APPROPRIATE TECHNOLOGY AND LOW COST TRANSPORT

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This paper is concerned with the provision of appropriate transport facilities in the rural areas of developing countries. It is argued that the technologies applied in the past have been inappropriate to, and ineffective in meeting the transport needs of their poorest people. Further, that there are alternative and more appropriate transport technologies which can better meet many of these needs. Past transport strategy has been dominated by an institutional preoccupation with the provision of roads suitable for conventional motor vehicles. The supply of those vehicles has been left largely to the private sector and their technological appropriateness unquestioned to the extent that the type of vehicle is not a variable in road design. The result has been high road construction costs, slow network development, and the neglect of the movement needs of small scale farmers and of traditional forms of transport. A range of basic vehicles is described whose technology is shown to be more appropriate to the needs of many rural developing communities. It is suggested that attention should be focussed on improving the technology of basic vehicles with a corresponding re-appraisal of track requirements. The application of a more appropriate technology requires that rural transport planning should explicitly include an appraisal of the small farmer's movement needs and the constraints within which these must be met.

This paper is specifically concerned with low cost transport *in developing countries*. Since 1969 the International Labour Office and the World Bank have challenged many of the orthodox views about the type of technology most appropriate for the construction of roads in developing countries. We go further to consider not just the construction of the road, but to question the whole notion of the most appropriate forms of *low-cost transport* for developing countries and the scope for technologies intermediate between the traditional and those introduced from the developing world.

In most developing countries transport has generally received more resources in the past three decades than any other sector, yet in the same period the number of persons living in absolute poverty has increased and their conditions of life worsened (1). Whilst past transport policies may not have caused the increase in poverty, they have not prevented it. The implication is that a *continuation of past strategies is unlikely to alleviate or improve the conditions of the poor.* For this reason it is important to examine past transport strategy to determine in what way it might be modified to better serve the needs of the poor.

Past Transport Strategy

The 'rural transport problem' in developing countries has been seen as one of providing or improving the quality of access. The term *access* has meant almost exclusively 'road access'. Past road investments have favoured the construction or improvement of major rural highways rather than urban or minor rural roads, although this emphasis is changing slowly (2). The only recognition that developing countries might have special rural transport problems has been the effort devoted to the subject of 'low-cost roads'. Until 1976 there had been no comparable effort devoted to 'low-cost vehicles' or to any other type of road vehicle particular to developing country needs (3, 4).

In retrospect this omission is very odd. Transport comprises a system: some form of vehicle and a 'track or route upon which that vehicle moves'. We have expended considerable time, money and effort in seeking to optimise the one to the almost total exclusion of the other.

Road Design Standards

Concepts such as 'design speed','safe stopping sight distance' and many others that underlie the geometric design of modern highways have never been satisfactorily interpreted for developing country needs. One of the few recognised text-books on road design for developing countries recommends essentially US standards - probably the most generous ever developed - for the geometric elements of 'low-cost' highways (5). Moreover, the design, and hence cost, of a modern road is predicated upon the performance characteristics of the private car and goods lorry: the assumed speed that car drivers 'desire' dictates the standards of horizontal and vertical curvature, and the expected axle load of goods lorries dictates the road's structural strength. Yet neither of these vehicles has been shown to be essential, much less optimum, for rural developing regions. In most developing countries the current level of motor vehicles per head of population is extremely low (Table 1) (29) and the expectation is that it is unlikely to increase very rapidly. A UNIDO study of 93 developing countries (6) showed that in 1968 average motor vehicle density was 9.2 units/1000 population. By 1980 it was forecast that this will have risen to only 11.8 units/1000 population.

For rural societies, simpler and cheaper vehicles might be more appropriate. Slower and lighter vehicles would allow the alignment, strength, and width of roads to be reduced, with, potentially, a considerable saving in costs.

The usual argument against such a course of action is that by so doing user costs would rise, leading to an increase in the total cost of transportation. However, the appeal of this argument is superficial. It has merit only because we are unable to account fully for the consequences of road improvements, a situation which artificially exaggerates the importance of those benefits we can quantify. Time savings are not taken into account with current techniques for the economic appraisal of road improvements, (7) and by general admission the so-called 'secondary' or developmental and social benefits are as yet unquantifiable. In fact the most recent evidence suggests that the secondary effects of transport investments in isolation - such as the building of rural highways - may in fact be *harmful* to certain sections of the community. Studies (8, 9) have shown that benefits resulting from transport improvements tend to accrue to the already advantaged. Often there are also appreciable dis-benefits which are usually overlooked and, invariably, affect the poorest groups. Examples found were:

1. Reductions in labour demands following the replacement of traditional movement methods by motor vehicles.
2. Concentration of capital as cottage industries are bankrupted by the increased competition from larger-scale industries in the towns.
3. Changes in agricultural production towards transport-intensive products which do not necessarily benefit the poor.
4. Concentration of land holdings.

Road Construction Costs

A direct consequence of road design for use by conventional motor vehicles is that construction costs remain high, particularly when equated with the resources of the poorer developing countries. The World Bank recognises three classes of 'rural roads', by which is meant low volume, feeder or tertiary roads (2). These are:

Class I — major roads which also fulfil principally a rural access (as opposed to inter-urban) function but which cannot be classified as feeder roads because of their regional importance. Approximate costs: \$20,000-\$350,000 per km.

Class II — Feeder roads connecting villages and small markets with larger regional centres and/or major transport arteries. Approximate costs: \$10,000-\$100,000 per km.

Class III: — Farm-to-market roads representing the lowest class of roads available for transport and normally linking a number of farms to the closest market/administrative centre or transport artery. Approximate costs: \$5,000-\$25,000 per km. for major construction not minor upgrading.

If one compares the figures in Table 2 (30) with the construction costs for rural roads it is apparent that many of the poorer countries can afford only relatively insignificant additions to existing road systems. Consider the case of Sierra Leone. If *all* the current annual expenditure on highways were concentrated on Class I rural roads then it could afford between 5 and 80 km of road per year, which would add between 0.2 and 2.6 per cent to the length of the present system. The significance of this is that in most developing countries the density of the *existing* road network is very sparse (Table 3) (30) and lags far behind the rest of the world. In practice the overall length added to the sytem would be *lower* than the figures quoted above since part of the expenditure would be on more expensive primary highways.

Unless the cost of road building can be drastically lowered, then for most of the poorest countries road network development will be extremely slow. A reduction in construction costs is unlikely so long as road design is necessarily equated to use by conventional motor vehicles.

The Role of Conventional Motor Vehicles

For many years a belief has been fostered in what might be termed the 'economies of modernity'. The figures in Table 2 illustrate the foundations of this belief (10). The implication is that 'primitive is slow and expensive' and 'modern is fast and cheap'. But the comparisons assume either full loads or equal load factors, (i.e. similar degrees of utilisation) not just in the short term, but over long periods of a year or more. Is this likely? It is not always clear if the figures are costs or charges to the user. If they are costs, are they based on market or economic prices? Has any allowance been made for the fact that it costs society nothing for the track over which loads are carried on the head, by mule or bicycle, but a road suitable for motor vehicles will cost several thousand dollars per kilometre to build and several hundred a year to maintain? What, if anything, are the employment consequences of substitution among different modes of transport? Are all modes of transport equally possible: will the terrain, length of journey, size of consignment, etc. allow a free choice between them. *Most important, are they equally available and affordable to all would-be users?*

In reality different modes of transport serve characteristically different movement demands, yet supposed unit costs are the most common basis of comparison in analyses of the suitability of transport modes.

Government and Institutional Involvement in Road Transport

Government involvement in the provision of motor vehicles has, by and large, been regulatory: either permitting reasonably free import or making it very difficult where foreign exchange has been an acute and continual problem (e.g. Burma, Bangladesh, Sri Lanka and Tanzania); although some have participated in capitalizing production ventures, the bulk of the capital has come from international motor vehicle suppliers. In developing road transport the implicit assumption has been that the private sector would supply whatever vehicles were necessary to make efficient use of the roads provided by the government. That this supply would appear has been taken for granted and that it might not be appropriate hardly considered. There are countries that have simultaneously made significant (public) investment in highways combined with severe restrictions on the (private) import of vehicles: the latter restrictions negate the possibilities of receiving benefits from the former investments.

Few developing countries - China, India and Papua New Guinea (11) being exceptions - have attempted to restrict the number and type of vehicles to those considered appropriate to their stage of development. Restrictions because of foreign-exchange considerations or the desire for local manufacture are not uncommon: but restrictions because of alleged technological inappropriateness are.

Transport Needs of the Poor

The available evidence (12, 13, 14, 15) suggests that typically the poor:

1. Are engaged in agriculture working small plots of land either for themselves or as landless workers.
2. Are engaged in subsistence farming or generate only small marketable surpluses.
3. Have a family cash income of only a few tens of dollars a year.
4. Are poorly served by almost all public amenities including transport.

The most significant transport needs of the poor are those which relate to agricultural activities, since it is through the generation of marketable surpluses (and thus income) that other goods and services become affordable. However, transport needs *at the farm level* have very rarely been studied. Roadside surveys of the commodities carried by motor vehicles are a poor substitute since (i) they are too far along the marketing chain to be able to isolate individual consignments and the distance over which they are being moved; (ii) none of the studies have been sufficiently extensive to give any adequate measure of seasonal fluctuations in travel; and (iii) they give no indication of on-farm transport needs.

One farm level study was carried out in Kenya by the World Bank in 1976 (16, 17). This suggested that most transport needs could be characterised as the movement of small loads (10-150kg units) over relatively short distances (1-25km). On-farm the range of loads was likely to be the same, but the typical distances were shorter (1-13km). The amounts of water and wood required for household use were noteworthy (50 and 30kg respectively), since it was estimated that their collection occupied 3-6 hours per day.

Since the farmer must follow a fairly rigid schedule to obtain optimum yields, it is important that on-farm transport for crop production and household needs should not be so time-consuming as to delay operations. For example, if some crops are not sprayed on time the results may be disastrous. Yet the spraying of cotton with insecticide required about 200-300 litres of water/hectare. For a four hectare plot this is 800-1200 litres and between 7-10 sprayings are normally recommended, i.e. between 6-12 tonnes of water, a formidable amount if headloading is the only available means of transport (17). In the studies in Kenya it was concluded that on-farm transport was already a burden if not an outright constraint on small farm activities.

Off-farm transport comprises two elements: between farm and roadside, and between roadside and collection point/market. An example of how large these elements can be is given by the definition in a study of Nepalese peasant agriculture (8) of the terms 'on road' to mean at the roadside or within a few hundred metres, 'near road' to mean up to half a day's walk from the road, and 'off-road' to mean more than half a day's walk.

There is a dearth of information about the magnitude, frequency and duration of the small farmer's movement needs. What is clear, however, is that the transport requirements can be substantial, even when only small areas are planted. Table 5 presents data from Malawi on the yields and inputs per hectare for different crops (18).

Discussion

Recent rural transport strategy has pursued development from the top downwards using developed country technology. That is, a progression from major primary, to secondary and only latterly to tertiary highways all built on the basis of design philosophies imported from the developed countries: equally, a reliance on developed country motor-vehicles with only very recently (3) a small step in the direction of lower cost, but still motorised, vehicles and the complete neglect of traditional forms of transport. The result is skeletal road networks that in the poorer countries plainly do not serve effectively the majority of the population, and vehicles so expensive that they are beyond the means of all but the affluent. Moreover, past transport planning has failed to recognise that many people live remote from the (motor-vehicle) road system, and have movement needs that could never be satisfied by conventional vehicles.

Thus for the rural poor it would be difficult to conceive of a more inappropriate technology: often unrelated to basic movement needs, inaccessible, scarce, expensive, difficult to use and maintain, and frequently wholly dependent on foreign resources in terms of manufacture, energy, spare parts and operating skills.

To define a more appropriate *transport* technology it is necessary to ask the question: 'What are the appropriate *vehicles* for rural areas of developing countries'?

Appropriate Vehicle Technology

Most attempts at defining 'appropriate technologies for developing countries' agree on the necessity of meeting 'local needs' and the requirements that they be employment generating, compatible with incomes, and capable of manufacture and maintenance using indigenous skills and resources.

Given the variations in incomes; in topographical, road, farming and social systems; and in local resources and capabilities, there cannot be '*a universal vehicle*' appropriate to all the rural transport needs of developing countries. *Rather, the need is for a graduated choice of vehicles whose performance matches need and whose cost is in sensible relation to income.*

Consideration of the characteristics of the rural poor, their transport needs and the criteria of an appropriate technology leads to vehicles radically different in concept from conventional motor vehicles. The consequences of variations in operating environment, loads, cost, technical simplicity and the use of local resources lead to a progression of human, animal and, at the extreme, simple motorised means of movement. We term these collectively as *basic vehicles*, which may be defined as:

the range of devices from aids to goods movement by man himself up to but excluding, conventional cars, vans, buses and trucks.

Six categories of basic vehicles can be defined:

1. Aids to head, shoulder and backloading
2. Handcarts and wheelbarrows
3. Pedal driven vehicles
4. Animal transport
5. Motor cycles
6. Basic motorised vehicles

Many such basic vehicles already exist in different parts of the developing world, though often their use is localised. Some are primitive, being traditional devices which have remained unchanged for many years. Almost all are capable of improvement, using contemporary technical knowledge, so as to increase significantly their efficiency and usefulness.

Head, Shoulder and Back Loading

These are the most common methods of load-carrying in rural areas. Loads can be carried over steep, hilly or rocky terrain and aids to human porterage can usually be made at token cost by local people using available materials. However, human porterage is arduous physical work; it is also slow, and therefore time consuming. As a result loads are limited to about 40kg, and can only be moved short distances. There is also widespread concern that the habitual carrying of very heavy loads can cause physical disabilities and injuries. Yet for the foreseeable future human porterage is likely to remain an important means of rural transport. Therefore, efforts should be made to improve its efficiency and minimise its harmful effects. There have been few attempts to improve this means of transport. One notable attempt is the joint work of the Georgia Institute of Technology (USA) and Soong Jun University (Korea) on the Korean Chee-ke (19). The Chee-ke is a traditional form of back loading frame and "is very inefficient, difficult to handle, and very heavy when it is fully loaded. Nevertheless, in the light of Korea's hilly and rocky terrain, this piece of equipment can hardly be discarded (19) (Figure 1). Through a programme of research and development involving farmers, rural blacksmiths, traditional chee-ke makers, specialists in farm equipment and engineers, an improved chee-ke was produced. Six successive models were evolved before a satisfactory design was achieved (Figure 2). The improved chee-ke converts easily from a back-frame to a wheeled carrier.

Wheelbarrows

Except in China, the wheelbarrow does not appear to be widely used for rural goods movement. The Chinese wheelbarrow is of quite different design from the Western wheelbarrow found in most other parts of the world (20).

The Western wheelbarrow has a relatively small diameter (up to 400mm) wheel positioned below the sloping front of the load tray. The centre of gravity of the load is well behind the line of the wheel axle.

The Chinese wheelbarrow uses a larger diameter wheel (about 700mm) with the load placed directly above it on a horizontal platform so that the centre of gravity is just behind the wheel axle (Figure 3).

The Chinese wheelbarrow is a more effective device than the Western type. Because the load is placed close to the wheel-axle the operator only has to support a small proportion of the load, sufficient to maintain control of the barrow. Thus more of his energy can be devoted to propelling the barrow forward. The large diameter wheel reduces rolling resistance. The tendency of the barrow to tip sideways is mitigated by the use of a shoulder strap attached to the handles of the barrow.

Studies carried out by the World Bank showed that the maximum load for a Chinese barrow was about 180kg, compared with about 120kg for the Western configuration (21).

Pedal Driven Vehicles

Bicycles are widely used in developing countries. They are relatively cheap (US$60-100), rugged and easy to use and maintain. They can carry a passenger or up to about 80kg of cargo, although the bicycle can become difficult to control when heavily loaded. Bicycles offer a significant increase in speed of travel over walking, average journey speeds of 16 km/hr being common, and can operate on narrow paths and tracks.

The type of bicycle which predominates in developing countries has not changed in any significant way for many years and is typical of the designs produced in Western countries thirty or forty years ago. It remains popular because its robustness and longevity better meet the needs of developing countries than more 'modern' designs. Its popularity reflects the fact that bicycles are used in a very different way in developing countries. They are habitually used to carry passengers and/or heavy cargo loads, on rough, unsurfaced tracks and paths, and are expected to stand up to arduous use for many years. They are a basic load carrier for rural areas rather than a convenient means of short distance personal transport. *Yet no bicycle has ever been designed to meet these very different operational requirements* (Figure 4).

There is a need for such a bicycle, specifically for use in developing countries, designed to carry a passenger and/or cargo and to be suitable for small scale local *manufacture* (Figure 5).

The load carrying capacity of a bicycle can be increased at low cost by attaching a trailer. Cycle trailers are widely used in many rural parts of Europe and are used by the Swiss Postal Service for the delivery of letters and parcels. However, except in French-speaking countries of Africa and Indo-China their use in developing countries is uncommon. This seems to be a case not of an inappropriate technology but of one that is *unknown*.

Animal Carts

Animal drawn carts are a major form of rural transport in the Asian region. In India it is estimated that they now number some 14 million and over 60 per cent of all goods carried from farm to market are moved by animal cart (22).

The traditional Asian cart costs US$100-180, has a maximum payload of about 1 tonne, and moves at 3.0-4.5 km/hr. It has large diameter iron-rimmed wooden wheels which cause damage to surfaced roads. To overcome this problem, manufacturers in India produce a pneumatic tyred ADV (animal drawn vehicle) wheel which runs on ball bearings and is fitted to a specially fabricated steel axle. The cost of a cart with a steel axle and ADV tyres is approximately twice that of the traditional vehicle (22). Such carts can carry loads of up to 2.5 tonnes, yet their penetration of the market has been very limited and use is concentrated in urban areas and in the affluent agricultural regions with relatively good roads.

The use of animal carts is less widespread in Africa, even in areas where animals are used for draught cultivation. Donkey carts, with a payload of about 400kg are relatively more important in Africa than in Asia and the use of steel wheels with pneumatic tyres appears to be more common.

There are major deficiencies in the design of existing carts so that the available power of the animals is used very inefficiently (Figure 6).

1. The carts are excessively heavy.
2. Many are badly balanced so that a significant portion of the load bears down on the necks of the animals.
3. The traditional bullock cart yoke is inefficient.
4. The traditional wooden wheel is heavy, and uses inefficient bearings. The pneumatic tyred wheel is expensive, causes maintenance problems and does not perform well in muddy conditions (23).

There is a need for a complete re-appraisal of cart design, leading to devices which utilise the energy of the animals efficiently. This would result in carts with increased carrying capacity, would mean that a given load could be moved with less effort and would offer the possibility, in many cases, of using only one bullock instead of two. It is likely therefore that the cost of transport would be decreased and its speed increased.

Basic Motorised Vehicles

The single axle tractor is used extensively in China. It has a 7.5kw single-cylinder diesel engine and in addition to its agricultural functions it can be hitched to a trailer and haul a payload of 1200kg at 15 km/hr (24) (Figure 7). A similar device with a 4-5kw petrol-engine has been developed at the International Rice Research Institute (IRRI) in the Philippines specifically to meet the needs of the many small-scale Asian rice farmers (25) The machine was designed to make maximum use of standard components that are readily available in most developing countries. The engine, roller chains, sprockets, bearings and seals used in the power tiller are imported in most Asian countries for other uses. The remaining components can be produced by small metalworking shops. The power tiller was introduced in 1972 and is now produced by 12 companies in six Asian countries. It is sold in the Philippines at (US$1000) approximately half that of comparable imported machines. In the first two years of manufacture in that country some 700 new jobs were created in the manufacturing sector at a capital investment of about US$200 per workplace.

IRRI have developed a three-wheeled self-propelled cart, with a single, driven and steered front wheel. It has a payload of 720kg and a top speed of 15 km/hr. In Crete three-wheeled rigid chassis vehicles powered by single cylinder diesel engines have been developed in the past few years (Figure 8). Their evolution appears to have resulted from the use of single-axle tractors and trailers for goods movement, leading to a demand for vehicles similar in concept but specifically designed for transport use. The vehicles are produced on the island by small-scale manufacturers.

Conclusion

There exists a range of 'basic vehicles' from simple aids to goods movement by man to cheap motorised forms of transport. *Their technology can be related to basic movement needs and they are accessible, available (or potentially so), in sensible relation to incomes, simple to use and maintain, and could utilise local resources in terms of manufacture, energy, spare parts and operating skills.*

The present status of basic vehicles is that much good technology already exists which could be widely applied, but whose use is at present very localised. Where information on such technologies exists it is obscure, uncollated and certainly unknown to those who could make use of it.

While devices which meet the transport needs of the rural poor must be simple and low cost, this does not imply that their development is an easy task. Rather, experience suggests that the development of effective basic vehicles requires the application of contemporary technical knowledge and the very best technological skills.

All the vehicles described could be operated on roads of a lower standard and hence cost, than that prescribed by the requirements of conventional motor vehicles. Some may be described as 'two-dimensional' in that they have height and length but no significant width. This makes them suitable for use on footpaths and narrow tracks.

The ideas outlined in this paper do not, as yet, enjoy wide currency and the application of more appropriate transport technology will require major changes in policy. The most fundamental change required is to ensure that rural transport planning explicitly includes an appraisal of the needs of the small farmer and the constraints within which *his* choice must be made. The implication is that the most appropriate type of vehicle and the 'track' it requires will be *issues to be decided by local circumstances* rather than to be externally imposed by the assumed use of conventional motor vehicles. A transport planning process which includes the appraisal of the needs of the small farmer will be very different from that currently practiced:

1. The first step would be a small-farmer specific analysis of the magnitude, frequency and duration of transport needs and of the distances over which movements were required.
2. Cognizance would need to be taken of the proximity and structure, (condition, degree of integration) of all existing routes (footpaths, tracks and roads) and motor vehicle services.
3. Consideration of (1) and (2), existing incomes and/or credit facilities, and attitudes towards different forms of transport would indicate the likely range of functionally and economically appropriate vehicles.
4. The consequences of (3) in terms of current availability, ease of manufacture and repair from local resources, and employment generation would then have to be evaluated.
5. Finally, a selection would be made of the vehicle(s)/route(s) combination that would best meet local needs and consideration given to what forms of assistance were necessary for it to be provided.

Two crucial elements of this process are: (a) greater flexibility in the methods of route design, and (b) the direct participation of Government and aid institutions in overcoming the problems associated with the provision of appropriate basic vehicles.

There is a need for developing countries to generate their own road design standards based on local conditions which would incorporate, as appropriate, the requirements imposed by basic vehicles. Road design has been based on the needs for motor vehicles for so long that there is little available experience of designing for anything else, at least in the developed countries. However, some developing countries have experience with the provision of routes for basic vehicles (26, 27, 28).

There seems to be no logical reason why governments and aid institutions should not play as dynamic a role in the provision of basic vehicles as they have done in the provision of roads. *Indeed it seems irrational for them to do otherwise, given that the track and vehicle are complementary and mutually dependent parts of the road transport system.*

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Table 1. Road vehicle statistics for selected countries (1975)

	Passenger Cars 000's A	Commercial Vehicles 000's B	Increase 1953-1975 per cent A	B	Motor Vehicles per 1000 persons	Commercial Motor Vehicles per 1000 persons
Botswana	3.4[1]	6.8[1]	610	920	15.2	10.1
Burma	36.1[1]	39.3[1]	210	320	2.3	1.2
Chad	5.8[2]	6.3[2]	1500	230	3.0	1.6
Ecuador	43.6[1]	68.4[1]	870	520	15.8	9.7
Ethiopia	41.0[3]	12.7[3]	680	330	1.9	0.4
Ghana	55.5[1]	43.9[1]	440	250	10.1	4.4
India	756.5	434.4	350	220	2.0	0.7
Indonesia	383.1	231.5	540	350	4.6	1.8
Kenya	130.9[1]	23.8[1]	350	160	11.6	1.8
Malagasy	55.0[1]	51.0[1]	480	320	12.0	5.8
Malawi	11.2[1]	9.5[1]	300	350	4.1	1.9
Mozambique	89.3[3]	21.5[3]	710	610	1.2	2.3
Sierra Leone	14.8	6.7	490	740	7.2	2.2
Somalia	8.0[3]	8.0[3]	670	230	5.0	2.5
Sri Lanka	91.7	48.6	80	150	10.3	3.6
Sudan	29.3[3]	21.2[3]	440	240	3.2	1.4
Tanzania	39.1[1]	42.3[1]	270	550	5.5	2.9
Thailand	286.2[1]	264.3[1]	1220	1020	13.1	6.3
Australia	5012	1200	350	110	460	89
Sweden	2760	171	540	50	357	21
UK	13949	1872	400	70	282	33
USA	106712	24837	130	170	616	116

[1] 1974, [2] 1973, [3] 1972.

Table 2. Annual expenditure on new road construction

Country	Year	Amount US $ (millions) at 1976 values
Benin	1973	4.8
Botswana	1975	7.4[1]
India	1974	64.8
Malawi	1975	9.0
Mali	1974	1.4
Mauritania	1971	4.9
Niger	1974	15.6
Sierra Leone	1975	1.6
Sri Lanka	1975	5.8
Thailand	1975	4.1

[1] including maintenance expenditure.

Table 3. Road statistics for selected developing and developed countries

	Change in length of road[1] network 1950-75 (per cent)	Percent paved[2] 1975	Density[3] in km/ 100 km²	GNP per capita $
Angola	110	11	6	370
India	200	35	37	140
Indonesia	40	25	4	220
Kenya	50	8	8	220
Malawi	70	14	11	130
Mozambique	40	9	5	180
Nigeria	140	17	10	340
Sierra Leone	130	17	10	200
Sri Lanka	110	70	48	190
Thailand	460	48	7	350
Tunisia	-	52	12	730
Uganda	70	-	8	230
Upper Volta	-	9	2	110
Zambia	140	11	5	420
Germany	260	95	187	6670
France	80	-	144	5950
Italy	50	93	96	2810
Spain	-	80	28	2750
Poland	-	57	95	2600
UK	20	96	150	3780
USA	20	80	66	7120

[1] These figures must be treated with caution since some of the changes are due to alterations in the classification of what is a 'road'

[2] Roads with an all-weather surface of bitumen or concrete

[3] To obtain approximate average road spacing divide 200 km by the figures in this column.

Table 4. Cost of transport by various means

Mode	Cost of Transport $ per tonne km.
Mule (on a track)	1.00 - 3.00
Landrover (on a trail)	1.00
Tractor (with trailer on an earth road)	0.50
Truck - on gravel road	0.25
- on asphalted road	1.10

Table 5. Quantities to be transported (kg/hectare) for different crops in Malawi

Item	Maize	Tobacco	Groundnuts	Cotton	Rice Rainfed	Rice Paddy	Coffee	Pulses
Inputs								
Seeds	45		80	30	65			35
Fertiliser	250	250			620	400		
Yield								
Average	1009	560	449	1120	1234	3362	335	449
Best	2804	2241	963	1881	3362	4708	1007	560

Figure 1. Traditional chee-ke and typical terrain.

Figure 2. Improved chee-ke.

Figure 3. Chinese wheelbarrow.

Figure 4. A basic load carrier.

Figure 5. Oxtrike.

Figure 6. Traditional ox-cart.

Figure 7. Chinese single-axle tractor

Figure 8. Cretian 3-wheeler.