

**THE NEW TRANSPORTATION FACULTY:**  
**THE EVOLUTION TO ENGINEERING SYSTEMS**

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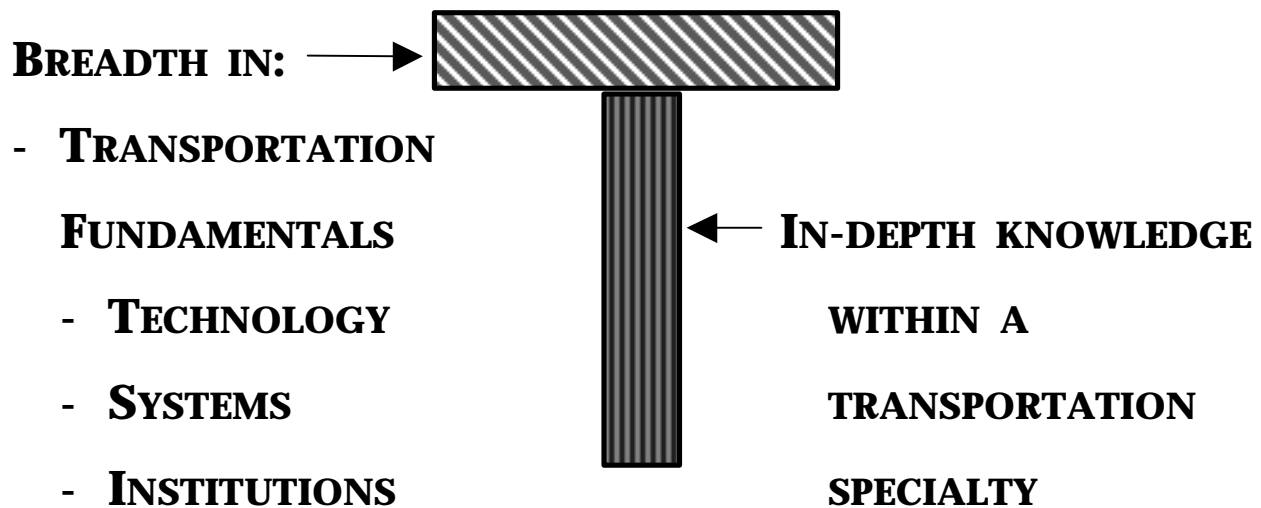
In 1995 I wrote “Educating the ‘New Transportation Professional’”.<sup>1</sup> Inspired by the changes in our field induced by Intelligent Transportation Systems (ITS), it described a broad concept of what knowledge the transportation professional in the 21<sup>st</sup> century will need to be effective. The paper discussed the “T”-shaped professional; this professional would have a broad understanding of technology, systems and institutions in the transportation domain, represented by the horizontal bar on the “T” and in-depth knowledge in one of these specialties, represented by the vertical bar. With this combination of breadth and depth, the New Transportation Professional could contribute substantively to the solution of transportation problems, both through detailed knowledge and through an enhanced understanding of the contributions of other professionals in what is inherently an interdisciplinary field.

The paper concluded by noting:

“An understanding of the world of transportation systems, together with analysis tools, a sound grasp of the institutional framework and knowledge in technology and its potential, are the sine qua non of the “New Transportation Professional”.

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<sup>1</sup> Sussman, Joseph M., “Educating the ‘New Transportation Professional’”, *ITS Quarterly*, Summer 1995.



But the question arises, “Who will educate this New Transportation Professional?” The responsibility for this education falls on the transportation faculty in our nation’s colleges and universities. So this paper focuses on that “New Transportation Faculty”, the educator of our New Transportation Professional.<sup>2</sup>

So our questions: What will that New Transportation Faculty need to *know* and *be* to carry out the educational mission? What is his/her future in academia?

To consider these questions, we first trace recent developments in the transportation field; then we go on to consider challenges in modern-day academia; then we investigate the job of the transportation faculty as defined by the changing transportation and academic contexts; and finally, we contemplate the future the transportation faculty faces in a field that is mature in a sense, fundamental and yet ever-changing.

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<sup>2</sup> Now in the earlier paper, I argued that “continuous education” for the New Transportation Professional means that s/he will have the learning tools to evolve his/her professional skills independently over a career. Still, the basic framework will be put in place by the New Transportation Faculty.

## **TRANSPORTATION IN THE 21<sup>ST</sup> CENTURY**

In the 1960s, many transportation faculty, recognizing the maturity of the physical design paradigm for transportation, led a radical change by introducing a *systems perspective* to both transportation research and education. This perspective focused on quantitative analysis of transportation as a complex, network-oriented system. Rather than concern with design of individual physical components, this approach recognized the systemic nature of transportation, and used operations research methodologies along with transportation economics and simulation as the appropriate tools for considering the planning and operation of the transportation system as a whole. The approach was inherently integrative in nature, adopting methodologies from many areas. Hundreds of students have been educated in this manner, giving rise to a number of educational programs around the country and the world.

But the world moves forward, and as the 21st century approaches, we recognize that this “new” system paradigm needs re-thinking, as did the “old” physical design paradigm in the 1960s.

## **TRANSPORTATION -- A BROADER AND DEEPER DEFINITION**

Transportation has always been understood to be a vital force for the social, political and economic well-being of a society. Further, it is a field long viewed as amenable to complex systems analyses that can give great insight into transportation investment, operations and design. However, the last 20 years have seen both a broadening and a deepening of the transportation field.

The transportation field now deals with operations on a *global* scale, considering the global economy and the implications for economic development and international

competition among the regions and nations of the world. Indeed, one can argue that advances in transportation enabled this globalization trend. This geographic broadening has important implications for the future of the field.

*Technology* has always been a key element in the transportation field.<sup>3</sup> In the past several decades, advances in information technology and communications technologies have had profound implications on the way in which transportation systems are operated. This will certainly continue. New opportunities for control of transportation systems -- particularly in real time -- is of fundamental importance.

We have long recognized the impact of transportation on the fabric of society, but recent years have seen a substantially increased focus on the *externalities* that relate to and shape our transportation decisions. Transportation impacts on economic development around the world were noted above but, in addition, we see the increased importance of externalities in the areas of environment (with the importance of policies concerning clean air and water, and global warming), energy, societal equity, use of scarce land resources and the fundamental tie of land-use to transportation -- our concerns with all of these drive much of what we do in the transportation field.

Finally, we have seen profoundly changing *organizational and institutional relationships* among entities concerned with providing and using transportation services. Among these changing relationships are a re-thinking of public and private roles in transportation service provision, as embodied in such trends as deregulation and privatization of the transportation enterprise. From an intragovernmental point of view, around the world we have seen trends towards devolution, as federal governments have pushed power out to regional entities, such as states, provinces, and large metropolitan areas, recognizing the key role of regions in economic

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<sup>3</sup> Sussman, Joseph M., "ITS: A Short History and a Perspective on the Future", *Transportation Quarterly*, Vol. 50, No. 4, Anniversary Issue, 1996, ENO Transportation Foundation, Inc., Lansdowne, VA, p. 115-125.

competitiveness.<sup>4</sup>

The trend toward intermodalism in both passenger and freight transportation, enabled by technology and demanded by the marketplace, requires important changes in interrelationships among transportation providers, for example, rail, truck and ships in the case of freight intermodalism. Integrated supply chain management, a central aspect of the logistics revolution, has fundamentally changed the relationship between transportation providers and their customers in, for example, the manufacturing industries, where transportation has become an integrated component of the overall logistics system of the customer.

All of these represent fundamental changes in the transportation field in *geographic* scale, in *technological* scope, in the *timeframes* for dealing with transportation issues, in the relationships of the transportation system to *societal and economic priorities* and, in the *organizational relationships* among transportation providers, customers and other stakeholders. It creates new challenges for transportation researchers, educators, and practitioners.

## **EXPANDING THE BOUNDARIES**

The above suggests a re-definition of the boundaries of the transportation field. We need to think on a broader, more ambitious scale on several dimensions; in addition, we need to create greater depth in our models and frameworks for analysis, as our problem space becomes more complex and vital. We need to create better methodologies for the increased scale of the transportation networks we deal with -- networks that we must control and operate in real time -- and we need to

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<sup>4</sup> Porter, Michael E., Competitive Strategy: Techniques for Analyzing Industries and Competitors, The Free Press, 1980.

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Kanter, Rosabeth Moss, World Class: Thriving Locally in the Global Economy, Simon & Schuster, New York, 1995.

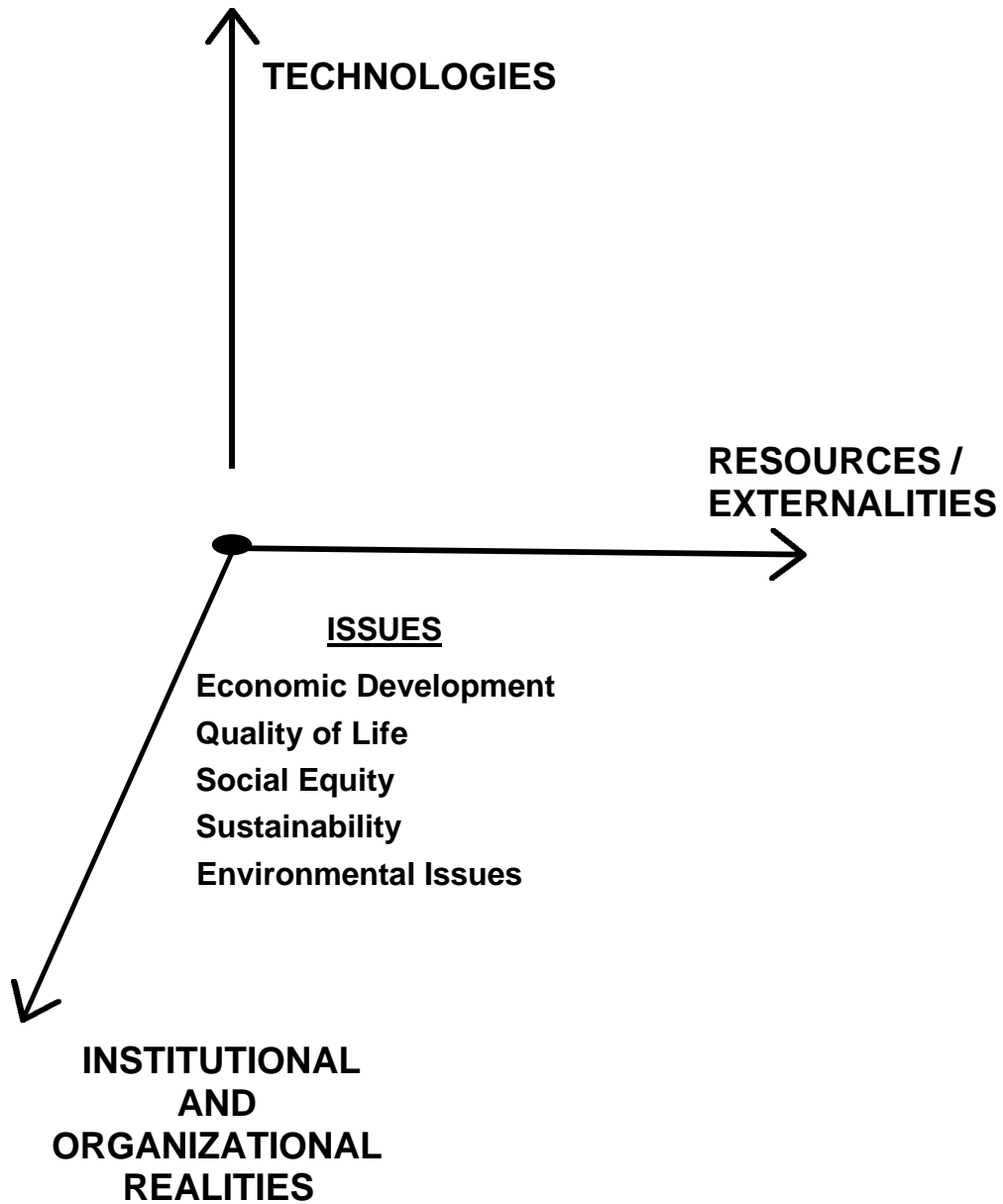
provide broader, more useful frameworks for qualitatively considering transportation issues as well. We need to focus not only on the operation of individual modes, but additionally on the way in which these modes interact intermodally, providing high-quality, low-cost service integrated with customers' operations.

We need a new definition of the field of transportation, both broader and deeper, more advanced technologically, and more sensitive institutionally. Our view goes beyond the systems analysis perspective invented in the 60s to a broader triplet in *technology, systems and institutions*,

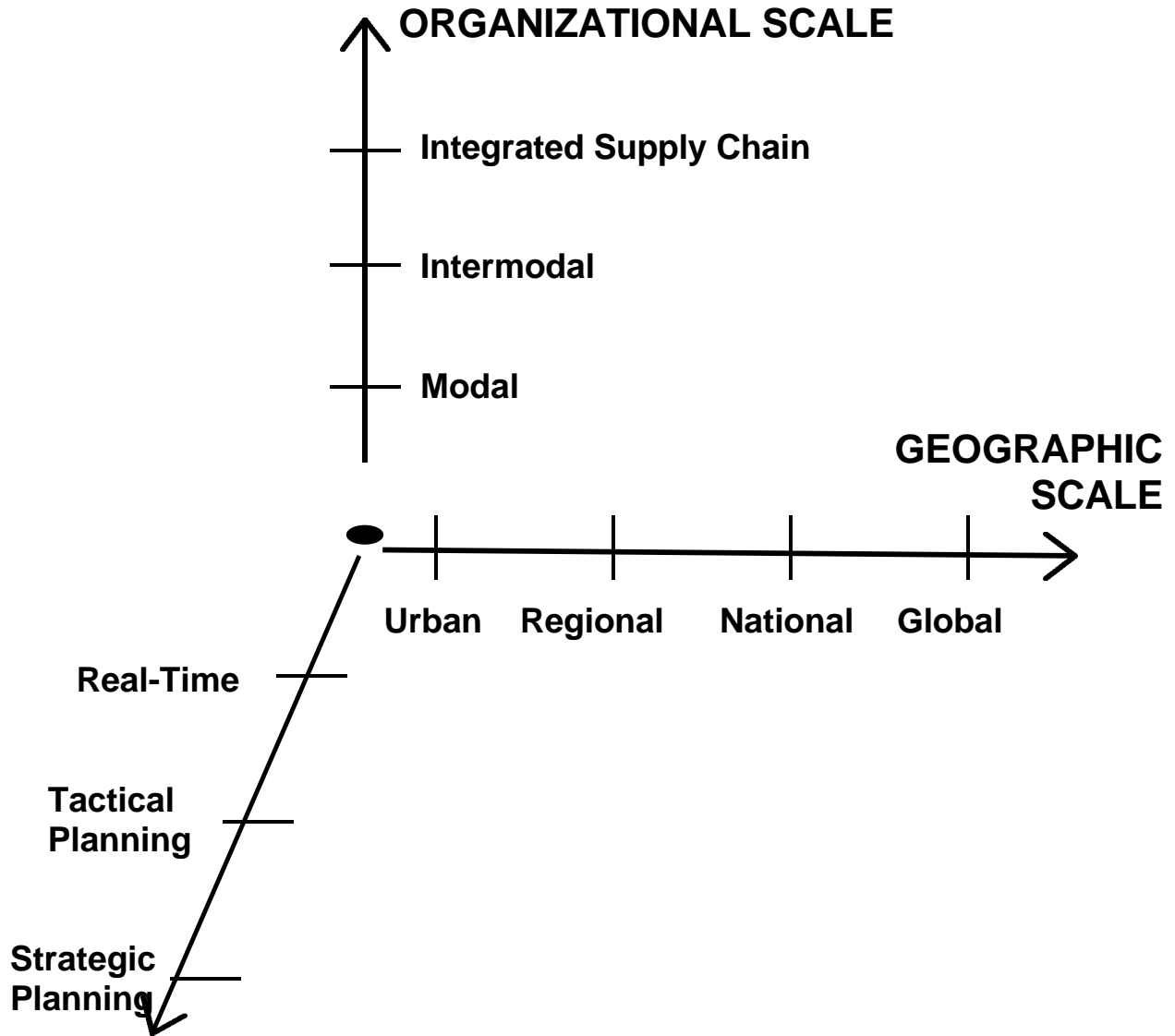
- dealing with transportation issues at all time scales, from real-time to strategic planning,
- on all geographic scales, from urban areas to the global,
- on all organizational scales from the modal to the integrated supply chain,
- and using various approaches, including advanced models in operations research, simulation and econometrics, to consider transportation systems that are larger, more interconnected, and at the same time made more amenable to real-time control through new technologies in information systems and communications, and
- qualitative frameworks of analysis to deal with the new and more complex institutional realities of the field.

As before, our educational approach is inherently integrative, but on an even broader scale than before -- we require a synthesis of quantitative and qualitative methodologies with transportation domain knowledge to deal in an integrated manner with our field.

The questions are graphically depicted in Figures 1 and 2.



## **DRIVING FACTORS IN TRANSPORTATION**



**TIME SCALE**

**APPROACHES**

Quantitative Models (OR, Simulation...)

Qualitative Frameworks for Analysis

Transportation Domain Knowledge

**TRANSPORTATION SYSTEM DIMENSIONS**

## ACADEMIA

While the field of transportation has undergone remarkable changes over the last three decades, these changes are no more remarkable than those in the academic environment. The post-World War II period in the United States gave rise to enormous growth in higher education and the development of the American research university. Blueprinted by Vannevar Bush during the war, and documented in his landmark paper “The Endless Frontier”, the research university established close working relationships with the federal government, which actively supported research and graduate education. Through this impetus, the research university became very different from the classic university structure advanced by Cardinal John Henry Newman, founder of the Catholic University in Dublin in the 19<sup>th</sup> century. A special section on universities in *The Economist*,<sup>5</sup> notes

Newman, like Cicero, believed in the need to separate the pursuit of truth from mankind’s “necessary cares”. His university would therefore be dedicated to the pursuit of knowledge for its own sake, would be “the high protecting power of all knowledge and science, of fact and principle, of inquiry and discovery, of experiment and speculation”.

*The Economist* goes on to note that “no institution will last nine centuries without adapting” and that today, “universities nowadays celebrate their achievements as producers of useful knowledge.” Further, the university as a regional and national economic engine is a widely-accepted and successful model.

Many current-day senior transportation faculty became academics in the heyday of academic growth, the 1960s and 1970s, fueled by federal support. Now, although universities are still “producers of useful knowledge” the close compact between universities and the federal government has atrophied as the Cold War ended with the

implosion of the old Soviet Union.

So, as a result, we find the research university reaching out much more actively to the private sector for the support of research in education. Further, many have developed major programs *abroad*, reflecting the global economy and the place of the United States within that competitive environment.

This change in the support base implies the need for academia to be more relevant than ever and to respond more quickly than ever. Further, U.S. society, feeling heavily invested in higher education, is looking to the nation's universities for effective contributions to solving the many problems that contemporary humankind faces, often on a global scale.

So the forces for change in academia are strong. Arthur Levine comments on the dramatic changes ahead for the academic profession,

“Five forces are propelling the change: 1) the changing attitudes and demands of higher education patrons; 2) the changing characteristics of college students; 3) the changing conditions of employment in higher education; 4) the rise of new technologies; and 5) the growth of private sector competitors.”<sup>6</sup>

Both government and the private sector have changed their perspectives on how relevant the universities should be and how quickly and new competitors to universities are emerging.

Theodore R. Mitchell characterizes higher education as “an industry under great stress” and notes that,

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<sup>5</sup> “Inside the Knowledge Factory”, *The Economist*, October 4, 1997, pp. 3-5.

<sup>6</sup> Levine, Arthur, “How the Academic Profession is Changing”, *Daedalus*, Fall 1997.

“Simultaneously, universities are challenged externally by the rise of competing providers of educational services by increasing demands for short-term relevance in both teaching and research, and by the spread of new technologies that seem, at one level, to threaten the meaning of the university as a place.”<sup>7</sup>

On another dimension, the technology of teaching has changed dramatically. A few years ago, it could reasonably be said that while a physician educated in 1890 would be lost in today’s operating room, a professor in 1890 would find the classroom largely the same as it was in 1990. *This is no longer the case.* The use of the Internet and the World-Wide Web as educational instruments, and the growth of distance learning as professors routinely teach courses being piped into a variety of industrial settings in real time, have forever changed the modalities of teaching. Some of us have taught paperless subjects where assignments, readings, etc., are all in electronic form.

In Charles H. Fine’s recent book Clock Speed, he wonders if, with the ability to project the image of world-class professors anywhere “...will our students still need to come to campus? For that matter, will the faculty still need to come to campus?” and he speculates whether or not, with world-wide fame, these faculty will even need a university affiliation!<sup>8</sup>

Not everyone is convinced of the efficacy of this approach, and argue that the core competence of the university remains the residential college. While this may indeed be so, changes in the way we work are certainly in the air, and some argue that the modern university is in its death throes. No less a sage than Peter Drucker says, “Thirty years from now the big university campuses will be relics. Universities won’t

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<sup>7</sup> Mitchell, Theodore R., “Border Crossings: Organizational Boundaries and Challenges to the American Professorate”, *Daedalus*, Fall 1997.

survive. It's as large a change as when we first got the printed book.”<sup>9</sup> Drucker speaks of the growth in educational costs and comments that “such totally uncontrollable expenditures without any visible improvement in either the content or quality of education means that the system is rapidly becoming untenable. Higher education is in deep crisis.” He suggests, “The college won't survive as a residential institution.”

So the modern research university is recognizing its need to educate more effectively and also, given fundamental change in the nature of its financial support, to be a central player in the solution of major issues facing society in a shorter timeframe than has been our wont.

It is in this search for university relevance that the importance of interdisciplinary, cross-cutting education and research becomes clear. For it would be difficult to identify any critical societal issue that is not interdisciplinary at its base. As stated by Charles Vest, President of MIT, “Humankind's advances will depend increasingly on new integrative approaches to complex systems, problems and structures. Design synthesis and synergy across traditional disciplinary boundaries will be essential elements of both research and education.”<sup>10</sup>

## **TOWARD THE NEW TRANSPORTATION FACULTY**

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<sup>8</sup> Fine, Charles H., Clock Speed: Winning Industry Control in the Age of Temporary Advantage, Perseus Books, October 1998.

<sup>9</sup> Lenzer, Robert and Stephen S. Johnson, “Seeing things as they really are”, *Forbes*, March 10, 1997.

<sup>10</sup> Vest, Charles, “MIT: The Path to Our Future”, Report of the President, Academic Year 1997-1998, Massachusetts Institute of Technology, September 1998.

It is in this challenge for academia that the “New Transportation Faculty” comes to the fore. For we can argue that this kind of integrative approach is precisely what we have been about for the last 30 years, bringing together various technologies, mathematical approaches, microeconomics, political science, management and institutional studies into an integrated set of methodologies germane to our field.

The transportation field has become the exemplar of the nascent field of modern engineering systems, characterized by a cross-cutting, interdisciplinary approach to research and education. This integrative approach, motivated both intellectually and pragmatically as a result of changing relationships between academia, the federal government and the private sector, is the *competitive edge for the new transportation faculty*. We have shown our ability to integrate new knowledge into our field and to apply it effectively in our domain -- transportation.

So, given this perspective, what is the *future* role for the New Transportation Faculty in academia? Think about what attracted many of us to the field of transportation. First, it was the notion of working on a real and serious societal issue in which improvements could have a direct effect on quality of life and economic development, and, second, it was our interest in integrating new intellectual approaches, that is, new methodologies, into the study of that domain.

But there are broader challenges accessible to the “New Transportation Faculty”. Consider the broader idea of “Complex Large-Scale Integrated Open Systems” (CLIOS). What do we mean by these terms?

A system is *complex* when it is composed of a group of related units (subsystems), for which the degree and nature of the relationships is imperfectly known. Its overall behavior is difficult to predict, even when subsystem behavior is readily predictable. Further, the time-scales of various subsystems may be very different (as we can see in transportation -- land-use changes, for example, vs. operating decisions).

CLIOS have impacts that are *large* in magnitude, and often *long-lived* and of *large-scale* geographical extent.

Subsystems within CLIOS are *integrated*, closely coupled through feedback loops.

By “*open*” we mean that CLIOS explicitly include social, political and economic aspects.

Often CLIOS are counterintuitive in their behavior. At the least, developing models that will predict their performance can be very difficult to do. Often the performance measures for CLIOS are difficult to define and, perhaps, even difficult to agree about, depending upon your viewpoint. In CLIOS there is often human agency involved.<sup>11</sup>

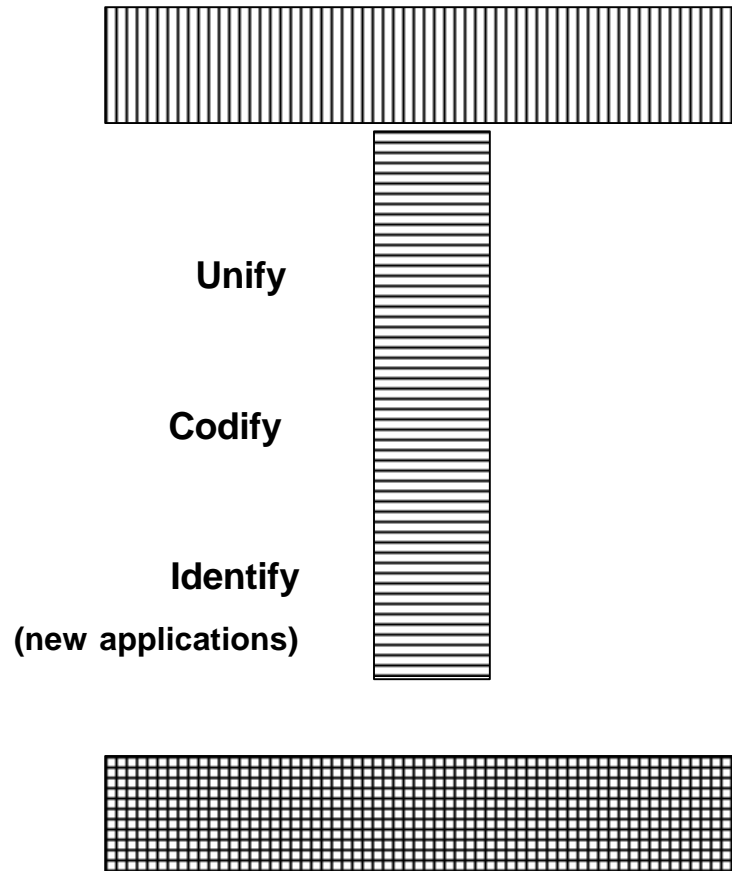
Transportation systems are simply a special case of CLIOS and we as the “New Transportation Faculty” have special capabilities to bring to the table.

So as we look to the future, to go along with our T-shaped transportation professional, described earlier, consider the *I-Beam-Shaped New Transportation Faculty*. (The “I-beam” image was suggested by Professor Lester Hoel of the University of Virginia.)

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<sup>11</sup> Sussman, Joseph M., “ITS and Rescuing Prometheus”, *ITS Quarterly*, Winter 1998.

# Methodologies / Domain Knowledge in Transportation



**Re-apply to New Domains**

**THE “I-BEAM-SHAPED”**  
**NEW TRANSPORTATION FACULTY**

The top flange represents the disciplines that we have worked to integrate into the transportation domain. The web represents the unification and codification of these disciplines into a coherent approach to transportation applications and the identification of new areas within the engineering systems domain, to which our integrated approach can be relevant. Indeed, a recent NSF report calls for this codification,

“Curriculum developments are needed that synthesize and codify knowledge from currently separate disciplines and fields, by leaders from those fields, to create appropriate basic or “core” subjects for transportation systems education. Another way to state this need is that the science base (broadly defined to include the social sciences) for the interdisciplinary field of transportation systems is in need of codification and presentation in a form suitable for graduate education. This development must be built on research developments of the kind discussed above. Subjects developed in this process will be useful both for transportation systems degree programs, and in departmental programs in transportation, and in some cases for continuing education.”<sup>12</sup>

And finally, the bottom flange represents a re-application of these concepts to other applications’ domains.

This is part of a broader reform in engineering education. William A. Wulf, in a recent article entitled “The Urgency of Engineering Education Reform”,<sup>13</sup> speaks eloquently of the need for incorporating a set of “new fundamentals” into the engineering

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<sup>12</sup> “A Report to the National Science Foundation on the Workshop on Planning, Design, Management and Control of Transportation Systems”, June 15, 1998.

<sup>13</sup> Wulf, William A., “The Urgency of Engineering Education Reform”, *The Bridge*, Spring 1998.

curriculum. This is certainly correct; the question is what these new fundamentals are. I argue here that these are the basis of a new field called engineering systems, the integrated set of quantitative and qualitative methodologies, of which transportation systems is at the leading edge.

Why am I confident that our integrated approach may well be valid in other applications? Transportation can be characterized by big infrastructure investments, a network structure for delivery of services, a (relatively recent) application of real-time control, a global scale and a changing institutional structure, particularly between public and private sectors. Some or all of these characteristics are germane to other domains of societal relevance: telecommunications and energy are but two examples of systems with big infrastructure investments and a network structure. The urban region as a system could also be characterized in this way.

So the future for the New Transportation Faculty is clear. Building on our strengths in integrating new disciplines, we can help create the new unified field of engineering systems and help in the application of this approach to a broad set of societal issues.

So what becomes of transportation, you may ask, if the New Transportation Faculty focuses on a broader applications domain? First, I emphasize this is an evolution, not a revolution, and there is still much richness in integrating new ideas and codifying those ideas in the transportation domain. That well is by no means dry. Indeed, if we interpret the word “faculty” as a *collective* noun, there will always be individual faculty *members* focusing on the core transportation applications.

But more importantly, through the re-application to broader issues of the engineering systems approach developed by transportation faculty, I suggest we will invent new concepts and discover new relevant disciplines that can be applied within the transportation domain. We will also attract specialists in those disciplines to transportation studies.

Those of us in academia should never lose sight of the fact that transportation is part of a broader set of societal systems. The interconnections between transportation and other domains is fundamental to our broad-based understanding of our own field. So I see no conflict in this evolutionary re-application of transportation concepts within a broader application space and, indeed, envision us integrating still more interesting concepts into the study of the transportation enterprise.

### **THE NEW TRANSPORTATION FACULTY'S TRADITIONAL ROLE**

While we see a broader role for the new transportation faculty, there are traditional tasks as well -- *our job is still to Integrate, Innovate and Instruct.*

To *integrate*, we must constantly be alert for new methodologies and technologies that can be brought into transportation applications. We have done so effectively on the quantitative side of our field, bringing such methodologies as operations research, econometrics into our milieu. We perhaps have been less effective on the qualitative side in understanding the power of various kinds of political and institutional analyses as we seek to categorize transportation systems and the impediments to their development and effective deployment. Professor Tom Hughes, in his recent book, Rescuing Prometheus,<sup>14</sup> brings a style of analysis for large-scale, technologically-based systems, including the Central Artery/Tunnel Project in Boston as an example of how qualitative analyses can advance our field.

As always, those of us in academia have a special responsibility to *innovate*. We push the envelope of the transportation domain and develop a deeper understanding of its behavior; traditionally we do this through research, and it is an accepted principle that “through research, faculty members gain insight into the questions at the frontiers of

their field, enabling them to build this excitement and focus into their teaching and coursework”.<sup>15</sup> However, I argue here that this innovation should extend to a new style of research concerned with advanced practice in the transportation field. Following from our colleagues in Urban Studies and Architecture, we need to implement “studios” for our transportation students, working closely with faculty and practitioners on innovative transportation projects.

Finally, we have our traditional role in *instruction*. With pressures on us to “solve society’s problems” and to conduct cutting-edge research, we must not lose sight of our fundamental mission; our responsibility for educating our students, with the classroom remaining an important component of that overall process. Here I argue that we all must diligently apply our creativity to our teaching in the same way as we do to our research. To quote from Donald Kennedy in Academic Duty,

“Great teachers exhibit, in their teaching, forms of creativity that may not be usually thought of as research, but nevertheless, they analyze, synthesize and present knowledge in new and effective ways.”<sup>16</sup>

In the integrative world in which we teach, such imagination in teaching is important and, indeed, it is helpful to the maturation and growth of all of us as faculty members. To again quote Kennedy, “Even in a world in which research seems to get the most attention, faculty members feel deeply rewarded if they sense they have made a difference in the lives of their students.”

So, in addition to moving to become the I-Beam-Shaped New Transportation Faculty, we must continue to *integrate* knowledge into the transportation domain, continue to *innovate* in research and in practice, and recognize the special importance that

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<sup>14</sup> Hughes, Thomas P., Rescuing Prometheus, Pantheon Books, New York, 1998.

<sup>15</sup> “The Report of the MIT Task Force on Student Life and Learning”, 1998.

<sup>16</sup> Kennedy, Donald, Academic Duty, Harvard University Press, Cambridge, MA, 1997.

*instruction* has in our interdisciplinary field.

## **CONCLUSION**

The challenges of the transportation field continue and expand and the New Transportation Faculty -- the I-Beam-Shaped New Transportation Faculty -- has a special role therein in integrating knowledge, innovating and effectively instructing the T-shaped “New Transportation Professional”.

But here we argue that the challenge and opportunity is broader. Consider transportation as a special case of “Complex Large-Scale Integrated Open Systems” (CLIOS) and the special advantage the “New Transportation Faculty” has, given the inherently integrative nature of their intellectual approach and their track record in establishing how this integrated approach can impact the important societal domain of transportation. The future role of the New Transportation Faculty can include an engineering systems attack on societal issues using the CLIOS construct.

This positions us to make important broader contributions to society and provides an intellectual growth path within academia, one which is in total concert with the new post-Cold War mission of the university for relevant, shorter-timeframe approaches to important societal and industry problems.

Nor is the transportation field disadvantaged by this. The intellectual stimulation for the “New Transportation Faculty” can only make our approaches to the core issues of transportation more effective.

## **REFERENCES**

1. Sussman, Joseph M., "Educating the 'New Transportation Professional'", *ITS Quarterly*, Summer 1995.
2. Sussman, Joseph M., "ITS: A Short History and a Perspective on the Future", *Transportation Quarterly*, Vol. 50, No. 4, Anniversary Issue, 1996, ENO Transportation Foundation, Inc., Lansdowne, VA, p. 115-125.
3. Porter, Michael E., Competitive Strategy: Techniques for Analyzing Industries and Competitors, The Free Press, 1980.
4. Kanter, Rosabeth Moss, World Class: Thriving Locally in the Global Economy, Simon & Schuster, New York, 1995.
5. "Inside the Knowledge Factory", *The Economist*, October 4, 1997, pp. 3-5.
6. Levine, Arthur, "How the Academic Profession is Changing", *Daedalus*, Fall 1997.
7. Mitchell, Theodore R., "Border Crossings: Organizational Boundaries and Challenges to the American Professorate", *Daedalus*, Fall 1997.
8. Fine, Charles H., Clock Speed: Winning Industry Control in the Age of Temporary Advantage, Perseus Books, October 1998.
9. Lenzer, Robert and Stephen S. Johnson, "Seeing things as they really are", *Forbes*, March 10, 1997.
10. Vest, Charles, "MIT: The Path to Our Future", Report of the President, Academic Year 1997-1998, Massachusetts Institute of Technology, September 1998.
11. Sussman, Joseph M., "ITS and Rescuing Prometheus", *ITS Quarterly*, Winter 1998.
12. "A Report to the National Science Foundation on the Workshop on Planning, Design, Management and Control of Transportation Systems", June 15, 1998.
13. Wulf, William A., "The Urgency of Engineering Education Reform", *The Bridge*, Spring 1998.
14. Hughes, Thomas P., Rescuing Prometheus, Pantheon Books, New York, 1998.
15. "The Report of the MIT Task Force on Student Life and Learning", 1998.
16. Kennedy, Donald, Academic Duty, Harvard University Press, Cambridge, MA, 1997.

