

Transportation Engineering and Planning Program for Postgraduate Studies in a Small Developing Country

S. C. WIRASINGHE AND L. L. RATNAYAKE

The proper planning, design, and operation of the transportation system is essential for the development of a country. However, the level of adequacy of the local professional human resources that are available in developing countries is poor. A single postgraduate program that trains the transportation engineering and planning (TE&P) professionals that are needed is appropriate for a small developing country with limited resources. The program can also be disseminated through distance education services. A program that can offer M.Sc. degrees in TE&P as well as M.Phil. (course work and research) degrees is proposed. The target pool of students, the basic principles for curriculum development, and the staff requirements for offering such a program are discussed. It is suggested that three full-time local staff that are trained abroad under scholarship programs as well as part-time staff be used. The courses should be open not only to engineering graduates but others who are suitably qualified. Typical course outlines for the proposed courses are given.

Transportation engineering and planning (TE&P) courses are rare in developing countries despite the obvious importance of transportation in the socioeconomic fabric of a country and for development. However, highway and traffic engineering courses are usually offered as a part of civil engineering bachelor's degree courses. Although an additional undergraduate course in TE&P would be of use to all civil engineers, it is also appropriate to teach the discipline as a postgraduate program, given its broad scope.

An ITE technical committee surveyed transportation education needs in developing countries (1) and concluded that the level of adequacy of local professional human resources was poor. The following were suggested as possible remedies:

1. Professional training programs (3 to 6 months);
2. Foreign scholarships for M.S. and Ph.D. programs;
3. Undergraduate programs in civil engineering, planning, and architecture; and
4. Correspondence courses.

The committee also concluded that "very few universities in the United States (and presumably in other countries) have adequate resources to offer such a specialized program" (i.e., TE&P in developing countries) and that "serious efforts should be made to offer (such) programs in the developing countries themselves." The committee also felt that "lack of foreign

exchange would not allow these countries to send any appreciable number of professionals abroad."

Most developing countries do have undergraduate civil engineering programs. Professional training programs are appropriate short-term solutions to retrain existing human resources. The long-term solution to the lack of specialized professionals in developing countries is for postgraduate programs to be offered in those countries. Whenever possible, the postgraduate programs should be staffed by people from the same country that understand indigenous problems and can suggest indigenous solutions. Initially, the academic staff for the postgraduate programs can be trained in developed countries.

Small developing countries (SDCs) (e.g., Sri Lanka, Guatemala, Ghana, Rumania) have limited resources for training the professionals needed for development in areas such as transportation, water supply, agriculture, and public health. Consequently, it would be wasteful to offer more than one postgraduate program in any one of these areas. On the other hand, that program should be designed to provide expertise in all aspects of the discipline. Once developed, the program can also be disseminated through distance education services. In some cases, one program could cater to a group of several countries in one region, for example Sri Lanka, Nepal, Bhutan, and the Maldives. In appropriate cases, such regional cooperation could result in economies of scale, reduction of staffing problems, and also easier access to funding from international agencies.

In the following, a model package for a postgraduate program in TE&P is proposed for SDCs. It was developed by Canadian and Sri Lankan academics with a background in TE&P problems facing SDCs. It has benefited greatly by the suggestions and criticisms offered by a panel of Sri Lankan experts with a strong and varied background in TE&P in SDCs. Sri Lanka, a typical SDC, was chosen for reviewing and testing various drafts of the proposal.

TE&P

The discipline of TE&P covers all aspects of the planning, design, and operation of transportation systems. For example, the feasibility analysis for a rural highway, the specification of its horizontal and vertical alignment and thickness of its pavement layers, and the ongoing maintenance of the highway could be considered to be the planning, design, and operations components, respectively, of a highway project.

S. C. Wirasinghe, Department of Civil Engineering, University of Calgary, Alberta, Canada T2N 1N4. L. L. Ratnayake, Department of Civil Engineering, University of Moratuwa, Moratuwa, Sri Lanka.

In addition to the highways, transportation professionals along with professionals with expertise in commerce and economics are responsible in various degrees for railways, light-rail and metro systems, bus systems, ports, urban transportation, freight transportation, water transportation (e.g., canals), and air transportation.

The design, manufacture, operation, and maintenance of the vehicles and power systems used for transportation are the responsibility of other professionals such as mechanical engineers. Further, the technologies associated with controlling the free movement of vehicles (e.g., the electronics of the controllers used for traffic signals) are in other domains.

The design of transportation infrastructure facilities (e.g., highways, railways, and canals) and the operation of the highway system (traffic engineering) have traditionally been and will continue to be the domain of civil engineers. The remaining areas have been staffed with engineers and others with varied backgrounds but with little formal training in transportation.

TARGET POOL OF STUDENTS

In many instances, transportation agencies are staffed by civil servants with varied backgrounds who have no understanding of the basic principles underlying the transportation disci-

pline. This will change in the long run if new recruits have a formal training in TE&P and middle-level officials are given retraining.

TE&P has little in common with traditional civil engineering subjects such as the theory of structures and hydraulics. Consequently, the background of students who can be admitted to a postgraduate course should not be restricted to civil engineering. However, an adequate background in mathematics equivalent to first-year university mathematics is essential.

Prospective students should have one of the qualifications listed in Table 1 for consideration for admission to a graduate program in TE&P. The students with a first degree in non-engineering subjects are unlikely to be considered for registration as professional or chartered engineers after they complete a postgraduate course in TE&P. However, they will likely be eligible for membership in societies of transport professionals.

CURRICULUM FRAMEWORK AND DEGREES

The following are the basic principles underlying the development of the curriculum given in the next section.

1. Transportation systems should be planned, designed, and operated by formally trained professionals.

TABLE 1 REQUIRED QUALIFICATIONS

Degree	Class/GPA (4.0)
1. *Engineering	Second/3.0
2. Transportation	Second/3.0
3. #Economics	Second/3.0
4. #Geography	Second/3.0
5. #Mathematics	Second/3.0
6. #Physics	Second/3.0
7. #Computer Science	Second/3.0
8. **General Degree with two or more of the above subjects	Upper Second/3.5
9. +Other Special Degree with minor in mathematics	First/3.75

Notes:

* A degree in any branch of Engineering

Special or Honours degree of 4 years duration

** An Upper Second Class (G.P.A. 3.5) is required because these are usually 3 year programmes

+ Students with Special Degrees in subjects such as Sociology and

Psychology may be considered if the mathematics background is sufficient

~ Experience in the Transport Sector may be considered to be equivalent to the G.P.A. or Class given above. The actual equivalence should be determined on a case by case basis.

2. Given the limited resources in SDCs, a single postgraduate program should be designed to cover the requirements of the TE&P sector. However, economists and M.B.A.s with expertise in transportation can be trained within existing general economics and business programs.

3. Although specialization in some aspects of transportation is desirable, a general understanding of the basic principles underlying the three major areas of planning, design, and operations is required for all professionals.

4. The course should be practically oriented so that the graduates will need little or no further training by particular agencies. However, it is noted that "nothing is more practical than a good theory."

5. Master's level qualifications are adequate for most professionals. However, the course should be designed to accommodate students proceeding subsequently to a Ph.D. program.

6. The course should be designed to accommodate both parttime and full-time students. It should be presented in class and also through distance education services.

7. The limited staff available in a small developing country for teaching a postgraduate course is a consideration in curriculum development.

CURRICULUM FRAMEWORK AND DEGREES

The framework of the curriculum is given in Table 2. The four main divisions of the curriculum are general (G), planning (P), engineering (E), and functional design and operations (F). Each of the courses is equivalent to 3 hours of lectures per week during a 13-week semester.

The individual courses listed in Table 2 were selected independently of the ITE proposals (I). However, a subsequent comparison revealed that 7 of the 18 topics suggested by the ITE committee are listed as courses in Table 2 and that 7 other topics are covered in four of the courses. The four topics suggested by the ITE committee and not covered here were all given low priorities (ranging from 5 to 7 on a scale of 1 to 10) by the committee. They would be more appropriately housed in a business administration program. On the other hand, Table 2 includes several courses under the general category (G2, 3, and 5) that were not proposed by the ITE committee.

Both the M.Sc. degree courses have been designed to provide a solid background in all aspects of transportation as well as specialization in certain areas. The four introductory courses in transportation economics, planning, designs, and operations, respectively, are mandatory for all students. Thus, engineers will appreciate economic and planning problems and vice versa.

Either program can be completed in three semesters by a full-time student.

M.Sc. In Transportation Engineering (T.E.)

This program should normally be available only to students with a first degree in an engineering discipline.

The M.Sc. (T.E.) degree will be awarded upon the successful completion of the following 10 courses and a final oral examination. This course is designed for those planning careers in highway and traffic engineering as well as for engineers dealing with airports, railways, and urban rail and bus systems design.

No. of Courses	Group or Course
2	E1, F1
Choice of 3	E, F
2	G1, G2
1	P1
Choice of 2	Optional

M.Sc. in Transportation Planning (T.P.)

This program should be available to all groups listed in Table 1. The M.Sc. (T.P.) degree will be awarded upon successful completion of the following 10 courses and a final oral examination. This course is designed for those planning careers in transportation planning, transportation systems analysis, and urban and rural development

No. of Courses	Group or Course
2	P1, F1
Choice of 3	P, F
2	G1, G2
1	E1
Choice of 2	Optional

TABLE 2 TRAFFIC ENGINEERING AND PLANNING COURSES

General (G)	Planning (P)	Engineering (E)	Functional Design and Operations (F)
1. "Introduction to Transport Economics	1. "Introduction to Transport Planning	1. "Introduction to Transport Facilities Design	1. "Introduction to Transport Operations
2. "Probability and Statistics for TE&P	2. Urban Transport Planning	2. Geometric Design of Highways and Railways	2. Traffic Engineering
3. Operations Research for TE&P	3. Freight Transportation	3. Pavement Design of Highways	3. Public Transport Operations
4. ^b Urban and Regional Planning			
5. ^b Computer Literacy			

NOTE: Duration of each course: 3 hr/week for 13 weeks or equivalent.

^aMandatory courses for all M.Sc and M.Phil. students.

^bThese courses are usually offered in other university departments. Course outlines are not provided in this paper.

M.Phil. Degree

The M.Phil. degree can be awarded upon the completion of (a) a thesis subsequent to 1 year of research and (b) the coursework requirements. It is recommended that the course G3 be mandatory for all M.Phil. students. This degree is appropriate for those planning careers in research agencies or planning to enter a Ph.D. program.

Staffing and Staff Training

Ideally, a full-time staff of three lectures should be available for teaching the courses given in the previous section. They should be specialists in Transportation Planning, Transportation Engineering, and Transportation Facilities Design and Operations, respectively. Then, each lecturer is required to teach three courses per academic year (two in one term, one in the other term in semester systems; one in each of three quarters in quarter systems). In addition, the support of other university departments is required to teach Section G courses.

If the M.Phil. degree is to be offered, at least two of the staff members should have Ph.D. degrees. Otherwise, one staff member with a Ph.D. degree and two experienced lecturers with master's degrees are sufficient. Ideally, all three should have the Ph.D. qualification.

It is recommended that the three lecturers should not only have varied specializations, but that they should be trained in various regions and countries of the world (e.g., Asia, Australia, continental Europe, North America, United Kingdom) whenever possible, rather than in one university or even one region. In recruiting staff for training abroad, it is essential to interview and handpick not only the brightest but those who are highly motivated to return.

If a minimum of two faculty members are available, the proposed program could be implemented with the use of visiting lecturers picked from the pool of practitioners that is normally available in any country. The visiting lecturers should have a significant amount of professional experience and preferably a master's degree. In fact, the use of visiting lecturers should be encouraged for specific lectures, even if full-time staff are available, to take advantage of their considerable experience and to strengthen the program by maintaining links to the practitioners.

PROPOSED POSTGRADUATE PROGRAM— UNIVERSITY OF MORATUWA, SRI LANKA

The University of Moratuwa proposes to conduct only one M.Sc. course in transportation. The course will be conducted by the Department of Civil Engineering with supporting staff from the Departments of Mathematics and Town and Country Planning in the university. There will be about four visiting staff. The course will be open to engineers, planners, economists, geographers, mathematicians, computer scientists, and others with suitable background preparation.

The M.Sc. degree will be awarded upon the successful completion of the following 10 courses and the successful completion of a dissertation and oral examination. This degree is equivalent to the M.Phil. degree proposed earlier.

• Term 1 (Weeks 1 to 13)

1. Introduction to Transport Economics.
2. Transport Planning (General).
3. Probability and Statistics.
4. Computer Literacy.

Written Examinations (Weeks 14 to 16).

• Term 2 (Weeks 17 to 30)

5. Introduction to Transport Operations.
6. Introduction to Transport Facilities Design.
7. Traffic Engineering and Public Transport Operations.

Written Examinations (Weeks 31 to 33).

• Term 3 (Weeks 34 to 46)

8. Highway Planning and Design, and Urban Transport Planning.
9. Pavement Design and Maintenance and Urban and Regional Planning
10. Operations Research and Freight Transportation

Written Examinations (Weeks 47 and 48).

Because local employers are usually not willing to release their staff on a full-time basis for a significant period, all M.Sc. courses in the Faculty of Engineering at the University of Moratuwa are conducted on a part-time basis. The lectures, practicals, project work, etc., are conducted on Fridays and Saturdays from 8:00 a.m. to 4:00 p.m. Hence, it takes 2 years to complete all 10 courses. In general, it takes about 1 to 2 years to complete the research project. The time table and the implementation program are given above.

The University of Moratuwa by-laws allow a student to opt for postgraduate diploma after the successful completion of the 10 courses. This diploma is equivalent to the M.Sc. degrees proposed earlier.

At the University of Moratuwa, M.Phil. degrees are awarded by research only. A student should perform at least 2 years of full-time research or equivalently more than 3 years on a part-time basis to be eligible for an M.Phil. degree. The student will be required to present one or more seminars on his research work and submit a thesis for an oral examination with external examiners. Only persons with a very good undergraduate degree (1st Class or 2nd Class, upper division) are allowed to register for an M.Phil. degree. Because only a very few transport-related courses are taught in undergraduate programs, students in general will not be encouraged to undertake M.Phil. degrees in transportation.

When the proposed M.Sc. course in transportation commences in 1991 there will be three staff members with postgraduate qualifications in traffic engineering (M.Sc.), transport planning (Ph.D.), and public transport operations (Ph.D.).

The Mathematics Department is expected to conduct two courses (probability and statistics and operations research) and the Town and Country Planning Department to conduct the urban and regional planning course. Visiting lecturers are expected to give four courses: Introduction to Transport Economics, Freight Transportation, Highway Planning and Design, and Pavement Design and Maintenance.

TYPICAL COURSE OUTLINES

The following outlines for the courses in Table 2 (with the exception of G2 to G5) are meant only to be used as guides in developing specific courses appropriate for specific countries. Detailed curricula and 74 references are given by Wirasinghe and Ratnayake (4). Though the outlines were developed with the intent of being generally applicable, all the authors and the experts who commented on drafts were either Sri Lankans or Canadians, and their biases are likely to have been a factor. However, the outlines given here will provide a good starting point and also considerably reduce the workload involved with curriculum development.

The course numbers in the following section refer to Table 2.

G.1. Introduction to Transport Economics

1. Introduction to Basic Microeconomic Theory.
2. Economic Significance of Improved Transportation.
 - a) Transportation and Availability of Goods.
 - b) Price Stabilization and Equalization.
 - c) Relation of Transportation to Land Values.
 - d) Transportation and Prices.
 - e) Territorial Division of Labor.
 - f) Transportation and Large-Scale Production.
 - g) Transportation and Competition.
 - h) Transportation and Urbanization.
 - i) Low Freight Rates in the Public Interest.
 - j) Transportation and Economic Development.
3. Demand for Transport.
 - a) Factors that Influence Demand.
 - b) Need for Transport.
 - c) Valuation of Travel Time Savings.
 - d) Demand Elasticities.
4. Direct Cost of Transport.
 - a) Supply of Transport.
 - b) Fixed and Variable Costs.
 - c) Specific, Joint, and Common Costs.
 - d) Problems of Common Cost Allocation.
 - e) Transport User Costs.
 - f) Resource Costs.
5. Economics of Transport Pricing.
 - a) Economic Structure of Transport.
 - b) Theory of Pricing and Price Elasticity.
 - c) Theory of Pricing of Transport.
 - d) General Level of Rates.
 - e) Rate Making in Practice.
 - f) Peak-Load Pricing.
6. Industry Study.
 - a) Economics of Urban Transport (Including Environmental and Health Care Costs).
 - b) Economics of Air Transportation.
 - c) Economics of Highway Trucking.
 - d) Economics of Railroad Transportation.
 - e) Economics of Shipping.
 - f) Economics of Pipeline Transportation.
7. Development and Transportation.
 - a) Transport Patterns.
 - b) Transport Means.

- c) Transport Policies.
- d) Conclusions and Policy Implication.

P.1. Introduction to Transport Planning

1. Transportation Planning Within the Context of National Planning.
 - a) Energy Costs of Transport Modes.
2. Role of Transportation in Economic Development.
3. Relationship Between the Transport System and the Environment.
 4. Concepts of Mobility, Accessibility, Congestion, and Free Movement of People and Freight.
5. Transport Modes and Networks.
 - a) Roles of Traditional Modes (e.g., carts and bicycles).
6. Urban Transport Planning.
 - a) Trip Generation, Distribution, Modal Split, and Assignment.
 - b) Alternate Approaches and Community Involvement.
 - c) Standard Computer Packages.
7. Freight Transportation Issues.
8. Rural Transportation Problems.
 - a) Mobility of the Rural Poor.
 - b) Network Connectivity.
 - c) Traditional Transport Modes.
9. Intercity Transportation.
 - a) Properties of Transport Modes.
 - b) Demand Estimation and Forecasting.
 - c) Assessment of Supply.
10. Feasibility Studies for Highways and Other Transport Systems.

P.2. Urban Transport Planning

1. Introduction to Urban Transport Planning.
 - a) History of Urban Transport Planning.
 - b) Areas of Urban Transport Planning.
 - c) Elements of Urban Transportation Planning.
2. Assessment of Need and Impact Studies.
 - a) Assessment and Ranking of Transportation Projects.
 - b) Selection of Appropriate Solutions.
 - c) Impact Evaluation.
3. Demand and Supply Analysis of Urban Transportation.
 - a) Demand Theories.
 - b) Supply Analysis.
 - c) Introduction to Methods of Demand Analysis and Forecasting.
4. Data Collection.
 - a) Methods of Data Collection.
 - b) Process of Data Collection.
5. Process of Urban Transport Planning and Some Case Studies.
 - a) Problem Definition (Examination of Some Classical Problems).
 - b) Solution Generation.
 - c) Solution Formulation.
 - d) Evaluation of Alternatives, Choice, and Policy-making.
 - e) Citizen Participation.
 - f) Implementation.

P.3. Freight Transportation

1. Introduction to Freight Transportation.
 - a) Description of Current Status by Mode for Urban, Intercity, and Rural Transport.
 - b) Role in the Economy and Relationship to GNP.
 - c) Containerization.
2. Urban Freight Transportation.
 - a) Operating Costs, Facility Costs, and the Warehouse Location Problem.
 - b) Traffic Effects of Urban Freight Vehicles.
 - c) Loading and Unloading Facilities.
3. Intercity Freight Transportation.
 - a) Economics of Freight Transport.
 - b) Prediction of Flows.
 - c) Freight Transport by Highways.
 - d) Freight Transport by Railways and Unit-Trains, and Problems of Access.
 - e) Water Transport.
 - f) Pipelines.
4. Rural Freight Transportation.
 - a) Joint Passenger-Freight Transport.
 - b) Transport of Produce to Markets and Processing Centers.
 - c) Animals and Portage.
5. Other Issues.
 - a) Air Cargo.
 - b) Ocean Freight.

E.1. Introduction to Transport Facilities Design

1. Design of Urban Streets, Sidewalks, and Bicycle Lanes.
 - a) Networks.
 - b) Typical Cross Sections.
 - c) Pedestrian Crossings (At-, Above-, and Subgrade).
2. Highway Design.
 - a) Horizontal and Vertical Curvature.
 - b) Superelevation and Sight Distance.
 - c) Signing.
 - d) Standards.
3. Pavement Design.
 - a) Urban Streets.
 - b) Highways.
 - c) Types of Pavements and Shoulders.
 - d) Standard Design Procedures.
4. Airports.
 - a) Airport Locations.
 - b) Runway Orientation and Design.
 - c) Runway Pavements.
 - d) Taxiways and Aprons.
 - e) Design of Marking and Lighting Systems.
5. Introduction to Railway Design.
6. Introduction to the Layout of Ports.

E.2. Geometric Design of Highways and Railways

1. Introduction.
 - a) Overview of Planning Process.
 - b) Location of Links and Route Layout.

- c) The Highway as a Multiple User Facility (Automobiles, Trucks, Bicycles, and Pedestrians).
2. Design Control Criteria.
 - a) Data Gathering.
 - b) Traffic Volumes.
3. Capacity.
 - a) Width of Roadway and Sidewalks.
 - b) Highway Intersection Capacity.
 - c) Railroad and Transit Guideway Tracks.
4. Horizontal Alignment of Highways and Railways.
 - a) Circular Curves.
 - b) Superelevation.
 - c) Spiral and Transition Curves.
5. Vertical Alignment of Highways and Railways.
 - a) Vertical Curves (Crest and Sag).
 - b) Passing Sight Distance.
 - c) Stopping Sight Distance.
6. Cross-Sectional Elements of Highways.
 - a) Right of Way.
 - b) Parking Lanes, Bicycle Lanes, Shoulders, and Sidewalks.
 - c) Pavement Crown and Slope.
 - d) Guardrails.
 - e) Curbs, Gutters, and Drainage Ditches.
7. Intersections.
 - a) Channelized Intersections.
 - b) Rotary Intersections.
 - c) Grade-Separated Intersections.
 - d) Railway Crossings.
8. Drainage.
 - a) Surface Run-Off.
 - b) Rain Fall Intensity and Coefficient of Run-Off.
 - c) Culverts and Drainage Channels.

E.3. Pavement Design of Highways

1. Pavement types, Wheel Loads, and Design Factors.
2. Stresses in Flexible Pavements.
3. Vehicle and Traffic Consideration.
4. Climate and Environment.
 - a) Effect of Water in Pavement.
5. Material Characterization.
6. Subgrade.
7. Bases.
8. Bituminous Surfaces.
 - a) Surface Types and Thickness Requirements.
9. Design of Flexible Airport Pavements.
 - a) CBR, FAA, and Asphalt Institute Methods.
10. Design of Flexible Highway Pavements.
11. Pavement Evaluation.
 - a) Present Serviceability Index and Skid Resistance.
12. Highway Rehabilitation.
13. Equipment Used in Highway Construction.

F.1. Introduction to Transport Operations

1. Highway Traffic.
 - a) Reasons for Congestion.
 - b) Wardrop's Principles of Highway Traffic Assignment.

- c) Methods of Traffic Control
- d) Mobility, Accessibility, Congestion, and Environmental Impact.
- 2. Traffic Management in Small Towns
- 3. Basic Principles of Traffic Signalization.
- 4. Operations of Urban Bus Systems.
 - a) Types of Service.
 - b) Routing and Transfers.
 - c) Scheduling.
 - d) Location of Stops.
- 5. Urban Rail Services.
 - a) Trams.
 - b) Light-Rail Transit.
 - c) Metro Rails.
 - d) Feeder Bus Systems.
- 6. Safety Management and Accident Analysis.
 - a) Collection of Accident Data.
 - b) Sorting and Analysis of Data.
 - c) Identification of Blackspots.
 - d) Identification and Selection of Countermeasures.
 - e) Implementation and Monitoring.
 - f) Safety Management.
- 7. Management of Pedestrian Travel.
 - a) Significance of Pedestrian Travel and the Need for Pedestrian Studies.
 - b) Need for Information and Methods of Information Acquisition.
 - c) Pedestrian Corridor Analysis.
 - d) Methods of Forecasting Pedestrian Demand.
 - e) Pedestrian Safety Needs.
 - f) Incorporation of Pedestrian Plans into Overall Transportation Plans.

F.2. Traffic Engineering

- 1. Traffic Flow Theory.
 - a) Speed, Density, and Flow Relationships at Micro and Macro Levels.
 - b) Measurements and Probability Distributions.
 - c) Analysis of Traffic Shock Waves and Delay Calculations.
- 2. Traffic Surveys and Analysis.
 - a) Traffic Surveys, Survey Methods, Sampling, Home Interviews, and Questionnaire Survey procedures.
- 3. Traffic Control Systems.
 - a) Major/Minor Priority Intersection Design Methods and Capacity Determination.
 - b) Capacity of Intersection with Roundabouts (Conventional, Small, and Mini), Design, and Warrants for Roundabouts.
 - c) Capacity and Warrants for Undersaturated Intersections, with Signals, Phasing, Cycle Time, Green-Red Split, and Vehicle-Actuated Signals.
 - d) Coordinated Signal Systems, Area Traffic Control.
 - e) Signalization at Saturated Intersections.
- 4. Parking.
 - a) Parking Surveys, Characteristics, Generation, Parking Methods, Location, and Standards.
- 5. Traffic Management.
 - a) One-Way Streets, Turning Traffic, Clearways, Tidal

- Flow, Pedestrian Management, Segregation Methods, and Public Transport Priority Methods.
- 6. The Road User, the Vehicle, and the Road.
 - a) Physiological Factors Influencing Behavior of Road User.
 - b) Visibility, Lighting, and Braking Characteristics of Vehicles.
- 7. Street Lighting, Signs and Markings.

F.3. Public Transport Operations

- 1. Introduction.
- 2. Transit Technology.
- 3. Dispatching Policy.
 - a) Capacity, Round-Trip Time.
 - b) Headway.
 - c) Fleet Size.
- 4. Scheduling.
 - a) Schedule Writing.
 - b) Vehicle Assignment.
 - c) Run Cutting.
 - d) Crew Assignment.
- 5. Stop Spacing and Location.
 - a) Stop Categories.
 - b) Spacing and Locations.
 - c) Pedestrian Access and Other Considerations.
- 6. Terminals.
 - a) Terminal Types.
 - b) Sizing Terminal Facilities.
 - c) Parking.
 - d) Access Roads.
- 7. Service Monitoring and Control.
 - a) Service Data Required and Surveys.
 - b) Performance Indicators.
 - c) Reliability.
 - d) Route Control Strategies.
- 8. Routes and Networks.
- 9. Fare System and Collection.
- 10. Transit Policies.

CONCLUDING REMARKS AND SUMMARY

In order to break out from the vicious cycle of underdevelopment, the developing countries essentially have to be helped to be self-sufficient. In some cases, poorly designed foreign aid packages can make a country lose its internal strengths and become even more dependent.

The appropriate and cost-effective way to train the necessary human resources required in TE&P is to encourage developing countries to set up their own postgraduate programs by training the academic staff and equipping laboratories. In the case of SDCs, a single program may be sufficient. Although specialization in some aspects of transportation is desirable, a general understanding of the basic principles underlying the three major areas of planning, design and operations is required of all professionals. A postgraduate master's level program can be offered with three full-time staff or with a minimum of two supported by visiting lecturers. The target pool of students should not be restricted to those with a bachelor's degree in engineering.

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REFERENCES

1. ITE Technical Committee 2-21. Transportation Engineering Curriculum for Developing Countries. *ITE Journal*, June 1984, pp. 20-23.
2. *Post Graduate Study Programmes in International Highway and Traffic Engineering*. Department of Civil Engineering, University of Birmingham, Birmingham, U.K. (undated).
3. *Graduate Study in Transportation Planning and Engineering*. Department of Civil Engineering, University of Calgary, Calgary, Alberta, 1987.
4. S. C. Wirasinghe and L. L. Ratnayake. *Transportation Planning and Engineering Curriculum for Post Graduate Studies in a Small Developing Country*. Research Report CE90-4. Department of Civil Engineering, University of Calgary, Calgary, Alberta, 1990, 28 p.

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