TRANS-JAVA HIGHWAY—TRANSPORTATION ECONOMY—NEW ANALYSIS PROCEDURES

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Economic analysis of the proposed trans-Java highway, as described in this paper, involves several procedures that have rarely, if ever, been reported in the literature. It includes (a) calculating vehicle running costs on the basis of vehicle speed distribution rather than by using one specific average speed, (b) including the changes in vehicle speeds as a running cost item, (c) estimating highway construction costs and vehicle running costs for segments of the highway rather than for the entire length of the proposed project, (d) calculating rates of return for segments of the proposed highway, (e) calculating the rate of return for each year for each highway segment, (f) using seven classes of vehicles, including separate costs for gasoline- and diesel- fueled vehicles, (g) making the complete analysis for six levels of design (traffic service) as contrasted to use of one design, and (h) applying the analysis to the network of existing highways affected by the trans-Java highway. The analysis is applied to the 237-km west portion and the 284-km east portion. Traffic is much heavier in the west than in the east. The six levels of design for both two- and four-lane basic designs include alternatives of all intersections at grade, major intersections separated, and all intersections separated. Traffic was estimated for 1980 to 1999 yearly for each of the six levels of design and for all existing roads affected. Fifteen percent per year was considered to be the minimum attractive rate of return. Because of increasing traffic volumes, the rates of return increased from a low in 1980 to a high in 1999. The rate of return varied from less than 1 percent to 15 percent depending on the route section, the level of design, and the year.

•WHEN WORK BEGAN in February 1972 to determine the engineering and economic feasibility of the proposed east to west trans-Java highway, it was soon realized that the project presented some unusual features. Java's 76 million population, mountains and lowlands, existing and possible agricultural and industrial development, and contrasts in culture and state of development in the east and west portions all were challenging factors to consider. This paper, however, discusses only the analysis of transportation economy, which offered opportunities for procedures not used before to any great extent. Full details of the study are given in the final report (1).

Traffic was forecast for 1972 to 1999 for each route segment (a distance from one highway crossing to the next or one interchange to the next) on a yearly basis. This forecast was also made for existing routes that would be affected by the opening to traffic of any segment of the trans-Java highway. Motor vehicle running costs and road user costs were calculated for all existing highway routes affected by any segment of the trans-Java highway. Thus, the analysis of transportation economy was considered on a systems basis.

The transportation economy analysis included the following features that, although not new in concept, have seldom, if ever, been applied in U.S. or other studies:

1. Calculating vehicle running costs on the basis of vehicle speed distribution rather than one general average speed,
2. Including the cost of changes in vehicle speeds in the calculation of running costs,

3. Estimating highway construction costs and road user costs by segments so that the transportation economy could be calculated by segment for the full route distance,
4. Calculating by segment a rate of return for each year so that the optimum year to open the new route could be determined,
5. Using seven classes of vehicles for calculating running costs with gasoline- and diesel-fueled vehicles separated,
6. Making the complete analysis of alternative designs for six levels of traffic service as contrasted to one level of design, and
7. Applying the analysis to the network of existing highways affected by the construction of any part of the proposed new route, thus approaching the system concept of analysis.

GENERAL CHARACTER OF THE PROJECT

Figure 1 shows the general location of the trans-Java highway. There are three main sections: The west from Djakarta to Tjirebon is 237 km; the central from Tjirebon to Semarang is 230 km; the east from Semarang to Surabaja is 284 km; and a spur south to Bandung is 55 km. The study was made in detail for the west, east, and spur portions.

The network of paved and unpaved highways connecting the major cities have physically deteriorated surfaces, narrow or no shoulders, poor horizontal and vertical alignments, narrow bridges, congested roadside development, and congested city and town traffic. Traffic within urban areas, and to a lesser extent in rural areas, is a dense mixture of pedestrians, animal-drawn carts, bicycles, motorcycles, scooters, betjaks (a hooded tricycle for passengers), bemoes (three-wheeled minibuses), passenger cars, pickup trucks converted to people carriers, small and large buses, two-axle trucks, three-axle trucks, and tractor-semitrailer combinations. With this mixture, vehicular flow in urban areas moves at slow average speeds (10 to 20 km/h) with constant speed changes due to stops, slowdowns, and speedups.

The population of Java in 1971 was 62,371,000 rural and 13,732,000 urban. Overall population density per square kilometer in 1971 was 467 in west Java, 640 in central Java, and 533 in east Java. Djakarta's population density is 7,931.

PRELIMINARY AND FINAL ANALYSES

Because of existing narrow rights-of-way, heavy roadside development, and drainage problems, it was evident that redeveloping the existing rights-of-way for improved facilities was more unfavorable than favorable. For all portions of the trans-Java highway, alternative locations were considered with respect to servicing the urban areas, transportation needs, and preserving and developing land uses.

In the preliminary economic evaluation phase, various possible route locations were studied and an economic analysis was made of the west and east portions on a total distance basis. It was determined that the trans-Java route would be sound economically over the 20-year analysis period, 1980 to 1999, but the year economic feasibility would be reached was not determined.

The objective of the second phase, the project formulation study, was to determine the relative economy on a yearly basis of six levels of design and to make a comparison with the existing highways. This phase was restricted to the one route identified in the first phase. Thus the final engineering design and construction cost estimates apply to only the location recommended for ultimate construction.

The design alternatives were chosen to provide a range of traffic service measured by number of lanes and access-control factors. The specific design alternatives evaluated for both the two-lane bidirectional highway and four-lane divided facility are

1. All highway and railway crossings at grade,
2. Major grade-separated crossings, and
3. All grade-separated highway and railway crossings.

All design alternatives were based on ultimate construction with full access control. Therefore, each of the six design alternatives includes rights-of-way required for a four-lane freeway. The two-lane alternatives included earthwork and drainage for only two lanes.

EXISTING TRAFFIC INFORMATION

Most of the necessary traffic information was available to determine existing traffic flows, to make traffic forecasts, and to estimate traffic diversion for each of the six design alternatives considered.

Traffic Volume

A continuing program conducted by Bina Marga for all of Indonesia makes vehicle classification counts on motorcycles, three-wheeled motorized vehicles, cars, pickups, microbuses, 36-seat buses, two-axle trucks, three-axle trucks, tractor semitrailers, bicycles, and animal-drawn vehicles.

Counting stations are located some distance from urban areas. Of 71 stations, 63 or 90 percent of the segments studied had the count station located farther than one-fourth of the segment length to the nearest terminus. Therefore, traffic volumes were considered to represent a low count because a large number of short-haul trips near urban termini were not counted. The consultant estimated that a 25 percent addition to the counted traffic volumes would reflect short-haul trips.

Traffic Characteristics

The following traffic characteristics were established:

1. A 60-40 directional distribution,
2. A mix of levels of service C and E, and
3. More than 1 hour of peak flow in the morning and afternoon.

From a review of local data and from reference sources (2, 4), it was established that 30 percent of the average daily traffic would flow in the peak 4 hours of the day.

Passenger Car Units

Equivalent passenger car unit (PCU) factors for flat terrain were determined locally, whereas those for rolling and mountainous terrain were based on data in the Highway Capacity Manual (2). Because factors in the Manual pertain to vehicle operation in the United States, engineering judgment dictated that the values be revised upward in some cases to allow for the greater average vehicle age and generally poor physical condition of vehicles operating in Java. It was determined that PCUs of the smaller vehicles do not vary significantly with terrain. For buses and trucks we decided to double the flat-terrain PCU values for rolling terrain, and double the rolling-terrain values for mountainous terrain.

SURVEYS AND ANALYSES

Existing traffic information was supplemented by surveys and special analyses of available data. Of particular significance were studies conducted to determine travel speeds and changes in speed.

Traffic Behavior

The analysis included effects of highway design and traffic control on vehicle running costs. Running cost data include the cost per kilometer for speeds on plus and minus vertical grades, horizontal curves, speed changes, and idle engine. Therefore, highway data such as design speed, distance, pavement condition, grades, and curvature, in conjunction with vehicle speed, make possible the estimation of total motor vehicle running cost on each existing and alternative route considered.

Traffic Speed and Speed Changes—Because of urban congestion and large numbers of speed changes, it was evident the trans-Java highway would produce a reduction in vehicle running costs. Benefits to traffic would be largely from lowering the number of speed changes and increasing both distance and speed driven at uniform speeds as compared to that driven by existing traffic. The poor quality of existing pavements, narrow roadway widths, and poor vertical and horizontal alignments also contribute to the high running cost of current traffic.

General travel speeds and changes in speeds were established by driving a test vehicle over existing routes under different conditions of traffic. Magnetic tape recordings were made by oral dictation of stopwatch time, odometer readings, readings of roadside kilometer posts, speedometer speeds for each 5-km speed change, and supplementary information on causes for speed changes, including stops, and elapsed time stopped. Table 1 gives the speed changes as adjusted from the observed field data for urban highways in flat terrain. In all field recordings of vehicle speeds, the test car was driven to approximate the behavior of the majority of traffic vehicles.

Speed change data indicate the total number of speed changes for increased and reduced speeds from an initial speed. For urban flat, rural flat, and rural rolling terrain, the number of speed changes was found to be similar for all vehicle types within the terrain type. For rural mountain terrain, cars and pickups have different numbers and types of speed changes from trucks and buses.

It was further found that slowdowns generally followed a pattern in the ratio of overall speed changes distributed to the 5-, 10-, 15-, and 20-km/h speed reductions, which were as follows:

Amount of Speed Reduction (km/h)	Percentage of Total Number of Speed Reductions
5	54
10	29
15	12
20	5

Distribution of Stops—The initial speeds from which stops were made are closely related to the number of speeds within a speed distribution (Table 2). For the operating speeds being analyzed, 40 percent of the lowest speeds in the distribution were considered as those from which stops were made.

Total numbers of stops were established for various existing and proposed conditions at individual speeds. The distribution of total number of stops to specific stop speeds was made as given in Table 3.

Idle Engine Time—For various terrain types and vehicle types, the average number of seconds vehicles remained stopped (idle-engine time) was established.

Speed Distributions—From tables of traffic speeds (2, 3), a series of traffic speed distributions was set up. These distributions were developed in 5-km/h intervals for existing highways, new two-lane highways, and new four-lane highways (Table 2). With these tables we could calculate vehicle running costs by speed distributions rather than by using one average speed.

The distributions were initially based on spot speeds from which an average running speed was obtained. The running speed was further analyzed to include stop time to establish an average operating speed. For each operating speed, the distribution was used to establish the theoretical distance a vehicle would cover at a set speed. This is based on the fact that, for example, if a vehicle averages 70 km/h over a length of road, it goes at various speeds over various distances. Running costs were thus obtained for level and gradient sections of road.

Vertical Grades and Horizontal Curvature—Based on field data, composite existing conditions were obtained for various terrains to reflect grades encountered, maximum speeds for two-vehicle groupings, and a length per kilometer for each grade. Similar data were also established for horizontal curvature.

Vehicle Weight Study

Roadside weighings of vehicles were used to assign existing vehicle types to the seven classes of vehicles for which running cost tables were developed and to establish

Figure 1. Proposed and existing highways.

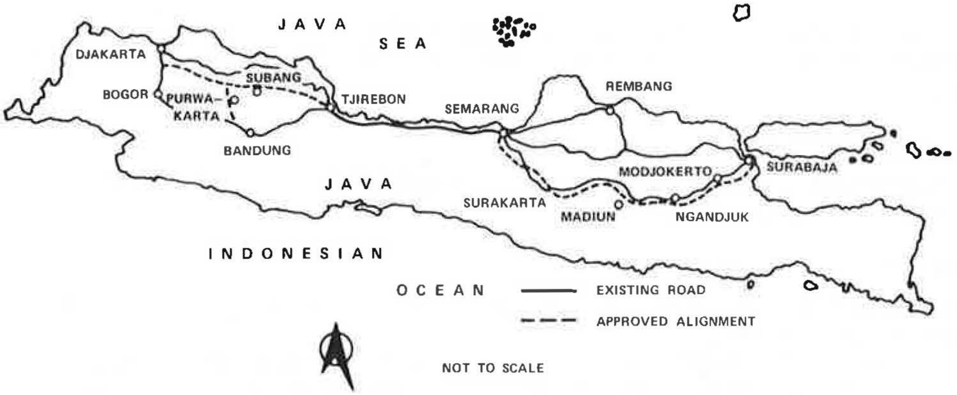

Table 1. Number of speed changes per 1,000 vehicle-kilometers on existing highway.

Initial Speed (km/h)	Speed Reduced to or Increased From Initial Speed															
	0	5	10	15	20	25	30	35	40	45	50	55	60	65	70	75
0	—	95	60	35	30	15	10	4								
5	125	—	135	72	27	13										
10	105	30	—	166	90	31	14									
15	68	64	100	—	225	108	45	23								
20	38	27	110	210	—	288	130	72	22							
25	18	22	55	158	295	—	378	162	81	29						
30	10		40	80	190	360	—	450	189	90	21					
35	4		10	50	100	200	400	—	459	216	74	12				
40				30	70	95	190	385	—	432	171	54	10			
45					10	30	80	160	340	—	346	157	45	6		
50						5	20	55	130	275	—	220	90	23	5	
55								10	30	100	210	—	162	49	11	
60										13	73	148	—	76	27	5
65											6	46	76	—	36	12
70												5	15	30	—	18
75														5	15	—

Table 2. Percentage distribution of weighted average speeds on existing highway.

Frequency Group Speed (km/h)	Weighted Average Speed of the Distribution Below												
	15	20	25	30	35	40	45	50	55	60	65	70	75
0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0				
5	11.8	7.6	4.5	3.0	2.1	1.6	1.0	0.4	0.2				
10	24.1	11.9	7.1	5.3	4.2	2.4	1.5	1.0	0.3	0.0			
15	35.5	17.3	10.9	7.4	5.4	3.5	2.1	1.3	0.7	0.2			
20	18.6	24.2	15.2	10.5	7.9	5.0	3.4	2.0	1.1	0.4	0.0		
25	6.9	22.8	20.8	13.6	9.8	6.7	4.2	2.8	1.7	0.9	0.2	0.0	
30	2.5	9.8	19.0	15.8	11.8	8.9	5.5	3.3	2.0	1.5	0.7	0.1	0.0
35	0.6	4.1	13.8	16.9	13.8	11.4	8.9	5.2	3.2	2.4	1.3	0.3	0.1
40	0.0	1.8	5.8	14.0	13.7	14.0	11.8	9.1	5.6	4.4	2.3	1.0	0.2
45		0.5	2.2	7.4	12.4	14.7	14.6	13.3	10.1	6.4	4.1	2.1	0.3
50		0.0	0.7	3.9	8.9	12.6	14.8	15.9	13.6	9.3	6.7	4.0	1.3
55			0.0	1.6	5.6	9.6	13.2	15.0	15.9	12.8	9.7	6.8	3.6
60				0.6	2.8	5.8	10.1	13.2	15.1	16.4	14.2	11.0	7.4
65				0.0	1.2	2.4	5.4	9.7	14.9	16.0	17.3	15.6	13.0
70					0.4	1.0	2.1	4.9	8.8	13.8	16.5	17.8	17.3
75					0.0	0.4	1.0	1.8	4.6	8.5	12.7	15.3	17.7
80						0.0	0.4	0.9	1.7	4.7	7.6	11.8	13.4
85							0.0	0.3	0.5	1.7	4.1	7.6	10.3
90								0.0	0.0	0.4	1.6	3.3	7.8
95										0.2	0.8	1.8	2.7
100										0.0	0.2	1.0	2.0
105											0.0	0.5	1.3
110												0.0	0.9
115													0.7

Table 3. Percentage distribution of total stops (speed range increasing).

No. of Initial Speeds to Stop	To Lowest Initial Speed	Next	Next	Next	Next	Next	Next	Next
4	40	31	19	10				
5	38	29	18	10	5			
6	36	28	18	10	5	3		
7	35	28	18	9	5	3	2	
8	34	28	18	9	5	3	2	1

the adjusting factor (Table 4) to apply to the running cost tables to approximate the characteristics of local vehicles. Vehicle weights were also used in structural design of pavement.

Origin-Destination Survey

The origin-destination survey was conducted to supplement existing data. The information obtained is given in Table 5.

Volume-Capacity (v-c) Analysis

A volume-capacity analysis was prepared to evaluate the existing road's ability to carry current traffic volumes.

The most critical factor found affecting the v-c ratio was considered the usable surface width, a refinement of actual surface width. A subjective evaluation was made of the actual surface width used by fast-moving vehicles. This was done because existing roads carry motorized vehicles—trucks, buses, automobiles, motorcycles, and scooters—and nonmotorized vehicles—bicycles, betjaks, horses, horse-drawn carriages, bullock carts, and people.

TRAFFIC PROJECTIONS

Traffic volumes were projected to 1999 on a yearly basis for each segment of the proposed highway and for the existing routes with and without the new highway.

Route Segments

Fifty-three total segments on the trans-Java highway were established, and 136 total segments for existing main roads were established. Each feeder road was considered an entire segment for the before situation, whereas for the after situation they may have been fragmented, depending on the origin-destination of traffic. When existing main roads also acted as feeder roads because of interchange locations, they were analyzed as main roads.

Traffic Volumes

Basic traffic volume was that on the existing road system. The base volumes for the three road categories (trans-Java, existing main, and feeder) were set up for the year 1972.

Existing roads were analyzed for both before and after situations. The before situation is the total traffic, which also includes the 25 percent surcharge explained previously. The after traffic volumes are those that would remain on the existing road after the diverted volumes transferred to the trans-Java route.

Feeder road traffic is that on roads providing access to interchange areas. Feeder roads were analyzed similarly to main routes. However, feeder road traffic, after a new highway is opened, will show a volume increase as opposed to existing road traffic, which will show a decrease.

Projections of Traffic Volumes

Projected traffic growth rates were established by the project economists and were used to project traffic volumes to the year 1999 on a yearly basis.

Diversion Analysis

The diversion analysis established traffic volumes assigned to the trans-Java highway. The assigned diverted trips were of two sources, through trips and long-haul trips. Through trips cover the longer distances as between Djakarta and Bandung or Djakarta and Tjirebon. Long-haul trips cover intermediate distances as between segment termini. In addition there is the 25 percent surcharge, or trips not physically counted.

Through trips were all considered diverted to the proposed route. Long-haul trips were assigned to the proposed or existing routes based on results of a traffic diversion analysis. Short-haul trips were all assigned to the existing roads.

Two basic sources of data were used to establish diversion volumes:

1. Origin-destination survey, which provided through trip patterns, especially to Djakarta; and
2. Traffic diversion curve, which is based on a travel time relationship and establishes proportions of traffic attracted to a new highway from an existing road network.

MOTOR VEHICLE RUNNING COSTS

The running cost tables developed by Winfrey (3) were used as the main framework for preparing similar tables for Java. From Winfrey's original work tables, the tables were updated to 1972 Java prices and converted to the Indonesian monetary system of rupiahs, at the rate of 415 rupiahs = \$1. Conversion was also made to kilometers from miles. Because of the lack of base information on the performance and running costs of vehicles in Indonesia, the Indonesian tables were used as indicated in Table 4. Three adjustments were used: (a) assignment of the Java vehicle types identified in the traffic classification counts to the vehicle types for which the running costs had been computed, (b) choice of a factor on the basis of vehicle weight and engine description to be applied to the updated and converted Winfrey tables to adjust the running costs to Java situations, and (c) development of a further factor to adjust for the roadway or pavement condition.

Winfrey (3) gives running cost tables for five classes of vehicles: 4-kip (1800-kg) passenger car, 5-kip (2260-kg) commercial delivery truck, 12-kip (5400-kg) gas-fueled single-unit truck, 40-kip (18 000-kg) gas-fueled and 50-kip (22 600-kg) diesel-fueled tractor-semitrailer. The 50-kip diesel tables were not converted to Indonesian prices. The running cost items included in the tables are fuel, engine oil, tires, vehicle maintenance and repairs, and vehicle depreciation. The unit cost per 1,000 vehicle-miles covers a range of uniform speeds suitable to each vehicle class operated on high types of pavements on a range of minus grades, plus grades, horizontal curves, and sharp 90-deg corners. In addition, running costs are established for a range of cycles of speed changes (a change from an initial speed to a lower speed and back to the initial speed). The speed changes range from a high speed suitable to each class of vehicle to a stop and return to the initial speed.

A table of idle-engine running cost is given for each of the five vehicle classes. Conversion, or adjusting factors, are given to convert running costs on high types of pavements in good condition to those on gravel and stone surfaces and for lower types of bituminous pavements.

In addition to the conversion of the four sets of tables to Java application, additional tables were developed for a 36-passenger diesel bus, a 12-kip diesel single-unit truck, and a 40-kip diesel tractor-semitrailer combination.

Excise taxes, import duties, and sales taxes were estimated on new vehicles, fuel, oil, tires, and vehicle replacement parts. Final vehicle running costs were compiled in two sets, one with taxes and one without taxes.

Intersection-Interchange Turning Movements and Delays

Vehicles using the new highway would make additional turns to get on and off at intersections and interchanges. Turns are included in the analysis as 90-deg turns.

Delays at intersections and interchanges were considered in the analysis because there would be expected conflicts between vehicles from the proposed route with vehicles on the feeder roads. All such costs are considered above and beyond other costs contained in the analysis.

Procedures for determining costs for turning movements and delays were computerized, but analysis of several interchanges disclosed that the added costs were negligible. Therefore, they were not included in total running cost calculations.

TRAFFIC ACCIDENT COSTS

Limited information was available on the rate of traffic accidents on Java highways and their costs. Therefore, total traffic accident cost data were compiled on the basis of judgment by using information from the literature and other sources, modified to Java conditions. It is noted that accident costs could also be measured in terms of insurance premiums with similar results.

VALUE OF TRAVEL TIME

Values of travel time were assigned to the different classes of vehicles on the basis of number of persons per vehicle, their probable employment, and wage rate. Commercial vehicles were assigned a travel time value on the basis of the driver and crew and their wage rates.

HIGHWAY COSTS

The highway capital and maintenance costs were estimated for each segment of the trans-Java highway. Maintenance costs were estimated for segments of existing highways.

Highway Capital Costs

Highway capital costs were obtained for the six levels of improvement from construction cost estimates. Cost estimates were prepared for 31 basic construction items that were combined into the following six investment components: right-of-way, earthwork, minor drainage structures, major bridges, pavement, and miscellaneous.

Subsequent to capital costs being grouped in six categories, the order in which the various construction costs would be analyzed was based on the five current construction types:

1. Two-lane highway, all crossings at grade,
2. Interchange only,
3. Major road and railroad crossings only,
4. Minor road and railroad crossings only, and
5. Four-lane highway, all crossings at grade.

A second-phase analysis for later construction was prepared subsequent to the review of initial results as follows:

1. Interchange only,
2. Minor road and railroad crossings only, and
3. Add two more lanes to existing two-lane highway.

Roadway Maintenance Costs

Roadway maintenance costs were established for existing roads, feeder roads, and proposed highways. Costs for proposed roads include costs for maintenance of interchanges.

For feeder roads, it was assumed that maintenance costs in 1972 for the before situation were one-half the existing road expenditure, whereas the after situation was analyzed on the basis of full existing road expenditures.

CONCEPTS AND PROCEDURES FOR THE ANALYSIS OF TRANSPORTATION ECONOMY

The economic analysis of the transportation economy of the proposed trans-Java highway compares the investment cost in the trans-Java highway to the road user costs plus highway maintenance costs without and with the new highway. A first analysis determined the degree of economic feasibility, or project evaluation of the proposed highway.

A second analysis determined the relative economy of varying designs and calendar timing of construction and may be called "project formulation."

The overall feasibility analysis was reported in the preliminary report in November 1972 and identifies the route to which the final report applies. In this final report, however, the economic feasibility of the chosen route and of its segments is redetermined. The project design formulation is directed to a comparison of the transportation economy of the six levels of design and their staging.

Highway Design Levels and Supplementary Stages

The analysis of the transportation economy of the trans-Java highway is based on six basic design levels and three supplementary stages for upgrading in design levels as follows:

1. Two lanes with at-grade highway and rail crossings,
2. Two lanes with partial access control (only major crossings and intersections are grade separated),
3. Two lanes with full access control and full grade separations,
4. Four lanes divided with at-grade highway and rail crossings,
5. Four lanes divided with partial access control (only major crossings and intersections are grade separated),
6. Four lanes divided with full access control and full grade separations,
7. Adding access control (grade separations and interchanges) in later years to alternative 1,
8. Adding access control (grade separations and interchanges) in later years to alternative 4, and
9. Adding two lanes to alternatives 1, 2, and 3 subsequent to their original construction.

The analysis of the first six alternatives was on the basis that each would be constructed initially without regard to future upgrading.

Highway Sections and Segments

Criteria used in selecting segments (one or more combined) for analysis of transportation economy were traffic volume (ADT); traffic volume exchange between routes; traffic attraction and accessibility to the trans-Java highway; topography, land use, and population distribution; continuity of design standards and adaption of traffic safety to changes in design (avoidance of frequent changes from at-grade crossings to grade separations and interchanges, and changes from two to four lanes and vice versa); and requirements for a construction contract.

COMPUTER ANALYSIS

All calculations of the transportation economy were done on an IBM 1130 computer. A combination of memory storage and direct input was used. The entire analysis procedure was designed to produce estimated yearly transportation costs for each segment of the proposed trans-Java highway and each existing route segment for the seven classes of vehicles.

Stored Data

Data stored in the computer consisted of the following items: PCU factors, volume-speed relationships showing the relationship between volumes of vehicles and theoretical speeds of various design criteria, vehicle running costs for seven vehicle classes, speed distributions, and vehicle by fuel type, which was used to convert input of six vehicle types to operating costs for seven types as follows:

Vehicle	Gasoline (percent)	Diesel (percent)	Vehicle	Gasoline (percent)	Diesel (percent)
Cars	100		Trucks, trailer and semi-trailer		100
Pickups	100		Buses	50	50
Trucks, single unit	40	60			

Direct Input

Direct input for each roadway segment consisted of initial (1971) traffic volumes by six vehicle types, length in kilometers, type of area (rural or urban), type of terrain (flat, rolling, or mountainous), design speed, operating speed (applicable to existing roads), traffic growth rates for each vehicle type, and construction and maintenance costs.

TRAFFIC PROJECTIONS AND ANALYSES

Vehicle traffic counts of six basic vehicle types were projected yearly to establish annual total PCU volumes, which were divided into peak-hour and remaining volumes. Speeds were established annually for corresponding PCUs for cars and pickups as a group and for trucks and buses as a group. Because of the capacity limitation placed on the proposed two-lane facility, speeds for reverted volumes were also noted. The six vehicle types were then converted to seven study types.

The traffic volume analysis was based on the acceptance of a designated level of congestion inasmuch as traffic volumes, both existing and projected, are quite high. The basic premise was that 4 hours of congestion was considered to be the tolerable or acceptable situation. It was further considered that 6 hours of congestion would be the maximum in the analysis.

For existing routes, the maximum acceptable congestion was 18,000 PCU per day with a minimum speed of 15 km/h with traffic volumes projected to the year 1999. The premise for projecting volumes higher than the maximum congestion level is that as traffic continues to grow road users find parallel routes to their destination, which is anticipated as normal growth and development.

The analysis of the proposed two-lane trans-Java highway was set up for combinations of volume and speed (Table 6). Traffic above 30,000 ADT was considered as reverting to the existing roads.

The criteria used in the analysis of the proposed four-lane trans-Java highway are given in Table 6.

VEHICLE OPERATING COST

Total operating costs for the proposed and existing routes were obtained by summing the following various items:

Item	Proposed Highway	Existing Roads
Running cost	x	x
Pavement factor	—	x
Load factor	x	x
Travel time	x	x
Accident costs	x	x
Investment costs	x	x
Time depreciation	x	x
Management	x	x

Pavement and load factors where applicable were applied to running costs to obtain actual running costs. The management factor applied to all vehicles except automobiles.

Running Costs

For the seven vehicle classes, running costs were established for five component items: grades (flat to ± 8 percent), horizontal curves (0 to 30 deg), speed changes, stops, and idle-engine.

Costs for these five items for each vehicle type were calculated and summed for total vehicle running costs. The costs were established for peak-hour volumes and remaining volumes.

Grades—Grades are the primary running cost item, with the remaining four items added to produce total vehicle running costs. Grades were analyzed on a speed distribution basis. Overall operating speed used was either that based on PCUs or the maximum speed at which the vehicle could traverse the grade as obtained from vehicle running cost tables. The lower of the two speeds was used in the analysis.

Composite data were prepared for the existing road system for the various areas and terrains. Data for the proposed highway were taken from the plan and profile sheets.

Horizontal Curves—Horizontal curvature was analyzed on the basis of a constant speed. This speed could be either the operating speed based on PCUs or the maximum speed at which the vehicle could traverse the curve as obtained from running cost tables. The lower of the two speeds was used in the analysis.

Composite data were prepared to reflect existing horizontal curvature conditions. Data for the proposed highway were taken from the plan and profile sheets.

Speed Changes—The excess cost of speed changes as compared to the cost at uniform speed was computed. Based on field data and judgment, total numbers of slowdowns were estimated for the six design standards and for various speeds. These total numbers of slowdowns were apportioned first by the ratio of time spent at any speed within the speed distribution and, secondly, by a set proportion to speed differentials of 5, 10, 15, and 20 km/h.

Stops and Idle Engine—Total numbers of stops were estimated for the six design standards at various operating speeds. A review of field data led to the analysis distribution of all stops. Idle-engine costs were computed in accordance with the amount of time vehicles were considered stopped.

Pavement Factor

For existing roads, because of surfaces in generally poor condition and surface types other than high type, a pavement factor correction was applied to the running cost.

Adjusting Factor Applied to Specific Vehicles

An adjusting load factor was applied to each of the vehicle types as given in Table 7. This factored cost was considered to be the total running cost of each vehicle.

CAPITAL COST

Most of the physical components of the highway have useful average service lives of 20 years or more. Therefore, the analysis provides for a terminal value credit for the years of available service remaining at the end of the year 1999. The following table shows the average service lives used. They are based on general usage (3).

Item	Average Service Life (years)
Right-of-way	100
Earthwork	75
Minor drainage structures	40
Pavement section	30
Major bridges	60
Miscellaneous	20

Terminal value is handled in the computer program as follows:

1. The investment cost of each of the six highway components is spread over its full service life by use of the capital recovery factor corresponding to the discount rate being used. This produces an equivalent uniform annual cost over the full service life.
2. At the end of the year 1999 the present worth of the remaining number of yearly equivalent uniform annual costs is calculated, which is the terminal value or value of remaining unused yearly service.

Table 4. Vehicle and passenger data.

Category of Vehicle Type Counted	Vehicle Class	Applicable Running Cost	
		Vehicle Class	Adjusting Factor
Motorcycle	Motorcycles, scooters	Excluded	
Bemo	Bemo (3 wheels)	Excluded	
Passenger car	Mobile penumpang	4-kip P. C.	0.80
	Opelet	4-kip P. C.	0.80
	Sedan	4-kip P. C.	0.80
	Suburban	4-kip P. C.	1.25
	Land Rover	4-kip P. C.	1.00
	Jeep	4-kip P. C.	1.00
	Overall weighted	4-kip P. C.	0.90
Pickup	Pickup	5-kip C. D.	1.00
Microbus	Microbus	5-kip C. D.	1.00
Delivery van	2-axle, 4-tire truck	5-kip C. D.	1.00
Bus	2-axle, 6-tire bus	36-seat bus	1.00
2-axle truck	2-axle, 6-tire truck	12-kip SUT	0.75
3-axle truck	3-axle, 10-tire truck	12-kip SUT	1.00
Trailer	Trailer	40-kip 2-S2	0.75
Semi-trailer	Semi-trailer	40-kip 2-S2	0.75

Table 5. Vehicle classification types and running cost adjusting factors.

Vehicle	Average Number of People (including driver)	Average Vehicle Age (years)
Passenger car	6.8	8.9
Van (pickup)	3.6	9.3
Truck	3.7	12.9
Bus	35.0	8.6
Trailer, full and semi	3.7	11.0

Table 6. Level of service for proposed highways.

Proposed Highway	Intersections Separated	Volume		Speed (km/h)		
					Maximum	
		Minimum	Maximum	Minimum[a]	Cars and Pickups	Trucks and Buses
Two-lane	None	25,000	30,000	30	60	60
	Only major	25,000	30,000	40	70	70
	All	25,000	30,000	50	80	70
Four-lane	None	90,000	120,000	40	70	70
	Only major	90,000	120,000	50	80	70
	All	90,000	120,000	60	90	80

[a]All vehicles.

Table 7. Incremental rates of return for trans-Java highway.

Base Alternative[a]	Design Level	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
T	U	28.0	30.7	35.8	37.4	40.9	43.0	44.1	44.8	46.7	49.7	50.9	52.6	57.6	60.0	61.7	61.0	59.3	61.5	62.8	63.4
	V	30.3	33.0	38.0	39.8	43.2	46.3	47.3	48.0	49.7	52.5	53.6	55.2	59.8	62.1	63.6	63.0	61.4	63.4	64.6	65.2
	W	30.1	32.7	37.5	39.5	43.0	46.2	47.2	47.8	49.4	52.1	53.1	54.6	59.0	61.2	62.6	62.0	60.5	62.5	63.6	64.1
	X	21.4	23.5	27.6	29.4	32.4	35.1	37.5	39.5	42.5	46.2	48.7	51.2	51.2	59.0	61.4	62.5	63.0	65.9	68.3	70.3
	Y	22.3	24.5	28.5	30.4	33.3	36.0	38.4	40.5	43.5	47.2	49.7	52.2	56.9	59.9	62.4	63.5	64.1	67.0	69.5	71.5
	Z	21.3	23.4	27.2	29.0	31.8	34.5	36.8	38.8	41.6	45.2	47.6	50.1	54.6	57.5	60.0	61.1	61.7	64.6	67.0	69.0
U	V	76.6	79.8	82.8	87.3	90.8	107.1	107.1	107.1	107.1	107.1	107.1	107.1	107.1	107.1	107.1	107.1	107.1	107.1	107.1	107.1
	W	47.3	49.6	52.1	57.0	60.6	71.5	71.5	71.5	71.5	71.5	71.5	71.5	71.5	71.5	71.5	71.5	71.5	71.5	71.5	71.5
	X	4.5	5.2	6.0	9.1	10.4	15.8	22.3	28.2	33.8	29.1	44.4	48.6	52.8	56.9	61.0	65.0	69.0	73.1	77.1	81.1
	Y	9.9	10.8	11.8	14.5	16.0	20.8	26.7	32.1	37.4	42.5	47.5	51.6	55.6	59.6	63.5	67.5	71.5	75.4	79.4	83.3
	Z	9.8	10.6	11.6	13.9	15.2	19.4	24.4	29.2	33.8	38.4	42.9	46.6	50.2	53.9	57.5	61.2	64.8	68.5	72.2	75.9
V	W	25.9	27.6	29.5	35.4	39.3	44.9	44.9	44.9	44.9	44.9	44.9	44.9	44.9	44.9	44.9	44.9	44.9	44.9	44.9	44.9
	X	—[b]	—[b]	—[b]	—[b]	—[b]	—[b]	6.7	15.9	23.7	30.7	37.3	42.4	47.3	52.1	56.8	61.4	66.0	70.4	74.9	79.2
	Y	—[b]	—[b]	—[b]	2.3	3.5	5.3	14.6	22.2	29.0	35.4	41.4	46.2	50.9	55.5	60.0	64.4	68.8	73.1	77.5	81.7
	Z	—[b]	1.5	2.3	4.9	6.0	7.4	14.5	20.8	26.6	32.1	37.4	41.7	45.9	50.1	54.1	58.2	62.2	66.2	70.2	74.1
W	X	—[b]	—[b]	—[b]	—[b]	—[b]	—[b]	—[b]	8.9	19.4	28.2	36.0	42.0	47.7	53.1	58.4	63.5	68.5	73.4	78.2	83.0
	Y	—[b]	—[b]	—[b]	—[b]	—[b]	—[b]	7.4	17.7	26.3	33.9	40.9	46.4	51.7	56.8	61.8	66.7	71.4	87.0	80.0	85.4
	Z	—[b]	—[b]	—[b]	—[b]	—[b]	—[b]	9.3	17.2	24.1	30.5	36.6	41.4	46.0	50.5	55.0	59.4	63.7	68.0	72.3	76.5
X	Y	55.6	58.3	61.1	63.9	66.8	69.8	72.9	76.1	79.4	82.8	86.2	89.1	92.1	95.2	98.3	101.4	104.7	108.0	111.3	114.6
	Z	21.0	22.4	23.8	25.3	26.9	28.6	30.3	32.1	34.0	35.9	38.0	39.7	41.5	43.4	45.4	47.4	49.5	51.6	53.8	56.1
Y	Z	9.1	9.9	10.6	11.4	12.3	13.2	14.2	15.3	16.3	17.5	18.8	19.9	21.0	22.2	23.5	25.0	26.3	27.8	29.5	31.1

[a]T = do nothing (existing highways); U = 2 lanes, no intersections separated; V = 2 lanes, only major intersections separated; W = 2 lanes, all intersections separated; X = 4 lanes, no intersections separated; Y = 4 lanes, only major intersections separated; and Z = 4 lanes, all intersections separated.
[b]Less than 1 percent.

3. The terminal value at year 1999 is the equivalent of an income to be received at the end of the year 1999. When discounted back to time zero, or 1980 (the first year of the analysis period), this reduces the effective amount of the investment cost to be charged off during the analysis period.

CALCULATION OF RATE OF RETURN

The computer was programmed to calculate both the benefit-cost ratio and the rate of return. The present worth procedure was used in which the computer solves for that discount rate that reduces the present worth of road user costs of a pair of alternatives to the present worth of the difference in the capital highway costs of the pair of alternatives. A minimum attractive rate of return of 15 percent per year is used.

For the rate of return for a single year the procedure was to calculate the equivalent uniform annual capital cost for the highway investment for 20 years. The individual-year road user cost reductions for the alternative under study (the challenger) as compared to the base alternative (the defender) were calculated for the specific-year traffic volume. The yearly rate of return is that discount rate that equates the equivalent uniform annual highway capital costs with the yearly net road user benefits.

CHARACTER OF GENERAL RESULTS

The analysis of transportation economy was designed to produce for each section (one or more segments) of the trans-Java highway the following determinations:

1. The economic feasibility of the proposed highway as compared to the existing highway without improvement,
2. The design economy of six traffic service levels,
3. Identification of the first year that each trans-Java section will produce the minimum acceptable rate of return of 15 percent, and
4. The year the design levels of less than four-lane divided with full access control could be upgraded to a higher service level with a 15 percent rate of return on the cost of upgrading.

When the six levels of design for the trans-Java highway are compared, pair by pair, the economic feasibility of the added capital investment to produce a higher level of service is determined. The year-by-year rate of return permits identification of the first year that the increase in capital investment required for the higher level of service will produce a rate of return of 15 percent or more.

Whereas an overall analysis for the 20-year period may show a rate of return in excess of the minimum attractive rate of 15 percent, the early years of the overall 20-year period may produce less than the desired 15 percent. To ensure the maximization of return on the investment requires that the analysis identify the first year the recommended design level will attain the 15 percent rate of return. In effect, then, if any section has an overall rate of return of 15 percent or greater and if the first few years have rates of return of less than 15 percent, the delay of that project until the initial year has a 15 percent or greater rate of return would ensure a greater rate of return in the following 20-year period than found in the initial overall analysis.

In selection of the design stage, all route sections were reviewed for their 20-year rate of return, and those with 15 percent or greater were considered without regard to monetary limitations. These selections were then reviewed a second time to establish the year that the minimum attractive rate of return would be greater than 15 percent.

Table 7 shows, for each year from 1980 to 1999, incremental rates of return on a trans-Java highway section by design levels compared to incrementally lower design levels. With the do-nothing (existing highways) alternative as a base of analysis, the six proposed design levels can be compared incrementally. Using the base alternative of the next higher design standard (the two-lane, no intersections separated situation), the incremental comparisons are made to the five incrementally higher design levels. This procedure is repetitive through the last analysis which consists of the base alternative of four-lane with only major intersections separated.

Figure 2. Incremental rates of return for proposed and existing highways (west Java section; do-nothing alternative as base).

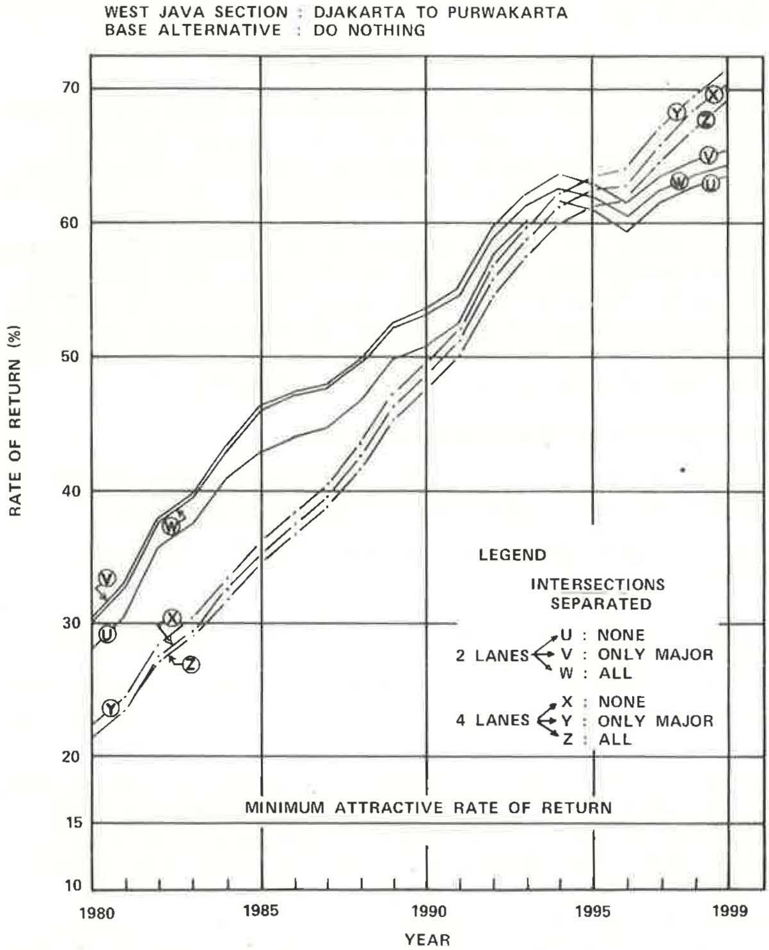

Table 8. Recommended construction for trans-Java highway sections.

	First-Phase Analysis			Second-Phase Analysis		
Termini	Design Level[a]	Year to Be Opened to Traffic	First Year Rate of Return	Design Level	Year to Be Opened to Traffic	First Year Rate of Return
Djakarta to Purwakarta	W	1980	30.09	Z	1987	16.53
Djombang to Surabaja	W	1980	18.62	Z	1993	21.01
Purwakarta to Bandung	W	1982	15.51	Z	1989	15.07
Purwakarta to Tjirebon	V	1983	15.69	W	1998	17.62
Semarang to Surakarta	V	1983	15.17	Y	1997	15.69
Madiun to Djombang	V	1985	15.79	—[b]		
Surakarta to Madiun	V	1987	15.71	—[b]		

[a] V = 2 lanes, only major intersections separated; W = 2 lanes, all intersections separated; Y = 4 lanes, only major intersections separated; and Z = 4 lanes, all intersections separated.
[b] No upgrading meets the minimum rate of return.

Figure 2 shows results of the analysis of the six design levels compared with the do-nothing situation as base. From the figure it is possible to establish the initial year in which the rate of return is 15 percent or greater. If the initial analysis shows a design level other than the proposed two-lane, no intersections separated as the best design level, subsequent analysis must be conducted for the incremental difference in costs to establish the viability of that design level at a rate of return of 15 percent.

Phased Construction Analysis

A first phase analysis was conducted to indicate initial construction. The results were such that in later years several initial recommendations could be upgraded to higher levels of design, and therefore a second phase analysis was undertaken. The only difference between the two analyses was increased construction costs used for the second phase analysis. Table 8 gives results of both first and second phase analyses.

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