

Critical Reviews of Selected Postgraduate Programs in Transportation Engineering against the Needs of Infrastructure Development

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Abstract : In this research critical reviews of selected outcome based postgraduate programs in Transportation Engineering (M.E/M.Tech.) are presented which are offered by a set of selected leading engineering colleges/institutions in India. Macro and micro analysis of the courses have been performed. Most of the postgraduate programs offer specialization in transportation engineering design, or transportation system engineering, or transportation engineering management. It is observed that there is a need for greater focus on the Transportation System Analysis (Performance and Optimization), Economic Analysis, and Planning Methods (Data Sciences for Transportation), Intelligent Transportation System, Safety and Security, Transportation Policy, Planning and Sustainability and Urban Transportation. In the past, most of the graduate students took up teaching jobs. Due to rapid economic development, they may end up in the corporate sector. It is learnt that only Indian Railways offers professional development programs for their engineers. Rarely transportation engineering departments depute their engineers to postgraduate programs. Considering the massive expansion of infrastructure development, it is suggested that more specialization is needed on Policy Analysis, Urban

Transportation, Performance and Optimization, Analysis and Planning Methods, Data Sciences for Transportation, Intelligent Transportation, Safety and Security, and Sustainability. The existing programs could be improved based on the needs analysis. Also, there is need to focus on the consultancy works so that these postgraduate engineers can establish consultancy units. The curriculum need to be continuously be updated to meet the needs of massive infrastructure needs.

Keywords: Postgraduate Transportation Engineering Programs, Transportation Systems, Transportation Management, Policy Analysis, Interdisciplinary program in Transport Engineering.

1. Introduction

There is a massive investment in the infrastructure development in India due to industrial expansion, creation of many industrial corridors, establishing Special Economic Zones (SEZ), developing multimodal transportation systems, creating major harbors and airports connecting the industrial corridors with container terminals through dedicated express highways.

Infrastructure development has become the backbone for economic development. All these demands call for competent engineers to plan, design, execute various projects and maintain them. The professional transportation engineers must coordinate between various project agencies, industrial

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development organizations, and government departments. Hence, the postgraduate programs in Transportation Engineering are to be developed to meet the challenges of the twenty-first century. Also, there is a need for in-service professional development programs for the engineers and managers.

Objectives of Research

1. Critically assess the needs of postgraduate engineers in transportation engineering based on the massive investments in the infrastructure development in the country.
2. Review the courses offered by some selected postgraduate programs planned by a set of leading institutions.
3. Suggest needed improvements in these programs considering the needs of infrastructure developments.

Research Methodology

Postgraduate Transportation Engineering Programs offered by three Indian Institutes of Technology (Chennai, Delhi, & Mumbai), Banaras Hindu University, National Institutes of Technology (Tiruchirappalli, & Warangal), State Technical Universities (Gujarat, Telangana, & Uttara Pradesh) and a State Engineering College (Trivandrum-Kerala) have been selected. MIT-Boston and other universities that focus on the interdisciplinary postgraduate programs have been selected. In addition, the needs of the design engineers have been identified from ABET standards. The courses offered by these colleges have been analyzed and compared. The deficiencies were identified and the suggestions were offered.

Desired Skills of the Engineering Graduates

Accrediting Bureau of Engineering and Technology ABET (2012) of USA specified the following learning outcomes for evaluating the achievement of the engineering graduates and considered the accrediting the program:

Hard Skills Identified by ABET

- An ability to apply knowledge of mathematics, science, and engineering (3.a).

- An ability to design and conduct experiments as well as analyze and interpret data (3.b).

- An ability to design a system, component, or process to meet desired needs within realistic constraints such as economic, environmental, social, political, ethical, health and safety, manufacturability and sustainability (3.c).

- An ability to identify, formulate, and solve engineering problems (3.e).

- An ability to use the techniques, skills, and modern engineering problem (3.k).

Professional Skills

- An ability to function on multi-disciplinary teams (3.d).

- An understanding of professional and ethical responsibility (3.f).

- A knowledge to use the techniques, skills, and modern engineering tools necessary for engineering practice (3.j).

Focus on the Abilities for Curriculum Design

Any curriculum in Transportation Engineering should consider the above abilities to design the courses. Also, the needs of the employers, development projects and global advancements are to be given focus. In addition, some of the specialized courses in Air Transport and Water Transport have to be considered.

The Engineer of 2020

Most of the leading international universities vigorously develop programs for competency development to meet the needs of the industries of 2020.

Prof. Bernard Amadea of the University of Colorado at Boulder developed a model “Engineers without Borders (EWB)” which provides a means of introducing open-ended problem-solving in conjunction with developing synthesis, analysis, teamwork, communication, business and entrepreneurial skills. Sheppard and Jenison (1997) and Dym et al. focused on designing systems and on attaining a broader understanding of their work's

impact on their communities and their surroundings. Nguyen (1998), Palmer (2002) and Goel et al. (2008) focused on the managerial skills. According to them, engineers have transitioned from their traditional and pure technical roles to managerial ones that require a sense of business practices and leadership skills.

The focused skills of engineers as perceived a set of universities are presented in Table.1.

Table 1-Professional Skills Focused by a set of Universities

University	Focus
Purdue University and Virginia Tech, USA	Interdisciplinary engineering education programs
University of Maryland - Clark School of Engineering, USA	Modular team training program in personal, interpersonal and project management.
Cornell University, College of Engineering	Community relevant and technology based projects.
University of Michigan, USA	Engineering Global Leadership Honors Program (EGHP)
Iowa State, USA	Global Academic Industrial Network (GAIN)

Accreditation of European Engineering Programs (ENAE, 2008)

Focused skills: Knowledge and understanding, engineering analysis and design, investigations, engineering practice, and transferable skills. They are supported by France and Germany.

UK's Royal Academy of Engineering (2007)

Focused on redesigning university courses for modern economy; more experience in problem solving, group design, applying theory to real projects; and support learning from the success of academic-industrial links.

Synthesis

Most of the American universities focus on the global exposure and bring partnership in planning and implementing the engineering programs. They also provide opportunities for collaboration and exposure to global design methods and internship. In this process, the engineering graduates acquires abilities to undertake complex projects.

MIT, Boston, USA.

Offers interdepartmental Master of Science in Transportation (MST) degree which emphasizes the complexity of transportation and its dependence on the technology, operations, planning, management and policy-making. It offers Air Transportation, Analysis and Planning Methods, Data Sciences for Transportation, Intelligent Transportation Systems, Safety and Security, Logistics and Supply Chain Management, Policy and Sustainability, and Urban Transportation.

Indian Postgraduate Programs Selected for Critical Review

The following Transportation Engineering Programs have been selected: (Table-2)

Table-2 Transportation Engineering Programs

1	Jawaharlal Nehru Technological University (JNTU), Hyderabad, Telangana
2	National Institute of Technology, Tiruchirappalli (NITT), Tamil Nadu
3	Indian Institute of Technology, Madras (IITM), Tamil Nadu
4	Banaras Hindu University, Varanasi, (BHU), Uttar Pradesh
5	Indian Institute of Technology, Bombay (IITB), Maharashtra
6	College of Engineering, (COET) Trivandrum, Kerala.

The following Transportation System Engineering Programs have been selected (Table-3).

Table-2 Transportation Engineering Programs

1	Gujarat Technological University (GTU), Ahmedabad, Gujarat
2	National Institute of Technology, (NITW) Warangal, Andhra Pradesh
3	Indian Institute of Technology, Delhi (IITD)

Macro Analysis

It appears that there is a need for an in-depth study on the needs of various transportation system to meet the growing economy, industrial corridors and industrial hubs. The institutes have to conduct needs analysis, develop Program Educational Objectives (PEOs), and define the Course Outcomes (Cos). These institutes have to create links with the transportation projects of the government, National Highways Authority, Indian Railways, Airport Authority of India, Port Trusts and major public-sector consulting companies and organizations. The dissertation works could be taken from these organizations. Many case studies could be developed based on the ongoing projects. The students could be offered internship while doing dissertation works. Ultimately, they can take up consultancy works in the planning, design, and implementation.

Micro Analysis**1. Basic and Applied Mathematics Courses**

The institutes offer the following varied courses:

- Applied Numerical Methods
- Applied Statistics
- Statistical Techniques, Design and Analysis
- Organization and Simulation Techniques
- Optimization Techniques

Observation

No institute has offered any course for technical proposal preparation, financial proposal preparation, bidding, negotiation, contract, bank guarantees and

project completion reports. A few institutes are very much successful in offering consultancy works to various State Governments and National Project Authorities. It is learnt that this expertise has not been passed on to the graduate students. If department conducts a needs analysis, they can develop more entrepreneurship development programs in planning, design and implementation. Also, no institute has planned a course for starting some consultant focused activities.

2. System Analysis in Transportation Engineering

The following courses are offered by these institutes:

Table-3 System Analysis

Course Title	Institute
Modeling, Analysis & Simulation	GTU
Intelligent Transportation Systems (ITS)	NITT, IITM, IITB
Transportation Systems Analysis	NIIT, BHU, NITW, GTU
Heterogeneous Traffic - Flow, Flow Modeling & Simulation	IITM
Dynamic & Stochastic Modeling of Transportation Networks	IITM
Traffic Modeling & Simulation	IITD, BHU, IITD
Transportation Network Analysis	IITB
Logistic Systems	IITB
Application of Software Computing Techniques	IITB
Principles of Geomatics	IITB
Advanced Transportation Modeling	IITD
Advanced Surveying and Cartography	IITB
Finite Element Method	BHU

Observation

IITs, and NITs are providing a large number of courses in System Analysis. Other Institutes can offer these courses which will help the postgraduate engineers to undertake consultancy projects. These courses would provide advanced cognitive strategies for planning.

3. Courses on Pavement Materials, Construction and Management System

Table-4 Pavement Materials

Course Title	Institute.
Pavement Materials	JNTU, NITT, BHU, COET
Advanced Pavement Materials (Elective)	IITB
Advanced Highway Materials	NITT
Materials, Design & Construction of Pavements	NITW
Highway Materials and Testing; Pavement Materials and Evaluation Lab	GTU, IITB

Table-5 Analysis, Evaluation, Construction & Maintenance

Course Title	Institutes
Analysis, Design of Pavements	GTU, NITT, BHU, IITB
Materials, Design & Construction of Pavements	NITW
Design & Evaluation of Pavements	JNTU
Design & Maintenance of Pavements	IITD
Pavement Evaluation, Rehabilitation and Maintenance	BHU
Pavement Management System (Elective)	IITB

Table-6 Specialized Courses in Pavements offered by IIT Madras

Micro-Mechanical Characteristics of Asphalt, Investigation on Modified Binders; Healing of Asphalt Mixtures; Performance based Design of Bituminous Mixes; Pavement Recycling; and Concrete Pavements for Highways and Airports

4. Design, Evaluation, Construction and Maintenance

Interpretation

Most of the institutes offer required courses in pavement materials, design, construction and maintenance. Indian Institute of Technology, Madras has developed need based courses in pavement design to suite various materials and needs of implementing

agencies. The courses could focus on regional deposits, subsoil improvements and ghat roads construction. There is a need for focusing on the heavy earth moving machinery, and mechanization of highway construction. The ongoing national projects in highways planning and execution could be included as case studies.

5. Courses on Transportation Planning

Table-7 Transport Planning

Course Title	Institute
Transit System Planning	IITB
Transport Planning	GTU, NITT
Transport Systems	NITT
Urban Transport Planning	JNTU, IITB
Urban Transport Planning	BHU, NITW, COET
Urban and Regional Transport Planning	IITD
Transport Engineering Software Lab	IITB
Planning and Design of Low Volume Roads	IITB
Planning and Design of Non-Motorized Transportation	IITB

Inferences

Two institutes did not focus on the Urban

Table-8 Traffic Engineering

Course Title	Institute
Traffic Engineering	JNTU, NITW, IITB, COET
Theory of Traffic Flow	NITT
Traffic Flow Theory	BHU
Traffic Analysis	IITB
Traffic Control and Management (Elective)	IITB
Theory of Traffic Flow and Management	BHU
Traffic Engineering and Management	GTU
Traffic Design Studies	NITW

Transportation. Most of the institutes have not given adequate focus on Transportation Planning. Further, there is an urgent need for the case studies on the national planning of various transportation corridors to link ports with industrial hubs.

6. Traffic Engineering

These set of courses are very much needed for the analyses of traffic that are generated in the cities and the movement of goods from commercial centers and industries and export through harbor.

Inferences

There is a need for the analysis for road marking to prevent accidents. Also, the signal systems must be introduced. The behavior of drivers should be focused.

7. Advanced Traffic Engineering

Table-9 Advanced Traffic Engineering

Course Title	Institute
Advanced Travel Demand Modelling	IITB
Advanced Traffic Engineering (Elective)	IITB
Traffic Design Studies	NITW

Inference

Only two institutes offer the advanced course in Traffic Design Studies. The graduates need more expertise for planning the fast-growing cities.

8. Geometric Design

Table- 10 Geometric Design

Course Title	Institute
Highway Geometric Design	JNTU
Geometric Design of Transportation	BHU
Geometric Design of Streets & Highways	IITD
Interaction Design and Analysis	GTU
Transportation and Traffic Infrastructure Design	IITD

9. CAD, Demand Model and Multimodal Transportation

Table-11 CAD, Demand Model and Multimodal Transportation

Course Title	Institute
CAD in Transportation Engineering	NITT
Activity Based Travel Demand Modeling	IITM
Multimodal Transportation System Planning and Design	GTU

Inferences

The needs of metro rail system, mass rapid transport system, tunnels, multimodal system and flyovers could also be considered. The problems faced by various projects could be reviewed and appropriate case studies considered. Accidents are to be analyzed and the suggestions for the redesign of the geometry could be offered. CAD is very essential for the modern transport planning. Activity based travel demand and multimodal transportation system have become essential for the megapolis. Only two institutes are offering these courses.

10. GIS and its Application

Table-11 GIS & Its Application

Course Title	Institute
GIS for Transportation Engineering	JNTU
GIS for Transportation (elective)	IITB
GIS and GPS in Civil Engineering	GTU
GIS and Remote Sensing	NITT
GIS Application in Transportation Engineering	BHU

Inference

Only five institutes have included GIS. Hence, others could include this essential course.

11. Air Transportation

Air transportation has repetitioned modern inter-continental transport. This forms the backbone for economic development.

Table-12 Air Transport

Course Title	Institute
Aviation Infrastructure Planning	JNTU
Airport Planning and Design (Elective)	GTU
Airport Infrastructure Planning and Design (Elective)	IITB

Inference

Only three institutes offer this course, but two as electives. Based on the economic growth, specialized programs could be offered to meet the demands of the fast-growing air transportation. A consortium of air transport industry and the government could take initiative to develop an industry relevant and multidisciplinary programs. The newly established Aviation University in Uttar Pradesh could offer this postgraduate program.

12. Water Transportation

Many states have very good perennial rivers. India has one of the longest sea coast. India is emerging as a leading manufacturing country due to government policy and the availability of human capital. Also, the ports and harbors are being expanded to meet the growing needs of exports and imports. Hence, there is an urgent need for planning specialized programs in water transportation. The Ports Trusts can establish research and development centers in collaboration with NITs or IITs or State Technical Universities. The National Institute of Ocean Technology (NIOT) could start a postgraduate institute in Water Transportation. Or the IITs which have Ocean Engineering Center could start a unit for Water Transportation.

Table -13 Water Transportation

Course Title	Institute
Water Transportation	NITW
Waterway Infrastructure Planning and Design	IITB

13. Structural and Geotechnical Engineering Related Courses

Inferences

These courses require in-depth expertise and could be offered as electives in other relevant postgraduate

programs like structural engineering and geotechnical engineering. For successful implementation, there is an urgent need for inclusion of case studies.

Table -14 Transportation Structures & Geotechnics

Course Title	Institute
Transportation Structures (Elective)	JNTU
Traffic and Transportation Structures	NITW
Bridge Engineering (Elective)	GTU
Advanced Bridge Design (Elective)	NITT
Analysis and Design of Bridges (Elective)	COET
Highway Construction Practice	BHU
Highway Construction and Management	GTU
Advanced Foundation Engineering	BHU
Ground Improvement Techniques	JNTU, NITT, BHU
Design with Geo-Synthetics	IITB

14. Safety Engineering

Millions of people die in the road accidents in India and the impact on the economy is maximum.

Table-15 Safety

Course Title	Institute
Road Safety	GTU
Road Safe Engineering(Elective)	IITB
Highway Safety Audits	GTU
Transportation Safety Environment	IITD

Inferences

Only four institutes focus on the safety. Other institutes can include courses on road safety.

15. Environment

Table -16 Environment

Course Title	Institute
Transport and Environment	BHU
Transportation and Environment	GTU

Environment Impact Assessment	JNTU
Environment Impact Assessment and Auditing	BHU
Environment Legislation & Audit	IITB
Environmental Analysis of Transport System (Elective)	IITB
Automobile Pollution Control	BHU
Sustainable Transportation	IITB
Climate Change and Sustainable Development	COET

Inferences

There is a great need to introduce environmental assessment and impact studies in the Transportation Engineering. All the institutes can include this in the curriculum.

16. Project Management

Table -16 Environment

Course Title	Institute
Project Engineering	JNTU
Highway Construction and Management	GTU
Project Management (Elective)	NITT, IITB
Design Models and Management	NITW
Asset Management (Elective)	IITB
Transportation System Management (Elective)	IITB, IITD
Qualitative Methods in Construction Management (Elective)	IITD
Public Transportation System	IITD

Inferences

Majority of the Institutes offer a course on Management. Project Management has become very essential to control the cost escalation. Many billions of Rupees were lost due to improper project management. Institutes can offer case studies on the project management. Public- Private- Participation (PPP) has to be introduced in the project management course. The computer based project management could also be included in the course. Most of the senior executives of the national projects have to be exposed to project management through in-service courses so that the cost escalation could be avoided.

17. Mass Transportation

Table- 18 Mass Transportation

Course Title	Institute
Mass Transportation (Elective)	GTU
Mass and Multimodal Transportation Systems	BHU
Regional and Rural Transportation Planning	NITW
Rail Road Engineering (Elective)	JNTU
Railway Infrastructure, Planning, and Design	IITB

Inference

Only two institutes concentrate on mass transportation and two other institutes focused on railways. Only one institute focused on rural transport planning. Indian Railways update the needed abilities of their engineers through training programs. They can plan advanced courses to develop cognitive strategies to plan, design, implement and manage projects. Railways can collaborate with the higher education institutes and plan postgraduate programs which will ensure very return on the investments.

18. Economics and Finance

Table-19 Economics and Finance

Course Title	Institute
Transportation Economics	BHU, COET
Transportation Economics and Project Evaluation	GTU
Transportation Economics and Finance	IITD
Transportation Policy and Financing (Elective)	IITB
Economics and Evaluation of Transportation Projects	NITW
Human Resource Management	NITT

Inference

Two institutes have not considered the need for economics even though it is very essential. They can employ part-time faculty to conduct the course on economics. The graduates have to be exposed to economics and policy planning well ahead of government so that they can assist the policy makers

on transportation. They can become think- tanks in transportation. The return on investments on transportation projects is very essential for decision making and allocation of project funds.

Snap Study

Views and feedbacks have been obtained from a set of representatives of Tamil Nadu State Highways Department, Indian Railways, Chennai Metro Transport and Private companies. Many of the Government departments offer more planning and design and testing works to consultants. Some of institutes undertake these projects. In the next five years, the postgraduate engineers could form consultancy firms. Hence, the postgraduate programs could be designed to meet these new professional activities. A few postgraduates in Structural Engineering have established consultancy units and they feel very confident to undertake projects in planning and design transportation structures. Many postgraduate departments of well established national and state institutes can undertake consultancy works in transportation works. This new culture should percolate into the graduate programs. Project planning, estimate, design, testing, management, training the junior engineers, long-term planning, feasibility studies, return on investments, and the impact of projects on economy are very essential. Hence, the programs should display the program educational objectives, and course outcomes. All these issues center around multidisciplinary approach in planning the Transportation Engineering.

19. Conclusion

Most of the programs center around the in-house expertise rather than systematic studies, needs analysis, and establishment of consultancy centers. The curricula should be continuously evaluated and be improved. The dissertation works are to be from the field. The postgraduate students should be given two months of industrial attachment. Airport Authorities of India(AAI), Port Trusts, National Highways project authorities, and Indian Railways could support postgraduate departments by providing research projects and sending their engineers for the postgraduate programs. The return on this expenditure would be very great. The state universities and national institutes can employ adjunct faculty from the governments and private organizations and bid for overseas consultancy projects. All the postgraduate programs are to be redesigned as multidisciplinary

programs so that the products could take up global consultancy projects.

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