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Notes on Simple Transport in Some Developing  
Countries Information Paper No. 2

by: I. J. Barwell

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Transport Panel

Information Paper 2

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in Some Developing Countries  
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I.T.D.G. TRANSPORT PANEL

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Notes on Simple Transport in Some Developing Countries

by

I.J. Barwell M.A. (Cantab)

I.T.D.G. Transport Project Officer

This series of Information Papers is circulated as a means of disseminating information and soliciting comments about the work of the I.T.D.G. Transport Panel. The Panel welcomes any ideas and suggestions arising from the content of the papers, and these should be forwarded to:-

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## Abstract

The report discusses intermediate transport in Papua New Guinea, The Philippines, China and India, and describes the simple vehicles, human powered, animal-powered and motorised, which are used in those countries. Simple vehicles can play an important role in the transport system of all developing countries, yet their use is largely confined to the urban areas of Asia, and their design is often based on imported technology rather than on local requirements.

## 1. Introduction

This report discusses the design and use of simple vehicles in four countries; Papua New Guinea, The Philippines, The Peoples' Republic of China, and India. It is based on information collected by the author during a four year stay (1972-75) in Papua New Guinea, and on visits to the other three countries between 1973 and early 1976. The report is not comprehensive in the sense that it does not claim to include a description of all vehicles in use in every part of each of the countries. However it is a valid review of simple transport in those countries and contains descriptive information on a wide range of vehicles.

While the four countries all qualify for the umbrella description of 'developing' they represent different political systems, different stages of economic and social development, and different approaches to the problems of development. They range in population size from the 2.5 million of Papua New Guinea to the 800 million of China and between them they encompass a spectrum of geographical and meteorological conditions.

There are four major descriptive sections to the report, one for each country. Each section commences with some general notes on intermediate transport in that country, followed by brief descriptions of simple vehicles used there. Four different categories of vehicles are discussed;

- i) human-drawn vehicles -- wheelbarrows, handcarts etc;
- ii) pedal-driven vehicles;
- iii) animal-drawn vehicles;
- iv) simple motorised vehicles.

It is clear that there are roles which can be played, and needs which can be fulfilled in developing countries by simple forms of transport less complex than the imported cars, vans and trucks which are often inappropriate for the uses to which they are put. Furthermore there already exist proven simple vehicle designs which could ease the burden of those who presently have to carry heavy loads on their heads or their backs.

## 2. Papua New Guinea

### 2.1 Transportation in Papua New Guinea

Papua New Guinea is situated between the north coast of Australia and the equator. The country, which has a population of about 2.5 million people is made up of one half of the main island of New Guinea (the other half, Irian Jaya is a part of Indonesia) together with a number of smaller islands of which New Britain, New Ireland, Bougainville and Manus are the most important. Much of the country is very mountainous, thickly vegetated and sprinkled with fast-flowing streams. However there are three large flat plains; the Markham Valley, the Sepik Plain and the Fly-Stickland and Purari flood-plain. Furthermore in the highlands region there are a number of broad valleys and plateaus.

Apart from a few isolated, short-term landings, the country had no contact with the outside world until the middle of the last century. It then came under the colonial influence of both Germany (New Guinea) and Great Britain (Papua). From the end of the first world war until September 1975 when it became independent, the whole of Papua New Guinea was administered by Australia. Compared with many other colonial nations the influence of the administering authority has, until recent years been fairly limited. Indeed it was not until the early 1930's that outsiders first ventured into the highlands region (Fig 1) which is the home of nearly half the indigenous population. Before the coming of outsiders the only means of land transport was on foot, and the only aids to such transport were hand-woven bags, and stout, bamboo carrying-poles, supported on the shoulders of two or more people. There were no draught animals in the country, indeed apart from the pig there are no large native animals, and the wheel was unknown. Because of the limited means of transport, and the difficult nature of the terrain, the inland people remained, to a large extent, a series of small, isolated, mutually distrustful communities. The extent of this isolation is demonstrated by the existence in Papua New Guinea of over seven hundred separate languages. However along the larger rivers and in the coastal areas wooden canoes were widely used, and in Papua sailing canoes of considerable size (known as lakatoi) were used for long coastal journeys.

Transport is today a major problem in Papua New Guinea. There are no railways and the road system is still very limited (Fig 1). The two major cities, Port Moresby and Lae, are not connected by road. There are roads radiating some distance from the major towns, and minor roads and four-wheel-drive tracks leading from these routes, often to mission stations or similar settlements. In certain instances, pairs of adjacent coastal towns are connected by road. However the most important road is that which runs from the New Guinea port of Lae to the inland highland provinces. Known as the Highlands Highway it is over 400 miles long, unmetalled for most of its length, and climbs two difficult mountain passes. Commercially it is used to transport imported and manufactured goods from the coast to the highlands, and to bring agricultural produce from there

down to the coast, much of it for export. It has also facilitated the migration of highland people to the coastal towns in search of work. At present the only methods of reaching the many places remote from a road or a major river are to walk, perhaps for several days, or to fly in by light aircraft, often to an airstrip built by the local people under mission guidance. The great majority of Papua New Guineans are subsistence farmers and for many of them the prospects of entering the cash economy are limited by the lack of suitable means of getting their produce to market. People living within headloading distance of the Highlands Highway carry their produce down to the main road and then accompany it on a large truck to the market in Lae. Some of them live so far from Lae that the money they earn for their produce there does not cover the cost of transport. However such a visit to Lae is very much a social occasion and the sale of produce in the market does contribute to the cost of the trip.

There are a number of problems which hinder the development of a more extensive conventional road system. Much of the country is very mountainous which makes it difficult to find a suitable route for a road, and makes the road very expensive to build once a route has been chosen. The nature of the terrain and the heavy rainfall combine to produce a multitude of streams which can turn overnight into raging torrents. These must either be bridged at great cost, or the road becomes impassable every time there is a substantial fall of rain. In addition, landslides are common in wet weather due to the unstable nature of much of the soil. The following specific example illustrates the difficulties faced. The Public Works Department has been trying for more than ten years to build a four-wheel-drive access road from the Highlands Highway to a settlement called Beana about twelve miles distant, a route which involves crossing a steep ridge. Despite the expenditure of a great deal of money the road is still not complete, and substantial portions of the section that has been built slip away each year during the heavy rains. Despite all these problems the road system is being slowly developed, albeit at great cost. For most Papua New Guineans, walking remains the basic means of transport and as a result, while there is only a limited road system there exists an extensive network of many thousands of miles of narrow walking tracks covering the whole of the country.

Although the road system is still fairly limited there are already two major problems associated with the vehicles used in Papua New Guinea. The first is the inappropriateness of many of the vehicles to the requirements of the country. The imported cars and trucks embody many features, in terms of performance, styling and equipment which are surplus to the needs of a relatively poor, developing country. Such vehicles are extremely expensive to purchase and to run, and their maintenance requirements are often beyond the skills available in Papua New Guinea. The second problem is the diversity of vehicles in use; between 1969 and 1974, 436 different makes and types of car and truck were imported. This has led to severe shortages of spare parts, and has exposed the lack of suitable

vehicle maintenance skills. In 1971 a Commission of Enquiry was appointed by the Government to look into these problems. In its report (Ref. 1) the Commission has made a number of interesting recommendations, some of which are summarised below:

- i) in future only a limited range of motorised vehicles should be imported, and within the next ten years the private car should be phased out completely, as it is inappropriate to the needs of Papua New Guinea;
- ii) the use of bicycles and pedal-driven cargo vehicles should be encouraged, and consideration should be given to the local manufacture/assembly of bicycles;
- iii) a bicycle path system should be built in the capital Port Moresby for evaluation purposes, and if successful similar systems should be introduced in the other major towns;
- iv) the use of simpler motor vehicles should be investigated, including motor-cycle based vehicles and the 'Asian utility vehicles' presently in use in the Philippines (see section 3.24);
- v) a detailed study of the feasibility of using electrically powered vehicles should be made (PNG has vast potential resources of hydro-electric power. Two major schemes are already in operation and a third, much bigger project is presently the subject of a detailed investigation);
- vi) the possibility of using aerial ropeway systems in the more mountainous areas should be investigated.

## 2.2 Simple Vehicles in Papua New Guinea

### 2.21 Human-drawn Vehicles

At present, handcarts and wheelbarrows are not used in Papua New Guinea, yet they would seem to have great potential. The people living in or near the towns often walk several miles carrying heavy loads, for example going to and from the market or collecting firewood. Such loads are usually carried by the women. In many of these situations the roads and the tracks are well suited to the use of two-wheeled handcarts, and their introduction would literally ease the women's burden. Similarly, there are many rural areas of the country where Chinese-style wheelbarrows could be used on existing tracks. These would increase the effective distances which loads could be carried, and hence would give more people access to the road system. Such wheelbarrows could also be of benefit in the everyday life of the village; they could be used to carry water or to transport items from the village to the fields and back again.



## 2.22 Pedal-driven Vehicles

Bicycles are used in fairly limited numbers; indeed in recent years imports of bicycles have actually declined (Fig. 2). However the potential of the bicycle in Papua New Guinea has now been appreciated, its use is being encouraged in a number of ways, and the local assembly of bicycles is a real possibility in the not too distant future. Unfortunately many of the bicycles imported in the past have been cheap models of very poor quality. Many of them have welded rather than lugged and brazed frames, braking only on the rear wheel, narrow-section tyres and light-duty wheel rims. Such bicycles are designed for short-distance and leisure use on smooth roads, and do not stand up to the demands made of a basic means of transport in a developing country. As a result in Papua New Guinea they have proved unreliable and have only a short working life. A more appropriate type of bicycle is that manufactured in India and China, with sturdy frame construction, wide-section tyres and heavy duty rims, and rod-actuated brakes on both wheels. At present pedal tricycles are not used, though again they are now the subject of some interest. First steps have been taken towards the manufacture of bicycle trailers (Fig 3), but their use is limited to some extent by the unsuitability of many of the bicycles.

## 2.23 Animal-drawn Vehicles

There are no draught animals indigenous to Papua New Guinea, and attempts to introduce donkeys and buffaloes have been largely unsuccessful. The main reason for these failures has been that the people lack any experience in feeding, training and caring for animals, and have paid no attention to their livestock, except when they want to work them. Livestock management is a skill which does not exist in the country at the moment except amongst a few trained agricultural experts. Since it is a difficult skill which is not acquired easily the scope for the development of animal powered transport in the immediate future is limited.

## 2.24 Motorised Vehicles

There are no three-wheeler motor-cycle based-vehicles in Papua New Guinea comparable with those widely used in Asia. Even the motor-cycle is only used to a limited extent though the government has recently recommended that one particular model of small motor-cycle, the Honda 90 Trail should be imported duty-free to encourage its use. This model was considered to be particularly appropriate to the country's needs for two reasons; it has a four-stroke engine which is thought to be preferable to a two-stroke as regards maintenance and tuning, and the transmission incorporates high and low gear-ranges which facilitates use of the motor-cycle in steep, rough conditions. This model is already used by government patrol officers because it will operate satisfactorily on many of the existing walking tracks and therefore allows access to places which cannot be reached by other motorised vehicles.

Four-wheel-drive vehicles are extensively used, for reasons which should be apparent from earlier comments about the road system. In the past these have been almost exclusively Land Rovers and Toyota Land Cruisers, the latter having a 4.7 litre, 6-cylinder, petrol engine and a fuel consumption of 12-15 mpg. However recently a vehicle called the Suzuki Prute (Fig. 4) has become very popular. This is a vehicle with open jeep-style bodywork, considerably smaller than the Land Rover, but using the same size of wheel and hence having excellent ground clearance. It has a 540 cc two-stroke engine, and four-wheel-drive with a choice of high or low ratio. It is light, economical to run, and can get to places which larger four-wheel-drive vehicles cannot reach, although its carrying capacity is limited.

The other vehicle of interest is known as a P.M.V. (passenger motor vehicle) and an example is shown in Fig 5. This is usually a Toyota Land Cruiser, a pick-up, or a flat-deck truck with simple wooden seats mounted on the back. Often a village group or clan will club together to buy such a vehicle, though many are owned by private operators. P.M.V.s are allowed to pick up fare-paying passengers on the road and are the basic form of public transport available to the local population.

A major problem with all motorised vehicles in the country is lack of maintenance skills. Many Papua New Guineans have taken a leap along the scale of technological complexity direct from the digging-stick to the internal-combustion engine. Therefore it is hardly surprising that not only do they not know how to maintain their vehicles, but they do not appreciate the importance of preventive maintenance. One great benefit which could accrue from widespread bicycle usage would be a gradual development of maintenance skills.

### 3. The Philippines

#### 3.1 Introduction

The Philippines is a large, diverse country made up of over 7,000 islands, and its state of development ranges from the environmentally disastrous high-rise congestion of Manila City to the primitive simplicity of the Tasaday tribe of southern Mindanao, a small group of gentle, cave-dwelling food-gatherers whose first contact with the outside world came as recently as 1971 (Ref.2). The descriptions which follow cover the simple vehicles used on the western side of Luzon, the largest island in the archipelago and the home of the majority of the Filipino population. This area includes Manila City itself, together with the large agricultural plain surrounding the city and the mountainous region of northern Luzon, whose main population centre is Baguio. While the centre of Manila is heavy with expensive, imported motor cars it is clear that these are within the means of only a small minority of the population. One does not have to travel very far from the tourist section of Manila to come upon squatter settlements consisting of homes constructed from discarded 'waste' materials, though it is worth noting that a forest of television aerials sprouts from the roofs of these homes.

Two categories of simple vehicles are in common use in the areas visited, namely animal-drawn and motorised vehicles. The use of animal-drawn vehicles stems from the widespread ownership of buffaloes (known locally as carabaos) which are used to work the fields, to carry the farmer to and from his land, and to haul the farm produce to market, either on a two-wheeled cart or a skid-mounted sled. The use of motorised vehicles was greatly stimulated by the vast stock of war material left behind by the American forces at the end of the second world war. The utilisation of this equipment together with the large number of older vehicles still to be seen on the roads testify to the high level of mechanical skill and ingenuity of the Filipinos. The widespread availability of such skills has been an important factor in the successful introduction into the Philippines, over the past few years, of a number of 'Asian utility vehicles' produced by the world's major car manufacturers.

### 3.2 Simple Vehicles in the Philippines

#### 3.21 Human-drawn Vehicles

Handcarts and wheelbarrows do not appear to be widely used in Luzon. There are a few three-wheeled carts with low-mounted bodies supported on small cast-iron wheels, one at the front and two at the rear. However these are only suitable for use over very short distances and are probably better thought of as industrial material-handling devices rather than as vehicles. The two-wheeled push-along carts used by ice-cream vendors in Manila City are of some interest on account of their wheel construction (Fig 6). Each wheel consists of a tubular steel hub and a simple steel rim joined together by eight radial spokes made of steel rod and welded in place. A solid rubber tyre is mounted onto the rim. This forms a spoked wheel which, while less efficient than a conventional bicycle wheel, is much easier to manufacture.

#### 3.22 Pedal-driven Vehicles

The Philippines is not a bicycle-orientated country in the way that China and India are. While bicycles are manufactured locally they seem to be used by only a small minority of the population and are not the basic means of transport for the common man that they are in other countries. This is rather surprising because much of Luzon is flat and ideally suited to cycling, and although the average standard of living appears higher than in some other Asian countries, there must be many Filipinos who cannot afford motorised transport. The traditional Filipino bicycle is very sturdily constructed, though there is now an increasing market for lightweight sports bicycles.

Two different types of pedal tricycle were observed, though neither appears in large numbers and both are used mainly for the transport of cargo rather than people. The first type is based on the configuration used for the traditional English ice-cream vendor's tricycle. This consists of a standard bicycle frame with the head-tube re-positioned vertically and the front fork and wheel replaced

by a fore-carriage made up of two wheels, mounted one on either side of a cargo box. The whole of this fore-carriage pivots about the head-tube axis for steering purposes (Fig 22 shows an Indian tricycle of similar configuration). The second type of tricycle is made up of a sidecar of tubular steel construction fitted with a bicycle wheel and mounted onto the side of a standard bicycle. This vehicle is often used for carrying a gas or kerosene stove and other equipment used for the vending of cooked food on the streets.

### 3.23, Animal-Drawn Vehicles

These are very common away from the cities, the most popular animals being the buffalo and the horse. Farmers often ride bareback on their buffaloes to and from the fields, and the buffaloes are also used to pull carts, many of them of traditional design with solid wooden wheels, while others use truck or car wheels. Buffaloes are also used to pull sleds which slide over the ground on skids. Horses are used mainly for passenger transport, one horse pulling a two-wheeled trap with wooden-spoked wheels. Occasionally bullock carts, grossly overloaded with cane furniture or some similar cargo, are to be seen wending their unconcerned way through the rush-hour traffic of central Manila.

### 3.24 Motorised Vehicles

There is a variety of simple motorised vehicles in use in the Philippines, and considerable evidence of local innovation in design. The most basic of these is a bicycle and sidecar with a 50cc. two-stroke engine mounted in the cycle frame (Fig 7). This drives the rear wheel through an additional chain drive, the original pedal chain drive being retained so that the rider can augment the power of the engine when necessary. This vehicle is used both in the less affluent parts of Manila and in the flat plain surrounding the city. It is used to carry fare-paying passengers, the sidecar being wide enough to hold one person in comfort, but alternatively goods can be carried in the same space. Motor-cycle and sidecar combinations are very common and are used in the same way and in the same areas as the vehicle described above. They normally used a locally assembled Honda, Yamaha or Suzuki motor-cycle of 90cc. or 100cc.

The most distinctively Filipino means of transport is the jeepney (Fig 8). When the American armed forces departed at the end of the war they left behind a large quantity of equipment, including many jeeps. In the difficult period following the war a number of these jeeps were converted by local mechanics to provide a basic means of motorised transport. The conversion involved extending the wheelbase of the jeep to increase its carrying capacity, fitting seats onto the lengthened rear platform, and constructing a canopy over the top to provide weather protection. From these origins the manufacture of jeepneys has developed into an important local industry and they are now the most familiar sight on the roads of the Philippines. As original supplies of parts have been exhausted, so more and more components have been manufactured locally (Ref.3). New jeepneys are

now available with a choice of different engines including a four-cylinder diesel and a six-cylinder Mercedes-Benz petrol engine. Considerable amounts of time and money are spent on the decoration of the jeepneys. They are brightly painted, heavily chromed, and carry as many polished ornaments as the owner can afford. A small number of jeepneys are now exported to Australia and America where they have novelty value. In Manila City, jeepneys are used mainly for passenger transport operating on set routes rather like a mini-bus system, and form a cheap and vital part of the public transport service. Away from the city they are used for the transport of both goods and passengers, and often tow a two-wheeled trailer to give extra load-carrying capacity. They are also used extensively in the hill regions, though standard wheelbase jeeps are also popular there.

A recent introduction to the Philippines are the so-called 'Asian utility vehicles'. A number of the major international motor manufacturers are now producing machines of this type, including the Ford Fiera (illustrated in Fig 9), the G.M. Harabas, the Chrysler Cimarron and the VW Trakbayan. All use major assemblies including engine, gearbox and rear axle, taken from the manufacturers' existing ranges, built into a simple, sturdy light-truck chassis with a beam front axle. A cap made up of flat panels which can be produced without using expensive tooling is added, and a number of rear bodywork styles are available, including flat-deck, closed-van, and passenger-carrying varieties. The intention is that these vehicles should be cheap to produce with significant local manufacturing content, durable, economical to run, and simple to maintain. They are appearing in increasing numbers on the roads of the Philippines in both passenger and cargo-carrying forms.

#### 4. The People's Republic of China

##### 4.1 Introduction

The Chinese way of life is very much orientated towards the use of simple vehicles. Self-reliance, and the utilisation of labour-intensive methods is encouraged, and this has led to the extensive use of muscle-powered, animal-powered and simple, motorised vehicles. In addition it has generated a high degree of innovation in the design of simple vehicles at the local level. The two most common sights on the roads of China are bicycles and handcarts. The private ownership of motor cars is illegal and the bicycle is the basic means of personal transport for most Chinese. A bicycle, locally produced, sells for about £35 as compared to a normal monthly wage for a single person of about £11, and therefore, though an expensive item, is within the purchasing capability of most people. The extent to which the transport system is bicycle-orientated is demonstrated by the existence of bicycle parks in the towns and cities where, for a nominal fee of 0.5p cycles can be parked under the watchful eye of an attendant. All bicycles in China are registered and carry a small identification plate on the rear mudguard.

Handcarts and wheelbarrows are the most common means of transporting

goods over fairly short distances, both in urban and rural areas, and in addition are widely used for earth-moving purposes in major construction projects such as irrigation schemes and dams. Apart from handcarts and bicycles, China also manufactures large numbers of two-wheeled tractors and light trucks. Manufacture of these vehicles is de-centralised, with a number of small factories in different parts of the country all producing the same basic design of vehicle.

- There has been considerable development of the Chinese road system since liberation, and the country now has a good network of sealed main roads. Many of the minor roads and tracks in the rural areas are narrow and unsealed but are quite satisfactory for the types of vehicle which travel on them.

#### 4.2 Simple Vehicles in China

##### 4.2.1 Human-drawn Vehicles

In areas where there are reasonably smooth road surfaces, two wheeled handcarts are used. One very common type of cart is of wooden construction, with two main longitudinal members supporting cross-pieces to form the load platform. Two shafts lead forward from the load platform and the cart is normally pulled by a single person working between these shafts. This wooden assembly simply sits on top of the axle which is made from steel bar and carries a wheel at each end. The axle is located by means of semi-circular recesses cut in the underside of the two main wooden longitudinal members (Fig. 10). Sometimes a leather strap is added to ensure that the platform does not lift off the axle. A variety of different wheel designs are used with these carts; cycle or motor-cycle tension-spoked wheels, steel spoked wheels of welded construction, or wooden spoked wheels with solid rubber tyres. This handcart design, where the platform can easily be removed from the axle, facilitates the stacking of two or three carts on top of one another when they are empty, allowing some of the carters to take a well-earned rest. Different bodies can be fitted onto the basic platform, such as a metal drum for carrying liquids, and a woven basketwork collar for holding loads in place on the platform (an example of this can be seen in the background of Fig. 16). These handcarts are used to carry prodigious loads and, should the load prove too great for one man, leather straps can be attached to the cart so that additional men can assist in the hauling operation. In some areas the same type of cart is harnessed to a donkey, attached to a front-wheel-drive monocycle (see Section 4.2.2 and Fig. 16), or tied to the back of a bicycle. If the wind is blowing in the appropriate direction then crude sails are hoisted on the carts to assist their passage.

In rural areas where the roads are rough or narrow, or where walking tracks are the channel of communication, then wheelbarrows of the traditional configuration used in China for many centuries are commonplace (Fig. 11). The single wheel is centrally mounted directly beneath the cargo platform so that the largest part of the load is supported by the wheel. The operator pushes the wheelbarrow along by means of two shafts extending rearwards from the platform. A

leather strap tied to each shaft and passing over the shoulder of the operator, ensures that his portion of the load is supported on his shoulders rather than by his arms. Contemporary wheelbarrows, usually manufactured by commune factories, have frames constructed from either wood or steel and use easily-obtainable spoked-wheels, of about 700mm diameter. (For further information on Chinese handcarts and wheelbarrows see Ref.4).

#### 4.22 Pedal-driven Vehicles

The popularity of bicycles in China has already been noted. They are locally manufactured and are mostly of very sturdy construction, featuring heavy-duty frames, forks and rims, wide-section tyres and rod-activated brakes on both wheels. However a number of small-wheeled bicycles are now being produced, including one design which incorporates a means of adjusting the wheelbase to suit the size of the rider. Many of the bicycles have panniers fitted on each side of the rear wheel to give some load carrying capacity, and in rural areas it is not uncommon to see bicycles carrying voluminous cargoes of firewood mounted over the rear wheel.

In addition to bicycles, tricycles are also common in the urban areas, and are used for both goods and passenger transport, though the major emphasis is on the carriage of cargo. While there are a small number of tricycles with two front wheels and a single rear wheel, the vast majority have one steered front wheel, and two rear wheels. However within this category there are a number of important variations in design. All tricycles of this type consist in principle of the front half of a bicycle, with the rear frame extended and widened to carry the rear axle and its two wheels. The load-carrying platform is mounted onto this frame. In most cases the front forks are strengthened by the addition of two small diameter tubes running from the fork-ends up to the handlebars. While some tricycles retain the conventional bicycle diamond frame for the forward part of the chassis, perhaps with the addition of a second top tube (Fig 12), others have a frame made up of a series of curved tubes welded together to form a complex structure (Fig 13).

It has been recognised by the Chinese that adequate braking is important on a load-carrying tricycle, and to achieve this a number of different methods are used to brake the rear wheels. One solution uses an external hand brake operating on a drum mounted on the solid rear axle (Fig 14). Another design, which incorporates a differential in an enclosed rear axle, has rod-operated drum brakes at each end of the axle. A third method uses centre-pull stirrup brakes mounted on each side of the chassis at the most forward point of the rear wheels (Fig 15) and operated by a system of rods and bell cranks. A fourth design uses a similar system of actuation to operate single brake blocks mounted on the end of levers pivoted inboard of the rear wheels, so that the block can be made to press against the inboard side of the rear wheel rim. In most designs these rear brakes are operated by a foot pedal.

It is desirable, on a tricycle used for hauling heavy loads, to have an overall gear ratio lower than that found on a standard bicycle. This is achieved in China by reducing the diameter of the chainwheel to give overall gearing equivalent to a 900-1000mm wheel (this can be seen in Fig 13). The performance of a tricycle can be improved by providing a choice of alternative gear ratios for use in different operating conditions. This is done on some Chinese tricycles by mounting two chainwheels of different diameters side by side on the pedal-axle, in a similar fashion to the double-chainwheel of a ten-speed derailleur system. This gives two alternative overall gear ratios and the rider selects the more suitable one by transferring the chain from one chainwheel to the other. There is no tensioning device included in this system so that the chain has to run very slack. A more complex method was observed on a tricycle in use in Macao, though its design comes originally from mainland China, where the drive is taken from the chainwheel to an intermediate shaft placed parallel to and forward of the rear axle. From this shaft two parallel chain drives with different ratios run back to the rear axle, and are selected in turn by means of dog-clutches on the intermediate shaft. This gives two alternative overall gear ratios, but is a rather complex design solution.

On most Chinese tricycles only one of the rear wheels is driven though, as mentioned earlier, there is one type which uses a differential and drives both wheels. There is one design in which both the rear wheels are driven without a differential being used (Fig 14), the chain drive being transferred direct to a solid rear axle. The cornering problems inherent in such a system are mitigated by having a very narrow rear track, the useful width of the load platform being maintained by mounting it above the top of the wheels, which raises the centre of gravity of the vehicle when loaded.

Generally, the rear tricycle wheels are of more substantial construction than normal bicycle wheels, using bigger hubs, wider rims and thicker spokes to cope with the increased loading imposed upon them. These tricycles carry very heavy loads and it is not uncommon to see people hauling in traces to assist the rider if the load is particularly onerous.

In the Chengchow area of China a front-wheel-drive monocyde is used in conjunction with handcarts (Fig 16). The monocyde consists of a fork carrying the wheel, handlebars and a chain drive, the chainwheel and pedals being mounted immediately to the rear of the wheel. This assembly fits into a standard bicycle head-tube, and a frame extends backwards from this to the saddle. The rear of this frame clamps onto the front of the handcart platform. There are brackets on either side of the head-tube into which fit the shafts of the handcart, and thus the two-wheeled handcart can quickly be converted into a three-wheeled tricycle. There appeared to be certain problems with this particular design, the major one being lack of torsional rigidity in the assembled structure. Finally, pedal-powered road-sweepers are a common sight in many Chinese cities.



#### 4.23 Animal-drawn Vehicles

These are very common in rural areas, with horses, mules and donkeys being the most popular sources of power, at least in the parts of China visited by the author, though buffaloes and bullocks are also used. The animals are used singly, in pairs or in groups of three, according to the size of the vehicle being hauled. The vehicles are mainly two-wheeled carts rather than four-wheeled wagons and range upwards in size from the handcarts described earlier which are sometimes hitched to donkeys. The larger carts use car or truck wheels and stub axles, these stub axles being mounted onto wooden cross-members to form a solid axle. No carts using traditional wheels of wooden construction were observed.

#### 4.24 Motorised Vehicles

Several types of simple motorised vehicle are used in China, and there is some variation in design from one region to another. Mopeds using a single-cylinder 50cc two-stroke petrol engine are locally manufactured and some of them have been converted into what is best described as a moped-tricycle, with the front section of the moped grafted onto the rear section of a pedal tricycle incorporating a differential and drive to both rear wheels.

There are a number of Chinese three-wheeled vehicles based on motor-cycle components which vary in details of design but have certain features in common. The front wheel, fork and handlebar assembly from the motor-cycle is retained, and the engine is kept in its normal position with the rider sitting astride it. The chassis is extended rearwards to an axle carrying a wheel at each end; a chain drive transmits power from the engine to these rear wheels. The chassis can be fitted either with passenger bodywork to carry two people under a canvas protective canopy, a closed van-body or an open flat-deck. The following description is of a vehicle inspected by the author in Wuhan (Fig 17). The rider's controls, in addition to the handlebar, consist of a twist-grip throttle, foot brake, conventional kick-start, foot-operated clutch and a hand lever extension of the standard motor-cycle gear-change. The drive is taken from the gearbox which is integral with the engine to an intermediate sprocket, and thence by a second chain drive to the axle-mounted differential. The rigid rear axle is supported on longitudinal semi-elliptic leaf springs, and the two rear wheels are connected by an anti-roll bar. There are cable-actuated drum brakes on each rear wheel; but no front wheel braking. There is cramped seating behind the rider for two passengers.

A much larger three-wheeled vehicle, of about the same overall size of a small truck, is a common sight in the cities. The single wheel is at the front and the two rear wheels are driven from the front mounted engine through a propeller shaft. The steering wheel and driving position are offset to the left, allowing space for a passenger in the cabin beside the driver.

The two-wheeled or single-axle tractor has played a vital role in the mechanisation of Chinese agriculture. It is manufactured in large numbers in factories in each of the provinces and, in addition to its strictly agricultural use, it plays an important role as a means of cargo and passenger transport, particularly from the country to the town or city and back again (Fig 18). The tractor has a single-cylinder 9kW diesel engine driving through a gearbox and half-shafts to the two wheels. There is a dog-clutch incorporated in the drive to each half-shaft controlled by a lever on the handlebar so that at any time the operator may opt to drive either one or both of the wheels. This gives the tractor exceptional manoeuvrability. The engine is mounted horizontally, above and in front of the axle line and the driver sits at the rear of the tractor. If the tractor is being used without any implement attached then a small castor wheel is fitted at the rear and is used to assist in steering the vehicle. However for transportation purposes the two-wheeled tractor is normally hitched to a two-wheeled trailer. The driver then sits on the front of the trailer and steering is effected by means of the pivot between the tractor and the trailer.

## 5. India.

### 5.1-Introduction

There are many similarities in the means of transport used in China and India. In both countries handcarts, bicycles, pedal-tricycles and animal-drawn vehicles play a predominant role. However there are also significant differences. In India there is a much greater availability of transport for fare-paying passengers including human-drawn rickshaws, cycle rickshaws and scooter rickshaws, while the simpler forms of motorised vehicle are more common in India than in China.

There are several large companies in India manufacturing motor-scooters and motor-cycles, and two of these also produce three-wheeled vehicles utilising the same basic components. However the demand for motor-cycles and scooters exceeds the supply to such an extent that the waiting list for these vehicles is now several years long.

Unlike China, the Indian social and political system tends to encourage the private ownership of motor cars, and such possession is still the ambition of many Indians. However they are within the financial means of only a small minority of the Indian population and indeed the demand for cars has decreased somewhat as a result of the large increase in petrol prices over the past two and a half years (petrol in India now costs well over £1 per gallon). India manufactures three different models of car, each of them based on an obsolete European design. They are manufactured on tooling transferred to India after the models went out of production in their countries of origin. The cars have been built for several years with little design change - for example the Ambassador, which until recently was the most popular Indian car, is virtually identical to the pre-1959 British Morris Oxford. Such a manufacturing policy

has certain advantages; tooling costs are kept down to a minimum, and the very limited range of cars on the road simplifies maintenance - both spare parts and the required maintenance skills can more easily be made available. However there are also disadvantages; the vehicle designs are imported from relatively affluent developed countries and therefore are not necessarily suited to India's needs, and no advantage can be taken of subsequent design innovations which might be beneficial, for example in relation to fuel economy measures. Foreign vehicles may only be imported into India after the payment of very heavy import duties.

India has a fundamentally good road system, though many of the rural roads are unsealed or sealed only to the width of one vehicle, and many of the town and city streets are in need of repair. Urban traffic is a noisy, crowded, disordered conglomeration of pedestrians, bicycles, cows, cycle rickshaws, handcarts, auto-rickshaws, motor scooters, cars, taxis, trucks and buses. Many urban streets are narrow and the conductors of both muscle-powered and fossil-fuelled vehicles appear to have energy conservation as their first priority. Hence a vehicle, once in motion, only slows down in circumstances of dire necessity. Traffic priority rules are ignored and travelling on the urban streets seems to involve a succession of near-collisions and near-misses.

## 5.2 Simple Vehicles in India

### 5.2.1 Human-drawn Vehicles

Handcarts are widely used in urban areas for short-range goods transport and for the vending of products on the streets. In some places the traditional rickshaw, pulled along by a man, is still used for passenger transport. In Calcutta many of the handcarts are of the long-established design using two large, wooden-spoked wheels of about one metre diameter. On these carts the heavily-greased hub is mounted directly onto a solid metal axle, the wheel being located by a flange on the axle and retained by a cotter pin passing through the axle. The cargo-carrying carts have wheels with thick spokes, and a load platform made of lengths of bamboo, from which two shafts extend forward, the person hauling the cart working between these shafts. The passenger-carrying rickshaws have more elegant wheels with much thinner wooden spokes and a narrower rim. The passenger seat is mounted above the axle on full elliptic springs (Fig 19).

In other parts of India a rather different design of handcart is used which incorporates standard automobile wheels. These carts are of largely wooden construction with the wheels mounted on stub axles fitted onto the ends of a stout wooden axle. A single central shaft extends forward from the load platform with a wooden bar mounted across its front end (Fig 20). The cart is normally worked by two people, one on each side of the shaft, pushing forward on this cross member. In addition a vertical leg extends downwards from the shaft so that the cart can be parked with the load platform in a horizontal position. In fact this design of cart is essentially a scaled-down bullock cart.

A third type of handcart has four close-coupled bicycle wheels fitted into a simple steel frame, with a flat wooden tray mounted above the top of the wheels (Fig 21). This type of cart is generally used for the street-vending of food and other goods, and although the high load platform makes the cart unsuitable for carrying heavy loads, or for carrying loads over any great distance, it is convenient for selling purposes. There are a number of variations on the basic spoked-wheel theme used on these carts. Some wheels have double spokes which pass from the rim, through the hub and out again to another point on the rim. Others use radially-spoked wheels, and some use wooden slats to strengthen the original spoked wheel, as in Fig 21.

## 5.22 Pedal-driven Vehicles

Pedal tricycles are widely used in India, mostly for passenger transport in and around the urban areas, though they are banned from the centre of some of the largest cities. The configuration of two front wheels and one at the rear is common in Calcutta, but in other parts of India cycle rickshaws with one front and two rear wheels are much more popular.

A pedal tricycle of the former type is shown in Fig 22. It has the same gearing as a standard bicycle and braking only on the rear wheel. The front wheels are of interesting design, using radially positioned spokes and eliminating the need for nipples. The hub flange is folded over to form a circumferential ring about 15mm wide, and a series of radial, tapped holes are formed in this ring. The spokes, which are headed at their outer end and threaded at the inner end, are passed through holes in the rim and then screwed into the tapped holes in the hub.

The more common tricycles with two rear wheels are similar in principle to their Chinese counterparts, the configuration consisting of a bicycle frame extended rearwards and widened to support a rear axle. The rear axle is positioned in bearings bolted onto the frame in plunger blocks, with the load-carrying bodywork placed above the axle. While in China there has been considerable development of this basic design, there is little evidence of similar innovation in India. On the Indian models only one rear wheel is driven, and there is no attempt to reduce the gear ratio below that of a standard bicycle. As a result it is not unusual to see a loaded tricycle which is stalled, with the rider applying his maximum force to the pedals but unable to propel the vehicle forward. This unsuitable gearing makes life very hard for Indian rickshaw riders. There is no means of braking the rear wheels, though on some examples braking performance has been improved somewhat by connecting both brake levers to the front brake. Wooden pedals are often used on these cycle rickshaws.

A further difference between Chinese and Indian tricycles is in the actual construction of the chassis or frame. While the Chinese design is closely based on bicycle practice the frame is normally made as a purpose-built unit for a three-wheeled vehicle. However,

many Indian tricycles are made by starting with an existing bicycle frame, removing part of the rear of the frame and replacing it with a specially fabricated structure. This rear frame is usually made of steel angle-section, welded or clamped to the cycle frame, though in parts of Gujarat a wooden structure is used.

### 5.23 Animal-drawn Vehicles

A number of different types of animal-drawn cart are found both in the rural areas and in the towns and cities of India. Pairs of bullocks are used to draw a cart very similar to, but larger than the two-man handcart described earlier. The two bullocks are harnessed one on either side of the central shaft so that the shoulder hump of the bullock presses against the crossbar on the shaft. Some of these carts use truck wheels while others use traditional solid wheels of wooden construction. It is worth noting that there are in excess of 12 million bullock carts in India.

Camel-drawn wagons are popular in certain areas; a simple, wooden wagon running on four car wheels is used; the front axle is pivoted about its centre and connected to two shafts leading forward, with a single camel harnessed between these shafts. In use the shafts slope upwards at an angle in excess of thirty degrees, owing to the height of the camel.

Finally, horses are used to pull carts with two large, spoked, wooden wheels, similar in design to pony traps.

### 5.24 Motorised Vehicles

Simple motorised vehicles play a significant role in the Indian transport system. A very common example is the auto-rickshaw, a three-wheeled vehicle based on the motor scooter. It consists of a lengthened scooter chassis, widening out at the rear to support two rear wheels. The standard front fork and handlebar steering is retained; the engine is mounted in its conventional position, and the rider is centrally seated astride the engine. There is a cab, incorporating a dashboard, built around the driving position, and the petrol tank is located in the right-hand side of this dashboard. A variety of different forms of rear bodywork is available for the auto-rickshaws, including passenger bodywork which is the most popular and has a bench seat wide enough to carry two people in comfort or three at a squeeze, an open truck body and a closed van body. The auto-rickshaw can also be used as the prime mover of an articulated vehicle, hauling a two-wheeled trailer behind it.

There are two makes of auto-rickshaw in India, based on two models of scooter. The major difference between the two designs is in the transmission system used. The first is based on the Lambretta scooter manufactured under licence by Automobile Products of India Ltd. The drive is taken from the gearbox by means of a propeller shaft to a differential mounted in the rigid rear axle. The rear axle is located on semi-elliptic leaf springs. The second make of auto-rickshaw is based on the Vespa motor-scooter, built under

licence in India by Bajaj Autos Ltd. The drive in this case is taken from the gearbox to a final drive and differential unit mounted directly behind the gearbox. Two horizontal half-shafts emerge laterally from this unit, and pass through trailing wishbones which pivot about the axis of the half-shafts. Each trailing wishbone carries a rear wheel and the drive is taken from each half-shaft to its wheel by means of a chain drive running inside the wishbone (Fig 23 shows this vehicle and the wishbone can be seen in the picture). This design results in an independent rear suspension system which utilises torsion bars as the springing medium. These auto-rickshaws are used both for passenger transport, operating on the same basis as taxis but at about half the price, and for the local transport and delivery of goods. They are economical to run, and sell for approximately £600 complete with passenger bodywork. Their major drawback seems to be that the wheel size is rather small for Indian roads, which are often quite rough even in the towns. As a result the riders of these vehicles have to dodge around the more substantial potholes.

In Delhi there is another design built on the same principle as the auto-rickshaw, but using an old Harley-Davidson V-twin engined motor-cycle as the basis. These vehicles can carry up to six people but apparently they are no longer built and will eventually be phased out of use.

A larger three-wheeled vehicle, available with either van, flat-deck or passenger bodywork is the Hanseat Tempo. This has a single, driven front wheel with the water-cooled engine mounted above the wheel and driving it by means of a chain, the whole assembly turning as a unit when the vehicle is steered (Fig 24). The vehicle is very long in relation to the track of its rear wheels which are independently suspended using swing axles. The vehicle is originally of German design and is built under licence in India.

## 6. Conclusions

There is a variety of different types of simple vehicle already in use in Asian countries, which have been developed or adapted in varying degrees to meet local requirements. There is much detail variation in the design of these vehicles, both from one part of a country to another and from one country to another.

There are other developing countries, notably in Africa, still totally reliant on imported vehicles which are often inappropriate to their needs. Papua New Guinea, which is in this situation, has only now begun to come to terms with this problem and to define the types of vehicle which meet its requirements.

Pedal-driven vehicles, as a most efficient means of utilising human muscular energy have an important role to play in the transport systems of developing countries. Existing pedal-driven vehicles are still bicycle-derived; that is to say that innovation has been restricted to the detailed improvement of existing designs, rather than to the development of fundamentally new forms of pedal-driven

transport. Similarly, simple motorised vehicles are still very closely related to the motor-cycles and scooters from which they are derived.

The use of pedal-driven and simple motorised vehicles is still largely restricted to the heavily-populated urban areas which have better roads than the surrounding rural districts. While the development of transport modes is a process that, to some extent at least, is likely to spread outwards from the urban to the rural areas, part of the reason for the restricted rural usage is the lack of pedal-driven and simple, motorised vehicles which can satisfactorily be used on poor roads. This is perhaps an area where the development of suitable vehicles is a necessary first step, in order to generate or to demonstrate a demand for them.

Handcarts and animal-drawn vehicles are traditional forms of transport in Asian countries, and their design and development seems to be an indigenous process, though evolution is slow. However with the partial exception of China where total self-reliance has been both policy and necessity, the pedal-driven and motorised vehicles are imported designs with little or no adaption to meet local needs. The fundamental design concepts have not been evolved in the developing countries.

In China, India and the Philippines, cycle, motor-cycle and automobile components are used in the construction of hand-drawn and animal-drawn vehicles. This is not a technique which is necessarily transferrable to other countries where the 'source' vehicles are not so commonly used and hence the components are more difficult to obtain.

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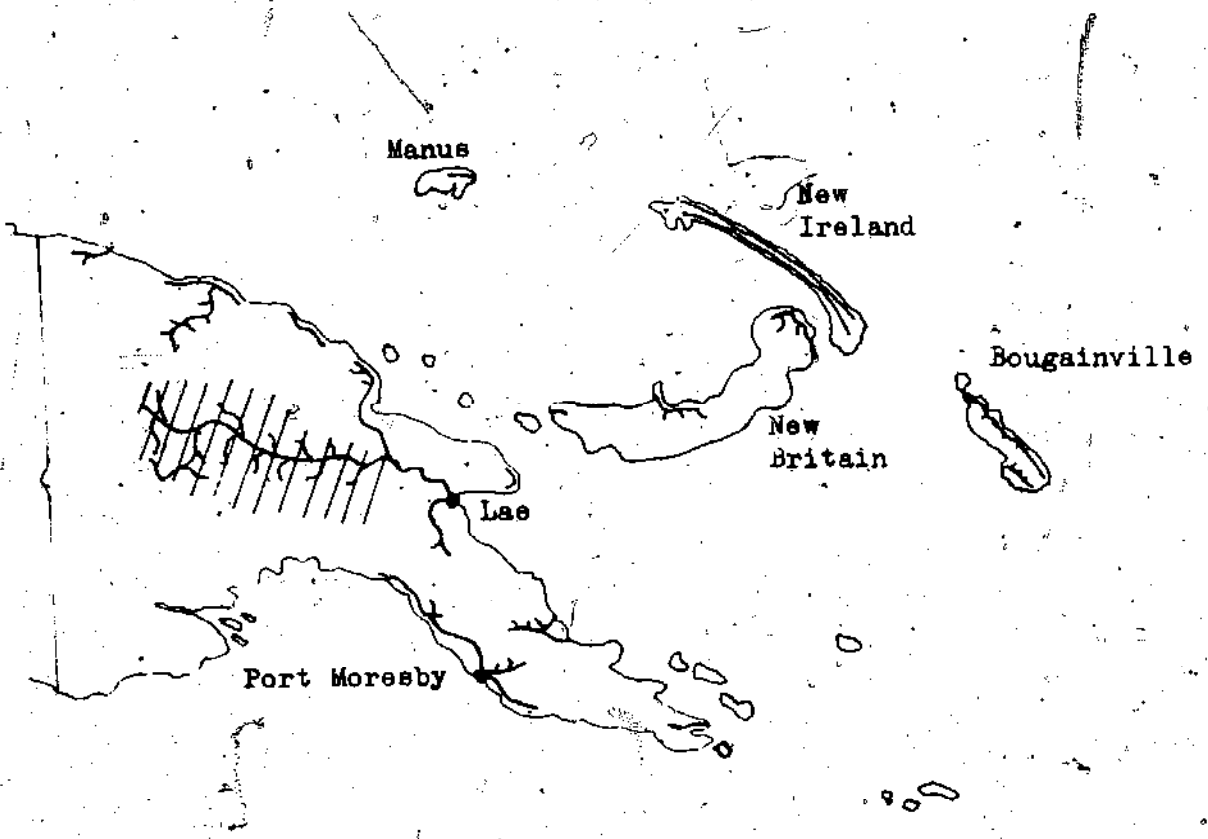




Fig 1 A map of Papua New Guinea showing: roads  Highlands region 

Number of bicycles imported per annum

Fig 2. Annual imports of bicycles into PNG 1968 - 1974

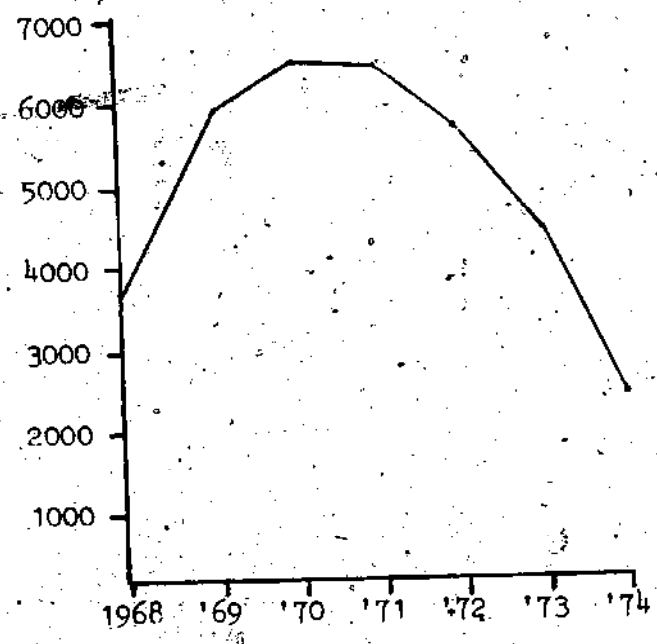






Fig 3 A cycle trailer chassis built in PNG.

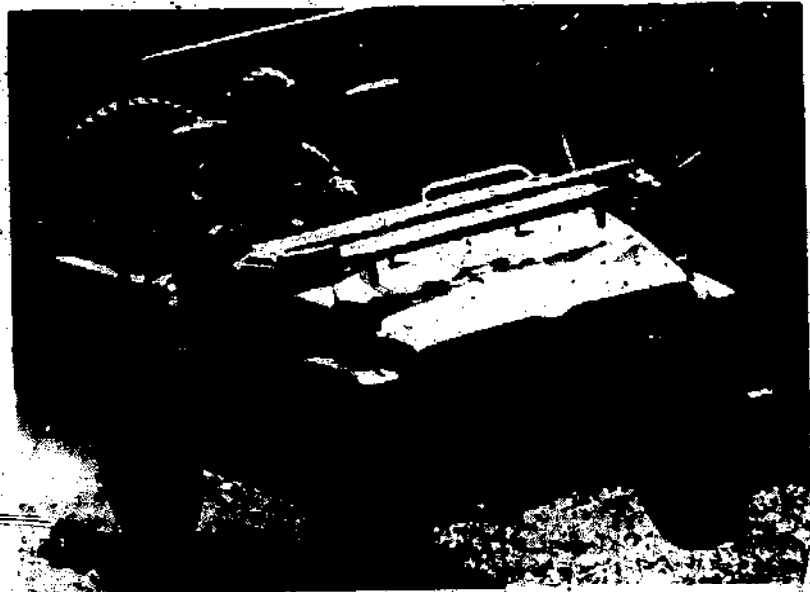


Fig 4 A Suzuki Brute



Fig 5 A P.M.V. crossing a flooded causeway.



FIG 7



FIG 6



FIG 9



FIG 8

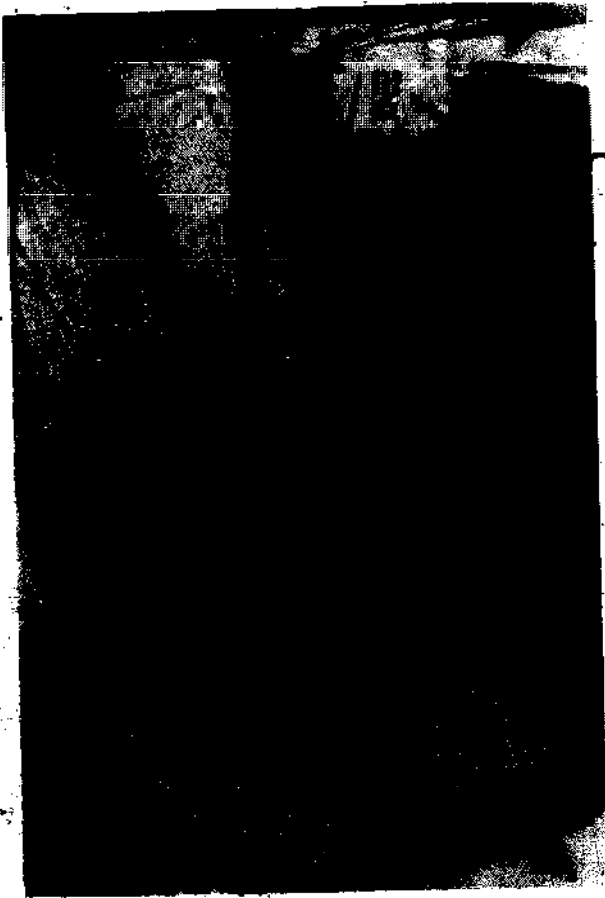


FIG 10.



FIG 11



FIG 12

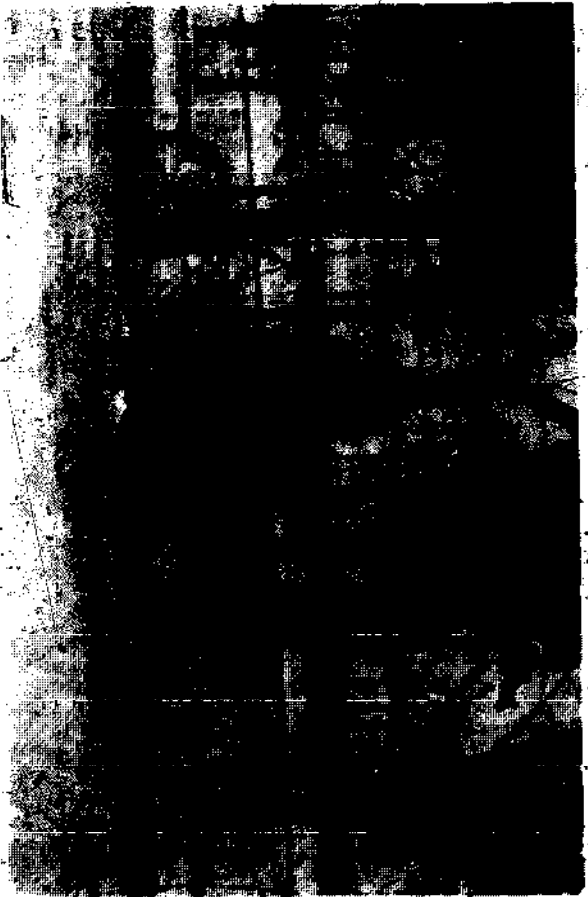


FIG 13



FIG 15

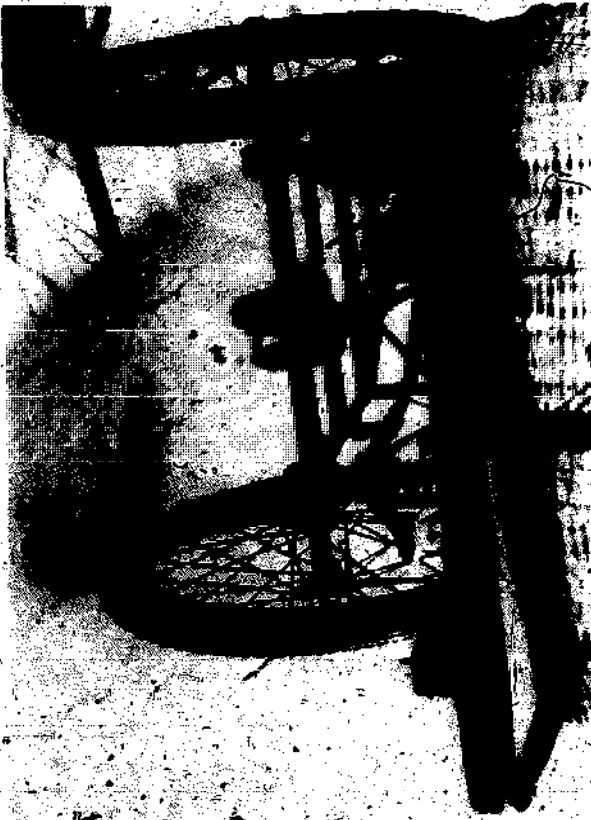


FIG 14



FIG 17



FIG 16



FIG. 18



Fig 19



FIG 20



FIG 21

Fig 22

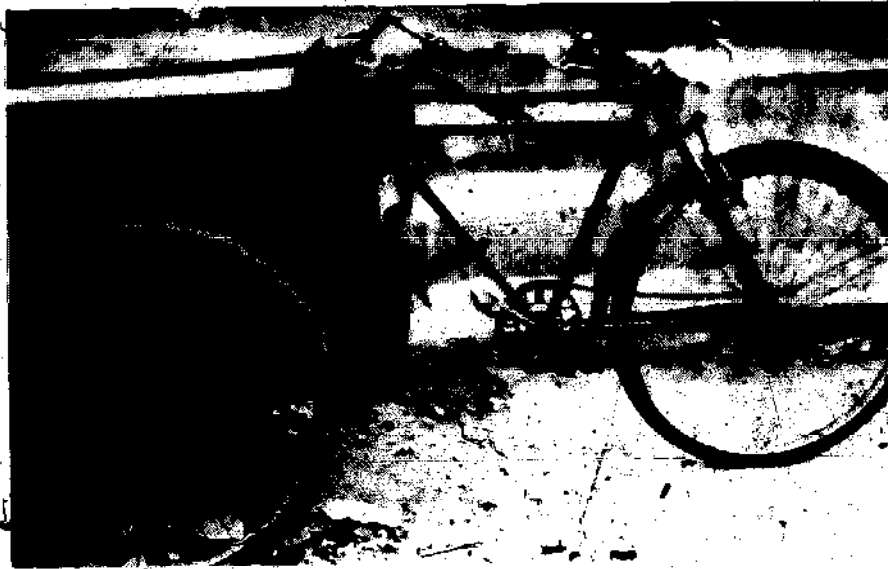


Fig 23



Fig 24