overlaid. Any number of additional layers can be added, but the alignment and the width of the road will remain unchanged. After an upgrading, the maintenance policy may also change.

Stage construction that involves changing the geometry of the road can only be studied by making separate runs of the model.

Costing

All calculations in the model are carried out on a quantity or nondimensional basis, and input unit rates are used to determine costs. Thus, the model can be used with any system of costs or prices and its relations do not become outdated because of the effects of inflation or changing relativities in commodity prices.

Prices should be expressed in either market or economic terms depending on the type of analysis being carried out.

An important aspect of the cost of building roads in developing countries is the foreign exchange requirement. The model has the capability to calculate the foreign exchange requirements for construction, road maintenance, and vehicle operation based on percentages of components such as fuel, construction plant, and materials, which must be bought with foreign exchange.

SUMMARY

An attempt has been made to obtain a better understanding of the interaction between road construction and maintenance standards and the cost of operating vehicles in order to improve the quality of decisions made at the planning stage of road investment projects. The relations derived from various studies have been built into a computer model that can be used to aid investment decisions within the roads sector in developing countries.

The relations in the model allow it to be used to study the interrelations among road design and construction standards, road maintenance policy, vehicle characteristics, traffic flow and growth rate, the environment, and road deterioration. The model can be used to study many aspects of a road investment project, such as the optimum maintenance standards for the road; the choice of an earth, gravel, or bituminous pavement; and the benefits of adopting any number of different stage construction options. The model also allows the planner to study the consequences of uncertainties in traffic forecasts or in the discount rate.

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Traditional Goods and Passenger Movements in Indonesia

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During an economic and engineering evaluation of a prototype rural road program, the study area of Yogyakarta Special Province in Indonesia was found to possess many effective, non-European types of transport methods. These were used for movement of passengers and goods. Counter to most international studies of this type, the consultants approached these transport functions as relevant to the needs of the community rather than discard their existence as novel and unimportant. Measures of productivity and costs of operation were derived by field study. The work suggests that other nations and parties should attempt to better document the benefits and costs of such local transport methods.

International transportation consultants frequently arrive at a host nation with all their conclusions about the transport needs in a state of final draft. Within Asian, African, and South American nations there is paltry documentation of existing types of local transportation and their characteristics. It may be acceptable to have a belief that modern powered transport is the answer to all land-based transport needs, but the specialist should not jump to that conclusion prior to applying professional tools and skills to the problem of nonurban transport activity.

During the Second Highway Development Loan by the International Bank for Reconstruction and Development (IBRD), a pilot project was initiated to assess the needs for local nonurban transport within the

Table 1. Transport types and service provided.

Transport Type	Used for: Goods	Passengers	Transport Type	Used for: Goods	Passengers
Porterage			Bicycle		
Pedestrian or rural walker		X	Village		X
Agricultural walker		X	Rural		X
Backpack	X		Agriculture	X	
Headload	X		Goods transport	X	
Shoulder bamboo (pikul)			Becak		
Goods	X		Old	X	X
Service	X		New	X	X
Animal transport			Powered vehicle		
Pack horse (lapak)	X		Motorcycle or scooter		X
Horse cart (dokar)	X	X	Bus	X	X
Horse carriage (andong)			Truck		
One horse	X	X	Old	X	
Two horses	X	X	New	X	
Oxcart (gerobag)			Light public vehicle[a]	X	X
Agriculture	X		Light public vehicle[b]	X	X
Building material	X				

Note: Data are from field inspections by the ENEX consortium of New Zealand in Wellington, New Zealand.

[a]Colt using benzine fuel. [b]Colt using diesel fuel.

Special Province of Yogyakarta. This province is composed of four counties and the main city of Yogyakarta. Excluding the city, the area encompasses 3200 km² and supports a residential population of more than 2.3 million. Since 1967, the national and provincial governments have undertaken some local road improvements, but by 1978 the condition of many roads was still poor to bad. Four remote districts remained without any alignment that would permit four-wheeled, powered vehicles to enter.

Four international specialists were retained to make this prototype study. They quickly determined that this rural area had already developed a system of transport in spite of the lack of good roads. The main problem was that the transport was fairly unconventional in the sense of current western experience. During the five months of the study, special measures were taken to understand the reasons for this diversity and to assess the costs for the transport function of each method. Table 1 shows passenger and goods transport types in use.

One of the major conclusions regarding this mixture of transport types was that many of the traditional methods continued to be used in locations and along corridors that have usable paved roads. Many methods of conveying and portering were used both within areas that have all-weather highways and within localities that have only pathway access.

While the characteristics of conventional road transport were documented within this study, this paper will be limited to the more nonconventional, nonwestern forms. These methods may be grouped into three major categories: animal transport; human transport, or porterage; and bicycle transport.

METHODS OF ANIMAL TRANSPORT

Pack horses are used in the western portions of Kulon Progo County to transport agricultural produce from the mountainous districts to the lowland areas that have weekly or daily markets. Within the three other counties, pack horses are used only for transport of roofing tile and ceramic pots.

Oxen, or kerbau, are used for the haulage of goods within Bantul County and the southern districts of Sleman County. This type of service concentrates on conveyance of building materials and farm produce. Within Bantul, the two-wheeled ox carts handle brick, stone, gravel, sand, firewood, bamboo, and occasionally logs. The agricultural commodities include rice husks used for brick kilns, fodder for livestock, sugarcane for processing, and rice straw. These commodities typically do not require rapid transport. Frequently, the waiting time for delivery and collection is very long. Consequently the local users of this transport method have little interest in higher-cost methods of powered transport when haulage distance is less than 20 km.

The oxen, or kerbau, are used for nontransport purposes, which includes ploughing and field clearing. Therefore the availability of these animals for transport fluctuates during cultivation and harvest periods.

Horses are used for passenger conveyance in villages and within many rural areas. This type of conveyance is found in many counties throughout provinces of Java and Sumatra. The majority of vehicles are two-wheeled carts, or dokar, but within Yogyakarta Province a concentration of four-wheeled carriages, or andong, is operated. The use of andong is most frequent within Sleman and Bantul Counties where minimum gradients are found. Within Kulon Progo and Sleman, the dokar function for transport of five to seven passengers or cargo and produce up to 600 kg.

METHODS OF HUMAN TRANSPORT

One major reason for undertaking this study was concern on the part of the Government of Indonesia and staff members of the World Bank that major amounts of human porterage were being used for routine transport. It was found that local needs for the movement of both goods and services within the province had resulted in the use of three methods of porterage. The methods ranged from headloading of charcoal and produce to the use of back packs for movement of rice, grain, and dried cassava and the pikul (shoulder-balanced bamboo stick) used by men for movement of agricultural and commercial products.

The consultants observed that foot traffic between two long-distance or medium-distance points was a type of porterage even when the individual was unburdened with goods. Walking between counties or villages is actually the porterage of oneself due to some aspect of transport or economic function. It makes travel on foot the most relevant transport means to the user.

If improvement of the rural road network resulted in the reduction of foot traffic for goods distribution, the individual could be more productive and perform the transport with less fatigue. However, porterage was used in different districts for many

Table 2. Transport cost on rural roads.

Transport Type	Productivity of Mode		Cost of Service (Rp)	
	Per Vehicle (passenger-km)	Per Day Used (ton-km)	Per Passenger-Kilometer	Per Ton-Kilometer
Porterage				
Pedestrian or rural walker	6.8		17.0	
Agricultural walker	8.0		14.4	
Backpack		0.25		502.0
Headload		0.52		933.0
Shoulder bamboo (pikul)		1.30		1167.0
Animal transport				
Oxcart (gerobag)		10.0		23.4
Horse carriage (andong)	210.0	31.0	3.0	20.2
Horse cart (dokar)	180.0	15.0	3.4	40.8
Pack horse (lapak)		1.3		23.2
Bicycle				
Village	10.0		5.9	
Rural	14.0		4.8	
Agriculture		0.7		65.7
General goods transport		4.2		69.3
Becak				
Old	39.0	9.0	9.3	49.0
New	39.0	9.0	10.2	54.0
Powered vehicle				
Motorcycle	56.0		5.0	
Light public vehicle[a]	1800.0	120.0	3.5	56.0

Note: Data are from field survey by the ENEX consortium of New Zealand in Wellington, New Zealand.

[a]Colt using benzine fuel.

reasons. Three facets of this method were considered:

1. Movement of potable water,
2. Movements directly related to house and field, and
3. Movements of goods or produce between villages or specific markets.

More than 40 percent of the pikul traffic that functions in hilly and mountainous districts is for distribution of potable water. The haulage is less than 1.5 km one way and represents a social and community function rather than a true transport function.

An additional 40 percent of the pikul and backpack haulage is required for performance of agricultural work. Tools are transported to the field and fodder or harvest to dwellings. This type of traffic is seen throughout the province and along all types of road conditions from paved national highways to impassable tracks. One-way travel was for less than 3 km. It was concluded that there would be no shift from this method to mechanical transport. The shift from porterage related to field work would be made when new agricultural machinery and changed methods of cultivation are introduced.

Porterage is used for the transport of personal items and small quantities of goods between villages or to a specific market. This method occurs in locations that have poor road conditions. There were some districts that still have this type of porterage even though paved roads have been functioning for several years. In such cases, it was concluded that porterage along paved roads related to

1. Income level of the individual;
2. Special needs of the commodity, such as ceramic pots; and
3. Perceived narrow margins between production costs and selling price.

This meant that even after districts received paved roads and better motor transport, there would still be pikul and porterage. Better roads would not automatically result in termination of porterage.

Specific porterage of commercial goods is found only in the more isolated districts of Gunung Kidul and Kulon Progo Counties. Some mountainous areas are accessible to foot and animal transport only. In some of these locations residents obtain some portion of their household income by providing their labor to others for porterage. It is this type of porterage that is considered the base point for transport demand.

The strongest pikul of bamboo has a capacity to lift 70 kg. If light public vehicles (LPV) were used and they hauled only their rated payload, each vehicle would transport the equivalent of 10 pikul persons. Therefore, any alignment in which 50-60 persons each day transport goods by pikul would require five small pickup trucks to handle such demand. In Sleman and Bantul Counties porterage is only by residents for their own produce, which is conveyed to the nearest roadside; the trip to market then continues by LPV. When a group of farmers has more than 1 ton of produce or rice, vehicles could be chartered. Normally, the wide footpaths permit such vehicles to reach the storage point.

The use of porterage varies with the season. Throughout the province, pikul and other porterage methods are used for harvest needs. The crop is partly cleaned or prepared in the field and then transported to the storage area for further drying and processing. During the rainy season within districts that do not have good roads, the local residents undertake the movement of consumer goods by porterage. In two locations this accounts for less than 75 persons carrying such burdens. With a short distance and reasonable use, one LPV could easily handle this demand each day.

CHARACTERISTICS AND COSTS OF TRANSPORT METHODS

Of the 24 significant methods of transport observed within Yogyakarta Province, each method provided some benefit to the local economy and each method performed a necessary function within the transport network. However, it was considered that changes within the economic growth pattern and the upgrading of roads might result in shifts between these methods. Some methods might be discontinued.

Evaluation of the transport methods was not based on vehicle size and cost of operation only (Table 2). The usefulness to the passengers and the owners of goods was considered. Each mode had a demand for which its type of service functioned successfully.

The service area in which the mode functioned related to the rural and terrain considerations. Unrestrained choice of mode by the user indicated the different patterns of local need and the individual's selection. The agriculturally oriented villages used types of transport considered unreasonable by residents of larger towns.

The type of right-of-way alignment required for each type of transport, when considered in moderate volume, indicated the general level of capital and annual maintenance for a road that would be sufficient for its operation.

The environmental aspects of each transport method were assessed in relation to both atmospheric pollution and other forms of pollution, including visual and audible. Air pollution was principally the problem of powered-vehicle operations, but much of this problem stemmed from poor adjustment and maintenance rather than the actual technology. One factor of pollution was the erosion of the right-of-way from the repeated passing of wheels, hooves, or feet on the exposed ground. The solid and liquid wastes emitted by nonmechanical transport were con-

sidered. The variations in noise levels for trucks and motorcycles were listed.

The demand for the use of a specific transport method had to be relevant to the distance involved and the capacity needed. The capacity was considered from the two viewpoints of the rated payload and the actual capacity used. The actual capacity used for either cargo or passengers can be well above the rated capacity of the vehicle. This was especially seen in wheeled vehicles where loads were frequently twice the rated payload.

The observed minimum and maximum trip lengths of the modes were assessed to provide understanding of the distances for which they were normally used. The interest of this study was not the ultimate physical endurance of the mode but rather the current use.

The average commercial speed was derived from the observed hourly operating speed obtained within the normal parameters of load, area, and method of operation. The peak speeds within rural or undeveloped areas were determined. This indicated the range of velocities available between the commercial speed and the top maneuvering speed. It became evident that the majority of transport methods reviewed were very limited in their ranges of speed. Only the high-powered mechanical vehicles had performance ability over a significant range of speeds. Porterage and animal-transport methods function in a narrow range of velocities. Oxcarts were the most limited mode in the review.

The types of fuel consumed indicate the resources that must be committed for each method. Porterage requires various types of human fuel (food), whereas animal transport needs fodder, grasses, and grains. Mechanized transport requires petroleum-derived fuels. The cost of the fuels was listed.

The road space needs of the transport methods were obtained. The actual space related to the parked condition and the running condition of the vehicles. This was determined by length and width for each method. Height was of secondary importance due to the oversize and/or overweight conditions found in many modes. This was true for pikul, dokar, and truck transport.

The operational availability of each vehicle type was determined. This provided an understanding for the potential and the actual use. When combined with additional information on hours used per day and hours offered for service per revenue day, it indicated the various merits of the transport method that did not directly relate to the distance covered. This availability of low-capital forms for transport was attractive to many users and operators. For the days and the hours of use, the actual distances operated were shown and listed in revenue and nonrevenue kilometers. This separation was needed since some transport methods require positioning, parking, or other operational considerations that are not normally part of the revenue service. Unlike minibuses, the dokar and the becak do not cruise for patrons. However, they are taken home by the operator each day.

From the above-mentioned factors, the productivity of each method was calculated on an operational hourly basis. This provided the number of passenger kilometers or ton kilometers generated. Although this measure showed the efficiency of one vehicle, it did not convey the total economic importance of the method. Therefore, the number of vehicles required to handle 100 passengers or 10 tons of medium-weight goods was given.

The daily productivity of a vehicle, on average, was derived. The number of vehicle hours or transport hours required to generate 1000 passenger-km or 1000 ton-km was given. Even with these figures it was found that transport methods used were not totally interchangeable even if values shown were similar.

The capital costs and operating costs of the transport methods were determined from a variety of in-field sources. At the time of the study, the Indonesian rupiah was exchanged at $1.00 U.S. = 435 Rp.

Pedestrians, agricultural workers, and porters were not assessed on a capital-cost basis since their predominant function is not related to transport activities. Within the province, few people were required to make their full-time living from pikul or porterage services. Therefore, on a national economic basis there was little human capital cost oriented to this function. However, food and surrogate wage rates were considered for the operating costs.

Both the capital and the operating costs were divided into three groups. Within the region, the most relevant costs were those that were incurred by the user or by the operator, who may or may not be the same person. From a national economic viewpoint, the costs excluded domestic transfers (taxes) and other cost distortions so as to show the actual cost to society for the service. The foreign-exchange component (FEC) of the costs was estimated. The more mechanized the transport method, the greater became the capital costs and the FEC. When further domestic substitution of motor vehicle parts is made and the actual vehicle production is undertaken, the FEC may be reduced.

The operating costs were calculated only for the operation of the vehicle. This did not include the value of time for the user of the service if he or she was not directly related to the operation or the propulsion. For example, the food required for a pedestrian or a porter was included, but the food required for a passenger in a bus or a dokar was excluded. It was considered that transport methods having human and animal energy inputs have time and food costs as part of the social surrogate for their operation. A pedestrian or cyclist clearly demonstrates this by using energy for the fulfillment of the transport method. This is not true of the passenger on a motorcycle or the passengers on a minibus.

Porterage

The Yogyakarta Rural Road Study considered a pedestrian to be a rural walker without an agricultural trip purpose. These could be village residents, rural residents, or other persons who were not walking to fields or carrying goods for market (Table 3).

The farmers and field workers were considered to be farm-related travel for a short distance and mostly local importance. However, it was noted that these trips have a high frequency of occurrence. With the proximity of agricultural lands to the various villages, the cost or labor component of such walking is reduced as compared with that of the nonagricultural walker. Wage values of Rp 300/day to Rp 500/day, as paid within the province, were used for comparison of the transport costs.

The basic costs of a walker (both agricultural and nonagricultural) are time and food. In part, the costs are based on the 1976 United Nations Development Program nutritional studies. Although the speed potential between these two transport forms is the same, the nonagricultural walker has a slightly higher overall speed. For planning purposes, the nonagricultural walkers were considered to generate Rp 17 000/1000 passenger-km compared with Rp 14 400 for the agricultural walkers.

Table 3. Porterage: characteristics and costs.

Characteristic or Cost	Pedestrian or Rural Walker	Agricultural Walker	Backpack	Headload	Pikul
Service scope provided	Short or medium	Short or medium	Short or medium	Short or medium	Short or medium
Service area	Rural or urban	Rural	Rural agriculture	Rural special	Rural or urban
Economic user	Unmotorable location, all; motorable location, low-income user	Agricultural personnel	Rural woman	Male porter	Unmotorable location, all
Roadway requirement (m)	0.60	0.60	0.60	1.00	1.30
Environmental pollution					
Air	None: smoking considered socially acceptable				
Other	Potential pathway erosion of exposed surface, varying degrees of litter, and contiguous vegetation destruction				
Capacity (passengers or tons)					
Normal	1 or 0	1 or 0	0 or 0.005-0.055	0 or 0.025-0.045	0 or 0.050-0.070
Normally occupied	1 or 0	1 or 0	0 or 0.035	0 or 0.035	0 or 0.060
Normal trip length (km)					
Minimum	Any	Any	0.1	0.5	0.3
Maximum	15	2-6	10.0	20.0	40.0
Speed (km/h)					
Commercial (avg)	4.5	4.0	3.5	3.0	3.5
Peak, rural area	7.0	7.0	7.0	6.0	6.0
Fuel type and cost per unit	Human food, generally rice, retailing between Rp 125 to Rp 160/kg				
Space size of unit (cm)					
Length	50	50	80	90	190
Width	70	70	70	80	90
Height	165(130-180)	165(130-180)	155(130-170)	185(180-240)	165(130-180)
Vehicle standing space (m^2)	0.35	0.35	0.56	0.72	1.70
Availability					
Days/month	30	30	15(4-25)	25	20
Hours/day	24	24	2.5(1-10)	12	12
Hours used/day	1.5(0.5-4.0)	2.0(0.2-5.0)	2.0(0.5-8.0)	8	6(4-8)
Avg daily distance operated (km)					
Revenue	6.8	8.0	Farm, 4; market, 7	15(5-25)	15(6-25)
Nonrevenue	-	-	Farm, 2; market, 3	-	-
Output/hour of operation (passenger-km or ton-km)	4.5 or 0	4.0 or 0	0 or 0.12	0 or 0.105	0 or 0.21
Vehicles required to handle 100 passengers or 10 tons	100 or 0	100 or 0	0 or 286	0 or 286	0 or 167
Passenger kilometers or ton kilometers generated/day/vehicle used	6.8 or 0	8.0 or 0	0 or 0.14-0.25	0 or 0.525	0 or 1.3
Vehicle hours required					
Per 1000 passenger-km	223	250	-	-	-
Per 1000 ton-km	-	-	8333	9524	4762
Capital cost of vehicle (Rp)					
User or total[a]	-	-	250	100	700
Economic[a]	-	-	245	95	675
Foreign-exchange cost[a]	-	-	0	0	0
Operating cost of vehicle/km (Rp)					
User	17	14	17.2	33	70
Economic	10	9	10.9	19	39
Foreign-exchange cost	1	1	1.0	1	0.9
Vehicle operating cost (Rp)					
Per 1000 passenger-km					
User	17 000	14 400	-	-	-
Economic	10 000	8900	-	-	-
Foreign-exchange component	1000	1000	-	-	-
Per 1000 ton-km					
User	-	-	501 650	933 400	1 156 700
Economic	-	-	317 900	542 900	642 900
Foreign-exchange component	-	-	25 000	28 600	14 290
Avg time (min) required to generate:					
1 passenger-km/person	13.3	15.0	-	-	-
1 ton-km/ton	-	-	500	570	286
Wage surrogate (h or days)	40 h	30 h	25 h, 200 days	63 h, 500 days	60 h, 300 days

[a]Capital costs of porter are not allocated on this basis. Figures shown are for carrying baskets, ropes, and miscellaneous.

In goods transport three types of carriage are used. The most frequently used is the back pack, or pundak. It is predominantly used by women traveling to markets or to the fields. Pikuls are second in popularity. However, they are used only by men. In a few locations headloading is used.

The commercial speed found for the three methods reflects the terrain traversed rather than the potential. Also, the weight handled and the position of the weight are relevant to the lower speed as compared with that of a pedestrian on the same alignment. The phenomenon is similar to having two same-model trucks operating, one fully laden and the other empty.

The pikul was found to be nearly twice as effective as the back pack in output of ton kilometers. However, the higher wage threshold of men within this region made the pikul more expensive than the back pack. In rural districts, many employment opportunities for women exist at Rp 200/day for 8-10 h of labor. However, men's wages are a minimum of Rp 300 and as much as Rp 500 for a 6- to 8-h day. This gave a value of Rp 60-65/h for men with pikuls compared with Rp 25/h for women with back packs. Therefore, although only 167 men were required to move 10 tons compared with 286 women, the costs for 1000 ton-km by back pack were Rp 502 000 compared with pikul costs of Rp 1 167 000.

Activities and social needs suggest that backpack and pikul methods will be used for at least the next decade. However, the headloading method will be discontinued when smoother roads penetrate the

Table 4. Animal transport: characteristics and costs.

Characteristic or Cost	Oxcart (Gerobag)	Horse Carriage (Andong)	Horse Cart (Dokar)	Pack Horse (Lapak)
Service scope provided	Short or medium	Short or medium	Short or medium	Short or medium
Service area	Rural or urban	High-activity area	High-activity area	Nonmotorable locations, low activity, mountainous
Economic user	Agriculturalists, construction material distribution	Families, traders, firewood sellers	Traders resident along line-haul service	Tile vendors residents of mountainous locations
Roadway requirement	Pathway 2.2 m wide	Low-design road 2.0 m wide	Pathway 1.8 m wide	Walking trail 1 m wide
Environmental pollution				
Air	None: smoking considered socially acceptable			
Other	Liquid and solid animal wastes, potential erosion of pathways, potential destruction of vegetation			
Capacity (passengers or tons)				
Normal	0 or 2.5	8 or 1.2	6 or 0.3	0 or 0.10
Normally occupied	0 or 2.0(1.5-3.5)	6 or 0.9	6 or 0.5(0.2-1.0)	0 or 0.09
Normal trip length (km)				
Minimum	0.5	1.0	0.5	3.0
Maximum	15.0	15.0	12.0	15.0
Speed (km/h)				
Commercial (avg)	4.7	10.0	12.0	4.0
Peak, rural area	5.0	25.0	30.0	15.0
Fuel type and cost per unit	Animal feed and fodder retailing for Rp 20/kg			
Space size of unit (cm)				
Length	500	510	360	2.3
Width	190	140	160	0.9
Height	300	195	205	1.8
Vehicle standing space (m^2)	9.5	7.2	5.8	2.1
Availability				
Days/month	25	25	25	20
Hours/day	12	10	10	8-10
Hours used/day	5	6	6	5
Avg daily distance operational (km)				
Revenue	5	35	30	14
Nonrevenue	3	7	7	7
Output/hour of operation (passenger-km or ton-km)	0 or 9.4	60 or 9	72 or 6	0 or 0.36
Vehicles required to handle 100 passengers or 10 tons	0 or 5	13 or 12	17 or 20	0 or 111
Passenger kilometers or ton kilometers generated/day/vehicle used	0 or 10	210 or 31	180 or 15	0 or 1.3
Vehicle hours required				
Per 1000 passenger-km	-	17		
Per 1000 ton-km	107	111		2780
Capital cost of vehicle (Rp)				
User or total	150 000	230 000	205 000	80 000
Economic			190 000	75 000
Foreign-exchange component			2000	750
Operating cost of vehicle/km (Rp)				
User	23.4			21.5
Economic	14.5			14.9
Foreign-exchange component	1.0			0.4
Vehicle operating cost (Rp)				
Per 1000 passenger-km				
User		3000-4300	3420	
Economic			3170	
Foreign-exchange component			40	
Per 1000 ton-km				
User	23 400	20 200-29 100	40 750	231 500
Economic	14 500		37 750	161 000
Foreign-exchange component	1000		465	4600
Avg time (min) required to generate:				
1 passenger-km/person			5	
1 ton-km/ton	13		10	167
Wage surrogate (days)	300	300	300	300

districts and greatly reduced damage to fragile commodities is experienced, as with the movement of charcoal.

Animal Transport

Four methods of animal transport were divided into two methods exclusively for cargo transport and two methods for combinations of passengers and goods (Table 4).

The use of pack horses is clear evidence of poor road links for a district. Pack horses are used in several mountainous portions of Kulon Progo County. The current capital cost of a pack horse at Rp 80 000 is considered high. Although horse transport appears economically cheaper than porterage, the majority of the citizens engage in goods porterage because they do not have the financial ability to invest in a horse. In this province the horse is not used in multipurpose tasks as is the ox. The pack horse has a service life of 15 years.

The deployment of oxcarts (gerobag) was similar to the use of older diesel-engine trucks. The basic transport and economic advantage of the oxcart is that it can stand and wait several hours as part of an industrial or agricultural process without tying up considerable amounts of capital. Oxcart operations were restricted to trip distances of less than 15 km. Their speed and size were found to cause much conflict with the flow of other vehicles on the roads.

Vehicles and transport methods such as the pack

Table 5. Bicycle transport: characteristics and costs.

Characteristic or Cost	Village Bicycle	Rural Bicycle	Agricultural Bicycle	Goods-Transport Bicycle	Becak	
					Old	New
Service scope provided	Short or medium	Short to long	Short to medium	Short to long	Short or medium	Short or medium
Service area	Any, excluding mountains	Any	Plateau or irrigated location	Any	Village, linear activity	Village, city
Economic user	Low- to middle-income users, children	-	-	-	-	-
Roadway requirement	Drained stable pathway					
Environmental pollution						
Air	None	None	None	None	None	None
Other	None	None	None	None	None	None
Capacity (passengers or tons)						
Normal	2 or 0	2 or 0	1-2 or 0.05-0.4	0 or 0.05-0.4	2 or 0.20	2 or 0.20
Normally occupied	1 or 0	1 or 0	1 or 0.15	0.105	1.3 or 0.30	1.3 or 0.30
Normal trip length (km)						
Minimum	0.2	0.2	0.2	10.0	0.2	0.2
Maximum	5.0	30.0	3.0	30.0	12.0	12.0
Speed (km/h)						
Commercial (avg)	12	8	5	8	9.0 urban or 12.0 rural	9.0 urban or 12.0 rural
Peak, rural area	30	30	15	25	25	25
Fuel type and cost per unit	Human food, generally rice, retailing at Rp 125 to Rp 160/kg					
Space size of unit (cm)						
Length	195	195	195	195		
Width	55	55	150[a]	120		
Height	105[b]	105[b]	105[b]	105[b]		
Vehicle standing space (m^2)	27	27	25	25	25	25
Availability						
Days/month	24	24	24	15	10-12/shift	10-12/shift
Hours/day	1	2	1	5	4	4
Hours used/day						
Avg daily distance operated (km)						
Revenue	10	14	5	40	30	30
Nonrevenue	-	-	-	-	5	5
Output/hour of operation (passenger-km or ton-km)	12 or 0	8 or 0	0 or 0.75	0 or 0.84	12 or 2.7	12 or 2.7
Vehicles required to handle 100 passengers or 10 tons	50-100 or 0	50-100 or 0	0 or 67	0 or 96	50 or 34	50 or 34
Passenger kilometers or ton kilometers generated/day/vehicle used	10 or 0	14 or 0	0 or 0.75	0 or 4.2	39 or 9.0	39 or 9.0
Vehicle hours required						
Per 1000 passenger-km	83	125	-	-	84	84
Per 1000 ton-km	-	-	1333	1190	371	371
Capital cost of vehicle (Rp)						
User or total	18 000	18 000	20 000	22 000	40 000	130 000
Economic	16 000	16 000	17 500	19 500	38 000	110 200
Foreign-exchange component	5000	5000		8000	8000	26 000
Operating cost of vehicle/km (Rp)						
User	5.9	5.5	9.8	7.3	14.7	16.2
Economic	4.2	3.9	4.3	4.1	8.0	9.3
Foreign-exchange component	0.25	0.25	1.0	0.2	0.4	0.5
Vehicle operating cost (Rp)						
Per 1000 passenger-km						
User	5900	5500	-	-	9260	10 210
Economic	4200	3900	-	-	5040	5860
Foreign-exchange component	250	250	-	-	250	315
Per 1000 ton-km						
User	-	-	65 660	69 350	49 000	53 950
Economic	-	-	28 810	38 950	26 640	31 000
Foreign-exchange component	-	-	6700	1900	1330	1675
Avg time (min) required to generate:						
1 passenger-km/person	4	7.5	-	-	7	7
1 ton-km/ton	-	-	80	72	23	23
Wage surrogate (h or days)	65 h, 500 days	38 h, 300 days	25 h, 200 days	50 h, 400 days	63 h, 500 days	63 h, 600 days

[a]Width may be greater due to type of load being conveyed. [b]Height stated is that of idle vehicle; operator/user is highest dimension when pedaling.

horse, andong, and oxcart can have very low ton-kilometer and passenger-kilometer costs. In some cases, these were only 50 percent of the cost of pick-up trucks or minibuses. This conclusion is not at variance with the desire to develop greater use of mechanically powered transport and greater productivity within the rural transport sector. These vehicles and methods have, and will continue to have, specialized services that they can provide best within the agrarian economy.

The andong is used predominantly by vendors and families to convey several persons or large amounts of personal goods. The andong is used for goods movement when the consignment is more than could be handled in a becak but less than the capacity of an LPV under charter.

Although the dokar (two-wheel) and the andong (four-wheel) methods were similar in their productivity for passenger services, the conveyance of goods was 50 percent more cost-effective in the latter. It was observed that andongs used either one or two horses per vehicle. Use of a second horse increased costs by 40 percent. No significant reason could be found for preference of the two-horse operation. This does not include the times when a second horse is hitched for training pur-

poses. Some villages used andong exclusively, whereas others had only dokar. A few communities had a mix of the two methods.

Bicycles and Trishaws (Becaks)

Bicycles (pedacycles) were found to provide a most efficient low-capacity transport method within the province. Four discernible types of bicycle operation were provided. Two types were related to passenger needs and two were for goods demand (Table 5).

For passenger demands, the two methods were designated village bicycle and rural bicycle. The characteristics for passenger services were similar to those for rural walkers and agricultural walkers. Village bicycles tend to be new and have a higher productivity. This was due to the better condition of pathways and road surfaces. Within the study, the use of such bicycles by children was excluded. Interest was directed to the adult use of the vehicle. In many households several bicycles were owned and used. As such they provided a method for undertaking several trip purposes for family members throughout the day.

Two-thirds of the bicycle cost was derived from the surrogate wage of the user. When used in the village, the daily wage of Rp 500 was applied. In rural operation, the daily wage of Rp 300 was used.

Table 6. Powered-vehicle transport: characteristics and costs.

Characteristic or Cost	Motorcycle	Light Public Vehicle	
		Colt (Benzine)	Colt (Diesel)
Service scope provided	Short to long	Short to long	Short to long
Service area	Any	Any	Any
Economic user	Middle- to upper-income user	Trades, professionals, economically active user	Trades, professionals, economically active user
Roadway requirement	Any stable alignment 1 m wide	Bad to excellent roads 3.0 m wide	Bad to excellent roads 3.0 m wide
Environmental pollution			
Air	HC, DO, NO (severe due to operation method, not technology)	HC, DO, NO	Particles, SO
Other	Noise	Noise, surface erosion	Noise, surface erosion
Capacity (passengers or tons)			
Normal	2[a] or 0.1	14 or 1.0	20 or 2.2
Normally occupied	1.4 or 0.05	12(8-20) or 0.8(0.4-1.5)	15(8-30) or 1.8(1.2-3.5)
Normal trip length (km)			
Minimum	0.25	5.0	5.0
Maximum	100.0	70.0	70.0
Speed (km/h)			
Commercial (avg)	25(20-50)	25	25
Peak, rural area	80	80	80
Fuel type and cost per unit	Benzine or Benzine-oil, Rp 70 or Rp 90/L	Benzine, Rp 70/L	Diesel, Rp 25/L
Space size of unit (cm)			
Length	190(180-205)	395	580
Width	80	155	198
Height	110	195	245
Vehicle standing space (m^2)	1.7	6.1	11.5
Availability			
Days/month	29	22	25
Hours/day	15	14	14
Hours used/day	2.5	9	10
Avg daily distance operated (km)			
Revenue	30	150	175
Nonrevenue	-	15	25
Output/hour of operation (passenger-km or ton-km)	35 or 1.2	300 or 20	375 or 45
Vehicles required to handle 100 passengers or 10 tons	50[a] or 100	9 or 13	5 or 5
Passenger kilometers or ton kilometers generated/day/vehicle used	42 or 1.5	1800 or 120	2625 or 315
Vehicle hours required			
Per 1000 passenger-km	29	4	3
Per 1000 ton-km	400	50	22
Capital cost of vehicle (Rp)			
User or total	320 000	2 100 000	3 200 000
Economic	230 000	1 725 000	2 590 000
Foreign-exchange component	128 000	1 104 000	1 658 000
Operating cost of vehicle/km (Rp)			
User	7.0	49.0	56.0
Economic	NA	38.0	46.0
Foreign-exchange component	NA	15.0	19.0
Vehicle operating cost (Rp)			
Per 1000 passenger-km			
User	5000	3500	3300
Economic	NA	2700	2700
Foreign-exchange component	NA	1100	1100
Per 1000 ton-km			
User	NA	56 000	31 100
Economic	NA	43 400	25 600
Foreign-exchange component	NA	17 100	10 600
Avg time (min) required to generate:			
1 passenger-km/person	2.5	2.5	2.5
1 ton-km/ton		195	245
Wage surrogate (days)	600	1150	1150

Note: NA = not applicable.

[a]With one-half of users having ability to operate vehicle.

For many trip purposes the bicycle is an excellent method. Its cost to the user and to the economy is modest. The capital cost of the bicycle is one-quarter the price of a horse. The method did not require a separate right-of-way. On footpaths it could intermix with pedestrians without serious conflict.

Bicycle use for cargo movement was divided between agricultural and general goods. The agricultural bicycle was used for transport to and from the field and from the field to the market. The characteristics of such use were different from the methods used by vendors and merchants.

Goods transport by bicycle permitted more than 100 kg to be moved. Items such as pottery, tiles, food, textiles, processed goods, and petroleum products are handled. Typically, agricultural bicycles are used for heavier loads than those found for goods transport. In Bantul and Sleman Counties the farmers convey two to five sacks of rice from the field to the village on the frame of the bicycle. Such loading creates considerable wear on the vehicle, but the distance of operation is quite short. The frequency of use of the bicycle is more concentrated for agricultural bicycles since the tilled land was within a 5-km radius of the village.

With its heavy load, the agricultural bicycle is frequently pushed, even on level surfaces. Goods-transport bicycles are pedaled in the normal way, except on major gradients. The study concluded that the agricultural bicycle was used 1500 km/year, whereas the goods-transport bicycle was used more than 6000 km/year.

The fuel requirements for these methods were human food, especially rice.

Goods-transport bicycles incur a greater FEC to the economy than do the passenger-only operations. This is due to the heavier frequency of maintenance and repair. The agricultural bicycle has a lower economic cost to society due to the lower wages. However, it has a higher FEC due to the frequent replacement of spokes, chains, and other parts--including the frame--that resulted from the excessive loads.

Indonesia, along with 13 other nations, performs part of its transport needs with a pedal-powered three-wheeled vehicle generally called a trishaw in English. In Indonesian, it is called a becak. Becaks are considered to be an urban transport function, but they are found to some extent in rural districts, including Yogyakarta. For this study two types of becaks were evaluated based on the difference in their availability and age.

A second-hand becak can be purchased for Rp 40 000, whereas the newest becak costs Rp 130 000. Both types were used in nonhilly villages of the province. They predominantly worked along reasonably well-surfaced roads. Due to the major difference in capital costs, the analysis was done to see whether significant differences existed in the total cost of operation. The operation of the two types turned out to be the same, although maintenance costs for the older vehicles were higher.

The wages obtained from providing this service fluctuate daily. They are strongly influenced by market days, climate, and disposable income within the village. Generally, the operators receive Rp 200 to Rp 800 net per day, a reasonable wage level within rural areas.

Commercial speeds differed by 30 percent, from 9 km/h in urban areas to better than 12 km/h in rural locations that were flat.

For passenger movements, the older becaks incurred costs of Rp 9250/1000 passenger-km compared with Rp 10 210 for the new becaks. This represents a 10 percent range in costs.

For goods movements, even when the overloading was considered, the cost per 1000 ton-km was Rp 49 000 for the older units and Rp 54 000 for the new units.

Becaks provide employment and subsistance opportunities for low-skilled persons within the village and the city. In addition, they provide an introduction into the cash economy for many citizens.

Powered-Vehicle Transport

Data on powered-vehicle characteristics and costs may be found in Table 6.

SUMMARY

Within the rural road study, other, more conventional transport methods were also reviewed. However, in this paper I wanted to convey to the reader the various transport-related aspects that were found in the effective but less conventional systems operating within rural Indonesia. To be able to attach data and cost figures to systems of transport that may not be found outside nations of Asia is not an exercise in fancy. Rather, it helps to establish the current foundation of the transport activity and to monitor, in a more exacting way, the changes that may result from road development and economic shifts. To understand and accept these types of vehicles and transport modes does not mean that the engineer, economist, or planner has surrendered wholly to their operation as the perfect system. They exist and they should be treated like any other form of transport within an analysis.

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I take full responsibility for the statements made here. Such comments may not represent the policies or ideas of any other individual, firm, agency, or ministry of the Government of Indonesia. Such viewpoints may not reflect the plans or policies of international agencies or bilateral national trading partners.