	9.90/m	2.97
Nuts and Bolts	M12	6	3.20	19.20
Spokes	50 x 50 x 4 angle	0.9m	19.25/m	17.33
				98.90
Hub:				
Outer Hub	3" pipe	110mm	105.40/m	11.60
Inner Spacer	2.5" pipe	70mm	88/m	6.16
Bearing Spacer	1.5" pipe	72mm	52.30/m	3.77
Bearings	62082RS	2	25.00	50.00
				71.53
Stub Axle:				
Axle	40 dia bright mild steel round	200mm	91.00/m	18.20
End Stud and Washer	M24 stud and nut 3mm thick washer	1	14.00	14.00
Total Wheel and Stub Axle				202.63
2 Wheels and Stub Axles			202.63	405.26
Axle Beam	50 x 50 x 5 angle	2 pieces x 1.5m	24.10/m	72.30
Total Wheel/Axle Assembly				477.56
Add 10% for paint and consumable items				47.80
				525.36
Tyres:	New agricultural (ADV tyres)	2	275.00	550.00
	Scrap 16" tyres	2	100.00	200.00
Tubes:	New 16"	2	70.00	140.00

Summary:

- cost of wheel/axle assembly (without tyres) Z$525
- cost of axle assembly with new ADV tyres Z$1,215
- cost of axle assembly with scrap tyres Z$865
- labour cost - approximately 3 man days at a total cost of Z$60

Table 4.2: BREAKDOWN OF COST FOR AN OX-CART

Item	Material Specification	Quantity Required	Unit Cost (Z$)	Total Cost (Z$)
Base Frame and Corner Posts	40 x 40 x 5 angle	15m	15.4/m	231.00
Upper Frame	30 x 30 x 4 angle 25 x 4 flat bar	6m 0.8m	9.64 3.65	57.84 2.92
Body (floor and sides)	1.6mm thick sheet steel	2 sheets 2.44m x 1.22m	310	620.00
Drawpole	120mm diameter wooden pole	4m	-	25.00
Stays for Pole	25 x 5 flat bar	1.8m	4.55	8.20
Total Cart Frame and Body				945.00
10% for paint and consumables				95.00 Z$1,040.00
Wheel axle assembly with new ADV tyres				1,215.00
Wheel axle assembly with scrap tyres				865.00

Summary:

- cost of cart with new ADV tyres Z$2,255
- cost of cart with scrap tyres Z$1,905
- labour cost - approximately 6 to 8 man-days at a total cost of Z$120 to 160

Bearings are another costly item. The cost quoted in Table 4.1 is for new ball bearings imported from China. Scrap bearings can be obtained at lower cost but they are variable in quality and availability. Any significant use of scrap bearings tends to quickly restrict supply and increase prices.

The cost of materials to make up the wheel/axle assembly is about 20 to 25% of the total cost. There is little scope for reducing cost without compromising strength and quality.

It is difficult to make a comparison between the cost of an axle assembly made with the wheel technology and other options, particularly scrap-axles which have been the type used on most of the lower-cost carts. Around Harare, scrap-axles are still available at reasonably low cost, but in other regions they are very difficult to find and their purchase cost may be roughly the same as the manufactured axle assemblies. There may also be significant extra costs involved in the time and travel needed to locate scrap-axles and to transport them back to the workshop. The use of scrap-axles may be acceptable to the small workshop or artisan that is only making a few carts per year but for the small to medium size workshop that is running a small business in cart-making the supply of scrap-axles is too irregular and unreliable. The advantages of the wheel technology to these workshops are:

- it removes the main constraint on production of ox-carts enabling the workshops to produce carts on a regular and reliable basis;
- the manufactured axle-assemblies with new bearings are of a better quality and generally more reliable than scrap-axles. Scrap-axles often have badly worn bearings which may fail after a fairly short period in service. It is usually very difficult to find replacement bearings and carts may be out of service for lengthy periods. Surveys of cart-owners (see phase 1 report) have shown that up to 20% of carts may be out of operation due to bearing failures;
- the wheel technology therefore gives workshops the opportunity to use their skills to produce better quality and more reliable carts and so create a demand for their carts.

The approximate range of selling price of different types of carts is as follows:

• carts supplied by larger, centralised producers		Z$3.500
• carts produced by trained workshops	- new tyres	Z$2,500 to 3,000
	- scrap tyres	Z$2,300 to 2,800
• carts with scrap axles		Z$1,500 to 2,500

The lower cost carts are usually of poor quality, shoddily made, using scrap materials and are mainly available only around Harare. The prices listed for carts produced by trained workshops are for carts with a new sheet steel body. Prices could be reduced by Z$300 to 400 by using scrap sheet or a wooden plank body. Both these are acceptable options if properly made, particularly a wooden body mounted on a steel frame, and are the main possibility for producing a reliable, lower-cost cart.

In terms of initial selling price, the carts produced by trained workshops are in the mid-range bracket. However, it is considered that the most important criteria are the total-life cost which includes repair costs, and value for money. If a low-cost cart breaks down after one or two years and then is out of use for a lengthy period it is of little value to the owner. Since carts represent a large investment for their owners, they must be reliable to produce the economic

benefit which the owners expect to receive from the investment. It is considered that a major impact of the programme will be to increase the supply of carts of low total-life cost (initial cost plus running costs) and of good value to their owners.
Other products being produced by the workshops as a result of the training programme are described in Section 7 covering the development programme.

4.4 Problems Faced by Workshops

The main complaints of almost all workshops were:

- poor cash flow which creates problems in purchasing the materials needed for production. Managing cash flow requires a reasonable degree of good business sense. Small workshops can sometimes offer more flexible terms to their customers and may accept bags of maize or other produce as part payment to allow farmers to acquire a cart;

- high interest rates for business loans, 25 to 30%, place a major constraint on workshop development, for instance improving facilities or buying a piece of equipment to increase production;

- the cost of materials is high for small workshops since they are unable to buy in sufficient bulk to obtain better access to materials at lower cost. They are unable to hold sufficient stocks to counter variations in the availability of materials;

- the dependence of business on agricultural production and therefore the climate. Most small workshops involved in cart production have secondary product lines such as door and window frames but nevertheless were badly hit by the 1992 drought.

Workshop owners with good business acumen tend to cope better with these problems and many small to medium size workshops could benefit from business training. Courses in business training for small-scale enterprises have therefore been started recently at IAE. The first course for workshops involved in cart production was held in September 1994.

4.5 Selection of Workshops

An objective of the project was to train 40 to 50 workshops in the use of the wheel-making technology, with 6 to 8 workshops attending each course. The main selection criteria were that workshops should have the resources needed to use the technology, were already involved with cart manufacture and were facing problems with poor access to axle assemblies. An attempt was also made to assess the likelihood of the workshop using the technology (based on capability, quality of work, business sense etc.) but in order to meet the training quota a number of marginal selections were made. There was therefore some wastage in the training programme. Workshops were provided with production tools at 25% of cost, and time and transport expenses were used up in follow-up visits to workshops that did not take up the technology.

There was a learning curve in the process of selecting workshops. After the first few surveys and training courses it became possible to assess fairly accurately which workshops were likely to benefit from the training and it would have been possible to have eliminated some of the marginal selections. Some wastage is inevitable, but with more stringent selection it would probably have been possible to select 30 to 35 workshops with an 80% chance of them taking up the technology. It is suggested that the primary objective should be to maximise the impact of the technology and this could be more effectively achieved by concentrating effort on a smaller number of more capable and committed workshops - for instance more time could then be spent on follow-up training on issues such as quality control.

Although only about half of the trained workshops have taken up the wheel technology to date, it seems likely that others will take it up as rural communities become more aware of the benefits of the manufactured axle assemblies and demand for carts with these axles increases. This will probably create a need for follow-up training by IAE. both in terms of refresher courses and in improving capability and quality of manufacture.

5. CO-ORDINATION OF INPUTS FOR TRAINED WORKSHOPS

5.1 Constraints on Cart Production

One of the major disadvantages faced by small enterprises compared to large-scale producers is the inability to order materials and components in large enough quantities to justify discount prices or to be able to import goods when local supplies are limited. The two main problems of materials supply for workshops trained in the programme are for sheet steel for the cart body and wheel bearings. The project looked at ways of overcoming both of these constraints.

Sheet steel is not produced in Zimbabwe and therefore has to be imported. Until recently supplies have been limited by restrictions on foreign exchange and consequently prices have been high. However, the introduction of the economic structural adjustment programme (ESAP) has made foreign exchange much more readily available and several importers are now importing sheet steel, mainly from South Africa. Competition has increased the availability of sheet steel and reduced prices. It was therefore not necessary for the project to become involved in co-ordinating supplies of sheet steel for trained workshops.

Rolling element (ball or roller) bearings are widely preferred for cart wheels. These have to be imported and are generally expensive - brand-name bearings (SKF, Timken, Koyo etc.) from industrialised countries cost at least Z$100 each. Since four bearings are needed per cart, this cost is too high for smaller producers. Scrap bearings can be used but these reduce the reliability of the cart and when used in any quantity they soon become scarce and costs increase accordingly. Other types of lower-cost bearings, such as bush bearings, have not performed well on carts because of inadequate lubrication and sealing against ingress of dust and sand. The supply of suitable bearings is always a problem to workshops manufacturing wheels and was one of the main constraints on introducing the wheel-making technology into the trained workshops. In order to remove this constraint, considerable effort was put into locating a low-cost source of rolling element bearings, obtaining a sample batch for assessment and then setting up an arrangement for trained workshops to be able to purchase these bearings.

Although taper-roller bearings are usually used on motor-vehicle wheels, it was decided that because of lower wheel loads, deep-groove ball bearings would be adequate for cart wheels. These bearings are substantially cheaper than the taper-roller type and can be obtained in a sealed and pre-lubricated form which is a significant benefit for carts. They also require less skill to fit.

A low-cost source was located in China and a preliminary batch of 1000 bearings imported at about Z$25 each. A wheel incorporating these bearings was tested on the wheel test rig (see Section 6) and also two cart wheels were field tested. The bearings performed satisfactorily and the remaining batch was sold off to trained workshops during 1993 and 94 at Z$30 each to cover the import and handling costs.

Workshops have pledged to purchase a further 1000 bearings during 1994 and the Zimbabwe State Trading Company has agreed to import 2000 units at their own risk and to sell these in small quantities at a very competitive price of Z$25 each.

5.2 Problems of Availability and Cost of Materials

Although, as described above, the main constraints on cart production by trained workshops appear to have been overcome, variations in the availability of and the relatively high cost of materials continue to be problems for smaller producers. Preferred sizes of steel section have been identified for wheel/axle assemblies and for cart construction, but these are not always readily available. Workshops may have to spend substantial effort in checking on availability of sections with the different steel suppliers and in the last resort may have to use the nearest available size. The latter option can increase the weight and cost of the cart.

The relatively high cost of materials is a particular problem for workshops attempting to produce goods to complete with imported versions. A good example is the local construction of wheelbarrows. Wheelbarrows are widely used in rural areas and were identified as an option to increase the product range of trained workshops using wheels made with the wheel production tools.

A design was developed incorporating a steel frame and fabricated steel tray (see Section 7) and introduced in the training courses.

A breakdown of the construction cost of the wheelbarrow is shown in Table 5.1.

Table 5.1: CONSTRUCTION COST OF A WHEELBARROW

Item	Material	Quantity	Unit Cost (Z$)	Cost (Z$)
Main frame	30x30x4mm angle	3m	9.64/m	28.92
Tray	1.5mm steel sheet	0.4 sheet	270/sheet	108.00
Corners of tray	25x25x4mm angle	2m	7.87/m	15.74
Edge reinforcement of tray and stands	25x4mm flat	3.4m	2.75/m	9.35
Wheel rim and spokes	30x30x4mm angle	2.3m	9.64/m	22.17
Hub	1" steel pipe	0.2m	25.43/m	5.10
Axle	25mm dia BMS (bright mild steel)	0.25m	47.70/m	11.93
Nuts and bolts	-	4	1 each	4.00
Tyre	Rubber section	-	41.50	41.50
		Total material cost		246.71
		Add on 20% for consumable materials		49.34
		TOTAL		Z$296.05

The total cost of all materials is Z$296.

A minimum mark-up of 25% (Z$75) is needed to cover labour, overheads and profit so that the minimum selling price is around Z$370 direct from the workshop and probably Z$475 through a retailer.

Imported wheelbarrows can presently be purchased in hardware shops for about Z$375. These appear attractive and robust, with a tubular frame and pressed-metal tray and are likely to have greater appeal and acceptability than the locally-made versions. It is reported that wheelbarrows imported from China are being sold for under Z$300 but none have so far been located.

Since materials account for about 80% of the cost of the locally made wheelbarrow, and a tubular frame would be significantly more expensive than the 30x30x4mm angle frame used, it is clear that the costs of materials for the imported wheelbarrows are considerably less than the material costs for local small-scale producers. To be competitive, local producers ideally need to sell their wheelbarrows at less than Z$300 and this only appears possible by reducing material costs by around 30% or using scrap sheet for the tray which would reduce the quality and strength of the wheelbarrows. Nevertheless a number of wheelbarrows have been sold by trained workshops, possibly because local production makes them more readily available and reparable in some rural areas.

A more viable proposition appears to be to manufacture replacement wheels for wheelbarrows as these can be produced at a lower cost than versions available in hardware stores. This is to be investigated now that a satisfactory process for producing the tyres has been developed.

6. DEVELOPMENT AND TESTING PROGRAMME

This programme has covered two main areas:

- development and testing of components of wheel/axle assemblies covered in the training courses;
- development and testing of various low-cost transport devices which could be manufactured by small to medium size workshops to meet the needs of rural communities.

This section describes the first area of work, whilst the second area of work is covered in Section 7.

6.1 Loads on Ox-Cart Wheels

Fabricated steel wheels of the type produced in the project are susceptible to fatigue failures at the welded joints. Failures are mainly dependent on three factors:

- impact loads on the wheel from running over bumps, ruts, pot-holes etc.;
- the variation of stress in the wheel at the welded joints as the wheel rotates;
- the quality of the welded joints.

Therefore in order to design the wheels to avoid fatigue failures, information is needed on the first two factors, whilst the need for good quality welds is emphasised in the training courses.

The loads acting on a cart wheel were measured in field tests of a loaded cart pulled over an earth track. The tests are described in Annex 6. The results obtained are very useful for checking the strength of wheel and axle designs to make sure that they will be strong enough for their intended use. They have been used to check the strength of designs developed in the project.

6.2 Development of an Ox-Cart Wheel

At the initiation of the project, the wheel design to be made for ox-carts was of a split-rim type which had been used for a number of years on carts produced by the Driefontein Mission Workshop and a few other workshops trained by the Mission. In this design the rim is made in two parts which are bolted together to hold the tyre in place. The tyre is clamped by beads made from 16mm diameter round bar which are welded around the outer edge of each part of the rim.

This design requires the bending of two rims and there can be some risk of nipping the inner-tube when the two parts of the rim are bolted together. It was therefore decided to re-design the wheel so that the rim was made as one part with one bead bolted rather than welded on in order to hold the tyre in position. A drawing of this wheel is shown in Annex 5 - it requires less time and effort to make and avoids problems of damage to the inner-tube. It is therefore considerably more suitable for manufacture by trained workshops.

The re-design of the wheel considerably changed its structural strength because in the new design the rim was reinforced by only one welded-on bead. The strength of the re-designed wheel was therefore checked by statically testing it in the wheel test-rig using strain gauges to measure and compare the stresses with the allowable design stresses derived in Annex 6. These tests and the modifications needed to the wheel are described in Annex 7.

The tests showed that it was necessary to increase the number of spokes to six in order to provide more support for the rim but at the same time it was possible to use a lighter angle section for the spokes.

6.3 Development of a Hub and Stub-Axle for an Ox-Cart Wheel

The problem of wheel bearings has already been discussed in Section 5.1. An associated problem for smaller workshops is the manufacture of a hub for housing the bearings and an axle on which the bearings run. Ideally these components should be machined on a lathe so that the bearings are a precision fit in the hub and on the axle. However, few of the trained workshops have access to a lathe and therefore an alternative design was needed.

Initial efforts were put into identifying workshops with a lathe that could manufacture hub and axle assemblies to sell to other workshops. However, this did not prove a generally acceptable option because of the relatively high cost of the machined items and the fact that it involved reliance on another workshop. Effort was therefore put into developing a design which did not need machining on a lathe. The design adopted is described in the training course manual (Annex 4) in the section on Axles and Hubs. The hub is made from a length of standard 3" steel pipe which is cut axially to remove a section about 3mm wide and then carefully squeezed up so that the bearings are a tight fit in each end. The seam is then re-welded and a spacer plug-welded inside to locate the bearings. The stub-axle is cut from bright mild steel round bar (shafting) and a stud welded centrally at one end for a retaining nut. Although this design is not recommended practice for mounting bearings, if carefully made it is adequate for low-speed cart wheels and has so far performed satisfactorily in field trials. It is a level of technology which is appropriate for workshops which do not have machining facilities.

6.4 Bearing Development

As discussed in Section 5.1, obtaining suitable wheel bearings was one of the main problems faced by trained workshops during the early stages of the project. In addition to searching for low-cost sources of bearings, another approach to this problem was to investigate bearings that could be locally produced. Two possibilities were investigated:

i) **a fabricated roller bearing** using unhardened rollers. In this, rollers are cut from standard round steel bar (bright mild steel or silver steel are best because of the accuracy and quality of finish) and fitted inside a tube which may be the hub or a sleeve fitted inside the hub of the wheel. As the wheel revolves, the rollers rotate inside the hub and may run directly on the wheel axle or on a sleeve fitted over the axle. The rollers should preferably be separated either by fitting them inside a cage or, less effectively, by placing thin strips of material between them.

   This type of low-technology roller bearing has been used on low-duty applications on farm machinery and is also reported to have been used on animal-drawn cart wheels in India. Unfortunately no information is available on the performance of the bearing in this latter application. A prototype was therefore constructed and tested on the wheel test rig. It was run for the equivalent of 900km at a load of 300kg. It performed satisfactorily but inspection of the axle showed wear grooves and also cracks in the axle surface at each end of the rollers. This problem could probably be partially overcome by chamfering the ends of the rollers and fitting a sleeve over the axle which could be changed when it became excessively worn. However, discussions with workshops during training courses showed little interest in the bearing and because of the progress made in identifying a source of bearings in China it was decided not to continue development of the roller bearing.

ii) a polymer bearing material was found to be locally available and a sample was obtained for testing. The sample was sent to the UK for testing on the bearing test-rig at I.T. Transport. The wear rate of the material was found to be too high even for use on lower-duty application such as handcart wheels.

Commercial rolling element bearings are by far the best option for animal-drawn cart wheels and provided the source of low-cost bearings from China is maintained, trained workshops should have few problems with bearings for ox-cart wheels. However, it may be necessary to organise the supply of a smaller bearing, possibly 25mm bore, for lighter duty applications such as handcarts and light donkey carts.

6.5 Puncture-Resistant Tyres

Puncturing of pneumatic tyres is a major problem for ox-cart users, largely because most cart-wheels are fitted with scrap tyres which have little tread thickness to resist penetration of sharp objects. As far as is known no investigations have been carried out in Zimbabwe of the frequency of puncturing but surveys in Zambia[1] have shown the incidence of punctures in scrap tyres to be 1 per 50 to 80km, compared to 1 per 500 to 800km for new tyres. However, pneumatic tyres are preferred by most cart users because by cushioning bumps and impacts they provide a smoother operation of the cart with less risk of damage.

It is clear from discussions with workshops and cart users that there is considerable potential for a puncture-resistant tyre that retains some of the cushioning effect of pneumatic tyres. However, the cost of this tyre would have to be competitive with existing options, about Z$170 for a scrap tyre and new tube and Z$350 for a new ADV tyre and tube. To be viable, a puncture-resistant tyre would need to sell for less than Z$300, ideally around Z$200 to 250.

A number of options have been investigated in a programme of collaborative work between the project and the home-based workshop of I.T. Transport.

1. **Mechanically reinforced tyre**. This option involves supporting the tyre tread with some form of mechanical stiffener rather than air pressure. A simple method is to clamp the sidewalls of the tyre between rings or discs to prevent them collapsing under load. This form of tyre can support low loads up to about 100kg but tests

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[1] Animal Draught Power Research and Development Project; Magoye Regional Research Station, Zambia

on the wheel test-rig showed considerable chafing between the stiffeners and tyre which quickly wore through the sidewall.

Another option is to fit additional side-wall sections (cut from scrap tyres) inside a tyre. If three sidewall sections can be fitted, the tyre can support loads up to 500kg but fitting of the side-walls is very difficult and requires considerable effort. It is unlikely that this method would be acceptable to a workshop.

In general, puncture-resistant tyres based on this concept are likely to involve too much time and effort in construction to be acceptable to workshops.

2. **Filled tyres**. Tyres filled with urethane foam are used on some earth-moving equipment, but this process is far too costly for cart tyres. A low-cost alternative using sawdust has been tried in Kenya and found partially effective providing the sawdust can be kept dry. However, the method is only practical on a small scale and the time and effort involved would not be acceptable to a workshop involved in cart production.

   The project has attempted to identify alternative low-cost fillers but to date none have been found.

3. **Semi-solid tyres**. Tyre manufacturers have developed a number of prototypes of "run-flat" tyres for light vehicles which can be driven on after puncturing. These types usually have a ribbed interior which will not collapse even if the tyre pressure is lost. Investigations of a similar design for a cart-wheel were reported in the Phase 2 Progress Report Number 2 (December 1993). A prototype section was constructed and tested to prove its performance and discussions were held with Dunlop Zimbabwe with regard to moulding of the tyre. Initial estimates of cost seemed promising and it appeared that there was good potential for the tyre. However, the initial cost of producing the mould was high and discussions on its manufacture did not come to a resolution. Eventually a sudden jump in the price of rubber pushed the cost of the tyre too high and it was decided to investigate other simpler and cheaper options.

A simple tyre sometimes used on carts is made by bolting or riveting a length of tread section, cut from a scrap tyre, around a steel rim. An improved version of this was made by cutting away most of the sidewall section and levering the remaining tyre onto a steel rim. This approach is possible with the wheel making technology since rims can be accurately formed to any diameter so that the tyre can be made a good fit on the rim, although considerable effort is needed to lever it into position. This tyre performed quite well and generated considerable interest when demonstrated at an agricultural field day. It provides little cushioning but it is a substantial improvement over a steel rim/tyre.

It was therefore decided to develop this concept using a thicker rubber section with outer treads to improve cushioning and appearance. A design was developed comprising a new tyre retread section vulcanised onto a rubber ring about 25mm thick. Two prototypes have been made by Tyre Treads Ltd. of Zimbabwe and tested on a cart. Further details of the tyres and the test programme are presented in Annex 8.

The main problem experienced in the tests has been the tendency for the tyres to twist off the rim when the cart is cornering with a reasonably heavy load. Initially the tyres have been held on by rings or beads and it appears that these are inadequate to cope with the stretch of the rubber (since the retread sections have no inner braiding to provide strength and stiffening they are more elastic than a tyre carcase). It seems likely that the tyre will have to be bonded to the rim. Production of a further prototype of this form has been discussed with Tyre Treads and developed and testing will continue at IAE in collaboration with I.T. Transport.

It is considered that a solid or semi-solid rubber tyre of good appearance and reasonable cost will have considerable appeal both in Zimbabwe and other countries in the region. This is confirmed by discussions with workshops and cart users. Since this development will depend upon the use of the wheel-making technology to produce a rim which can be matched to the tyre, if a satisfactory design can be developed it will provide a major boost for trained workshops. Although considerable development is still needed it is considered that this work is well worth continuing.

7. DEVELOPMENT OF LOW-COST TRANSPORT DEVICES

The aim of this part of the project was to develop other transport devices to meet the needs of rural communities and which could be produced by trained workshops to allow them to make wider use of the wheel technology and increase their range of products.

The devices developed are illustrated in Figures 7.1 and 7.2 and briefly described below. Drawings of the devices are included in Annex 10.

Wheelbarrow

The production of wheelbarrows by trained workshops has been described in Section 5.2. Wheelbarrows are usually the most affordable wheeled vehicle to rural communities and are particularly appropriate for poorer households. They can transport two to three times the load that can be carried by headloading and can be used for carrying a wide range of different types of load. Increasing the availability of wheelbarrows in rural areas at a low cost could therefore have a significant impact on the transport needs of poorer households. The project has increased the capacity to produce wheelbarrows in rural areas but it is difficult to reduce costs because of problems of material supplies and costs to smaller workshops. Production of the wheel and tyre are usually the most difficult problems for smaller workshops and now that a satisfactory design has been developed, it is possible that workshops may be able to develop lower-cost designs of barrows, possibly using scrap steel sheet or wooden planks for the body.

Waterbarrow

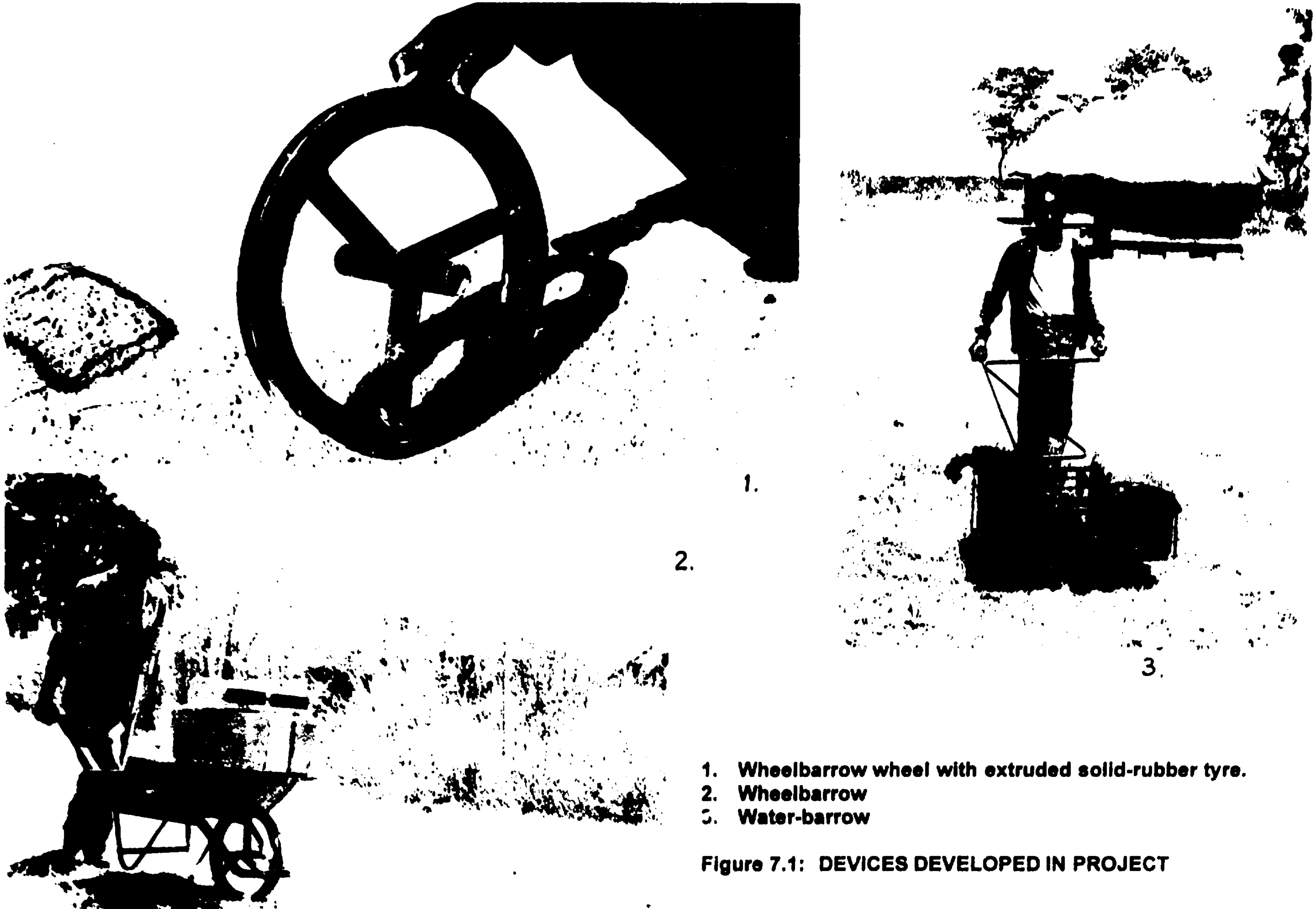
Collection of water is often the major transport burden for women in rural areas, particularly in drier areas. Water is usually transported by headloading, although ox-carts may sometimes be used or boys of the household may collect water in a wheelbarrow. However, in the latter cases transport of water will have low priority compared to income-generating activities and women will generally have limited access to these modes of transport.

Women may therefore benefit more from a low-cost means of transport which is specifically designed to carry water rather than for general transport activities. However, the cost must be very low since rural households are reluctant to invest in transport for non-income generating activities. The design developed comprises a simple frame to carry two 20 or 25 litre containers either side of a wheelbarrow wheel. The low centre of gravity close to the axle of the wheel makes the barrow very light to handle and manoeuverable.

The waterbarrow can be produced for about Z$200. A number have already been manufactured and sold by trained workshops, while eight are at present being field tested by small groups, mainly women, involved in dairy or farming projects where there is a need for transporting considerable volumes of water.

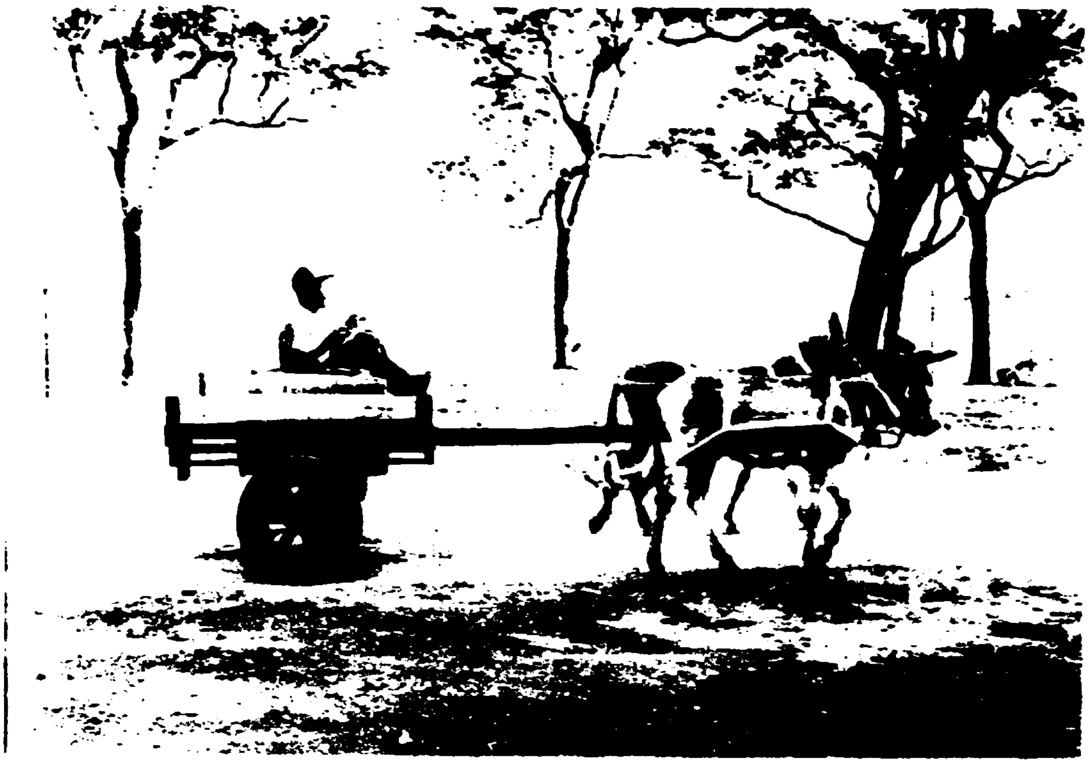
Handcart

Handcarts are mainly used in more urban areas, particularly around markets and bus termini. However, they are also very appropriate for rural areas where tracks are wide enough for their use. They can carry double the load of a wheelbarrow and are much less tiring on the arms so that they are more suitable for transporting loads over long distances.

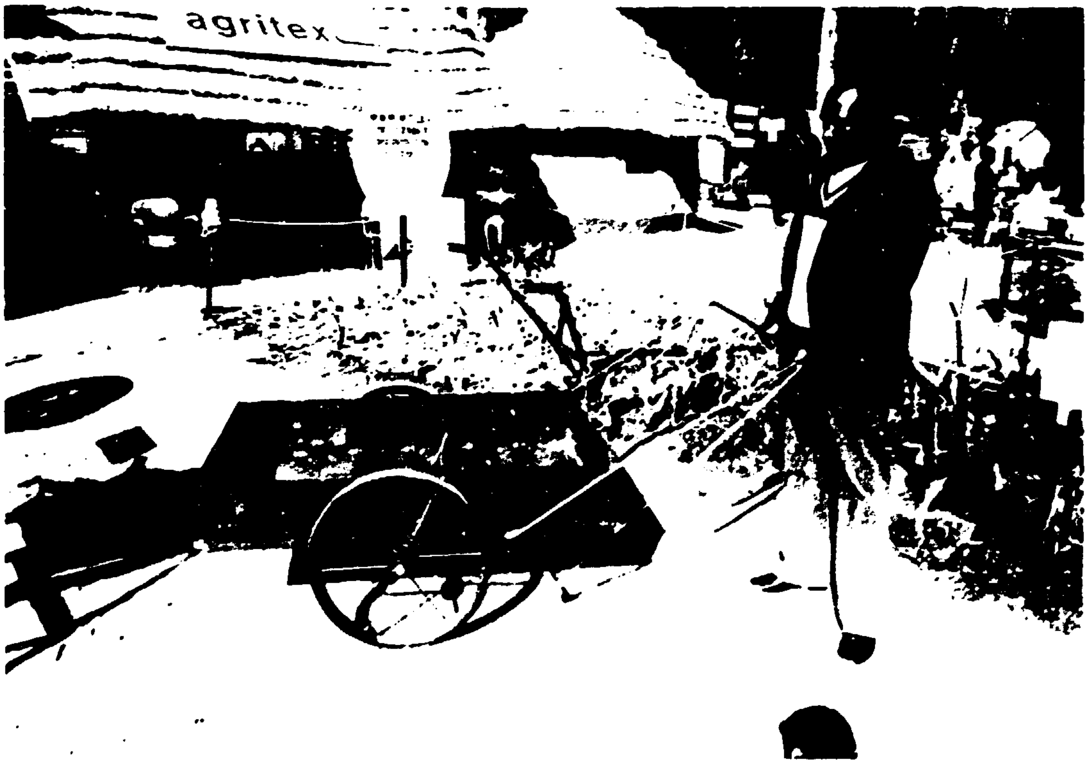


1. **Wheelbarrow wheel with extruded solid-rubber tyre.**
2. **Wheelbarrow**
3. **Water-barrow**

Figure 7.1: DEVICES DEVELOPED IN PROJECT



Animal-drawn water bowser



Handcart on show at agricultural field day

Figure 7.2: DEVICES DEVELOPED IN PROJECT

The main problem in producing handcarts is to find suitable wheels and axles. Scrap wheels of various types are usually used and often the frame and body are also made at low cost from scrap materials. The handcart shown in Figure 7.2 has a sheet metal body which will make the cost relatively high. However, the wheels with extruded solid-rubber tyres can be manufactured at a reasonable cost and could be used by artisans or small workshops to produce lower-cost versions of the handcart using a wooden, scrap metal or steel mesh body.

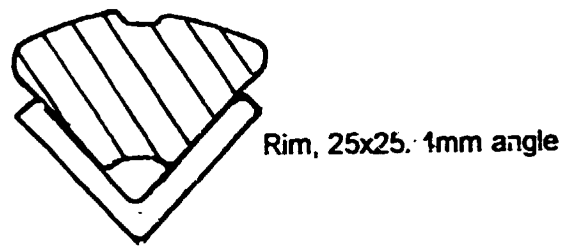
A number of the handcarts have been modified by fitting two wooden pole shafts so that they can be pulled by donkeys. Four of these are at present being field tested as part of the dissemination programme of Phase 3 of the project. The adaptation produces a very low-cost donkey cart which should be affordable to many households which cannot afford an ox-cart. However, it is possible that the cart may be too small and the wheels too narrow for the cart to be popular and a more acceptable version may be to produce a light, low-cost version of an ox-cart with 13" pneumatic tyres and wooden body. This type of cart is popular in other countries where donkeys are widely used and it is considered worthwhile producing a few prototypes for demonstration as part of the ongoing work at IAE.

Wheels for handcarts and wheelbarrows

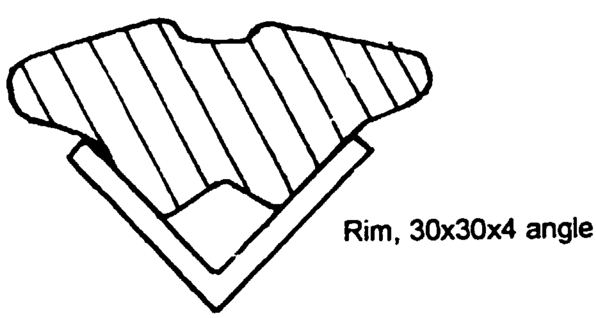
The wheels shown in Figures 7.1 and 7.2 have rims formed from angle section into which triangular shaped solid-rubber tyres are fitted. The tyres have been developed in collaboration with Dunlop Zimbabwe. They are an extruded section formed using dies manufactured in the project workshop at IAE. The shapes of the sections are shown in Figure 7.3. The tyres are made by cutting off a length of the extruded section and joining the ends to form a ring. Initially considerable difficulties were experienced in making the joints. A number of rubber bonding and compounding materials were tried with limited success. Eventually a solution has been developed with Tyre Treads Ltd. in which the joints are properly vulcanised in a steam autoclave. This method appears to be successful and is expected to lead to an increasing demand for these types of wheels.

Waterbowser

The donkey-pulled waterbowser shown in Figure 7.2 was developed in response to an order from an agricultural project. Two have so far been supplied and there is considerable interest from other projects. The cart has been designed for flexible use as it can either be used as a bowser, or the drums removed and wooden planks fitted as a floor for carrying other types of loads.



Tyre section for a bicycle-type wheel for use on a bicycle-trailer (actual size)



Tyre section for use on wheelbarrow and handcart wheels (actual size)

Figure A7.3: EXTRUDED RUBBER TYRE SECTIONS DEVELOPED IN PROJECT

8. INSTITUTION BUILDING AT IAE

The development of the capability of IAE to take over the activities of the project has been described in the two progress reports of Phase 2 of the project. In the latter part of the project. IAE staff have taken over all the workshop survey, training and follow-up activities. At the end of Phase 2, the wheel manufacturing technology has been fully integrated into the programme of the Rural Technology Training Centre at IAE and the staff are very capable of continuing dissemination of and back-up support for the technology. There is a good commitment from IAE because they can see the beneficial impact that the technology is having in rural areas.

The wheel technology programme fits in well with the blacksmith training programme at IAE and with Agritex extension activities. For example, trainee blacksmiths are using the technology to make large pulleys for the forge blowers they produce in the training courses. Also joint monitoring of blacksmiths and trained workshops is carried out by IAE staff. Agritex extension staff are active in promoting and disseminating the technology and in providing feedback to IAE from workshops and cart users.

An important recent innovation at IAE has been the introduction of training courses in business management for small enterprises. These should prove very beneficial to trained workshops in improving approaches to cash flow, materials acquisition, marketing, customer relations and quality control.

An agreement has been reached between IAE and IT to continue collaboration on technical development with technical support from I.T. Transport. This will initially concentrate on the development of the puncture-resistant tyres and of low-cost donkey carts.

9. SOCIO-ECONOMIC MONITORING AND EVALUATION

This programme was delayed during the first year of the project because it was felt that the effects of the severe drought on the rural economy would limit the amount of useful information that could be obtained and therefore the work would not be cost-effective. The programme therefore effectively began in mid-1993 and the two main areas of work completed are described in the Phase 2. Progress Report No. 2 of December 1993. These were:

- a survey of owners of broken-down carts to assess the problem of rehabilitation of these carts and the inputs, if any, that could be made by the project;
- a visit of the consultant socio-economist which covered surveys of trained workshops and users of carts, a review of dissemination strategy and planning of the on-going socio-economic programme.

Summaries of this work, taken from the Phase 2 progress Report, are included below: (Note that the annexes referred to are in the progress report)

9.1 Rehabilitation of Scotchcarts

Owing to limitations on transport available to the project, the survey relating to the rehabilitation of carts had to be integrated with other field activities and could therefore only be carried out in one area, around Gutu in the Midlands. However, the similarity in responses from both owners of broken-down carts and from workshops involved in repair work indicates that the findings can confidently be extended to other areas.

19 owners of broken-down carts were interviewed. A summary of the responses from 8 of these owners is included in Annex 2 of the report. It is seen that all the carts are quite old, half of them in the table being over 10 years old. It should be pointed out that the assessments of the nature of the breakdowns and the reasons why these occurred are those of the owners - no technical inspection of the carts was made. All the carts were fitted with scrap axles from motorised vehicles and therefore it is not surprising that the common causes of breakdowns are failure of bearings and worn stub-axles. The reasons for this are likely to be:

- the bearings would already be coming to the end of the their life when the axles were fitted to the carts;
- the bearings may not have been adequately lubricated and it is likely that dust and sand would have got into the bearings;
- the fact that stub-axles were worn suggests that the bearings had partially seized and the rings were rotating on the axles.

The other main problem mentioned was the puncturing of tyres. Several of the owners listed this as a re-occurring problem which was largely due to the use of second-hand tyres.

Three common reasons were given for non-repair of carts:

- financial problems, particularly as a result of the recent drought;
- problems of finding suitable replacement bearings, axles or hub assemblies;
- problems of transporting the cart to the repair workshop.

It may be noted that in several cases the carts had been out of service for quite long periods of time but in most cases there was an intent to repair the carts. Since the cart bodies were still in reasonably good condition this would be the most viable option since the cost of repair would probably be of the order of 20% to 30% of the cost of a new cart. Even so cost was still a significant constraint on effecting the repair of carts and provision of relatively small amounts of credit could have a considerable impact on getting carts back into service.

The responses from the workshops involved in repair of scotchcarts were all very similar and may be summarised as follows:

- the major part of this work involved repairs to axle assemblies i.e. rims, hubs, bearings and axles;
- the main problem faced was the very limited supply of rims, hubs and axles, particularly for 16" wheels which are the preferred size. Often smaller rim sizes, 13" and 14", have to be built up to take 16" tyres. This is not a satisfactory solution and the hubs and axles of these smaller size wheels are not considered robust enough for use on scotchcarts;
- there is a strong demand for repair work and none of the workshops go out looking for repair work;
- no repair work is carried out in the field so that owners have to transport their carts to the workshops.

Conclusions

Previous surveys (see Phase 1 report) have shown that the breakdown of scotchcarts is a significant constraint on the availability and use of carts, with up to 40% of carts being out of service in some areas.

This survey confirms that there is a strong demand for repair of carts and that one of the main constraints on repair work is the very limited availability of suitable rims, hubs, bearings and axles. In most cases the frame and body of the cart are still in reasonable condition and therefore it is substantially cheaper to replace the wheel and axle components than to purchase a new cart.

It seems likely that as the rural economy continues to recover after the recent drought that there will be an increasing demand for the repair of broken-down carts. It is clear that the project can make a significant contribution to bringing these carts back into service by providing a readily available supply of wheel and axle assemblies which will be of better quality and longer lasting than the majority of replacement components which are being used at present.

9.2 Visit of the Consultant Socio-Economist - October/November 1993

The report of consultant socio-economist's visit which took place in the period 14th October to 4th November is included as Annex 3. The following activities were carried out in collaboration with the local socio-economist:

1. A survey of owners of scotchcarts and other vehicles produced by workshops trained in the project to assess the benefits of ownership and to attempt to obtain some preliminary insight into the impact of the project on ownership and hiring of carts.

2. A survey of a sample of trained workshops to ascertain the level of take-up of the wheel manufacturing technology and the impact it is having on the production and supply of scotchcarts and other vehicles.

3. A review of dissemination strategy in order to identify mechanisms for more directly benefiting the groups which are the targets of the project i.e. poorer households and women.

4. Planning of the on-going socio-economic monitoring and evaluation programme.

The principal findings and outcomes of these activities are outlined in the following summary taken from the consultant socio-economist's report:

This report provides details of a visit to Zimbabwe by the consultant socio-economist, during which he worked with the local project socio-economist. The visit had three objectives: to monitor the socio-economic impact of the project to date. particularly as it relates to the project's primary target groups, women and poorer households; to design a dissemination strategy aimed at improving the access of these target groups to non-motorised vehicles made by project trained artisans; and to make recommendations on the form which future socio-economic inputs should take.

It was found that the impact of the project, in terms of an increase in the number of operational scotchcarts, has so far been modest. This is principally due to the drought in 1992 which severely depressed demand for the vehicles: the failure of a number of trained artisans to make substantial use of the techniques taught in the training courses; and the fact that the techniques are very new - their popularity will grow only after the vehicles made using them develop a reputation for durability and strength. Those artisans who have embraced the new techniques are prospering and a significant number of scotchcarts have been manufactured or rehabilitated, which would not have been possible in the absence of the project.

None of the purchasers of scotchcarts interviewed during the visit have used their vehicles through a farming season, since all were bought with the proceeds of the last harvest. Attempts were made to estimate the impact of improved access to scotchcarts. These confirmed the findings of previous surveys that benefits are likely to be widely and deeply felt, with the project's target groups being among the beneficiaries.

There was, however, felt to be scope to target the benefits of scotchcart ownership more directly to these groups. A four-pronged dissemination strategy was drawn up comprising the following elements: collaboration with organisations working directly with the project's target groups; promoting the use of scotchcarts in labour-based road works; helping government to develop a national transport strategy to address women's transport needs, and; working with cooperative and commercial retail outlets.

It is recommended that the emphasis of socio-economic work on the project should be aimed at further developing and implementing this dissemination strategy. Further field visits to identify the uses to which scotchcarts are used and to quantify the benefits, it is argued, will deliver diminishing returns.

9.3 Further Work, December 1993 to June 1994

Rehabilitation of Carts

It is clear from the feedback from trained workshops that the project is making a useful contribution to the rehabilitation of carts - to February 1994, 112 axle-assemblies for ox-carts had been sold (Section 4.2). Workshops and IAE staff attending agricultural field days report a considerable interest from cart users in replacement axles, but it appears that cost is constraining greater demand. A good quality axle assembly needs to be sold for at least Z$600 to cover costs and some profit margin and it is evident that some users either find this too high or unaffordable. In these cases they may decide to look for cheaper ways of repairing their carts, for instance attempting to find replacement bearings or a cheap scrap axle, and put up with the disadvantages of their carts being out of use for lengthy periods. However, these cheaper methods are often unreliable and in the longer term it is probably more cost-effective to rehabilitate the cart with a good quality, reliable axle. This is still a relatively low-cost method of getting more carts into use and it is therefore felt worthwhile to continue dissemination in this area, including further surveys of owners of broken-down carts to obtain information on the constraints on demand for replacement axles.

Development and implementation of dissemination strategy

Following the recommendations of the consultant socio-economist, work in the first half of 1994 has concentrated mainly on dissemination. This has included the following activities:

- an Open Day was held in January 1994 to follow up contacts made with organisations working with the project's target groups and to give them the opportunity to inspect the wheel-making technology and the transport devices produced within the project. Letters of invitation were sent to all organisations identified as working with target groups. A list of those attending and a brief report on the open day is included in Annex 9. Although participants showed considerable interest there has been little direct output from the event. However, the open day has increased the awareness of the devices that can be produced using the wheel technology and it is possible that this will show results in the future;

- a proposal was submitted to DANIDA for a pilot project to assess the use of ox-carts in labour-based road construction. Unfortunately the labour-based road construction programme is now on-hold and consequently there has been no action on the proposal;

- a number of projects have been identified which are willing to field test and assess transport devices developed in the programme. Two waterbarrows and one donkey/hand cart have been distributed to each of the following projects:

  - ITDG agricultural project in Chivi
  - Christian Care project with women's groups in Masvingo
  - ORAP agricultural project with women's groups in Bulawayo
  - Christian Care dairy project in Zvimba

  The usage and performance of these devices will be monitored in Phase 3 of the project.

  Since this dissemination work is aimed mainly at testing and increasing awareness of the devices, direct outputs in terms of increased demand for the devices may take some time to show up. Monitoring will concentrate on assessing people's attitudes and opinions with respect to using the devices or their reasons for not using them;

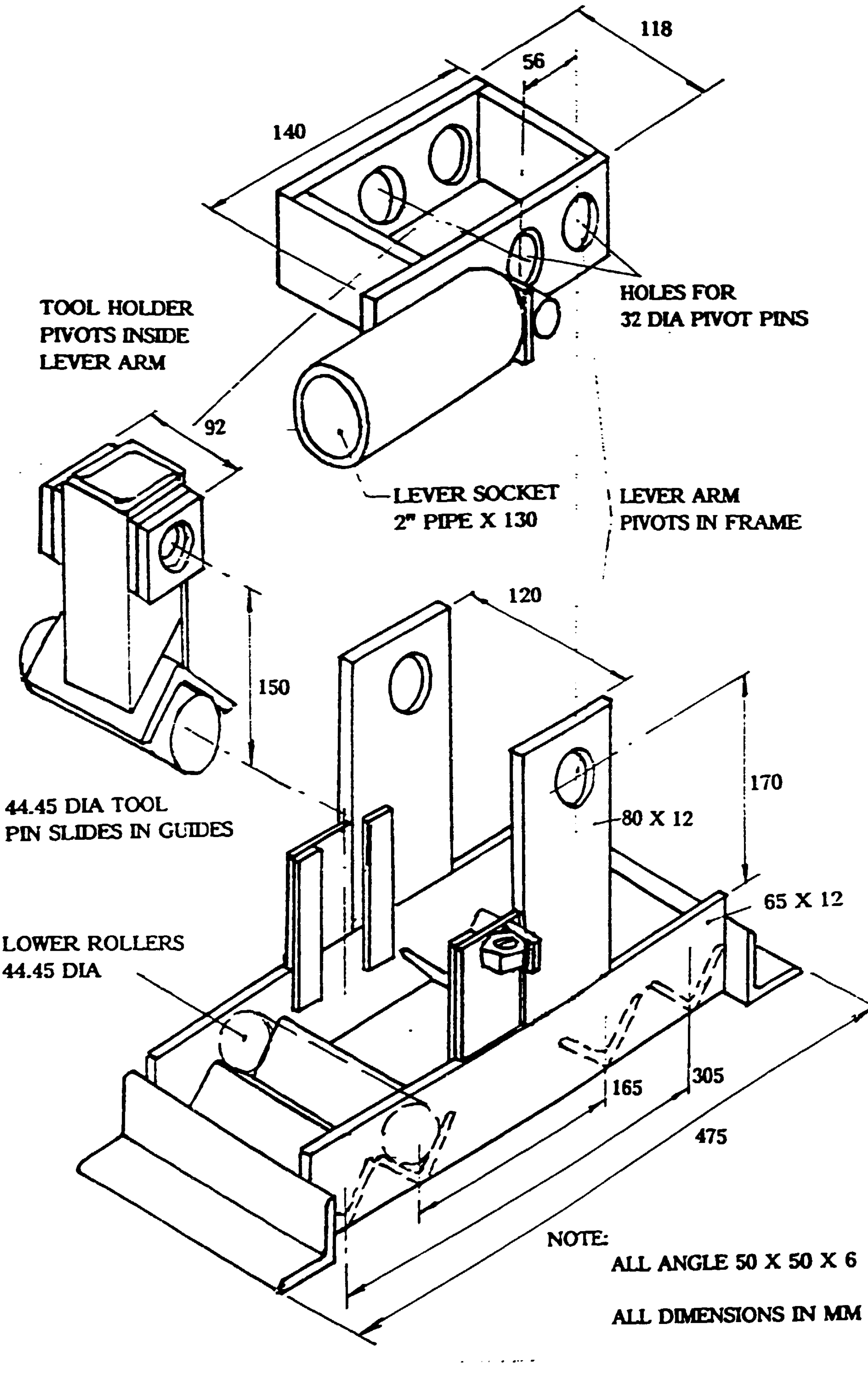
- some attempts have been made to interest retailers in displaying and marketing devices produced in the project. There has been some interest but generally retailers have quoted purchase prices from workshops which are below the prices at which the devices can economically be produced by the workshops. The dissemination programme therefore needs to look at ways of improving the advertising and marketing strategy of workshops

ANNEX 1: DETAILS OF PRODUCTION TOOLS

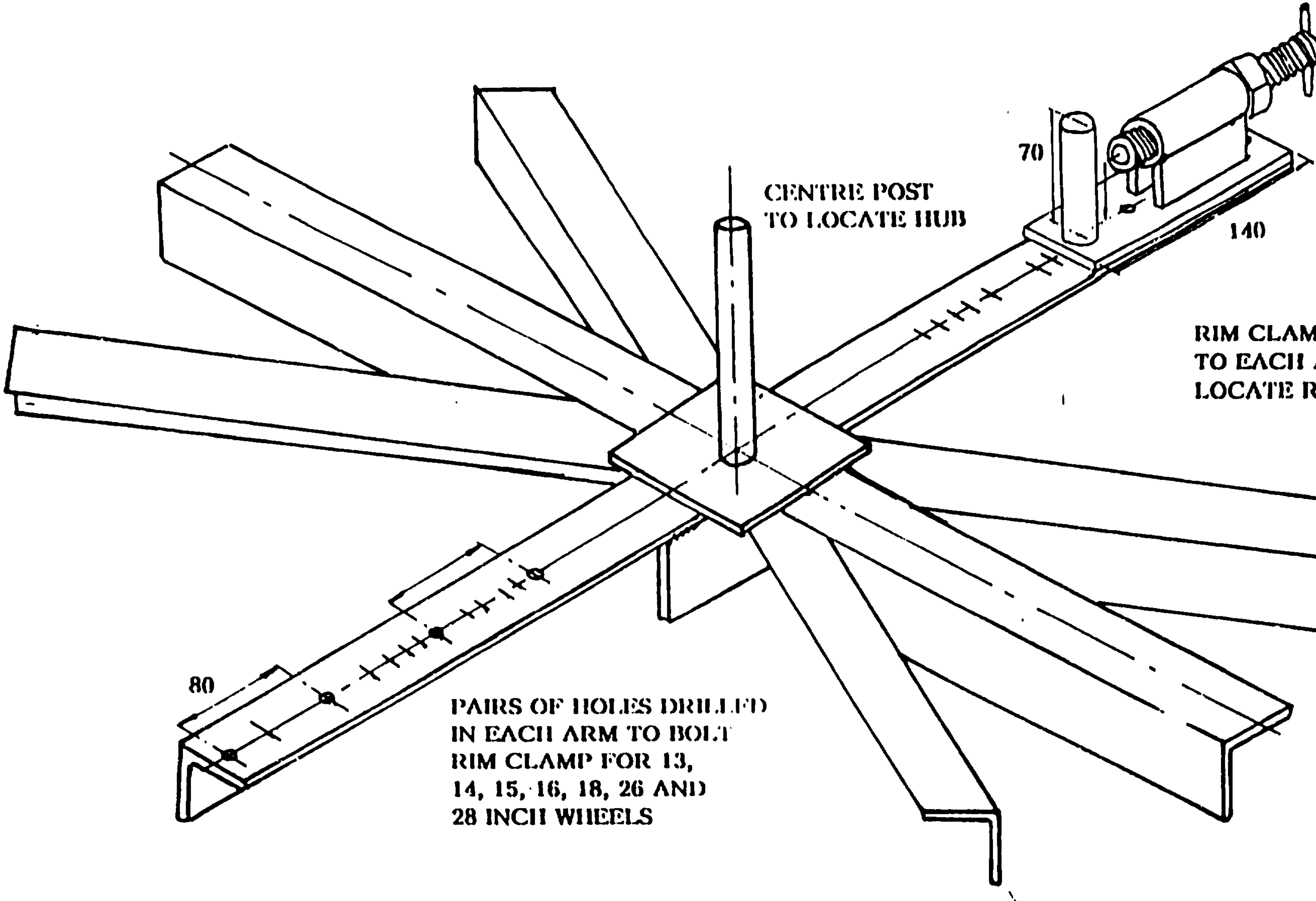
ANNEX 1: DETAILS OF PRODUCTION TOOLS

The production tools comprise a hand-operated bending machine for forming wheel rims and an assembly jig to clamp up the wheel components for welding to ensure accurate construction of the wheel. Details of the tools are shown in the accompanying drawings.

The bender can bend a wide range of steel sections into accurate rings of various sizes in order to make wheel rims to take any type and size of tyre. The assembly jig has settings for rims for vehicle tyres from 12" to 16" rims, motorcycle tyres and bicycle tyres. These settings can also be used to produce rims for solid-rubber tyres.



RIM BENDING DEVICE



JIG FOR ASSEMBLING WHEELS

MATERIALS REQUIRED

Material		Qty with 20% added (mm)	Unit Cost $/metre	Material Cost Z$
Assembly Jig				
Angle	50x50x6	4,322	14.03	= 60.65
Flat	25x6	1,171	3.23	= 3.78
	50x8	1,176	10.11	= 12.00
	80x6	384	11.86	= 4.55
Tube	20mm bore	504	25.92	= 13.06
Threaded Bar	M20	1,220	41.87	= 51.08
Re-bar	20mm	540	3.13	= 1.70
Nuts	M8	#22	0.14	= 3.08
	M20	#11	2.19	= 24.00
Bolts	M8x25	#22	0.31	= 6.82
				TOTAL 180.81
Bending Machine				
Flat	80x12	480	23.73	= 11.39
	65x12	1,572	19.25	= 30.26
	50x8	234	10.17	= 2.39
	20x5	528	2.57	= 1.36
Angle	50x50x6	1,728	14.03	= 24.24
Water Pipe	2"	180	50.00	= 9.00
	3/4"	50	25.92	= 1.30
Round BMS	32	320	48.00	= 15.36
	44.45	566	70.00	= 39.60
Nuts	M20	#3	2.19	= 6.57
Threaded Bar	M20	216	41.97	= 9.04
				TOTAL 149.87

Prices correct April 1992 (Baldwins Steel, Harare)

ANNEX 2: TYPICAL TRAINING COURSE TIMETABLE

ANNEX 2: TYPICAL TRAINING COURSE TIMETABLE

Day 1: Machines handed out, owners name stamped on machine.
Machines assembled and checked.
Material cut for scotchcart wheel.
Demonstration rim bent by instructor.
Rims bent by trainees.

Day 2: Finish wheel rim.
Demonstrate axle and hub.
Trainees make own axle and hub.

Day 3: Finish scotchcart wheel.
Discussion session.

Day 4: Bend angle rim for bicycle tyre.
Make hub and axle.

Day 5: Demonstration of solid rubber tyres.
Make pushcart wheels.

Day 6: "Catch-up" session.
Discussions.

Day 7: Make wheelbarrow wheel.
Start wheelbarrow frame.

Day 8: Finish wheelbarrow.
Split into 2 groups to make 2 pushcarts.

Day 9: Finish all products, correct mistakes.

Day 10: Discussions, collect together all products and machines, travel home.

ANNEX 3: LIST OF TRAINED WORKSHOPS

The following have been trained by the project (see list below), at least another 8 by Silvera House, Driefontein and Chinhoyi Rural Trade School have ongoing courses, Hlekweni and Masvingo Tech intend to train next year, the supplier of kits does some basic training, apparently an artisan we trained in Harare trained another workshop and copied the kit.

1 **DATE & VENUE OF TRAINING COURSE:** July 1992 I.A.E.
LOCATION OF WORKSHOP: Bindura
NAME OF WORKSHOP: Sam's welding
COURSE PARTICIPANT'S NAME: Samuel Muuduri
ADDRESS: 848/4 Chiradze light industry Bindura
TELEPHONE: 6791
LOCATION OF PREMISES: Turn left after bus terminus on dust road.

2. DATE & VENUE OF TRAINING COURSE: July 1992 I.A.E.
LOCATION OF WORKSHOP: Chiweshe
NAME OF WORKSHOP: Chipoera Welders
COURSE PARTICIPANT'S NAME: Moffat Njaro

ADDRESS: P/Bag 2035 Gweshe Township Glendale
TELEPHONE: 53816 Glendale
LOCATION OF PREMISES: At Gweshe centre, look for Chipoera supermarket.

3. **DATE & VENUE OF TRAINING COURSE:** July 1992 I.A.E.
LOCATION OF WORKSHOP: Guruve
NAME OF WORKSHOP: Guruve Enterprises
COURSE PARTICIPANT'S NAME: Chamunorwa Kalingizi
ADDRESS: Box 145 Guruve
TELEPHONE: 2024
LOCATION OF PREMISES: Up main street, turn right, then left following dust road across bridge to township.

4. DATE & VENUE OF TRAINING COURSE: July 1992 I.A.E.
LOCATION OF WORKSHOP: Mutoko
NAME OF WORKSHOP: Masenda Welding
COURSE PARTICIPANT'S NAME: Douglas Kumbula
ADDRESS: Budjga co-op Box 165 Mutoko
TELEPHONE: 245
LOCATION OF PREMISES: Turn right at Mutoko Motel follow road for about 1km.

5. DATE & VENUE OF TRAINING COURSE: July 1992 I.A.E.
LOCATION OF WORKSHOP: Gazaland
NAME OF WORKSHOP: H.F.E.E. Engineers
COURSE PARTICIPANT'S NAME: Abednigo Murongazvombo
ADDRESS: Box HD 97 Highfield
TELEPHONE: 67113
LOCATION OF PREMISES: Turn right at Mushandira Pamwe bus garage and follow road around corner.

6. DATE & VENUE OF TRAINING COURSE: Nov 1992 I.A.E.
LOCATION OF WORKSHOP: Matapi and Gazaland
NAME OF WORKSHOP: Govo Investments
COURSE PARTICIPANT'S NAME: Douglas Muhwati
ADDRESS: Lundi Rd Matapi Mbare
or Box G455 Greendale
TELEPHONE: 706180 (or 48319 Home)
LOCATION OF PREMISES: Within Matapi square next to Govo steel or in Gazaland just past Mushandira Pamwe bus garage.

7. DATE & VENUE OF TRAINING COURSE: Nov 1992 I.A.E.
LOCATION OF WORKSHOP: Willowvale
NAME OF WORKSHOP: Welders Paradise
COURSE PARTICIPANT'S NAME: Alfred Rushambwa
(Note: Alfred was sacked, his replacement was trained March 93)
ADDRESS: Plot 1 Green trees
Willowvale
TELEPHONE: - 62476

LOCATION OF PREMISES: Turn into Green Trees at the sign for SIMBI WELDERS, follow the dust road to where chickens are sold.

8. DATE & VENUE OF TRAINING COURSE: Nov 1992 I.A.E.
LOCATION OF WORKSHOP: Hatcliffe
NAME OF WORKSHOP:
COURSE PARTICIPANT'S NAME: Levi Masheza
ADDRESS: House 605 9th Cres Hatcliffe
TELEPHONE:
LOCATION OF PREMISES: As above

9. DATE & VENUE OF TRAINING COURSE: Nov 1992 I.A.E.
LOCATION OF WORKSHOP: Tynewald
NAME OF WORKSHOP: Cold Comfort Farm
COURSE PARTICIPANT'S NAME: Ignatius Mutimbanyoka
ADDRESS: Box 8055 Causeway Harare
TELEPHONE: 703228/703251/732467
LOCATION OF PREMISES: Left after Tynewald rail crossing

10. DATE & VENUE OF TRAINING COURSE: Nov 1992 I.A.E.
LOCATION OF WORKSHOP: Msasa
NAME OF WORKSHOP: Hencas Enterprises
COURSE PARTICIPANT'S NAME: Tendai Zvanota
ADDRESS: 115 Fife Ave (office)
Box 4243 Harare
Unit 5 (just after Nat Vocational Training centre)
TELEPHONE: 723231
LOCATION OF PREMISES: New Industrial Unit on the corner after Vocational Training Centre.

11. DATE & VENUE OF TRAINING COURSE: Jan 1993 Mutare
LOCATION OF WORKSHOP: Mutare
NAME OF WORKSHOP:
COURSE PARTICIPANT'S NAME: Fungai Gowora
ADDRESS: Green Market
TELEPHONE:
DESCRIPTION OF PREMISES:

12. DATE & VENUE OF TRAINING COURSE: Jan 1993 Mutare
LOCATION OF WORKSHOP: Mutare
NAME OF WORKSHOP:
COURSE PARTICIPANT'S NAME: Thomas Mabvumbe
ADDRESS: Green Market
TELEPHONE:
DESCRIPTION OF PREMISES:

13. DATE & VENUE OF TRAINING COURSE: Jan 1993 Mutare
LOCATION OF WORKSHOP: Mutare
NAME OF WORKSHOP:
COURSE PARTICIPANT'S NAME: Caleb Mabvaringana
ADDRESS: Green Market
TELEPHONE:
DESCRIPTION OF PREMISES:

14. DATE & VENUE OF TRAINING COURSE: Jan 1993 Mutare
LOCATION OF WORKSHOP: Mutare
NAME OF WORKSHOP:
COURSE PARTICIPANT'S NAME: Morgan Mavhute
ADDRESS: Green Market
TELEPHONE:
DESCRIPTION OF PREMISES:

15. DATE & VENUE OF TRAINING COURSE: Jan 1993 Mutare
LOCATION OF WORKSHOP: Mutare
NAME OF WORKSHOP:
COURSE PARTICIPANT'S NAME: Prosper Mabika
ADDRESS: Green Market
TELEPHONE:
DESCRIPTION OF PREMISES:

16. DATE & VENUE OF TRAINING COURSE: Jan 1993 Mutare
LOCATION OF WORKSHOP: Mutare
NAME OF WORKSHOP:
COURSE PARTICIPANT'S NAME: R.F. Manganie
ADDRESS: Green Market
TELEPHONE:
DESCRIPTION OF PREMISES:

17. DATE & VENUE OF TRAINING COURSE: Jan 1993 Mutare
LOCATION OF WORKSHOP: Mutare
NAME OF WORKSHOP:
COURSE PARTICIPANT'S NAME: Chrispen Chapeyama
ADDRESS: Green Market
TELEPHONE:
DESCRIPTION OF PREMISES:

18. DATE & VENUE OF TRAINING COURSE: Jan 1993 Mutare
LOCATION OF WORKSHOP: Mutare
NAME OF WORKSHOP:
COURSE PARTICIPANT'S NAME: Washington Musimwa
ADDRESS: Green Market
TELEPHONE:
DESCRIPTION OF PREMISES:

19. DATE & VENUE OF TRAINING COURSE: Jan 1993 Mutare
LOCATION OF WORKSHOP: Mutare
NAME OF WORKSHOP:
COURSE PARTICIPANT'S NAME: Salisios Maimboti
ADDRESS: Green Market
TELEPHONE:
DESCRIPTION OF PREMISES:

20. DATE & VENUE OF TRAINING COURSE: Jan 1993 Mutare
LOCATION OF WORKSHOP: Mutare
NAME OF WORKSHOP:

COURSE PARTICIPANT'S NAME: Christopher Rakabopa
ADDRESS: Green market
TELEPHONE:
DESCRIPTION OF PREMISES:

21. DATE & VENUE OF TRAINING COURSE: Feb 1993 Bulawayo
LOCATION OF WORKSHOP: Bulawayo
NAME OF WORKSHOP:
COURSE PARTICIPANT'S NAME: Gipson Ndlovu
ADDRESS: Bambanani Supermarket shop 7
57006 Old Lobengula.

TELEPHONE:
LOCATION OF PREMISES: Along Lobengula road (left at bus terminus) continue until Mabutweni. Opposite the other workshop of Tadius Ndiweni.

22. DATE & VENUE OF TRAINING COURSE: Feb 1993 Bulawayo
LOCATION OF WORKSHOP: Mapisa
NAME OF WORKSHOP: Water workshops
COURSE PARTICIPANT'S NAME: Thomson Sibanda
ADDRESS: Tshelinyemba Sec School
Box 5751 Mapisa.
(w/shop address from Water workshops)

TELEPHONE:
LOCATION OF PREMISES:

23. DATE & VENUE OF TRAINING COURSE: Feb 1993 Bulawayo
LOCATION OF WORKSHOP: Nyama Ndlovu
NAME OF WORKSHOP:
COURSE PARTICIPANT'S NAME: Orderly Vundla
ADDRESS: Box 26 Nyama Ndlovu
TELEPHONE:
LOCATION OF PREMISES: Nyama Ndlovu centre, left just after rail crossing. May have moved up to Tcholocho.

24. DATE & VENUE OF TRAINING COURSE: Feb 1993 Bulawayo
LOCATION OF WORKSHOP: Bulawayo
NAME OF WORKSHOP: Water workshops
COURSE PARTICIPANT'S NAME: Donald Ncube
ADDRESS: Water workshops Box 3331 BYO
TELEPHONE:
LOCATION OF PREMISES:

25. DATE & VENUE OF TRAINING COURSE: Feb 1993 Bulawayo
LOCATION OF WORKSHOP: Bulawayo
NAME OF WORKSHOP:
COURSE PARTICIPANT'S NAME: Tadias Ndiweni
ADDRESS: Workshop 112 Mabutweni BYO
TELEPHONE:
LOCATION OF PREMISES: Left at bus terminus along Lobengula to Mabutweni.

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26. DATE & VENUE OF TRAINING COURSE: Feb 1993 Bulawayo
LOCATION OF WORKSHOP: Bulawayo
NAME OF WORKSHOP: Jack Nduna Motors
COURSE PARTICIPANT'S NAME: Alpheas Ncube
ADDRESS: 102 Mzilikazi BYO
TELEPHONE:
LOCATION OF PREMISES: Turn at first garage on right hand side in Mzilikazi. Just behind garage.

27. DATE & VENUE OF TRAINING COURSE: Feb 1993 Bulawayo
LOCATION OF WORKSHOP: Bulawayo
NAME OF WORKSHOP: Hlekweni Friends
COURSE PARTICIPANT'S NAME: Alevahani Dube
ADDRESS: Hlekweni Training Centre
Box 708 Bulawayo
TELEPHONE:
LOCATION OF PREMISES: Along Plumtree road

28. DATE & VENUE OF TRAINING COURSE: May 1993 I.A.E.
LOCATION OF WORKSHOP: Nyanga
NAME OF WORKSHOP:
COURSE PARTICIPANT'S NAME: Agustine Mubvuma
ADDRESS: Mapani Store Box 4 Nyanga
TELEPHONE:
LOCATION OF PREMISES: Through town travel about 1km then turn left at bottle store.

29. DATE & VENUE OF TRAINING COURSE: May 1993 I.A.E.
LOCATION OF WORKSHOP: Magunje
NAME OF WORKSHOP:
COURSE PARTICIPANT'S NAME: Toddy Major
ADDRESS: RGM Motors Box 64 Karoi
TELEPHONE:
LOCATION OF PREMISES: In Magunje town

30. DATE & VENUE OF TRAINING COURSE: May 1993 I.A.E.
LOCATION OF WORKSHOP: Karoi
NAME OF WORKSHOP:
COURSE PARTICIPANT'S NAME: Nekati Velapi
ADDRESS: Karoi Stationers Box 423
Karoi

TELEPHONE:
LOCATION OF PREMISES: Turn to the bus terminus, past the terminus turn right to Karoi Stationers.

31. DATE & VENUE OF TRAINING COURSE: May 1993 I.A.E.
LOCATION OF WORKSHOP: Nharira
NAME OF WORKSHOP:
COURSE PARTICIPANT'S NAME: Boniface Matamba
ADDRESS: Nharira Township Box 228
Chivu

TELEPHONE:
LOCATION OF PREMISES: In Nharira township on left hand side.

32. DATE & VENUE OF TRAINING COURSE: SEPT 1993 GOKWE
LOCATION OF WORKSHOP: KWEKWE
NAME OF WORKSHOP: I.M. AUTO SPARES & MANUFACTURES
COURSE PARTICIPANT'S NAME: WEBSTER KAMBA
ADDRESS: P/BAG 8082 KWEKWE
TELEPHONE: 2724
LOCATION OF PREMISES: Left at Caltex garage then left just after bus terminus.

33. DATE & VENUE OF TRAINING COURSE: SEPT 1993 GOKWE
LOCATION OF WORKSHOP: KWEKWE
NAME OF WORKSHOP:
COURSE PARTICIPANT'S NAME: MBONISI DUBE
ADDRESS: STAND 2061/2 AMAVENI
KWEKWE

TELEPHONE:
LOCATION OF PREMISES: Take Gokwe road to Amaveni township past the bus terminus just past the Hotel on the right next to a grinding mill.

34. DATE & VENUE OF TRAINING COURSE: SEPT 1993 GOKWE
LOCATION OF WORKSHOP: GWERU
NAME OF WORKSHOP: DA-LO WELDERS
COURSE PARTICIPANT'S NAME: PICK MTETWA
ADDRESS: BOX 597 MTAPA GWERU
TELEPHONE: 4911
DESCRIPTION OF PREMISES: Drive towards Mkoba township at the roundabout go right then first right again then turn left on to a dust road.

35. DATE & VENUE OF TRAINING COURSE: SEPT 1993 GOKWE
LOCATION OF WORKSHOP: GOKWE
NAME OF WORKSHOP: BAMBANANI SCOTCHCARTS
COURSE PARTICIPANT'S NAME: ESAU MTETWA
ADDRESS: STAND 975 GOKWE
TELEPHONE:
LOCATION OF PREMISES: Take Nkai road, less than 1km there is a sign for Bambanani Scotchcarts on the left.

36. DATE & VENUE OF TRAINING COURSE: SEPT 1993 GOKWE
LOCATION OF WORKSHOP: GOKWE
NAME OF WORKSHOP: GOKWE YOUTH WELDING PROJECT
COURSE PARTICIPANT'S NAME: DAVID MACKENZIE
ADDRESS: P/BAG 6099 GOKWE
TELEPHONE:
LOCATION OF PREMISES: Left on the main road before the cross roads. There is a sign.

37. DATE & VENUE OF TRAINING COURSE: SEPT 1993 GOKWE
LOCATION OF WORKSHOP: GOKWE
NAME OF WORKSHOP: - EVER BUSY WELDING
COURSE PARTICIPANT'S NAME: KENNEDY LUNGU
ADDRESS: BOX 6234 GOKWE
TELEPHONE:
DESCRIPTION OF PREMISES: Nkai road less than 1km there is a sign on the left.

38. DATE & VENUE OF TRAINING COURSE: SEPT 1993 GOKWE
LOCATION OF WORKSHOP: NKAI
NAME OF WORKSHOP: NKAI MAIN STORE
COURSE PARTICIPANT'S NAME: FERBION NKOMO
ADDRESS: BOX 21 NKAI
TELEPHONE:
LOCATION OF PREMISES: Behind Nkai main store in centre of Nkai.

39. DATE & VENUE OF TRAINING COURSE: NOVEMBER 1993 I.A.E.
LOCATION OF WORKSHOP: RUSAPE
NAME OF WORKSHOP: STAR ENGINEERING
COURSE PARTICIPANT'S NAME: RUSHAMBA CHITAPA
ADDRESS: BOX 188 RUASAPE
TELEPHONE:
LOCATION OF PREMISES: Turn right just before the first garage on the right comming into Rusape from Harare, over the railway line, turn right at the junction then first right on a dust road, follow road round to Star Engineering.

40. DATE & VENUE OF TRAINING COURSE: NOVEMBER 1993 I.A.E.
LOCATION OF WORKSHOP: DZIVARESEKWA
NAME OF WORKSHOP:
COURSE PARTICIPANT'S NAME: PETER GUNDA
ADDRESS: 2031 TAKAWIRA AVE DZIVARESEKWA
TELEPHONE:
LOCATION OF PREMISES:

41. LOCATION OF WORKSHOP:
NAME OF WORKSHOP: ADA VEGETABLE CO-OP
COURSE PARTICIPANT'S NAME: D.P. MUPARA and CHRISPEN CHIPENDO
ADDRESS: BOX 115 MUTOKO and BOX 85 MUTOKO
TELEPHONE:
LOCATION OF PREMISES: Turn right in Mutoko after bus terminus at beer hall on right.

42. DATE & VENUE OF TRAINING COURSE: NOVEMBER 1993 I.A.E.
LOCATION OF WORKSHOP: MUPANDAWANA
NAME OF WORKSHOP: GIBBS MANUFACTURING
COURSE PARTICIPANT'S NAME: FRANK ZVENYIKA and GALISTO MUKWATI
ADDRESS: BOX 66 MUPANDAWANA
TELEPHONE:
LOCATION OF PREMISES: Close to the far side of the bus terminus, down the hill on the right.

DATE & VENUE OF TRAINING COURSE: MARCH 1994 MASVINGO

43. LOCATION: BIKITA
NAME OF WORKSHOP: SOKO-MUKANYA WELDING
COURSE PARTICIPANT'S NAME: ELISHA MARUMURA
ADDRESS: P.BAG 50B BIKITA
TELEPHONE: NYIKA 244
LOCATION OF PREMISES: Just past petrol station on the left side of the main road.

44. DATE & VENUE OF TRAINING COURSE: MARCH 1994 MASVINGO
LOCATION: ZVISHAVANE
NAME OF WORKSHOP: MUROMBEDZI WELDERS
COURSE PARTICIPANT'S NAME: FRANCIS MUROMBEDZI
ADDRESS: BOX 48 ZVISHAVANE
TELEPHONE: ZVISHAVANE 3472 (HOME)
LOCATION OF PREMISES: Approaching Zvishavane from Masvingo turn off right to township and bus station, workshop is behind the bus terminus.

45. DATE & VENUE OF TRAINING COURSE: MARCH 1994 MASVINGO
LOCATION: CHIREDZI
NAME OF WORKSHOP: LIFE SOWING MINISTRIES
COURSE PARTICIPANT'S NAME: BONIFACE KWENDA
ADDRESS: BOX 17 CHIREDZI
TELEPHONE: CHIREDZI 3010
LOCATION OF PREMISES: Turn left off main road to Chiredzi just before shopping centre, on the left hand side on the way to the bus station.

46. DATE & VENUE OF TRAINING COURSE: MARCH 1994 MASVINGO
LOCATION: CHIVI
NAME OF WORKSHOP: Z.E.S.
COURSE PARTICIPANT'S NAME: DZIKAMAI GWAKU
ADDRESS: P.BAG 572 CHIBI
TELEPHONE: 24123
LOCATION OF PREMISES: In Chivi town

47. DATE & VENUE OF TRAINING COURSE: MARCH 1994 MASVINGO
LOCATION: DRIEFONTEIN
NAME OF WORKSHOP: DRIEFONTEIN METAL TRAINING
COURSE PARTICIPANT'S NAME: IGNATIUS MEKI
ADDRESS: P.BAG 7001 MVUMA
TELEPHONE: MVUMA 3003
LOCATION OF PREMISES: Part of the Driefontein Mission

48. DATE & VENUE OF TRAINING COURSE: MARCH 1994 MASVINGO
LOCATION: NYIKA
NAME OF WORKSHOP: MASHIRI WELDING
COURSE PARTICIPANT'S NAME: NEWYEAR MASHIRI
ADDRESS: P.BAG 36B NYIKA
TELEPHONE: NYIKA 244
LOCATION OF PREMISES: On the left after the petrol station comming from Masvingo.

49. DATE & VENUE OF TRAINING COURSE: MARCH 1994 MASVINGO
LOCATION: BULAWAYO
NAME OF WORKSHOP: O.R.A.P.
COURSE PARTICIPANT'S NAME: OBERT NDLOVU
ADDRESS: BOX 877 BYO
TELEPHONE: BYO 31009
LOCATION OF PREMISES: 16 Boon Ave, 6km along Vic Falls road.

50. DATE & VENUE OF TRAINING COURSE: MARCH 1994 MASVINGO
LOCATION: JERERA
NAME OF WORKSHOP: TORONGA ZIM ENGINEERING
COURSE PARTICIPANT'S NAME: A. MASIPIKI
ADDRESS: P.BAG 115 Z ZAKA
TELEPHONE: JERERA 262
LOCATION OF PREMISES: Turn right (heading south) after the petrol station before the shopping centre, follow the road past the bottle depot it's on the left.

51. DATE AND VENUE: MARCH 1994 MASVINGO
NAME /LOCATION: MASVINGO TECHNICAL COLLEGE
3 STAFF TRAINED

ANNEX-4: MANUAL USED IN TRAINING PROGRAMME

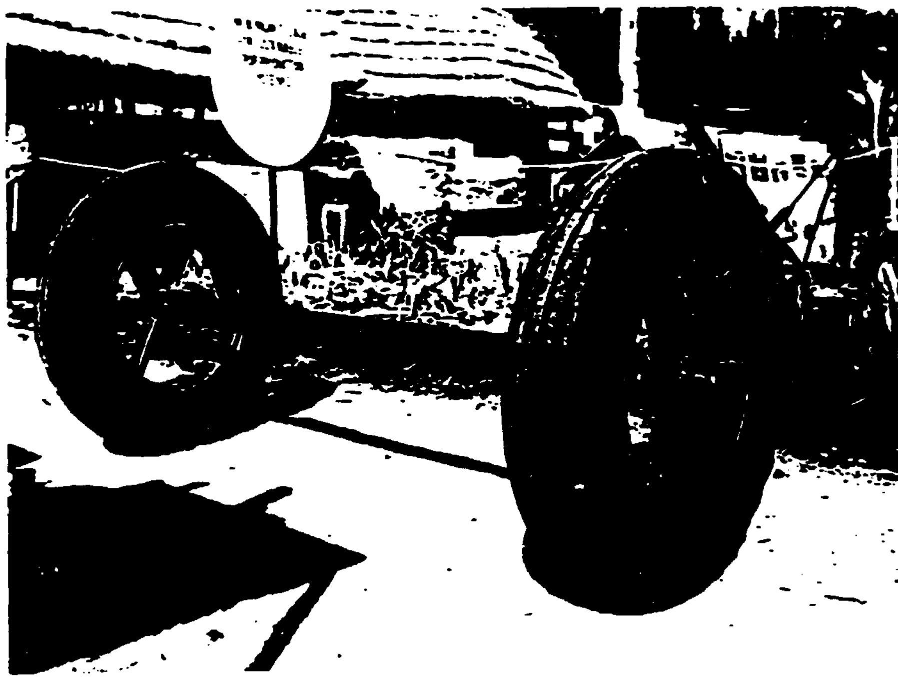
WHEEL MAKING COURSE

MASVINGO

FEBRUARY 1994

INSTITUTE OF AGRICULTURAL ENGINEERING
BOX BW330
BORROWDALE
HARARE

MAKING WHEELS SUITABLE FOR CAR TYRES (13,14,15 AND 16" WHEELS)



To make the wheel you need 100x6 flat bar to form the rim, if you can not find any 100x6 flat you can always bend two pieces of smaller flat (50x6 or 65x6 or whatever you can find) then weld them together after bending. The rim can be made wider than 100mm but not less.

MAKING THE WHEEL MADE FROM ONE PIECE OF 100x6 FLAT.

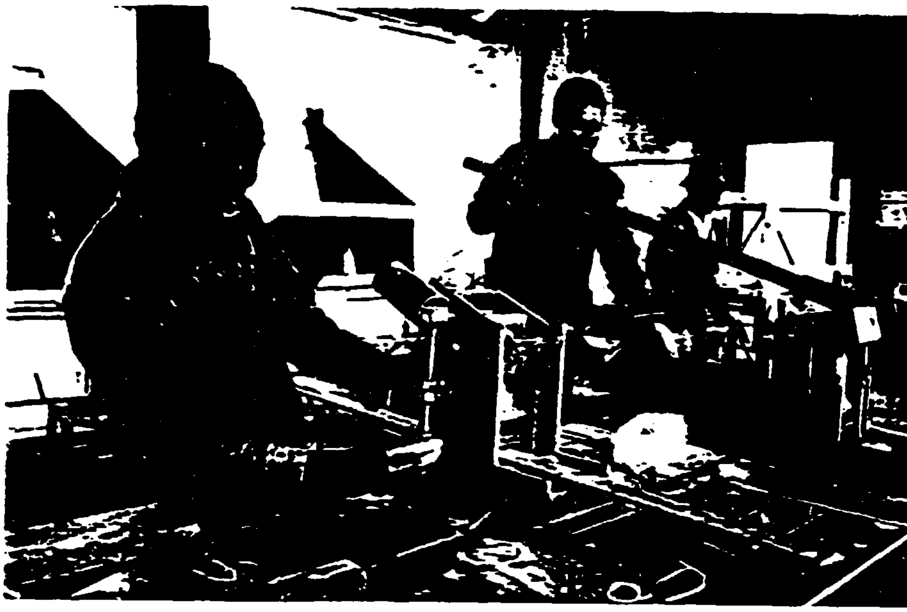
1. Fit the round tool to the bending machine and put the rollers in the inner position.

2. Cut a piece of 100x6 flat bar to the correct length (see the cutting table).

3. Bend the ends of the flat bars over another rim or an anvil to the correct curve.
   If you find it easier you can leave the ends flat and correct them after bending the rim.

4. Mark the bars with chalk every 25mm.

5. Zero the machine. To do this, put a straight piece of bar that you are going to bend into the machine and screw up the stop until it is just touching the lever arm.



6. Now check the settings table for the correct number of turns for the wheel size you want.
   Note: this is a rough guide, if the rim comes out too big or too small then change the number of turns and use the new setting for the rest of the rims.
7. Bend the rim moving it through the machine from one chalk mark to the next.
   *-Don't miss any !
   *-Don't bend between the marks.
   *-Don't use excessive force to pull down the lever.
   *-Keep the bar straight through the machine.

NOTE: If during bending the rim looks like it is coming out the wrong size, ie the wrong diameter, then continue bending DON'T change the setting half way through.
If it's too big the rim can be put through again with the stop turned down a little bit. If it's too small then either keep it to use on a smaller tyre or open it out a little in a vice.

7. The ends of the rim need to be hammered so that they line up and follow the curve of the rim properly.

8. Cut 2 pieces of 16mm re-bar for the beads, see the cutting table for the correct lengths.

9. Mark every 25mm.

10. Zero and bend in the same way as before, see the setting table for the correct number of turns. Check the fit on the rim and cut off the straight ends.

Don't weld them to the rim yet.

—FINISHING THE WHEEL IN THE ASSEMBLY JIG—

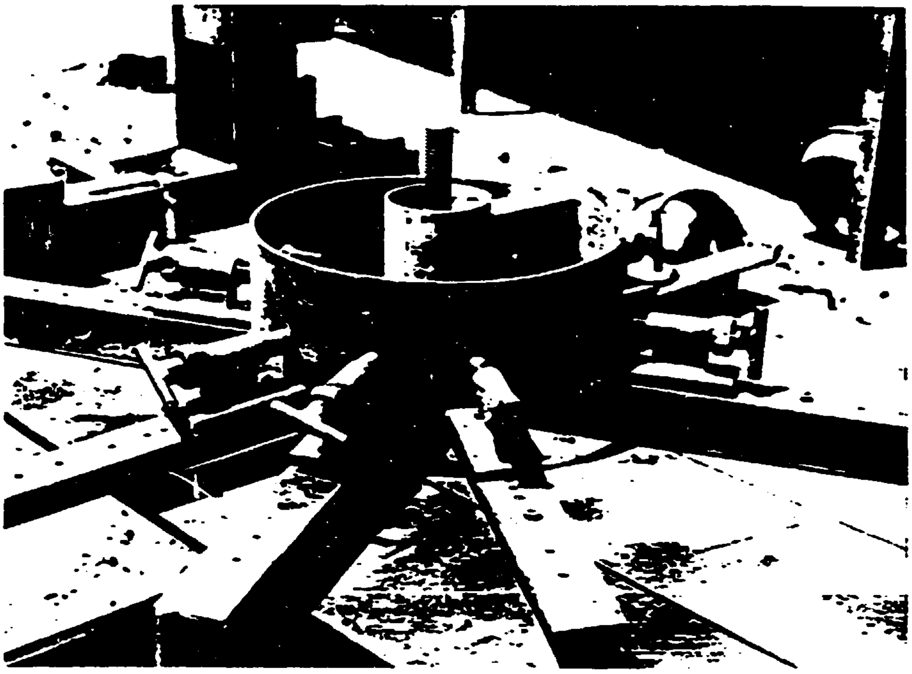
11. Set the jig for the correct wheel size.

12. Fit the rim and clamp it up.

13. Weld the two ends together.

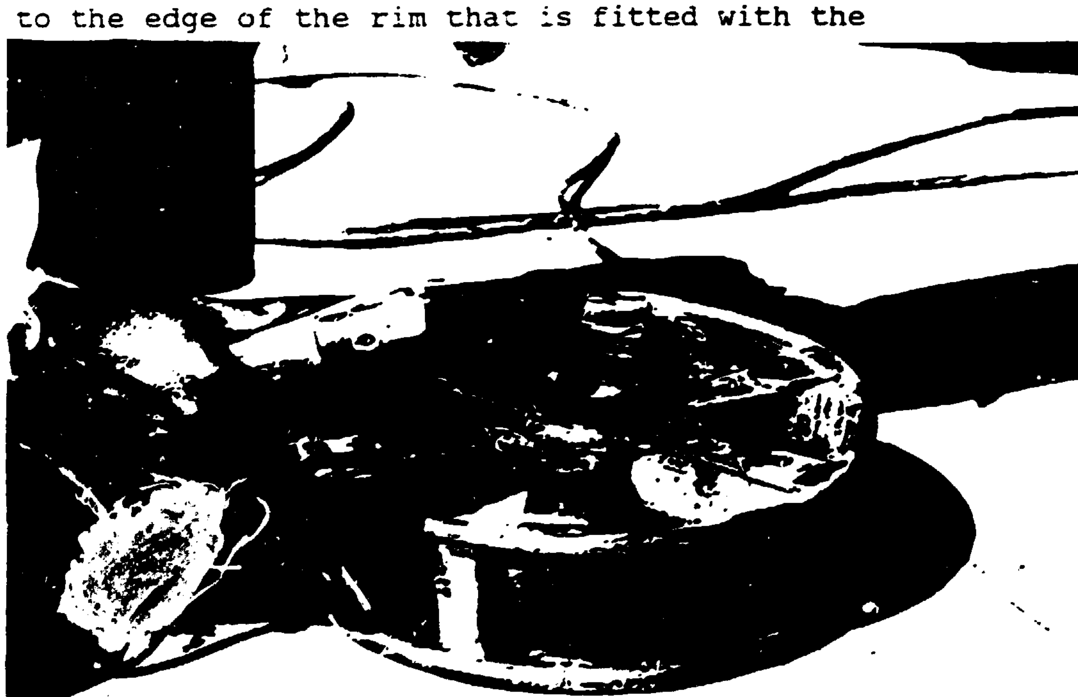
14. Fit the hub on the correct guides and position it at the correct hight, measure the length from the hub to the rim for the spokes.

15. Cut six spokes from 50x50x6 angle weld them in place. They must be flush with the top edge of the rim. Remove the rim from the jig to complete the welding.

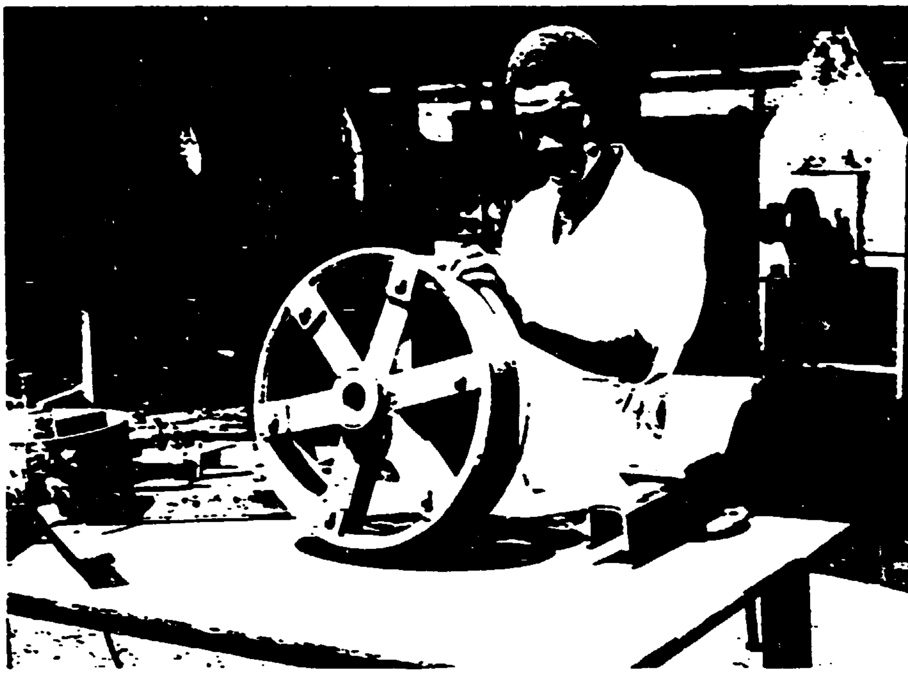


16. Hammer one bead ring so that it is a good, but loose, fit over the rim.

17. Tack it to the edge of the rim that is fitted with the spokes.



18. Cut six pieces of 50x6 or 50x8 flat 50mm long and place them on the spokes next to the bead ring. Weld them to the bead.

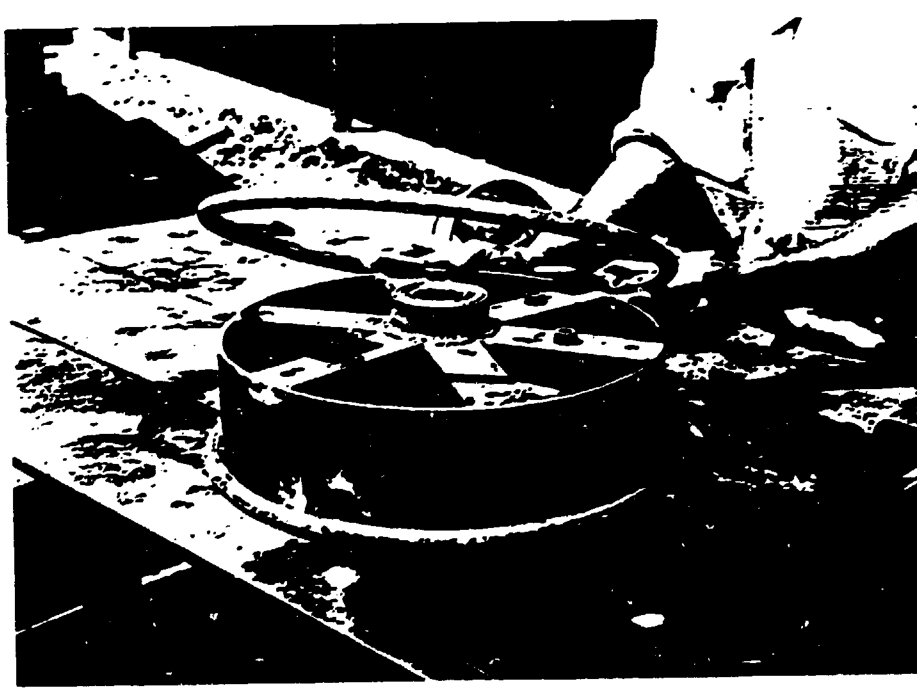


19.Drill 13mm holes to take 12mm bolts for clamping. Break the tacks and remove the bead ring, weld the pieces on the other side.

20.Fit the other bead and weld it to the other side of the rim. Weld it on the edge of the rim allowing as much space as possible for the tyre.

21.Drill an 13mm hole for the valve.

22.Grind and smooth off any welds or burrs that could cause punctures.



PUNCTURE PROOF WHEEL FOR SCOTCH CARTS

The wheel has 6 spokes and is basically an old style steel rim wheel but with a tyre tread streached over the rim to prevent soil erosion and allow quiet running on tar roads.

1. Measure the diameter of the old tyre you are going to use. To work out the length of flat bar you need multiply this diameter you have just measured by Pi (3.14).
For example:
    If the tyre is 600mm diameter then the length of flat bar you will need is: 600 x 3.14 = 1884mm

----

2. Bend this length of bar in the bending machine using the number of turns you estimate will be required by looking at the callibration graph at the end of this manual as a guide.

3. Fit the rim as best you can into the jig or make a dedicated jig.

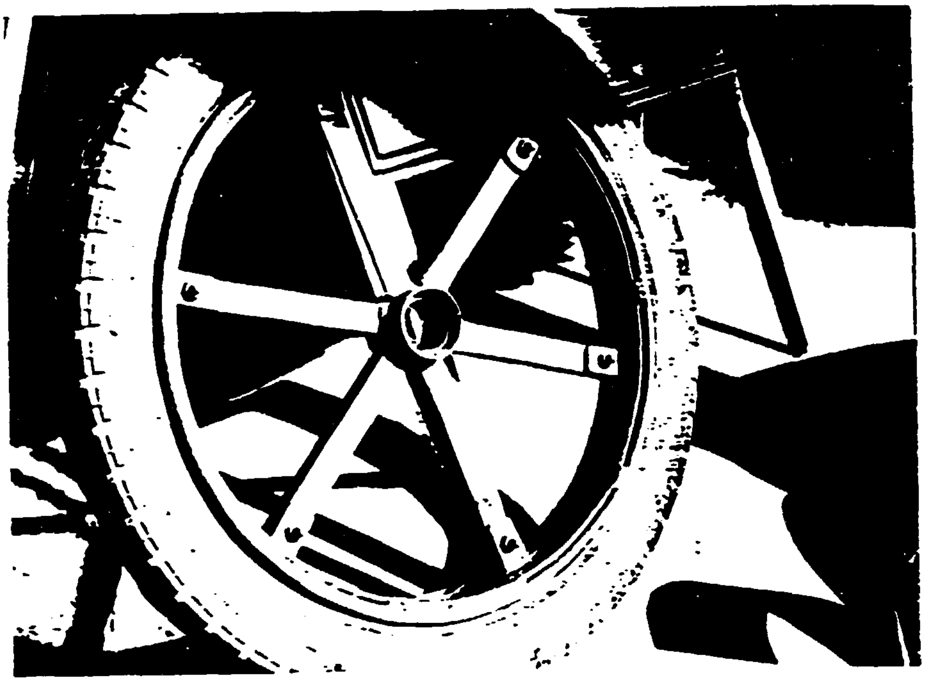
4. Make a hub as for a normal wheel.

5. Weld in the spokes. Use 50x50x6 angle or stronger material.

6. Cut the beads off the old tyre where the side wall is thin and easy to cut.

7. Stretch it onto the rim using levers and a hammer. It must be tight.

MAKING WHEELS SUITABLE FOR 18" MOTORCYCLE TYRES



1. Bend a former on the machine from any 6mm or 8mm flat bar.
   To do this:
   a) Cut a length 1366mm long.
   b) Bend as for a car tyre rim with the machine set at 6 & 1/4 turns.
   c) Weld up the ends of the rim and make sure it is a very good circle.
   d) Fit at least 3 pieces of round bar across the inside of the former to make it strong.
2. Cut a piece of 50 mm flat 1412mm long and 2 pieces of 10 or 12mm re-bar 1467mm long.
3. Bend the flat and re-bar around the former, clamp the ends and weld them together.
4. Fit one of the beads to the rim and weld in place.
5. Clamp the rim in the jig with the bead pulled up against the clamping screws and fit the hub on the centre of the jig using the correct guide. The best type of hub to use is one that takes 6205 bearings.
6. Cut 6 pieces of 25x25x4 (or 25x25x5) angle to fit between the hub and the rim. Weld them in place with a flat face flush with the edge of the rim. (This is the same method as used on the scotch cart rims).
7. Cut 12 pieces of 25 wide flat 30mm long.
8. Place the other bead on the rim and tack it in position. Place the pieces of 25mm flat on top of the spokes pushed up against the bead and weld them to the bead.
9. Drill through the angle pieces to take 8mm bolts.
11. Drill a valve hole.
12. Remove the tack weld holding the two halves together grind or file any welds or burrs that could cause punctures.

MAKING A PUNCTURE PROOF HAND CART TYRE

1. Cut a piece of 30x30x4 angle 1800mm long.

2. Mark it with chalk every 25mm.

3. Zero the machine then set it to   turns.
   (the rollers should be in the inner position)

4. Bend the angle in the machine, the ends should overlap when you are finished.

5. Clamp the whole piece in the jig so you can see where to cut off the ends to make a good wheel. Mark where to cut off the ends.

6. Cut the ends off where you have marked then put the rim back in the jig and clamp it up.

7. Weld the ends where they join.

8. Make a hub, 6205 bearings are best but a wheelbarrow type axle could be used.

9. Fit the hub onto the centre post of the jig using **the correct** guides.

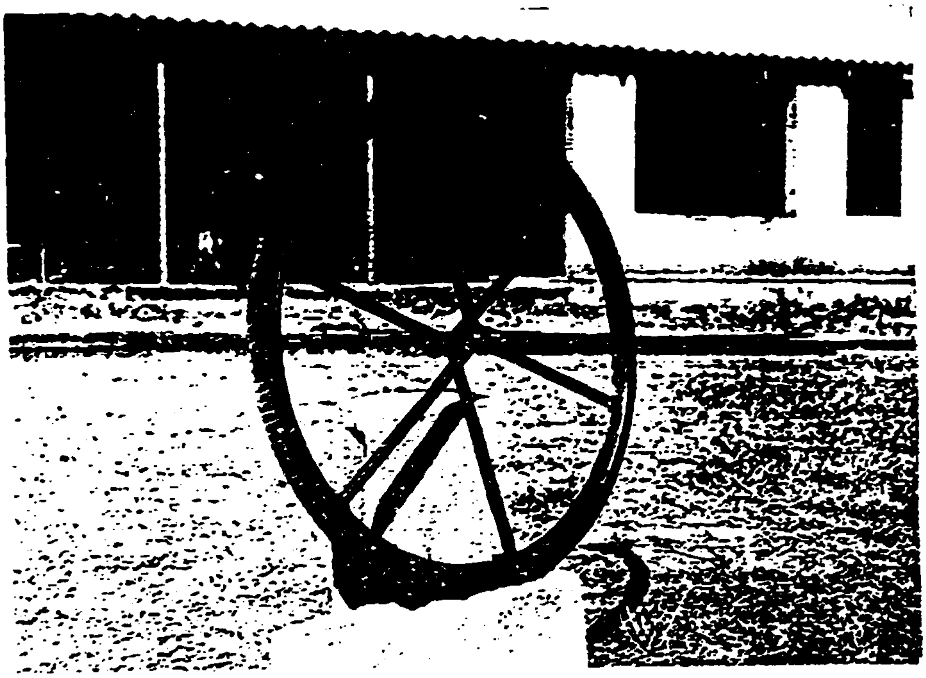
10. Measure the length for the spokes and cut 6 spokes **from 12mm** bar.

11. Weld the spokes in position.

12. Remove the wheel from the jig and complete the **welding.**

13. Fit the tyre with tyre levers.

MAKING WHEELS FOR BICYCLE TYRES



1. Put the rollers in the **outer** position.

2. Cut a length of 25x25x4 angle 2400mm long.

3. Mark the angle every **50mm** with chalk.

4. Zero the bender by putting a straight piece of **angle in and** screwing the stop up until it just touches the **lever arm.**

5. For a 26" wheel screw the stop down turns,
   For a 28" wheel screw the stop down turns.

6. Bend the rim, it will overlap towards the end.

7. Set the jig to the correct size and fit the rim . **Mark the rim** where the ends should be cut off. Remove from **the machine and** cut off the ends. Fit the rim back into the jig **and weld the ends** together.

The tyre should be a tight fit on the rim, difficult to fit by hand.

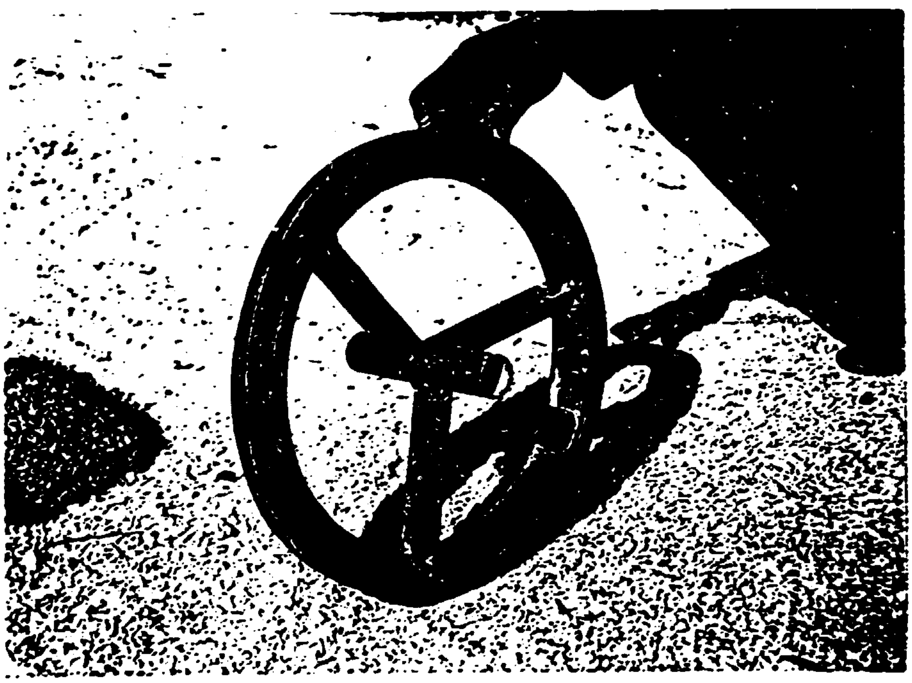
8. Fit the hub to the jig, measure the distance from the inside of the rim to the hub.

9. Cut 6 pieces of 12mm round bar (for spokes) to this length.

10. Weld in the spokes.

11. Drill a valve hole opposite the welded joint.
12. Remove any weld or burrs that could cause punctures.

WHEEL BARROW WHEELS



1. Cut a piece of 30x30x4 angle 1300mm long.

2. Zero the machine and set it to turns.

3. Mark the bar every 25mm and bend the rim.

4. This rim will fit in the jig on the 12" setting.

5. Cut a length of pipe for the hub.

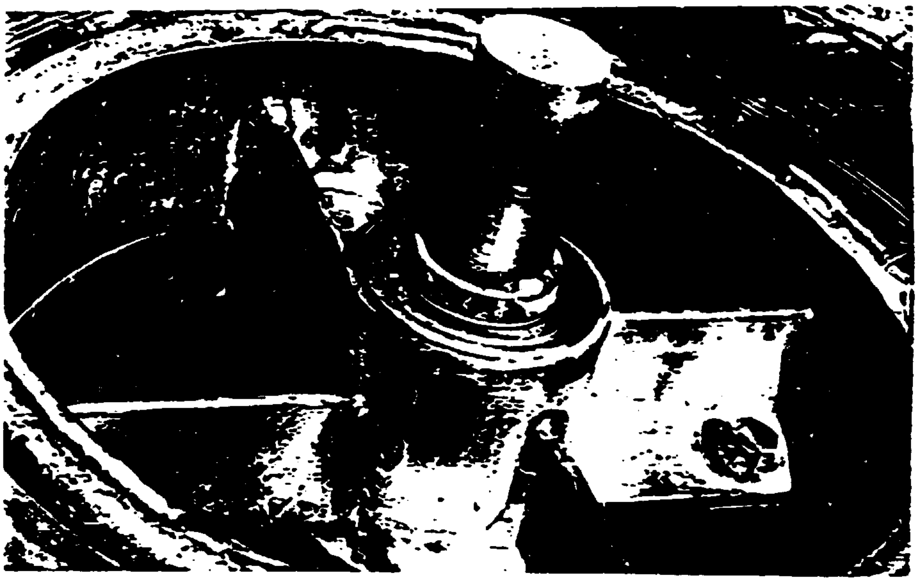
6. Fit spokes to your design.

7. Fit the tyre with tyre levers.

AXLES AND HUBS

The following axles and hubs can be made without using a lathe machine.

SCOTCH CART HUB AND AXLE (TO TAKE 6208 BEARINGS)

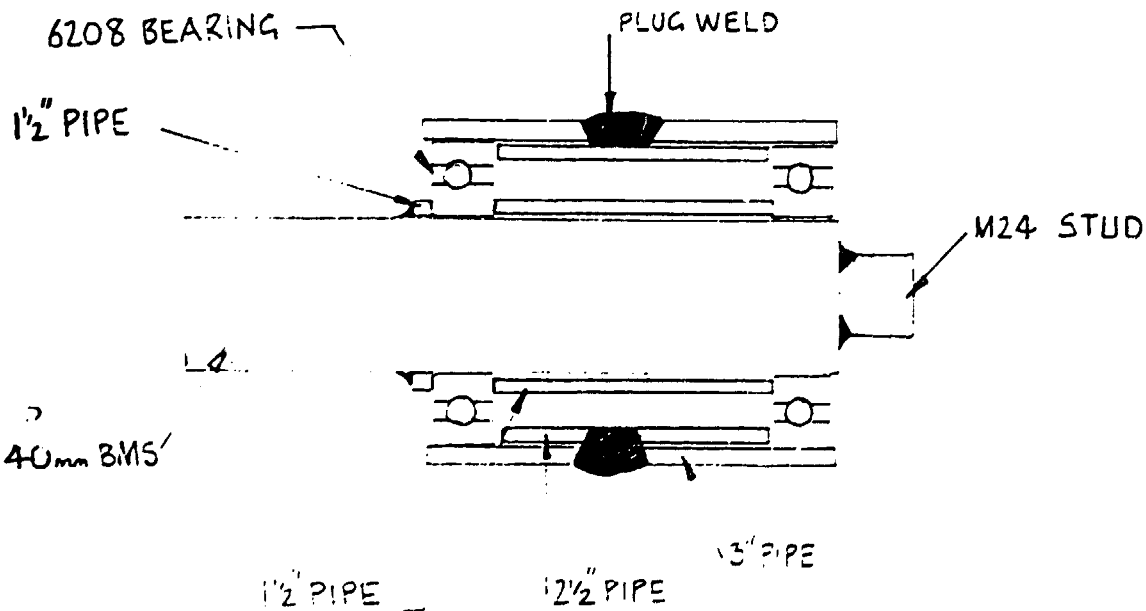


1. Cut 3 inch pipe 110mm long
   2&1/2 inch pipe 70mm long
   1&1/2 inch pipe 72mm long

NOTE: The 1&1/2 inch pipe MUST be slightly longer than the 2&1/2 inch pipe to prevent damage to the bearings when the axle nut is tightened up.

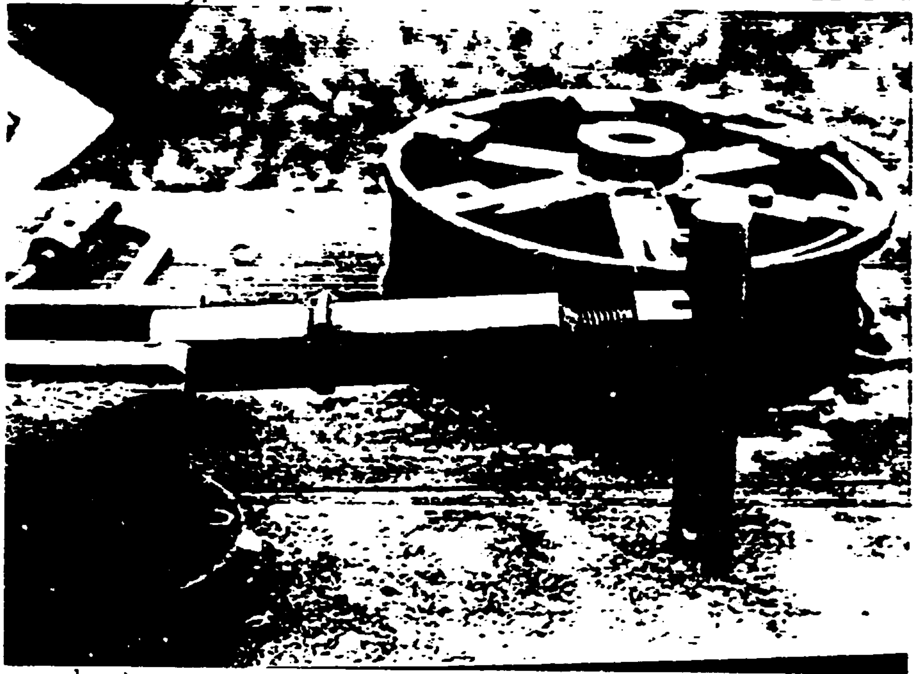
2. Slit the 3 inch pipe along the weld seam and nip it up so that the 6208 bearings are a tap fit in the pipe.

3. Drill 2 holes(as large as possible, eg 13mm or more) in the 3 inch pipe and plug weld the 2&1/2 pipe in place.



4. Cut a piece of 40mm BMS 200mm long and weld a 30 mm length of M20 studding to one end. Chamfer the studding well to give a strong weld.

4. Fit one bearing to the hub, drop in the 1&1/2 inch pipe and tap in the other bearing. Push the axle into the bearings and position it so that the threaded end is 2mm or 4mm out of the outer bearing (see the sketch). Tack a collar behind the inner bearing, remove the axle and weld the collar in place.



5. Make some dust caps.

IMPORTANT NOTES:

a) The small 1&1/2 inch pipe is essential to prevent damage to the bearings from over tightening, it must be longer than the 2&1/2 inch pipe and the ends must be square.

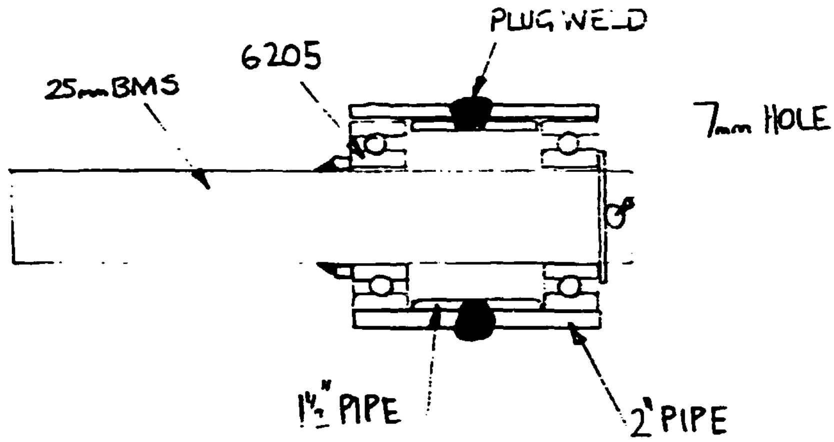
b) The bearings should be a light push fit on the axle NOT a hammer on fit. Use emery cloth to polish the shaft if necessary apply some oil so that the bearings slide freely.

c) The bearings should be a tap in fit into the 3 inch pipe you should NOT be able to push them in by hand.

d) Dust caps are very important, take time to make good ones.

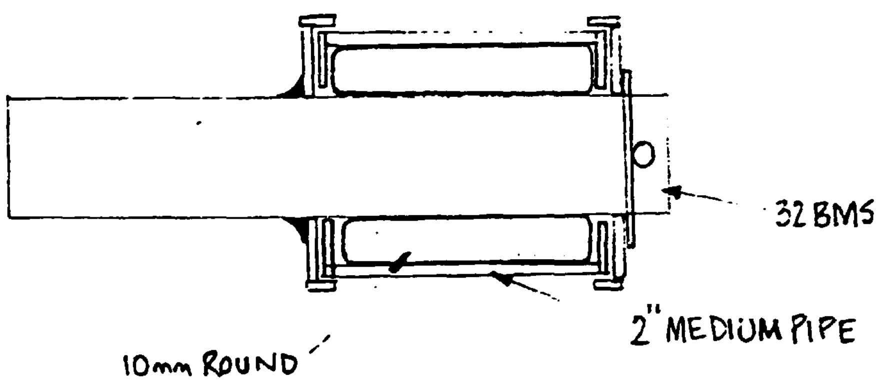
HAND CART HUB AND AXLE (TO TAKE 6205 BEARINGS)

This is similar to the scotch cart axle but uses 6205 bearings and is constructed in the same way. A hand cart fitted with this axle will be able to carry up to 350kg on rough ground.



HOME MADE HAND CART HUB AND AXLE

It is possible to make a very strong and long lasting bearing for a hand cart using mild steel. The design is shown below:



Using 32mm BMS for the axle means that the cart can carry larger loads than the axle with 6205 bearings around 500kg.

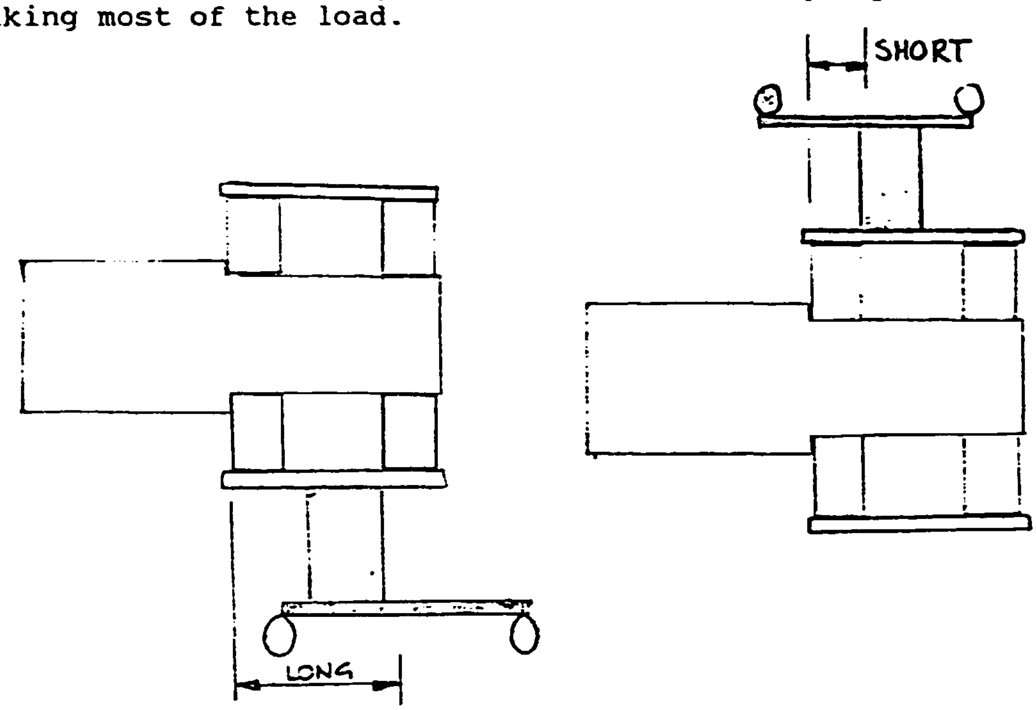
IMPORTANT: If you use this design make sure the weld seam is removed from the inside of the water pipe. The easiest way to do this is to grind the end of an old chisel or punch so that it can be used to carve or chisel out the weld.

HUB AND AXLE FOR BICYCLE TYPE WHEEL

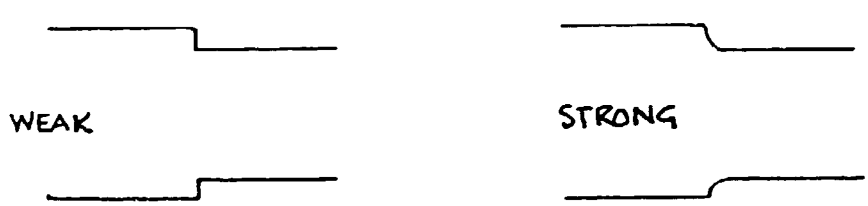
The same axles as the hand cart can be used for a cart or trailer fitted with the bicycle type wheel.
An alternative is to use a standard bicycle rear axle with a hub made from 1" pipe. Bicycle cones are tapped into the pipe to take the balls. Use light duty, thin wall pipe and cups from Victory stores Harare (address at the end of this manual).

SOME DESIGN TIPS FOR STRONG AXLES:

1. Keep the wheel centre as close to the box part of the axle as possible, ie. keep the stub short.
   But:
   Keep the wheel centre near the middle of the hub, in between the two bearings otherwise one bearing may be taking most of the load.

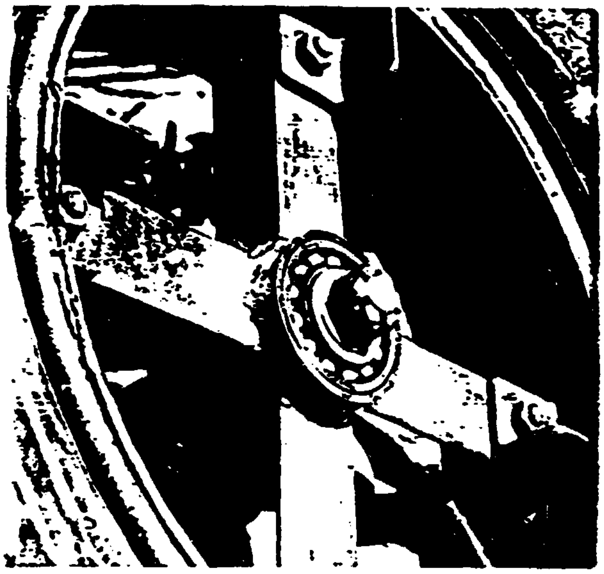


2. If you buy an axle that has been machined on a lathe (or you get one specially machined) make sure the step on the shaft is radiused, not sharp, a sharp step will lead to the axle cracking at this point after some time.

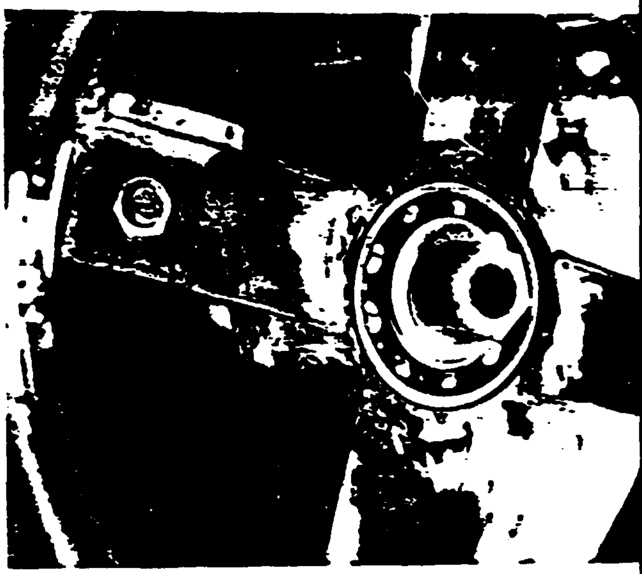


3. Weld the stub onto one half of the box part of the axle then fit the other half, don't just tack the stub in place then weld around the end with the box complete, the weld is sure to crack. If you are welding a broken stub then either open up the box and grind out the old stub or remove part of the box near the end to remove the old stub. If you must use the broken stub again then chamfer the ends and weld together removing the slag each layer of weld otherwise it will break again.

4. When making your own scotch cart hubs from pipe remember there will be distortion where the spokes are welded on to the hub pipe, make sure that there is at least 5mm clearance between the edge of the spoke and the place for the bearing. This is especially important with galvanised pipes since the zinc tends to bubble up inside the pipe. Black pipe is better and cheaper than galvanised.

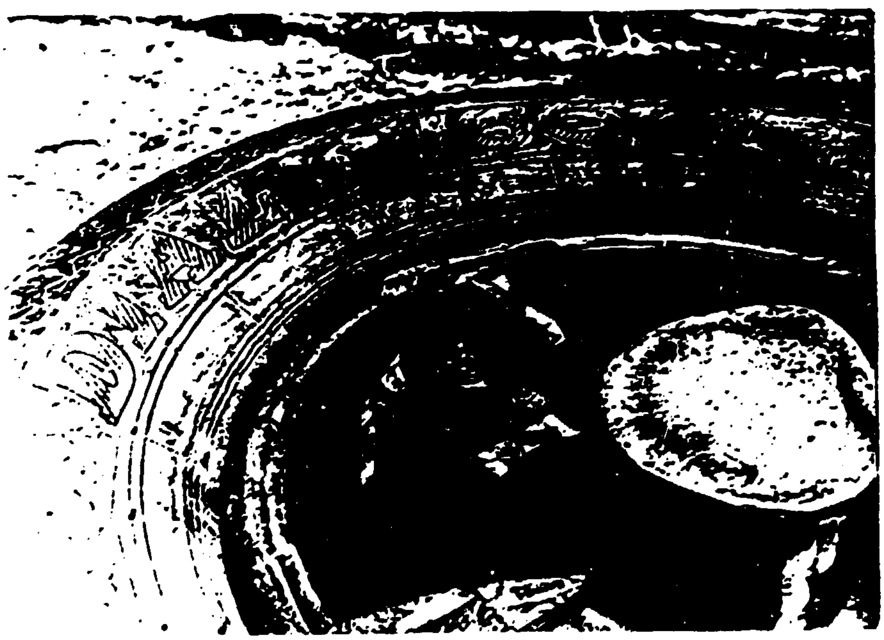


Correct position for spokes

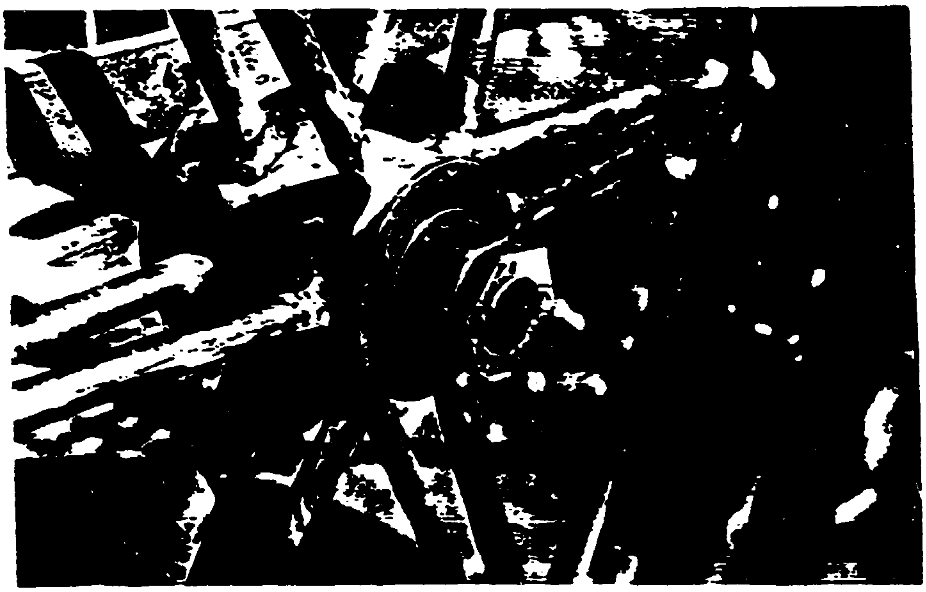


Wrong/welding will distort pipe where bearings fit.

5. Dust caps full of grease are very important. Once fitted the farmer should not need to touch the bearings at all. If good dust caps are fitted (that are difficult for the farmer to remove) then the axle and bearings will stay clean and last for many years. If the quick release nuts are fitted then when the cart gets a puncture it is easy to remove the tube and the farmer will not be tempted to remove the wheel by the axle nut.



6. Lock nuts or a locking pin are essential. Never leave an * axle with only one normal nut it WILL come loose especially on the left side.



7. When welding the axle with the bearings in place take care to fit the earth clamp to the axle NOT the rim otherwise the electricity will have to go through the bearing and arcing will occur in the bearing making it rough or seized and reducing its life.

MATERIALS SUPPLIERS IN HARARE

STEEL: BALDWINS (Southerton--Auckland Rd)

LAYSAGHT (Harare--Aspindale)

STEEL CENTRE

BUDGET

ENFIELD (Southerton--Plymouth/Hobbs Rd)
(ENFIELD STOCK BRIGHT MILD STEEL (BMS) AND HIGH CARBON STEELS)

PIPES: STEWARTS AND LLOYDS (Harare--Leopold Takawira/Bute St)

J.MANN (Southerton--Plymouth/Hobbs Rd)

SIYASO (Also a good source of water pipe for hubs)

NUTS, BOLTS, STUDDING AND WASHERS:

C.T. BOLTS (Harare--Leopold Takawira /Bute St)

GLYNNS (Workington--Bristol Rd)

GREATEROX WASHERS (Harare--Mbuya Nehanda St/Rudd St)

NEW BEARINGS: I.A.E. in Hatcliffe have a supply of cheap new bearings imported from china.

MACHINING SERVICES:

Most machining services in Harare are very expensive. The cheapest yet found that do a good job are:

D.I.C. Engineering,
Gazaland.
Next to Mushandira Pamwe Bus Garage
254th Street
Left off Willowvale Road after Budget steel.

Cold comfort farm,
Tynewald
Turn left just before the new bridge

The following table gives approximate diameters of water pipes and is useful for designing your own hubs.

Light

Nominal Bore		Average O/D	Thickness Light	
mm	inch	mm	mm	inch
8	¼	13.4	1.8	0.072
10	⅜	16.9	1.8	0.072
15	½	21.2	2.0	0.080
20	¾	26.6	2.35	0.092
25	1	33.5	2.65	0.104
32	1¼	42.2	2.65	0.104
40	1½	48.1	2.9	0.116
50	2	59.9	2.9	0.116
65	2½	75.6	3.25	0.128
80	3	88.3	3.25	0.128
100	4	113.4	3.65	0.144

A more accurate value for the bore of the pipe can be found using:

O/D minus 2 x thickness

eg. for 3" light pipe
88.3 minus 6.5 = 81.8
not 80mm shown as nominal bore.
That is why the 3" pipe must be cut and nipped up to give exactly 80mm.

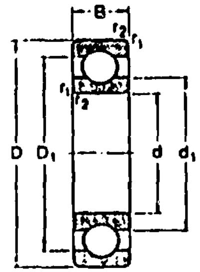
Medium and Heavy

Nominal Bore		Average O/D	Thickness			
			Medium		Heavy	
mm	inch	mm	mm	inch	mm	inch
8	¼	13.6	2.35	0.092	2.9	0.116
10	⅜	17.1	2.35	0.092	2.9	0.116
15	½	21.4	2.65	0.104	3.25	0.128
20	¾	26.9	2.65	0.104	3.25	0.128
25	1	33.8	3.25	0.128	4.05	0.160
32	1¼	42.5	3.25	0.128	4.05	0.160
40	1½	48.4	3.25	0.128	4.05	0.160
50	2	60.3	3.65	0.144	4.5	0.176
65	2½	76.0	3.65	0.144	4.5	0.176
80	3	88.8	4.05	0.160	4.85	0.192
100	4	114.1	4.5	0.176	5.4	0.212
125	5	139.6	4.85	0.192	5.4	0.212
150	6	165.1	4.85	0.192	5.4	0.212

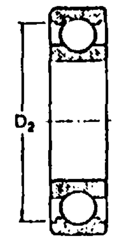
BS1387 Tubes are available, self colour, varnished, or galvanised, with plain ends, bevelled ends or screwed and coupled.
Our stocks normally consist of self colour tubes with plain ends, plus some galvanised tubes with plain ends and some varnished screwed and coupled.
The above charts are based on self colour tubes with plain ends.

The following are sizes and numbers of deep groove ball bearings some of which can be used as wheel bearings.

Deep groove ball bearings
single row
d 35–55 mm

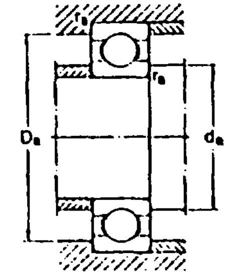


With full outer ring shoulders



With recessed outer ring shoulders

Principal dimensions d	D	B	Basic load ratings dynamic C	static C_0	Fatigue load limit P_u	Speed ratings Lubrication grease	oil	Mass	Designation
mm			N		N	r/min		kg	–
35	47	7	4 750	3 200	166	13 000	16 000	0,030	61807
	55	10	9 560	6 200	290	11 000	14 000	0,080	61907
	62	9	12 400	8 150	375	10 000	13 000	0,11	16007
	62	14	15 900	10 200	440	10 000	13 000	0,16	6007
	72	17	25 500	15 300	655	9 000	11 000	0,29	6207
	80	21	33 200	19 000	815	8 500	10 000	0,46	6307
	100	25	55 300	31 000	1 290	7 000	8 500	0,95	6407
40	52	7	4 940	3 450	186	11 000	14 000	0,034	61808
	62	12	13 800	9 300	425	10 000	13 000	0,12	61908
	68	9	13 300	9 150	440	9 500	12 000	0,13	16008
	68	15	16 800	11 600	490	9 500	12 000	0,19	6008
	80	18	30 700	19 000	800	8 500	10 000	0,37	6208
	90	23	41 000	24 000	1 020	7 500	9 000	0,63	6308
	110	27	63 700	36 500	1 530	6 700	8 000	1,25	6408
45	58	7	6 050	4 300	228	9 500	12 000	0,040	61809
	68	12	14 000	9 800	465	9 000	11 000	0,14	61909
	75	10	15 600	10 800	520	9 000	11 000	0,17	16009
	75	16	20 800	14 600	640	9 000	11 000	0,25	6009
	85	19	33 200	21 600	915	7 500	9 000	0,41	6209
	100	25	52 700	31 500	1 340	6 700	8 000	0,83	6309
	120	29	76 100	45 000	1 900	6 000	7 000	1,55	6409
50	65	7	6 240	4 750	250	9 000	11 000	0,052	61810
	72	12	14 600	10 400	500	8 500	10 000	0,14	61910
	80	10	16 300	11 400	560	8 500	10 000	0,18	16010
	80	16	21 600	16 000	710	8 500	10 000	0,26	6010
	90	20	35 100	23 200	980	7 000	8 500	0,46	6210
	110	27	61 800	38 000	1 600	6 300	7 500	1,05	6310
	130	31	87 100	52 000	2 200	5 300	6 300	1,90	6410
55	72	9	8 320	6 200	325	8 500	10 000	0,083	61811
	80	13	15 900	11 400	500	8 000	9 500	0,19	61911
	90	11	19 500	14 000	695	7 500	9 000	0,26	16011
	90	18	28 100	21 200	900	7 500	9 000	0,39	6011
	100	21	43 600	29 000	1 250	6 300	7 600	0,61	6211
	120	29	71 500	45 000	1 900	5 600	6 700	1,35	6311
	140	33	99 500	62 000	2 600	5 000	6 000	2,30	6411



Dimensions d	d_1 ≈	D_1 ≈	D_2 ≈	$r_{1,2}$ min	Abutment and fillet dimensions d_a min	D_a max	r_a max
mm					mm		
35	38,7	43,5	–	0.3	37	45	0.3
	41,6	48,6	–	0.6	39	51	0.6
	44	53,3	–	0.3	37	60	0.3
	43,7	53,6	55,7	1	40	57	1
	46,9	60,6	62,7	1,1	41,5	65,5	1
	49,5	66,1	69,2	1.5	43	72	1,5
	57,4	80,6	–	1.5	43	92	1,5
40	43,7	48,5	–	0.3	42	50	0.3
	47	55,2	–	0.6	44	58	0.6
	49,4	57	–	0.3	42	66	0.3
	49,2	59,1	61,1	1	45	63	1
	52,6	67,9	69,6	1,1	46,5	73,5	1
	56,1	74,7	77,7	1,5	48	82	1,5
	62,8	88	–	2	49	101	2
45	48,7	54,5	–	0.3	47	56	0.3
	52.3	60,8	–	0.6	49	64	0.6
	55	65,4	–	0.6	49	71	0.6
	54,7	65,6	67,8	1	50	70	1
	57,6	72,9	75,2	1.1	51,5	78,5	1
	62,1	83,7	86,7	1,5	53	92	1,5
	68,9	96,9	–	2	54	111	2
50	54,7	60,5	–	0.3	52	63	0.3
	56,8	65,3	–	0.6	54	66	0.6
	60	70,4	–	0.6	54	76	0.6
	59,7	70,6	72,8	1	55	75	1
	62,5	78,1	81,7	1,1	56.5	83.5	1
	68,7	92,1	95,2	2	59	101	2
	75,4	106	–	2,1	61	119	2
55	60.2	67	–	0,3	57	70	0.3
	63	72,1	–	1	60	75	1
	67	78	–	0.6	59	86	0.6
	66,3	79,1	81,5	1,1	61,5	83,5	1
	69	86,6	89,4	1,5	63	92	1,5
	75,3	101	104	2	64	111	2
	81,5	115	–	2,1	66	129	2

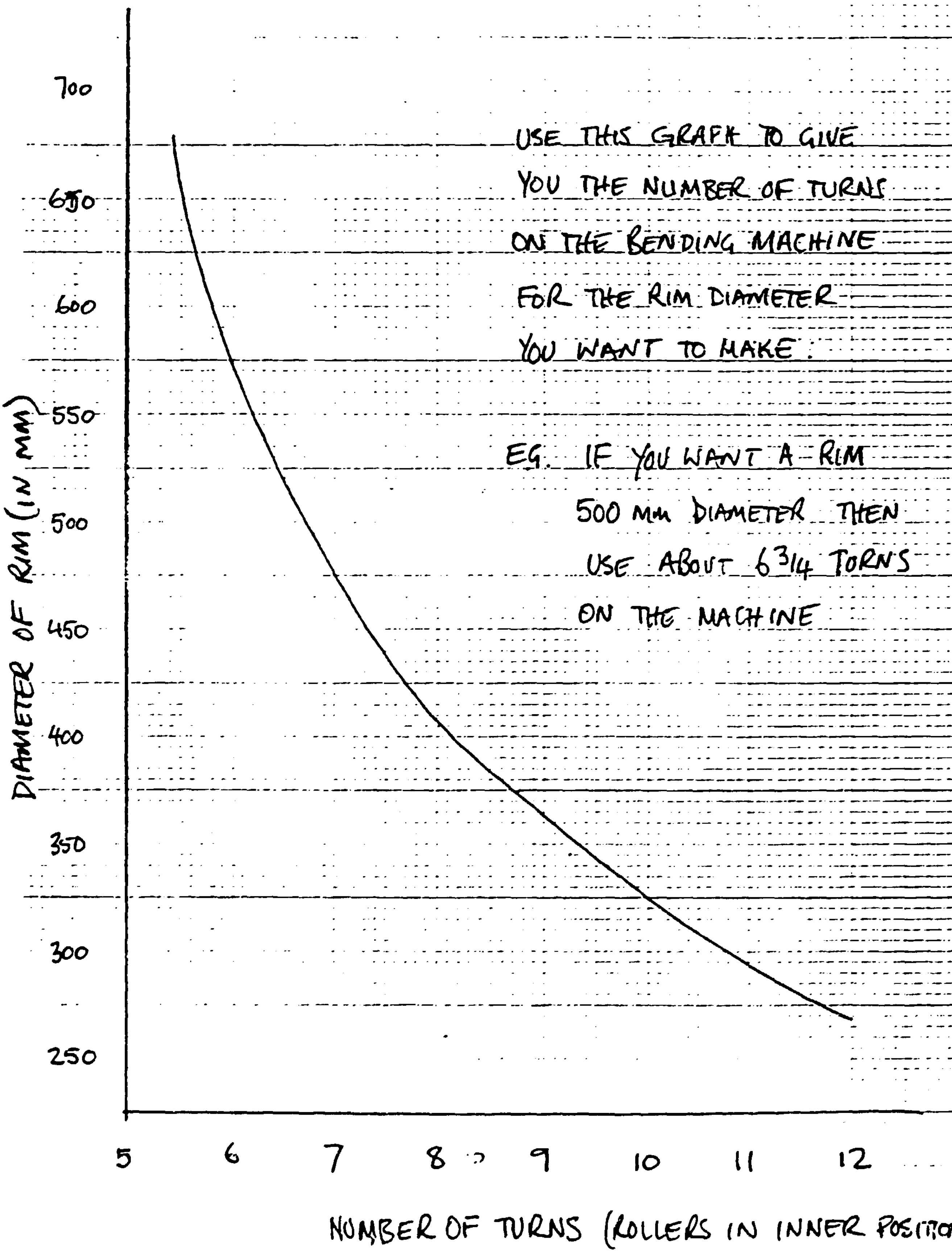
TYRE SIZE	LENGTH OF FLAT	LENGTH OF RE-BAR
13 INCH	983mm	1300mm
14 INCH	1065mm	1400mm
15 INCH	1140mm	1500mm
16 INCH	1230mm	1600mm
18 INCH	1412mm	1460mm
26"& 28"	2400mm of angle	

TYRE SIZE	TURNS FOR RIM	TURNS FOR ROUND BAR
13 INCH		
14 INCH		
15 INCH		
16 INCH		
18 INCH		
26 INCH		
28 INCH		
SCANIA WHEEL		
WHEELBARROW WHEEL		

The above is a rough guide, the exact number of turns will depend on the quality of the steel being used.

If the rim comes out the wrong diameter change the number of turns a small amount and use this new setting. Once the machine is set correctly bend all the rims at once that you need from a batch of steel on this setting rather than just bending rims for one wheel then changing the setting for another size then back again etc.

CALLIBRATION GRAPH

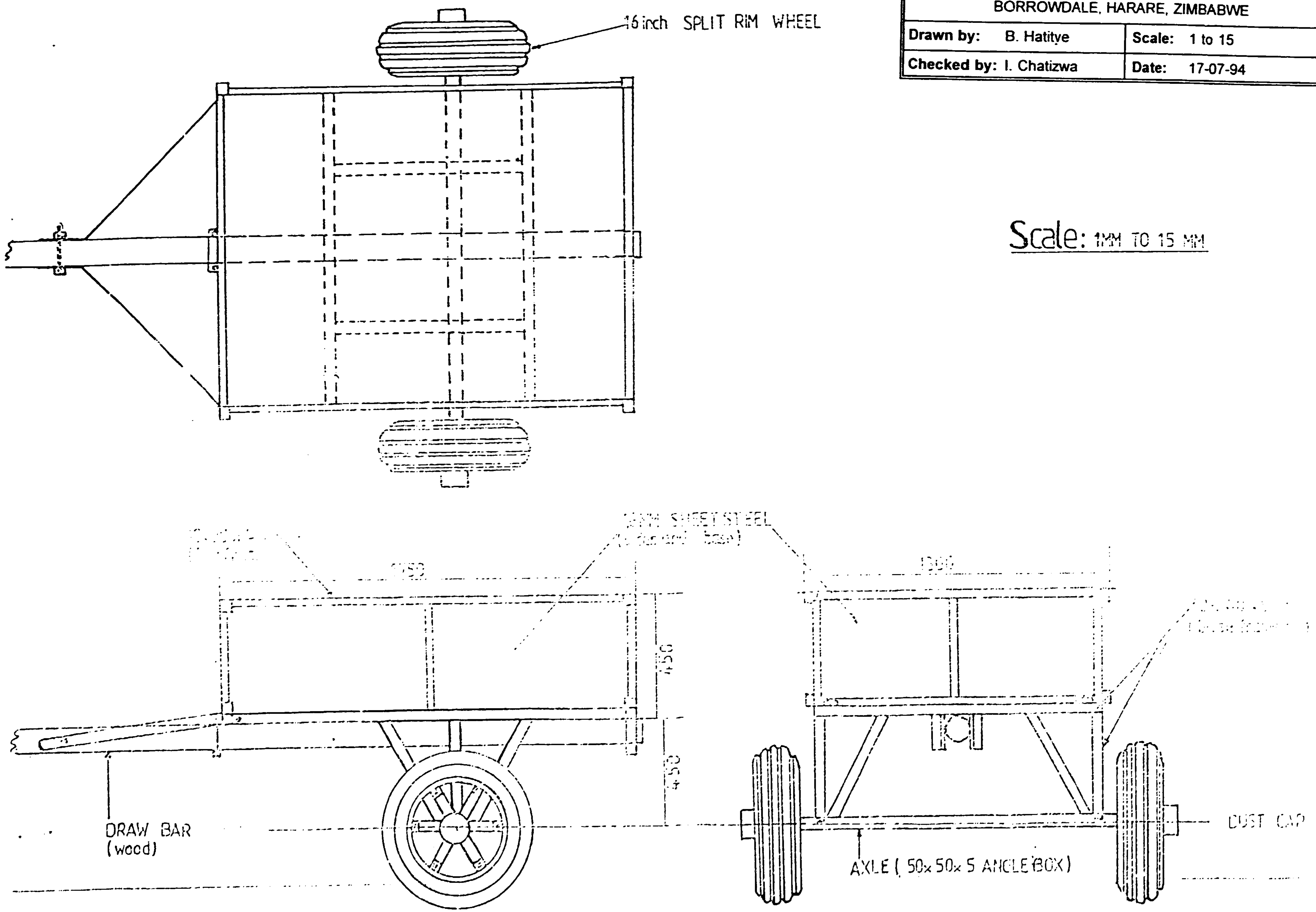


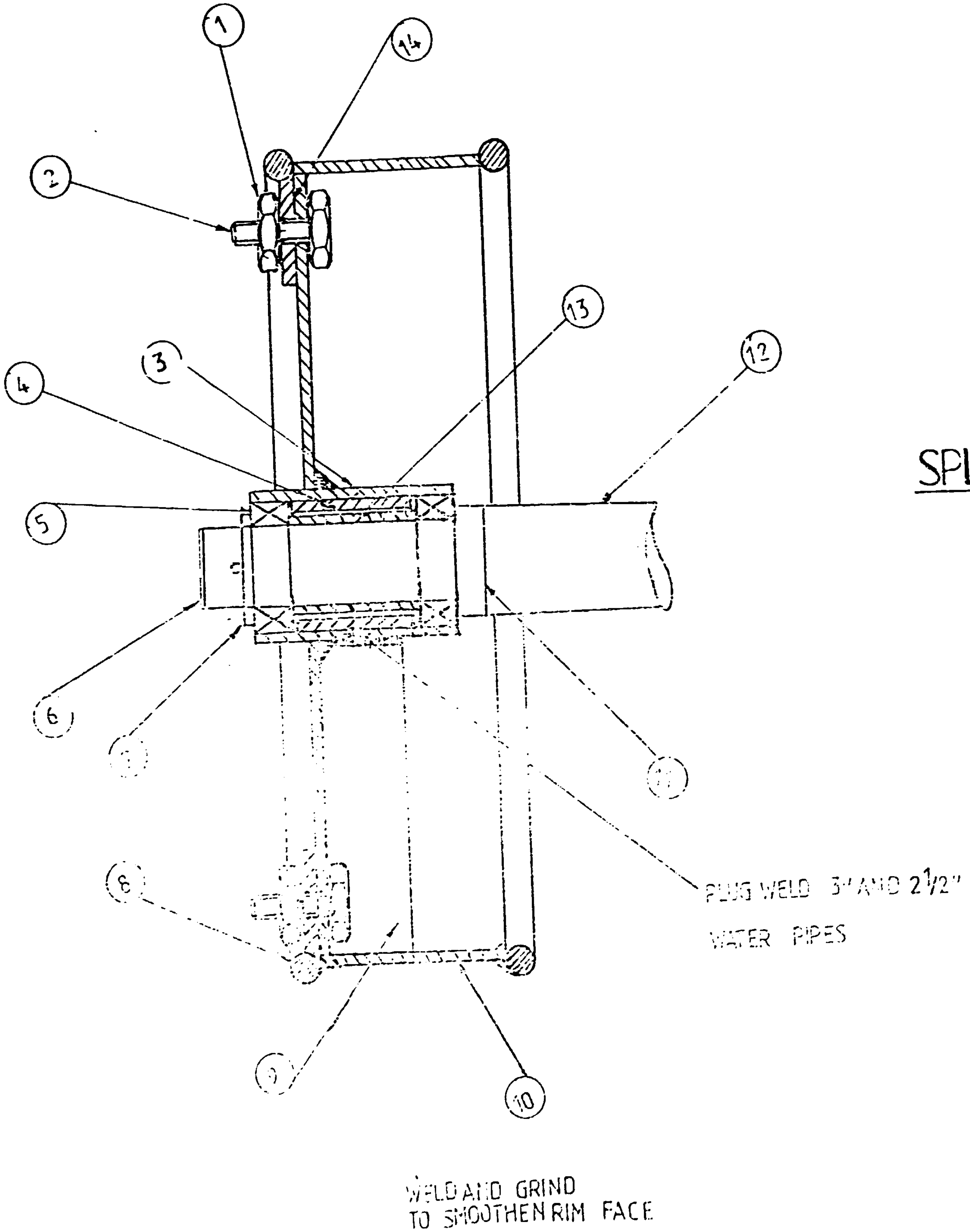
ANNEX 5: DESIGN DETAILS OF OX-CART AND AXLE ASSEMBLY

SCOTCH CART WITH SPLIT RIM WHEELS

INSTITUTE OF AGRICULTURAL ENGINEERING	
BORROWDALE, HARARE, ZIMBABWE	
Drawn by: B. Hatitye	**Scale:** 1 to 15
Checked by: I. Chatizwa	**Date:** 17-07-94

Scale: 1MM TO 15 MM





SPLIT RIM WHEEL (16 inch)

Scale: 1MM TO 2,5 MM

INSTITUTE OF AGRICULTURAL ENGINEERING	
BORROWDALE, HARARE, ZIMBABWE	
Drawn by: B. Hatitye	**Scale:** 1 to 2.5mm
Checked by: I. Chatizwa	**Date:** 17-07-94

MATERIAL LIST FOR AN 16 INCH SPLIT-RIM WHEEL

PART No.	ITEM	QTY	SIZE/OR SPECIFICATION	LENGTH	MtL
1	Nut	6	M12		
2	Bolt	6	M12	25mm	
3	Outer Hub Plate	1	3 Inch	110	Water/Pipe
4	Inner Hub Plate		2 1/2	70	Water/Pipe Galvanised
5.	Bearing	2	6203 2RS	-	
6.	Hub shaft	1	Dia-30mm	[illegible]	[illegible]
7.	Nut-Washer	1	1040 OD 65mm	3 (0.6mm) [illegible]	MS Sheet
8.	Bend	2	Dia 16mm	[illegible]	[illegible]
9.	Spoke	4	[illegible]	[illegible]	[illegible]
10.	Rim Bar	1	[illegible] Flat	[illegible]	[illegible]
11.	Spacer [illegible]	1	[illegible] (inside)	—	[illegible]
12.	Axle	1	[illegible]	[illegible]	[illegible]
13.	Bearing spacer	1	1 1/2 [illegible]	[illegible]	Water Pipe
14.	Bolt clamps	6	50.5 flat	50 [illegible]	MS

Note: MS = Mild Steel
BMS = Bright Mild Steel

POOR QUALITY ORIGINAL

ANNEX 6: MEASUREMENT OF LOADS ON OX-CART WHEELS

ANNEX 6: MEASUREMENT OF LOADS ON OX-CART WHEELS

Loads were measured by attaching strain-gauges to the stub axle of a wheel-axle assembly and carrying out static calibration tests to relate the strain-gauge outputs to the loads acting on the wheel. The gauges were mounted in such a way that the vertical and side loads acting on the wheel could be separated and also the net stress on the axle measured.

Results were recorded on a data logger (Campbell Scientific Type 21 X) owned by IAE. This can give outputs of dynamic strain variation if linked to a computer, but unfortunately the software needed to do this was not available. A built-in programme was therefore used to measure the frequency of occurrence of stress (and therefore load) levels in different band widths. If enough measurements are taken, this gives a reasonably accurate record of the range of impact loads on the wheel and axle and how frequently they occur. Six bands were used to cover the full range of loads acting on the wheels. Spot checks were also made using a storage oscilloscope (part of the instrumentation for the wheel test-rig) to record the dynamic strain variation (and hence impact loads) when running over particularly bumpy parts of the test track.

Tests were carried out on an ox-cart pulled by two donkeys. The total all-up weight (cart weight + load + operator) of the cart was 590kg. Tests were carried out on two surfaces:

- a reasonable earth track with some rocky sections;
- off-track on fairly rutted and uneven ground.

Two series of tests were carried out:

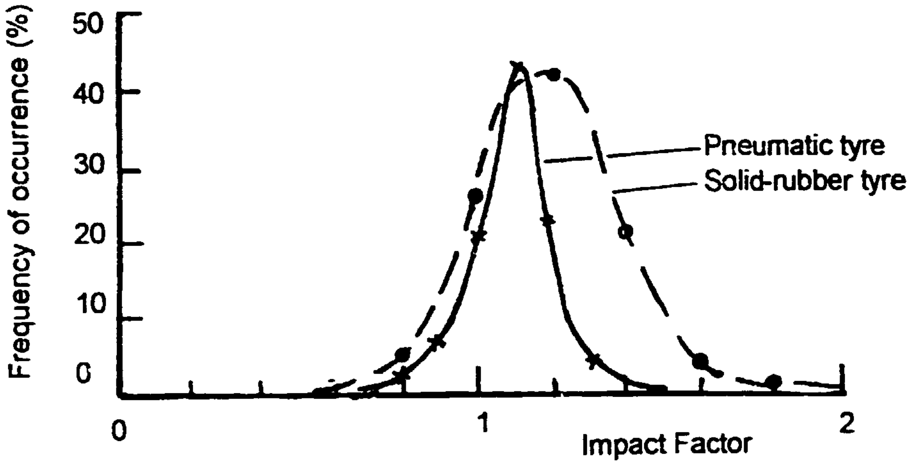
- June 1992, to establish testing techniques and procedures and to obtain preliminary measurements of wheel loads;
- July 1993, to obtain more comprehensive results of wheel and axle loads for different types of tyres.

A further series of tests were carried out in September 1994 to investigate the performance of puncture-resistant tyres. These did not separate out the wheel loads but compared the levels of impact loading for different tyres and were a useful comparison for the earlier test results.

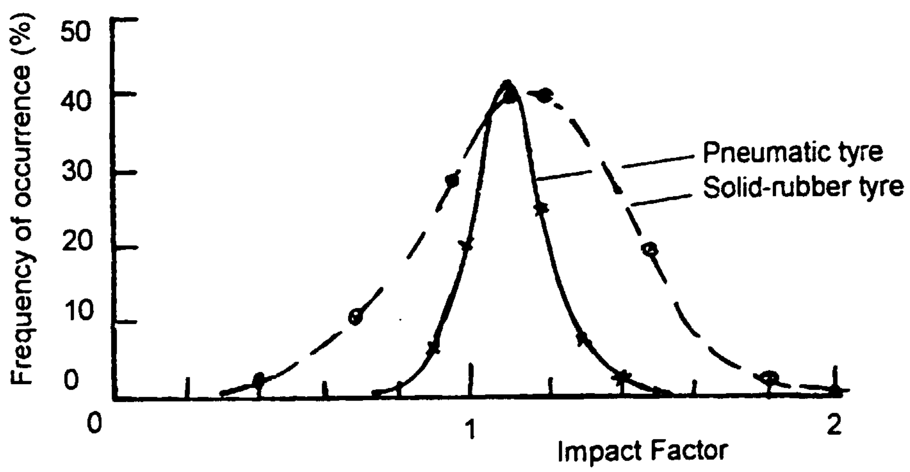
Results

Impact loads acting on wheel and axle are shown in Figure A5.1 for a pneumatic tyre and solid-rubber tyre. The results show that the range of impact loading for the solid-rubber tyre is almost double that for the pneumatic tyre, showing the beneficial cushioning effect of pneumatic tyres. This means that cart components such as wheels, axles and frame must be substantially stronger if pneumatic tyres are not used, in order to cope with the higher impact loads. This is of importance in developing puncture-resistant tyres which are unlikely to have the same level of cushioning as pneumatic tyres.

The fatigue strength of welded joints depends mainly on the **range** of stress acting at the joint and therefore on the range of loading as shown in the Figure. The analysis of wheel strength is complicated by the fact that the rotation of the wheel also causes variation of stress. The dynamic variation of load superimposed on the



(i) Tests on earth track



(ii) Tests off-track

Notes:

- the Impact Factor = Peak load ÷ steady (static) load
- the width of the curves indicates the range (variation) of loading that occurs due to impact loads.
  The range of loading for solid-rubber tyres is roughly double that for pneumatic tyres
- the Frequency of occurrence indicates how often a particular level of impact occurs

Figure A5.1: IMPACT LOADS ON A CART-WHEEL

cyclic variation of stress with wheel rotation produces a complex, random stress variation which is difficult to analyse. An approximate method of analysis has been developed[2] which estimates the allowable stress range at the welded joints at the rated load capacity of the cart. A desirable service life is set for the cart and a history of loading assumed (since it is not economical to design the cart to carry the maximum rated load all the time). The following assumptions were made:

- desirable service life of cart 15,000km (10 to 15 years);
- load history - 10% of time at full load (1,200kg)
  - 50% of time at 60% of load
  - 40% of time at 40% of load

Using these assumptions and data on fatigue strength of welded joints taken from British Standard BS5400: Pt.10: 1980 the allowable stress range for the welded joints of the wheel can be estimated. This gives the following range of design stress at the welded joints:

- Class F_1 weld (good quality fillet weld) - 75 MPa for pneumatic tyre
  - 64 MPa for solid rubber tyre

- Class F_2 weld (poor to average fillet weld) - 65 MPa for pneumatic tyre
  - 56 MPa for solid rubber tyre

These allowable design stresses can be used to check that a design of wheel is strong enough by measuring the range of stress at the critical welded joints of the wheel in a static test on the wheel test rig.

Side loads acting on the wheel are shown in Figure A5.2. The main effects of these loads are:

- they can cause high stresses in the wheel at the welded joints between the spokes and hub and possibly cause failure at the weld;

- because they act at the outside of the tyre, they apply a large moment on the axle and wheel bearings. They therefore have a significant influence on the strength of the axle and of the bearings.

Because the side loads can act in either direction on the wheel, they produce a relatively large stress range which needs to be carefully checked in relation to the fatigue strength of the axle and the welded joints at the hub of the wheel.

Resultant stresses in the axle from both the vertical and side loads on the wheel are shown in Figure A5.3. The measured stresses are only about 60 to 70% of the values calculated from the vertical and side loads applied to the axle. This suggests that the loads may not act in phase. However, the results indicate that the stresses in the axle caused by the side loads are at least three times those caused by the vertical loads on the wheel. Using the results to check the strength of the axle for a design load of 1,200kg (all-up weight of cart plus load) shows that a 40mm diameter axle is adequately strong for both pneumatic and solid-rubber tyres, whereas a 35mm diameter is only just strong enough for pneumatic tyres and not strong enough for solid-rubber tyres.

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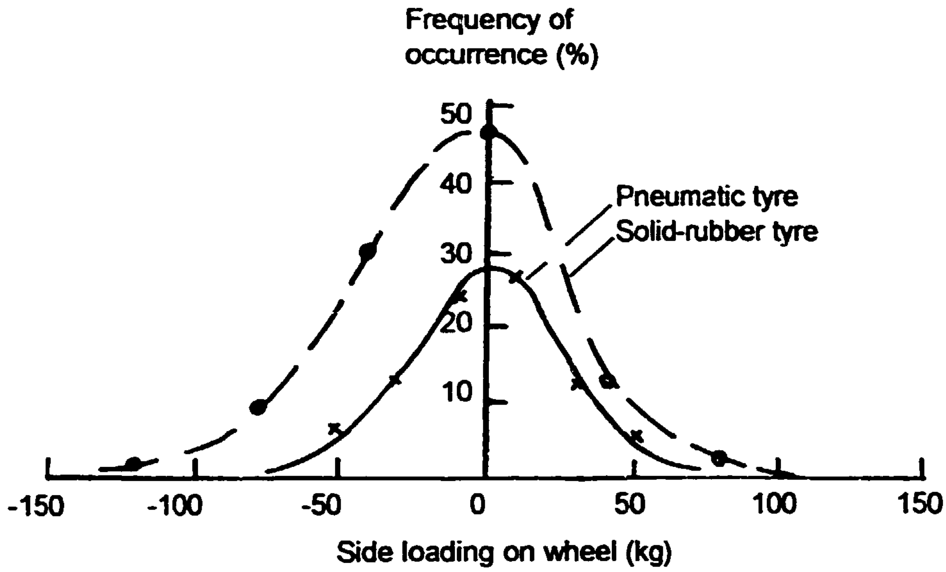
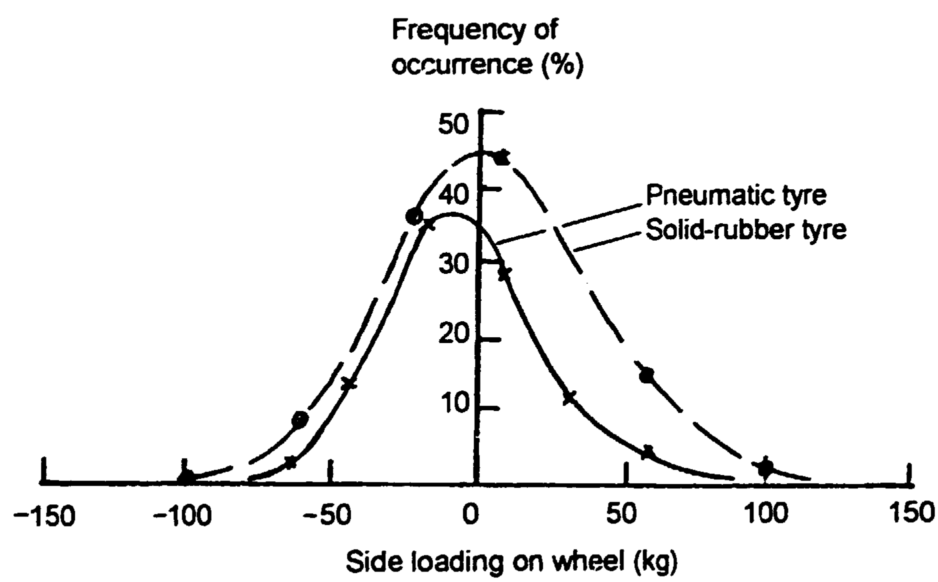
[2] Ron Dennis; *Procedures used in the Analysis and Testing of Wheels*; I.T. Transport report No. 273, October 1990.



(i) Tests on earth track

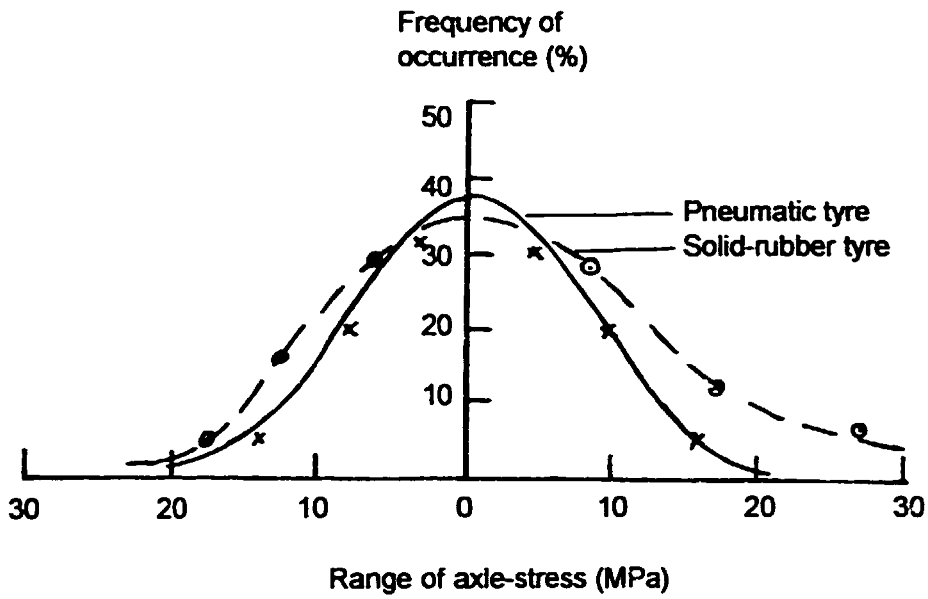


(ii) Tests off-track

Notes:

- the shape of the curves shows that side loads can act in either direction on the wheel
- total cart load is 590kg

Figure A5.2: SIDE LOADS ON A CART-WHEEL



Notes:

- the Range of axle-stress is measured about the static stress i.e. "O" (zero) is the stress in the axle when the cart is stationary
- total cart load is 590kg

Figure A5.3: STRESSES IN THE AXLE OF A CART-WHEEL

ANNEX 7: STATIC LOAD TESTING OF DETACHABLE-BEAD WHEEL

ANNEX 7: STATIC LOAD TESTING OF DETACHABLE-BEAD WHEEL

In order to check the strength of a wheel the stress range at the critical welded joints must be measured and compared with the allowable design stresses derived in Annex 6.

A prototype of the detachable-bead wheel with four angle-section spokes was constructed and strain gauges attached to the spoke and rim close to the welded joint between the two members. The wheel was mounted in the wheel test-rig (see Phase 1 report) and loaded up to 480kg. The wheel was then rotated through one revolution (360 degrees) and strains measured at 30 degree intervals to determine the stress variation in the wheel.

The results are shown in Figure A6.1 (i). The highest stress variation was found in the rim close to the weld either side of the spoke. The highest stress range measured was in Gauge 1 as follows:

Strain range at 480kg load = -200 to +150 = 350
Stress range at 480kg load = 71.8 MPa
Stress range at design load of 600kg = 86 MPa

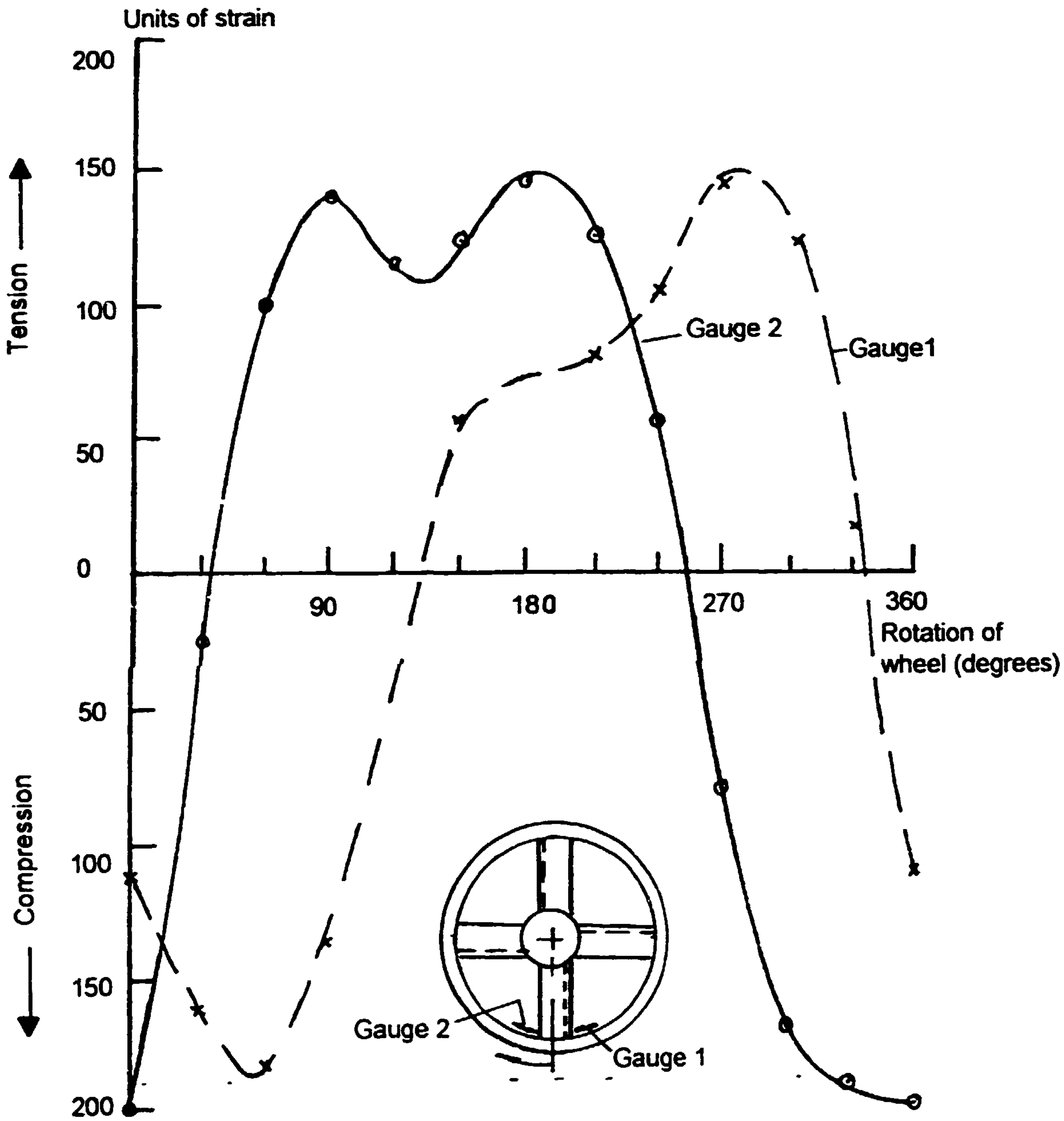
This exceeds the allowable stress range of 75 MPa for the wheel with a pneumatic tyre. The wheel was therefore modified by adding two additional spokes to provide more support for the rim.

The results for the six-spoke wheel are shown in Figure A6.1 (ii) giving the following stress range:

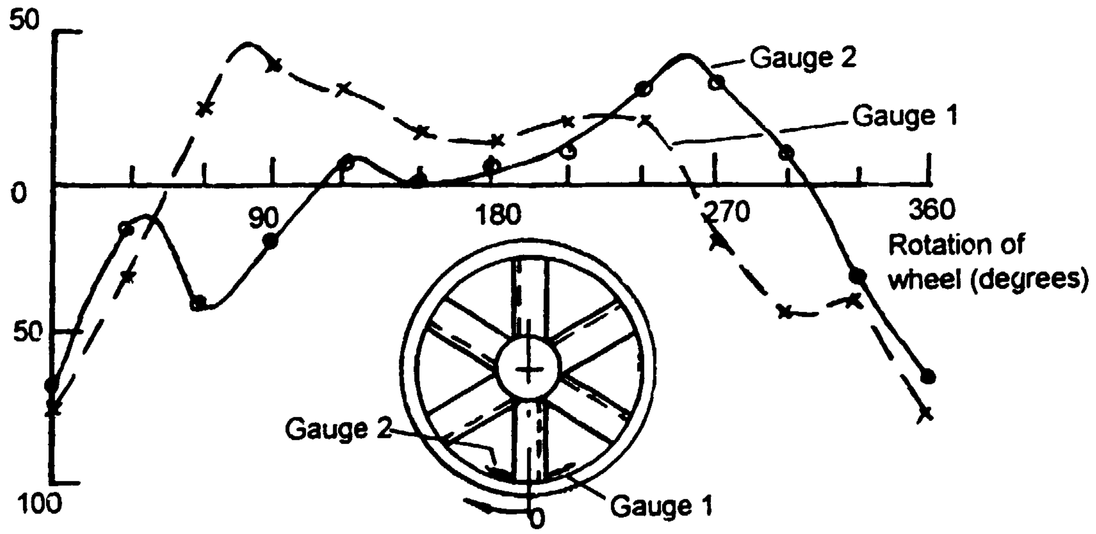
Strain range at 480kg load = -70 to +40 = 110
Stress range at 480kg load = 22.6 MPa
Stress range at design load of 600kg = 27 MPa

It is seen that increasing the number of spokes to six has a large effect in reducing the stress at the critical welds and the stress range is now well within the allowable limit.

The spokes could actually be reduced in section to reduce weight and cost. The prototypes were made with spokes of 50x50x6mm angle whereas the design being produced by trained workshops uses 50x50x5 angle.



(i) 4-spoked wheel



(ii) 6-spoked wheel

Figure A6.1: STRAIN VARIATION IN WHEEL

ANNEX 8: DEVELOPMENT AND TESTING OF PUNCTURE-RESISTANT TYRE

ANNEX 8: DEVELOPMENT AND TESTING OF PUNCTURE-RESISTANT TYRE

As explained in Section 6.5 it was decided to explore the possibility of developing a solid or semi-solid rubber tyre in order to simplify manufacture and avoid the need for expensive moulds. This might take two basic forms:

- a scrap tyre with side walls partially cut away with additional rubber section(s) fitted inside to improve cushioning;

- a tyre formed by bonding a retread section onto a rubber backing ring which might be solid or semi-solid.

The tyres tested to date are shown in Figure A7.1. The upper illustration shows a scrap tyre with side-walls cut away fitted directly onto a steel rim. The lower one shows a prototype of the second form with a retread section bonded onto a rubber ring. This is fitted onto a steel rim and held in position by steel rings or beads. However, testing showed that the tyre tends to twist off the rim when cornering under load and it is likely that it will need to be bonded onto the rim.

The important factors governing the performance of tyres of towed vehicles are their rolling resistance and cushioning properties.

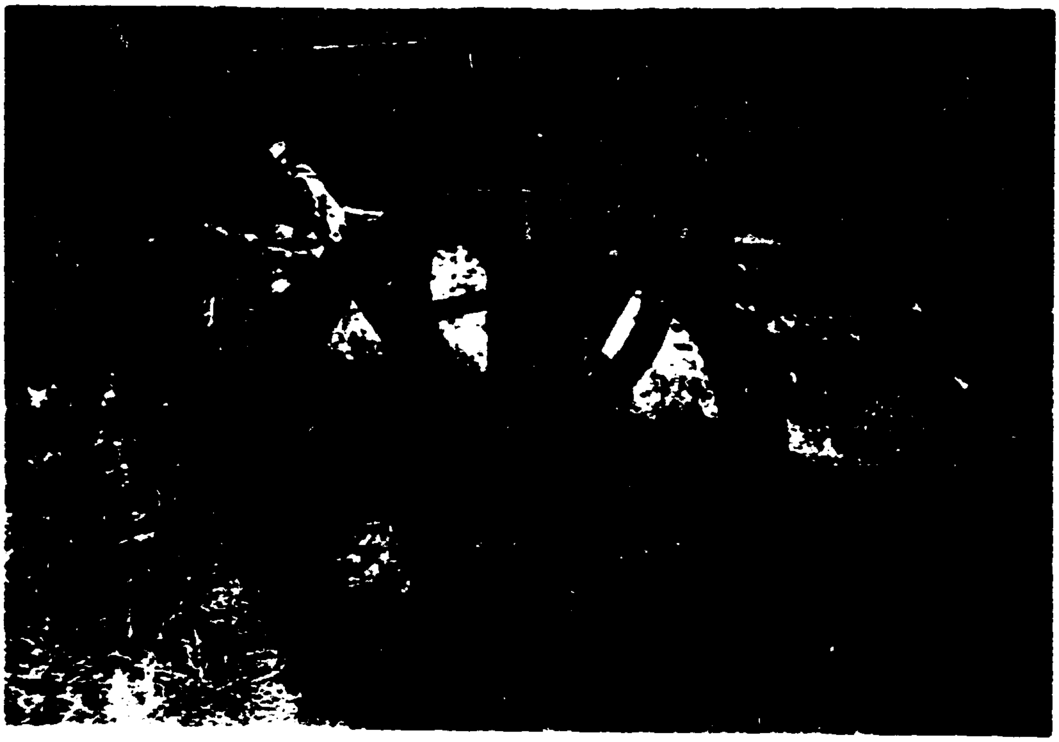
Rolling resistance is important in determining the draught needed to pull the cart. On level ground the load capacity of the cart will depend on the rolling resistance of the tyres and the draught available from the animals. On firm ground rolling resistance is dependent on hysteresis losses in the tyre as it distorts under load and on energy losses from vibrations (impacts) set up by the roughness of the ground. Flexible tyres, such as pneumatic tyres, therefore tend to give more benefits on rougher ground because of their cushioning properties. On soft ground, rolling resistance is dependent mainly on the sinkage of the tyre into the ground and the energy used up in compressing the ground. Flexible tyres therefore give an advantage by distorting and spreading the load over a larger area of ground to reduce sinkage. Pneumatic tyres tend to perform better on soft surfaces at low inflation pressures because the increased tyre distortion reduces sinkage.

The cushioning properties of the tyre affect rolling resistance on rougher tracks and also the level of impact loads transferred from the tyre to the wheels and the cart structure. Cushioning is therefore important in reducing the severity of shock loading on the cart, particularly at joints, and in providing a smoother operation of the cart.

The prototype solid rubber tyres were tested to compare their performance with pneumatic tyres and also with steel rim/tyres. Each set of tyres was fitted to the wheels of an ox-cart and the cart towed over a number of test tracks of different roughness. The towing force was measured by fitting a strain-gauged link in the line transferring the towing force from the animals to the cart. A programme built into the data logger was used to average the force out over 1 minute periods (approximately 80m of track). The impact loads transferred from the tyres were measured by strain-gauges attached to the axle.

The results of the test are shown in Figure A7.2.

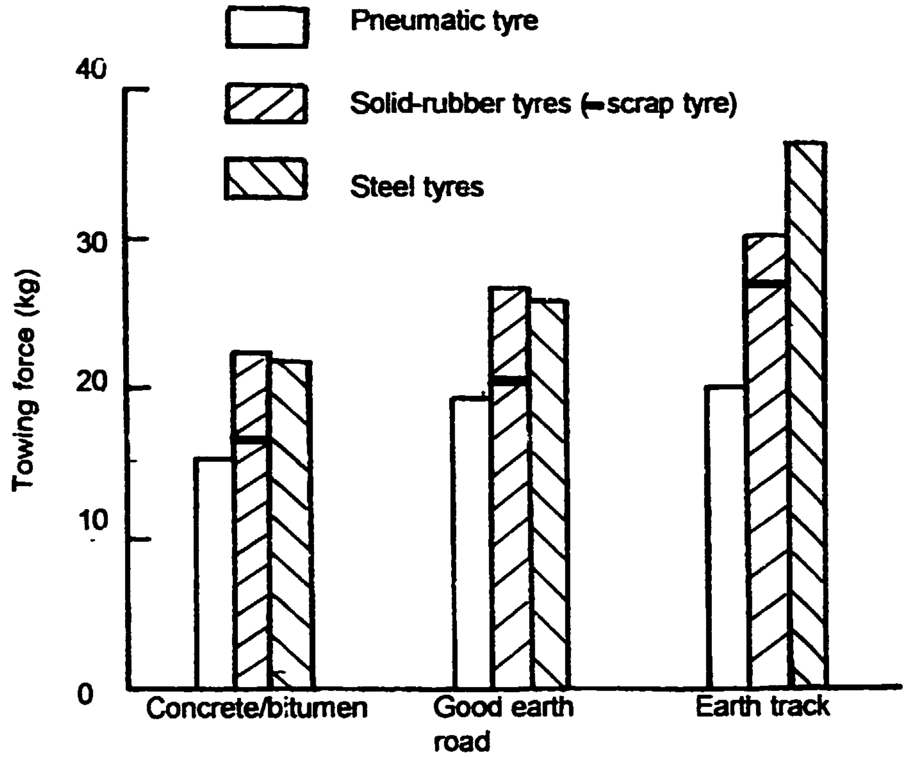
Comparison of rolling resistance of tyres. On smooth surfaces there is little difference between the towing forces for the solid scrap tyres and the pneumatic tyres but on the rougher earth track the pneumatic tyres give a significant advantage. The retread tyre has a higher rolling resistance than the scrap tyre on smooth tracks, probably because of greater



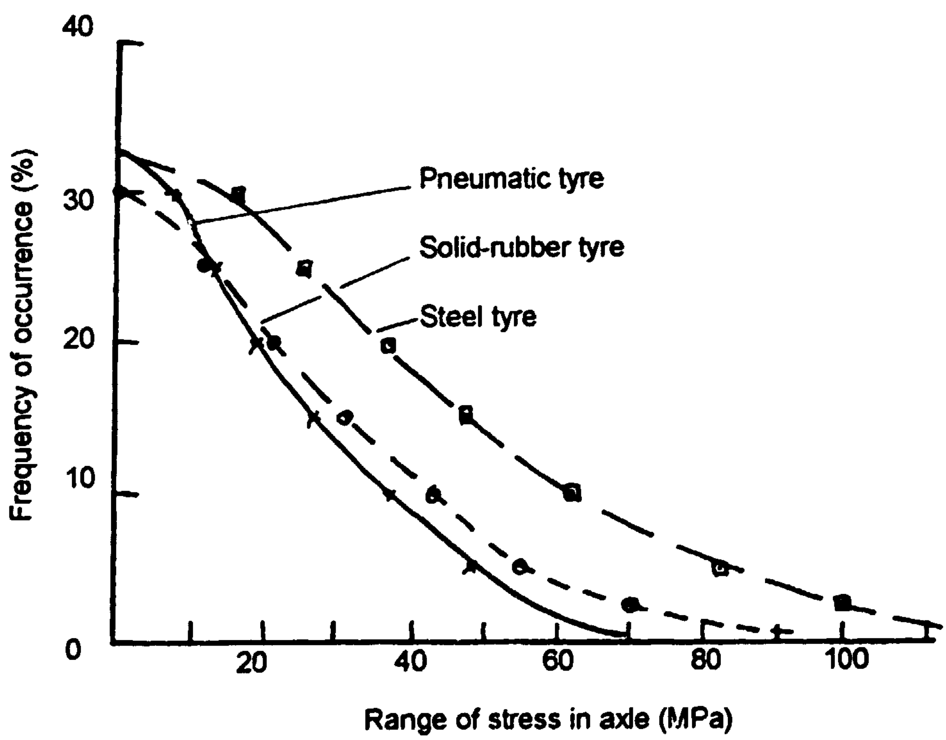
Scrap tyre with sidewalls cut away, fitted over a steel rim

Tyre formed by vulcanising a strip of retread section onto a rubber ring

Figure A7.1: PROTOTYPES OF PUNCTURE-RESISTANT TYRES TESTED IN THE PROJECT



Towing force for different tyres on various surfaces (load, 590kg)



Impact stresses in axle for different tyres on earth track

Figure A7.2: RESULTS OF PERFORMANCE TESTS ON DIFFERENT TYRES

hysteresis losses in the thicker rubber section, but the difference is not as great on the rougher track. The solid rubber tyres show an increasing improvement over a steel tyre as the ground gets rougher. No tests were carried out on soft surfaces such as sand or mud but it would be expected that towing forces for pneumatic tyres would be 30 to 40% less than for the solid tyres, rubber and steel, which would be roughly the same. Average values would be 180kg for pneumatic tyres and 250kg for solid tyres. However, these are very dependent on the softness of the surface.

Comparison of impact loads. It is clear that the solid rubber tyres are considerably better than steel tyres, even with their limited cushioning capacity. The benefits of pneumatic tyres are more apparent for higher impacts caused by running over rocks, pot-holes etc.

Conclusion

The solid rubber tyres are a considerable improvement over steel tyres. It is surprising that the scrap solid tyre performed slightly better than the retread version since it would be expected that the greater rubber thickness of the latter would provide more cushioning. Although the solid rubber tyres do not perform as well as pneumatic tyres it is considered that the difference in performance is within a range which can acceptably be balanced against their benefit of being puncture-resistant. It seems possible that the performance of the tyres may be improved by fitting a semi-solid rubber layer between the tread and rim to increase flexibility. This is one of the possibilities which will be investigated further.

ANNEX 9: REPORT OF OPEN DAY HELD AT IAE

ANNEX 9

REPORT ON TRANSPORT PROJECT OPEN DAY.

For introduction and invitation list see attached letter dated 23.12.93.

The open day was attended by the following:

NAME	ORGANISATION
T.Mativenga	A.H.S.
W.Machamire	A.H.S.
S.Nalumansi	U.N.I.F.E.M.
E.Mupunga	D.D.P. - A.R.D.A.
M.Mapuza	DDP-ARDA Chikwaka dairy project
J.Chimbadzwa	Women's Bureau
Shambare	Women's Bureau
M.Mapako	Women's Bureau
M.Gambe	Cold Comfort Farm
M.Schumacher	Cold Comfort Farm
T.Muwunganirwa	Natural Resources
M.Loof	Women's Institute
S.Mushaike	Women's Institute
S.Kamba	I.T.D.G.
M.Vela	I.T.D.G.
A.Zirema	Hashco

Alan Brewis introduced the project giving its aims and objectives. The idea of the open day was stated (as covered in the invitation letter).
Blessing Hatitye then explained the transport devices on show one by one explaining their relevance to the project and inviting comments on each device.
The visitors were then shown the test rig (which was at the time testing new bearings imported from China) and the wheel bending equipment was demonstrated.
Alan Brewis then explained that if any of the visitors felt that the project could assist them with any of their project's transport needs this was an ideal facility for them to develop their ideas into working products.

Conclusions:

Although the visitors claimed they were impressed with the open day actual hard results were very few.

1. Hashco were impressed with the quality of the Scotchcarts and would like to stock them if the price was lowered. Cold Comfort Farm will quote.
Cold Comfort had put in a tender for 900 wheelbarrows for a project in Zimbabwe and will use the project design.

2. Women's Bureau and Women's Institute would like to re-visit with "a group of our women". If this ever happens it may give the project a chance to discuss ideas with more end users.

3. ARDA discussed specific ideas but it was impossible to get a commitment from them re. further work. It is probably better to work direct with the individual projects eg. Nharira.
and ARDA Motoko.

4. Natural Resources would like us to work on a very cheap axle one step up from the wooden ones seen in some parts of the country. Mention was also made of an interview for Z.B.C.

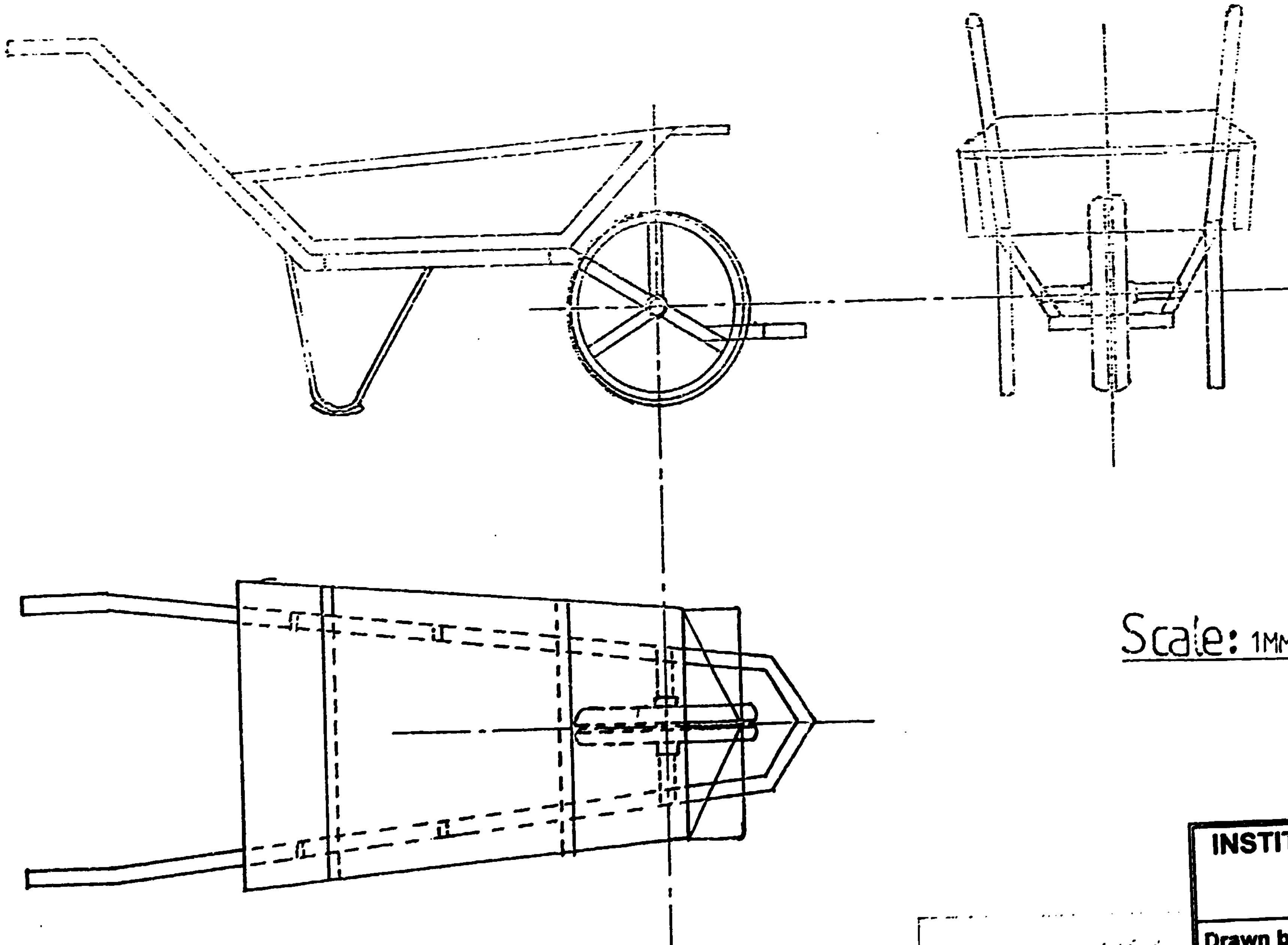
Although the idea of an open day seemed a good one it was very difficult to get any firm commitment from most people. Retail outlets prefer to deal direct with manufacturers and one got the impression that for the projects it was just a day out.
However project visibility has increased which may result in some future enquiries.

Prepared by: Alan Brewis.
January 1994.

ANNEX 10: DRAWINGS OF TRANSPORT DEVICES DEVELOPED IN PROJECT

- **wheelbarrow**
- **waterbarrow**
- **handcart**
- **waterbowser**

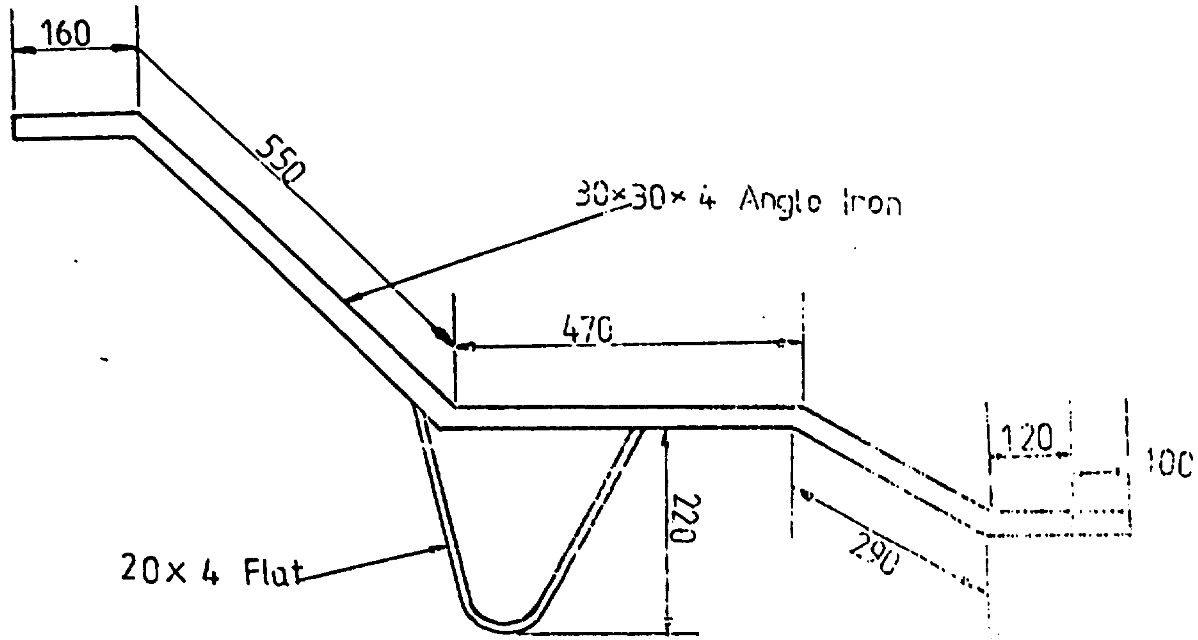
LOW COST WHEEL BARROW



Scale: 1MM TO 10 MM

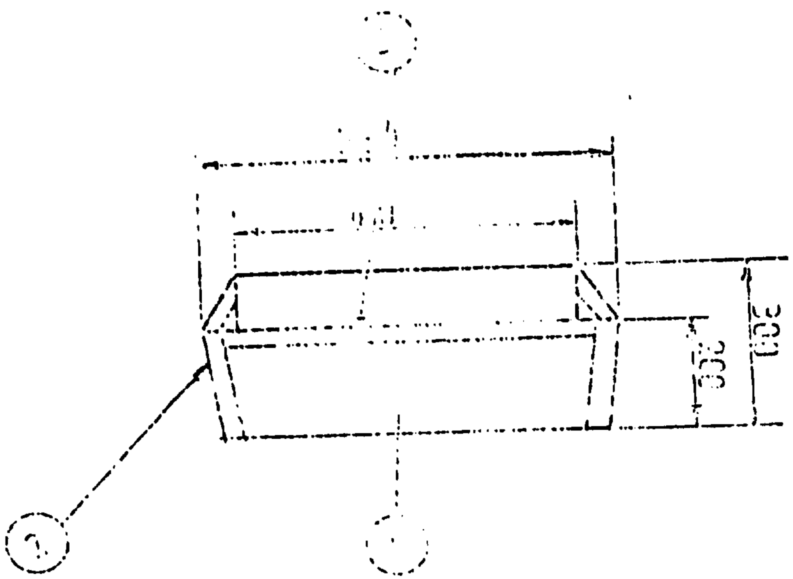
INSTITUTE OF AGRICULTURAL ENGINEERING	
BORROWDALE, HARARE, ZIMBABWE	
Drawn by: B. Hatitye	Scale: 1 to 10mm
Checked by: I. Chatizwa	Date: 17-07-94

WHEEL BARROW FRAME



SCALE: 1MM to100MM

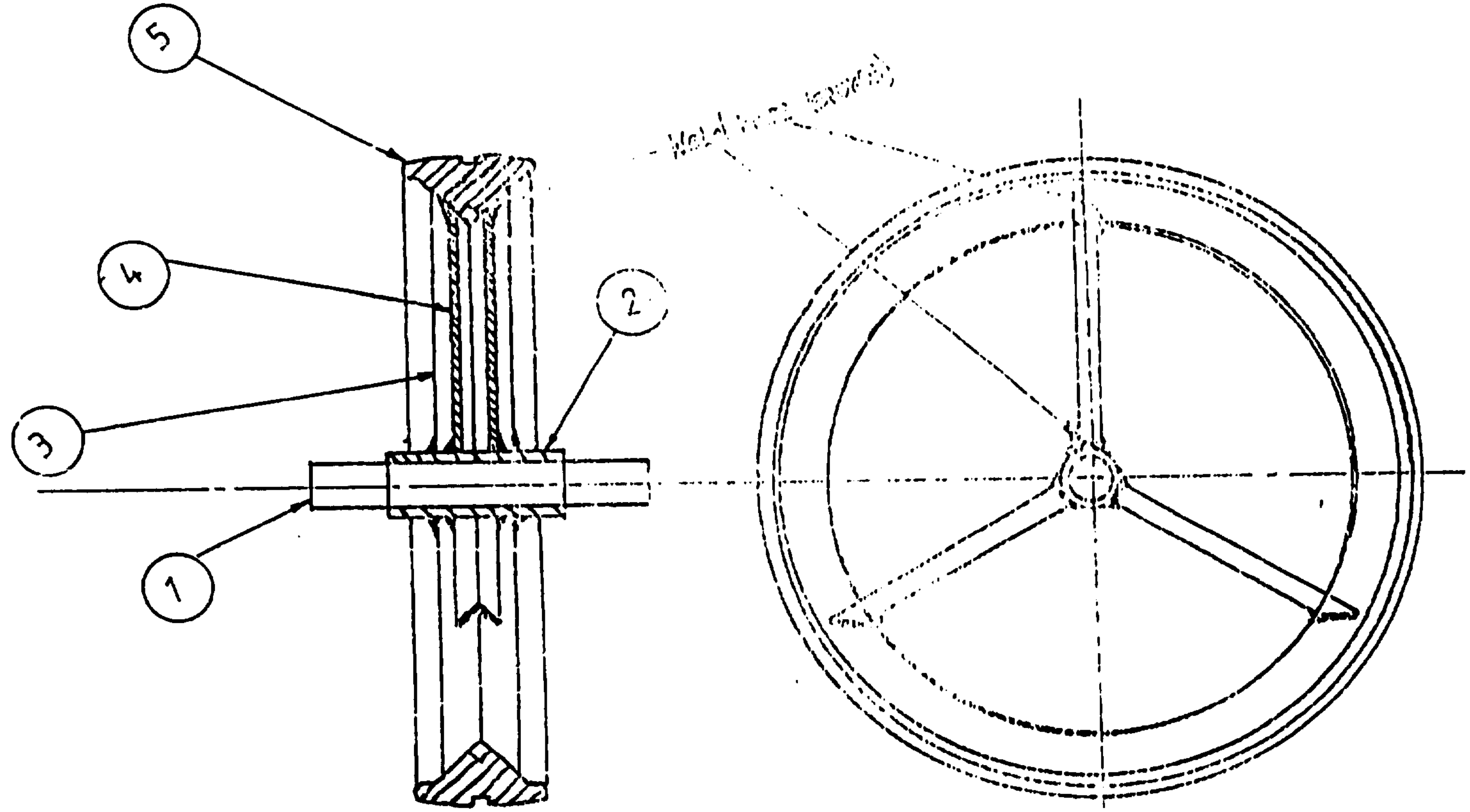
WHEELBARROW BASIN



PART NO	ITEM	QTY	MATERIAL
1	Sheet		2mm Sheet Metal
2	FRAME	2	25 x 25 x 4 Angle
3	Supports	4	20 x 4 Flat Bar

SCALE: 1MM TO 100MM

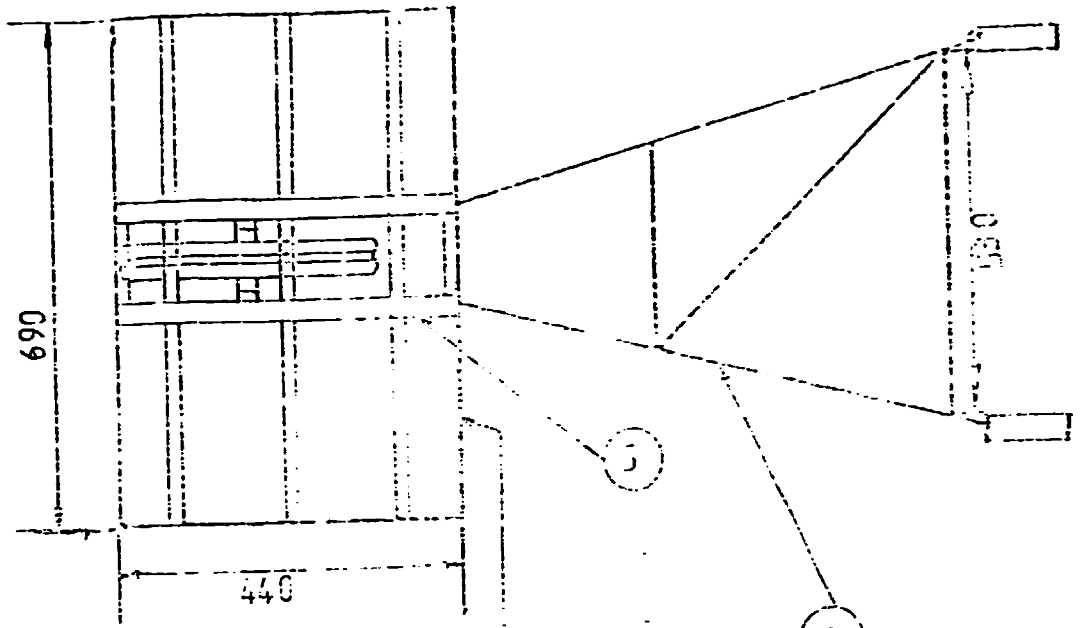
13 INCH (Angle Iron) RIM

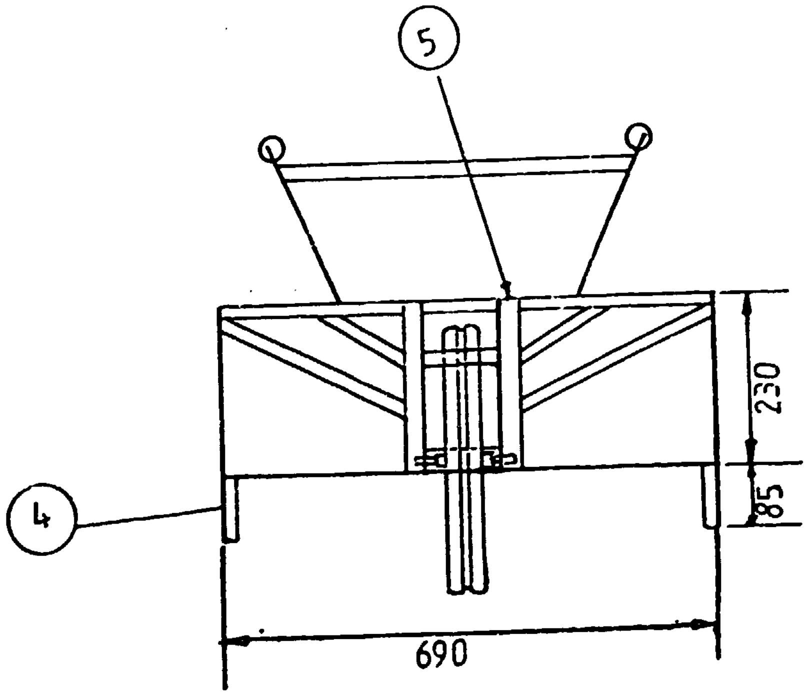


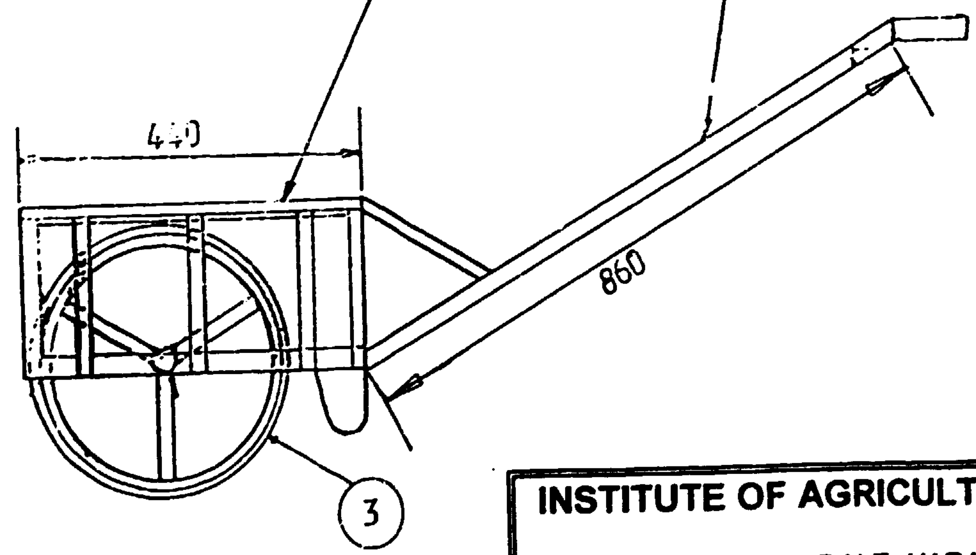
Part No	ITEM	QTY	SIZE(mm)	LENGTH	QUALITY
1	Axle	1	Dia 32.5	—	B.M.S.
2	HUB	1	OD 32	95 mm	HEAVY PIPE
3	RIM	1	30×30×4	1200 mm	M.S.
4	SPOKE	3	30×30×4	≈144 mm	M.S.
5	SOLID rubber	1	—	—	[illegible]

SCALE 1MM TO 100MM

PART NO	DESCRIPTION	QTY	MATERIAL
7			
6			
5	WHEEL CAGE	1	25×25×4 ANGLE IRON
4	LEG (SUPPORTER)	2	20×4 FLAT BAR
3	13" WHEEL	1	PUNCTURE PROOF TYPE
2	CONTAINER CAGE	2	OUT OF 20×4 FLAT
1	HANDLE BAR	2	OUT OF 25×4 FLAT







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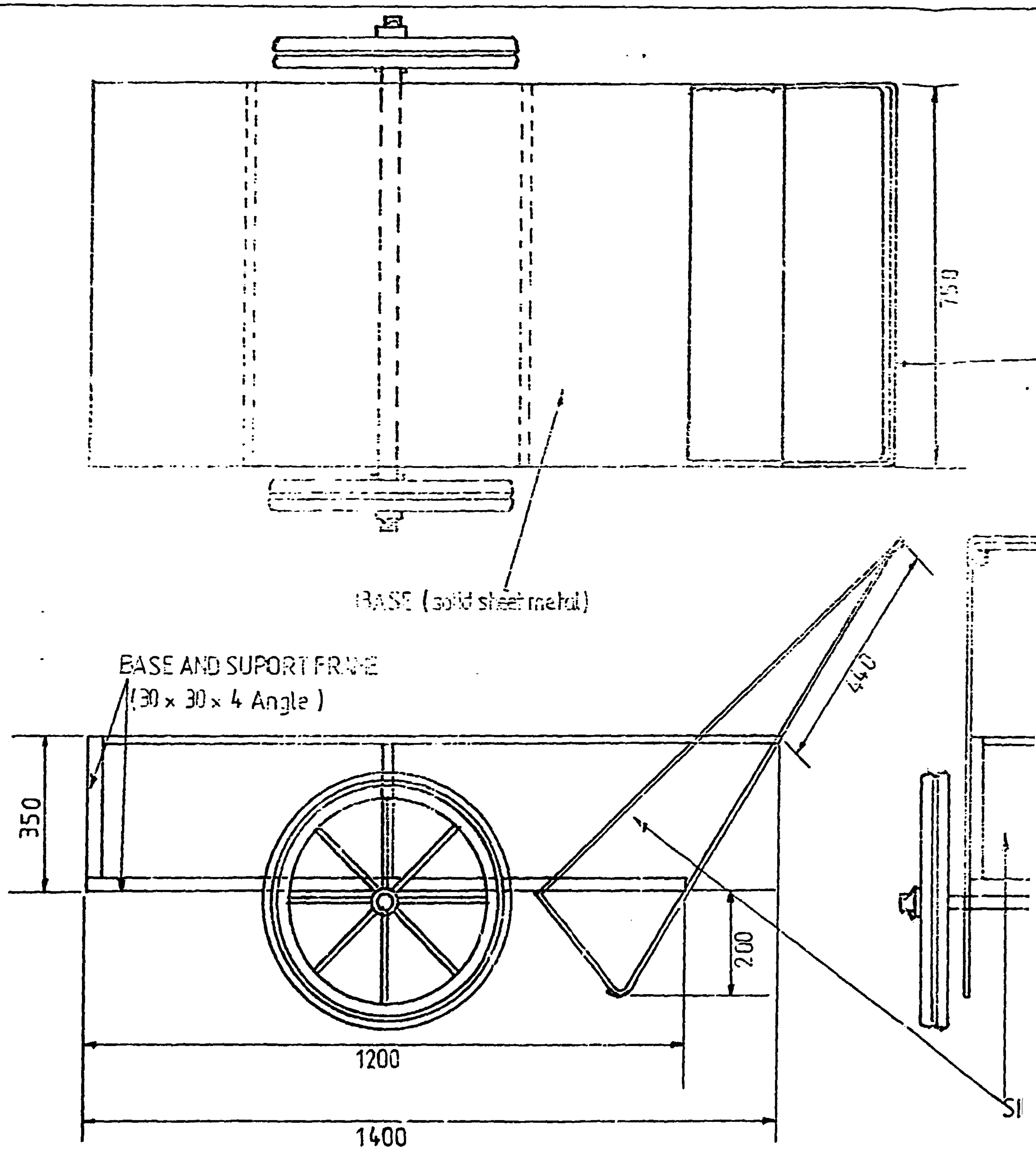
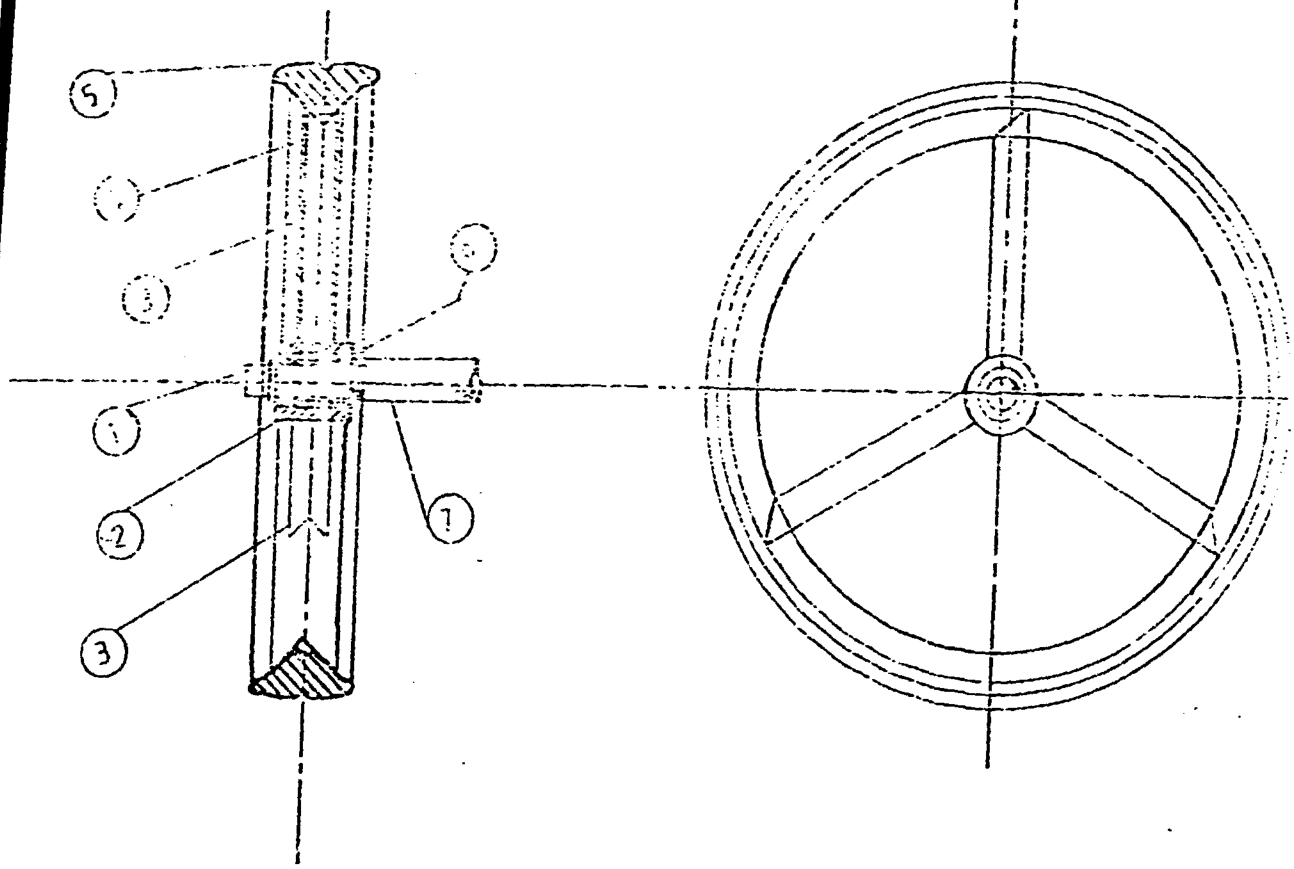
DRAWN BY	B. HATITYE	ALL DIMENSIONS IN (MM) OTHERWISE STATED	WATER BARROW
CHECKED BY	I. CHATIZWA	SCALE: 1mm to 10mm	DATE: 12 JULY 1994
APPROVED BY			



PUSH CART

Scale: 1MM TO 10 MM

18" Puncture Proof Wheel



MATERIAL LIST FOR AN 18INCH PUNCTURE PROOF WHEEL

PART NO.	ITEM	QTY	SIZE/ SPECIFICATION	LENGTH (MM)	QUALITY
1	Stub shaft	1	25mm Dia.	150mm	Bright mild steel
2	Hub	1	2 inch ϕ 1/2 inch	65 mm 67 mm	Water Pipe
3	Spoke	3	30 x 30 angle	≈200 mm	Mild Steel
4	Rim	1	30 x 30 x 4 angle	≈1800mm	Mild Steel
5	Puncture proof	1	special type (formed)	≈1400mm	Rubber
6	Bearings	2	6205	—	—
7	Axle	1	30x30x4	760 mm	Mild Steel

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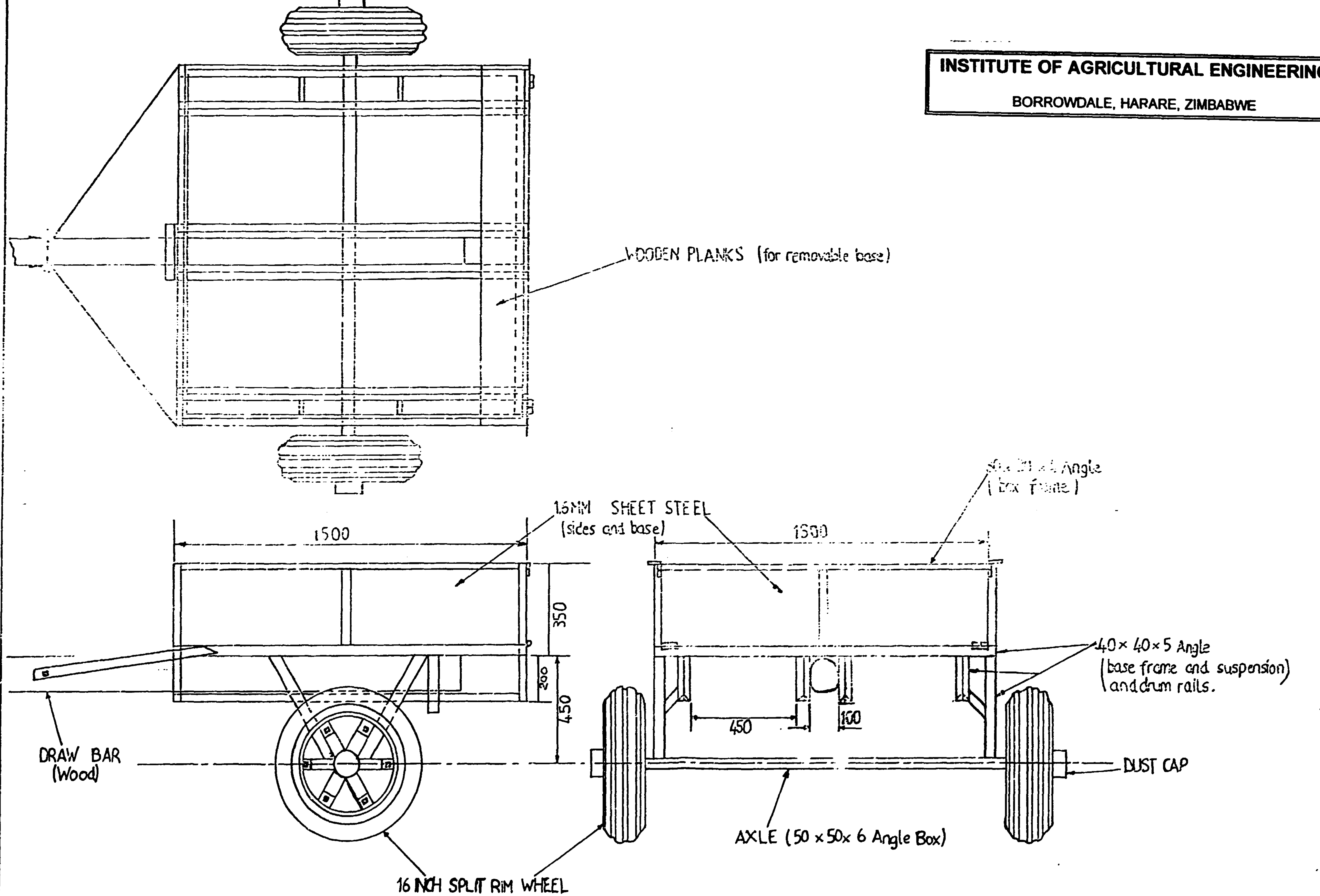

DRAWN BY	B.HATITYE	ALL DIMENSIONS IN MM		WATER CART - CUM-SCOTCHCART
CHECKED	I CHATIZWA			
APPROVED		SCALE 1mm to 10mm		DATE: 12 JULY 1994