GENERATING AND IMPLEMENTING FORWARD LOOKING INNOVATIONS IN PAVEMENT RESEARCH

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ABSTRACT

A forward looking approach which incorporates leading edge innovations is critical to long term sustainability and advancements in pavement technology. There are key elements which characterize innovation and the underlying motivation for researchers and their organizations. As well there are driving forces which encourage innovations, but also roadblocks which need to be recognized.

This paper first identifies and discusses the key elements, relevant factors in motivation and the driving forces, with examples of particularly innovative advances in the pavement field. The role of strategic planning and measurable performance indicators in research programs is also discussed, again with examples.

A number of forward looking opportunities, with the associated issues and challenges and future short to long term prospects are identified within the following categories: (A)Pavement Data, (B)Pavement Management and (C)Institutional Improvements.

Finally, the paper discusses a "model" for tackling the opportunities and advancing the state of pavement technology as a joint responsibility of the public and private sectors and academia.

INTRODUCTION

The success of any research program depends on a number of factors, including the people involved, level of support and resources available, and very importantly a perception of what the key issues and opportunities are not only today but also in the future. In essence, while today's problems need to be tackled, long term sustainability requires innovation and a forward looking approach.

It is for this reason that the United States Federal Highway Administration (FHWA) launched an initiative in 2010 to develop a "Roadmap" for the future of pavement management (1).

This initiative addresses ten district distinct but related focus areas, including the following:

1. Data collection techniques, equipment and emerging needs
2. Data quality
3. Data storage integration
4. Performance modeling
5. Treatment selection
6. Use of pavement management in the decision process
7. Changing needs and emerging technology in data collection and analysis
8. Quantifying the benefits of pavement management

9. Integrating pavement preservation and pavement management strategies
10. Institutional issues and other factors influencing the use of pavement management

The purpose of this paper is to describe the elements that characterize forward looking innovations in pavement engineering and research, including the driving forces, the motivating factors and the road blocks, the factors that stand out in unique and highly innovative technologies, the importance of strategic planning in research programs and the use of measureable performance indicators. Looking ahead, the FHWA's "Roadmap" provides valuable input in identifying future issues and related opportunities for technical advances in pavement engineering and management. Finally, the paper is directed to providing recommendations for private, public and academic sector involvement in tacking the opportunities.

ELEMENTS THAT CHARACTERIZE INNOVATION

Pavement and transportation research overall has to be forward looking. This implies innovation as an essential ingredient, which was succinctly captured in a Transportation Association of Canada Workshop, Quebec City, Sept., 2004:

> *"…..have to build, renew, maintain and manage a transport infrastructure which can support economic development…..preserve our quality of life…..requires search for new and better technologies and processes…..can be realized in part by creative individuals and innovation"*

The foregoing excerpt specifically identifies creative individuals, notwithstanding that organizations, resources, a "climate" of encouragement and various driving forces are also major ingredients. In fact the driving forces behind innovations in pavement engineering, and transportation in general, come from such sources as individuals themselves, economic/cost-efficiency concerns, environmental issues, science and engineering problems, resource issues, knowledge needs, security issues, social/political concerns and public-private-partnership (P3) initiatives. Figure 1 is a schematic portrayal of these driving forces (2).

Figure 1 Driving Forces Behind Innovations in Pavements and Transportation Engineering

MOTIVATING FACTORS

- Challenging problem
- Curiosity
- Improving practice
- Risk willingness
- Prospect of reward
- Industry demand/request
- Curiosity

ROAD BLOCKS

- Micro Management
- Short-term outlook
- Risk averse
- Institutional inertia
- Limited resources
- Comfortable with business as usual

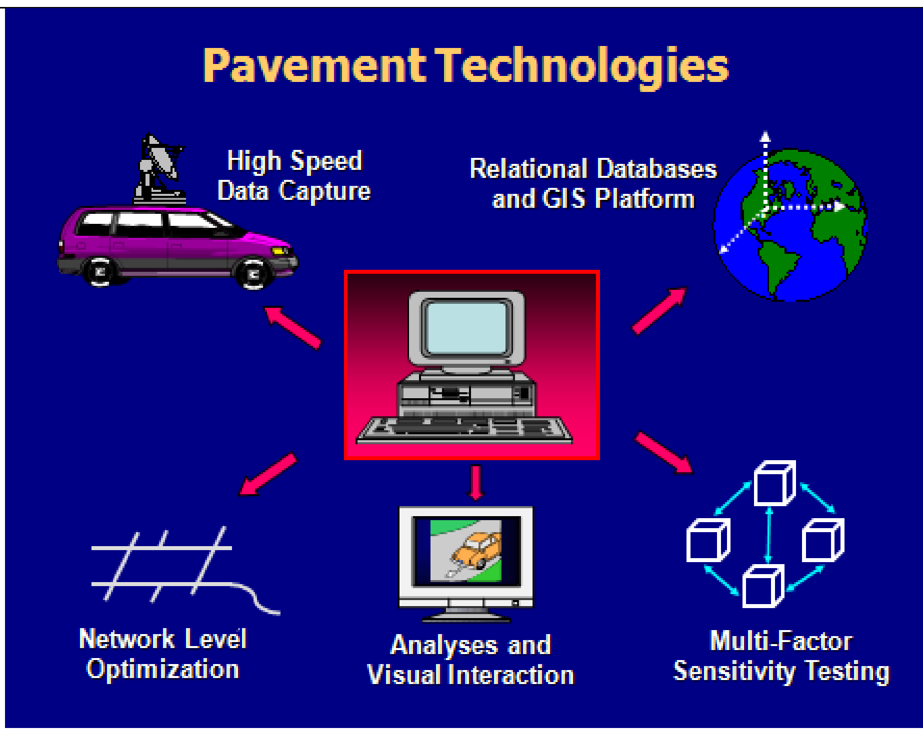
Figure 2 Motivation for Innovation and Road blocks

MOTIVATION FOR INNOVATION, AND ROAD BLOCKS

Given that pavement and transportation research has to be forward looking, that there is a number of key driving forces behind the innovations needed and that creative individuals are an essential element, the obvious question is what are the motivating factors? Figure 2 lists some of these factors, and recognizes though that there can be road blocks as identified on the right side of the diagram.

FACTORS IN AND EXAMPLES OF HIGHLY INNOVATIVE TECHNOLOGIES

The identification of unique and/or highly innovative technologies in transportation poses a dilemma, largely because there have been so many excellent advanceS in the area but they have been largely incremental in nature (3). Nevertheless, perhaps no example area in pavements has had more of a far reaching sustainability than pavement management. This area has been successful in integrating a wide range of technologies, in gaining widespread acceptance by the private and public sector user agencies, in providing a robust life cycle analysis methodology and in the decision support necessary for managing networks of roads, streets and airfields. Figure 3 is a schematic representation of some of the technology and analysis highlights in pavement management, together with a list of the factors that characterize this process as unique and innovative.



FACTORS
• High degree of acceptance by users
• Incorporation of creativity and advanced technologies
• Major impact
• Represents a quantum advance
• New knowledge and skills created
• Basically, better way of doing things

Figure 3 Some Technology and Analysis Highlights in Pavement Management, With Contributing Factors to Innovation

Other leading edge technologies in transportation have also been suggested in Ref. (3). Several that particularly exemplify forward looking advancements in the pavement area include the following:

- Superpave technology which provides a more scientific and engineering base to asphalt materials selection, characterization and use
- Long Term Pavement Performance Database which constitutes the most comprehensive repository of pavement performance data every assembled, over two decades and a total investment exceeding $800 million (7).
- Mechanistic Empirical Pavement Design Guide, the result of several AASHTO projects, made available in the mid 2000's and at the time of this paper undergoing calibration by various state, provincial, federal and local authorities
- Recycling of waste/reclaimed materials in asphalt and concrete pavements as a mature, cost-effective and widely used process toward a zero waste management policy
- Major advancements in engineered materials and processes, including polymer modified asphalt mixes, high performance concrete and warm asphalt mixes tailored to specific durability, strength, environmental, cost-efficiency and other requirements
- Pavement construction equipment and process advancements including infrared sensing for "hot and cold" areas (e.g., segregation), high frequency vibratory rollers, materials transfer equipment ("shuttle buggies") the ("PRSPAC") flat plate compactor and as-built evaluation of smoothness, density, etc.
- Micro electro-mechanical sensors (MEMS) in "smart" roads, airfields and other transportation structures
- Radio Frequency Identification (RFID) tags for materials and construction progress tracking
- Emerging nanotechnology applications in particle size and shape analysis (eg., molecular weight distributions), coatings such as titanium dioxide on concrete panels, fabrication of carbon nanotubes for concrete mixes, and many others
- Permeable asphalt and porous concrete pavements as environmentally important contributions to minimizing surface runoff and recharging ground water.

STRATEGIC PLANNING IN RESEARCH

The long term viability and success of a research program is particularly dependent on how well its strategic planning is formulated and executed. A presentation to TAC in 2008 (4) described how long term sustainability of the University of Waterloo's Centre for Pavement and Transportation Technology (CPATT) research program, for example was focused on a succession planning strategy, and on linking a number of interrelated key strategic elements with program areas. These strategic elements included the following:

- Activities within three basic knowledge types: (a) explicit knowledge in terms of documented research results and technology developments, data and information and professional involvements, (b) implicit knowledge in terms of skills and expertise resident in CPATT's researchers and staff, and (c) tacit knowledge in terms of the innovative/creative capabilities resident in CPATT's researchers and staff
- Mentoring, both formal and informal, involving a commitment to advising and encouraging students, the promotion of pavement engineering and research and assistance to newer researchers and staff by more senior and experienced people. In essence, a concerted team approach to mentoring is a cornerstone to the long term sustainability of a research program.
- Training and skills development is one of the most critical elements to ensuring sustainability of CPATT's research program. It involves hands-on work in the laboratories and field test sites, as well as regular instruction.
- Succession planning as an integral part of knowledge management, where this involves a process for the orderly planning/continuity of renewal and upgrading of the resources behind a research program, including people, technology and information.

The latter element has an underlying rationale of cost-effectiveness, promoting organizational cohesiveness, preserving investment and basically good business practice. It also requires top level commitment, providing the necessary resources, periodic assessment of effectiveness and documentation of activities and accomplishments. But obstacles also exist, including high staff turnover, a culture of "we can simply buy what we need", and a lack of balance between outsourcing and being a knowledgeable buyer.

MEASURABLE PERFORMANCE INDICATORS

The use of key performance indicators (KPI's), which are objectively based and measurable, became important in the long term performance and/or warranty based contracts, starting in about the early 1990's. It became clear that these KPI's should be tied to realistic policy objectives and that quantifiable implementation targets (or warranties in the case of performance based contracts) should be established (6).

The use or application of this approach to forward looking research programs, without being constraining, should be equally valid. An example set of KPI's, tied to research program policy objectives, together with suggested implementation targets for a university or institute based research units are provided in Table 1. While all eight of the policy objectives are essential to the sustainability of this type of organization's research program the first six are also applicable at least in part to research divisions based in a provincial, federal or large municipality transportation department.

In essence, any research organization living up to its mandate and responsibilities should establish a set of KPI's by which they can be evaluated, and while the implementation targets have to be consistent with the specific size, resources and nature of the organization they can provide a realistic tool for accountability.

FORWARD LOOKING OPPORTUNITIES FOR ADVANCES IN PAVEMENT ENGINEERING AND MANAGEMENT

The FHWA initiative on developing a "Roadmap" for the future of pavement management (1) provides an excellent context for identifying forward looking opportunities to advance pavement engineering and management. In the following, a number of such opportunities are suggested. Extensive use has been made of Ref. (1), supplemented by the author's own perspective and background in the area. Issues and challenges associated with these opportunities are also identified, together with the short, medium and long term prospects for realizing the opportunities. It may be noted that the intent is to examine some, but certainly not all possible, opportunities rather than describe the many state-of-the-art existing technologies and practices.

Table 2 is a consolidated but certainly not exhaustive listing, which categorizes the opportunities as follows:

A. Pavement Data (Needs and Cost-Effectiveness; Collection Technologies; Quality Assurance; Storage and Integration)
B. Pavement Management (Structural Design and LCAA; Performance Modeling; Treatment Selection; Quantifying Benefits; Decision Support)
C. Institutional Improvements (Organizational Structure; Location of PMS and AMS; Technology; Skills; Public-Private-Partnerships)

Table 1 Example Policy Objectives, Key Performance Indicators and Possible Implementation Targets Applicable to Forward Looking Research Programs

Adapted from Ref. (4, 5)

Policy Objectives	Key Performance Indicators	Implementation Targets
1.Research productivity, impacts and quality	• Research products a) No. of patents b) No. of major res reports c) No. of journal publications d) No. of conference publications e) No. of invited addresses f) Other (e.g., major awards)	a) If applicable, at least 2/yr b) At least 1/yr/researcher c) At least 1/yr/researcher d) At least 2/yr/researcher e) At least 1/yr/researcher f) At least 1 major award/yr
2. Preservation of research infrastructure investment (facilities, equipment, etc.)	• Asset Value ($)	• Increase (written down replacement cost) annually of 2% or greater
3.Cost Recovery	• Revenues/Budget ($)	• Annual increase at no less than rate of inflation
4.Organizational productivity and efficiency	• Annual staff turnover (%)	• 5% or less annually through commitment to training, work environment and advancement opportunities
5. Return on investment	• Internal rate-of-return (%) a) Implementation of research products into practice b) Return on internal and external training c) Seminars, workshops, etc.	a) Greater than 10% b) Greater than 5% c) Greater than 5%
6.Provision of education, training and outreach (university based research program)	• Graduate students • Undergraduate interns • Seminars, workshops, etc. • Liaison with other research organizations and researchers	• At least 1 graduated per year per full time faculty • At least 1 term intern per year per full time faculty • At least 1 for each 3 full time faculty per year • A functioning network nationally and internationally
7.Sustained partnerships (university based research program	• Private and public sector partners	• At least 5 per $1m research funding
8.Governance Structure	• Roles and responsibilities	• Clear defined reporting structure and responsibilities for directors, senior staff, etc.

TABLE 2 Forward Looking Opportunities for Advances in Pavement Engineering and Management

FORWARD LOOKING OPPORTUNITY AREAS	EXAMPLE ISSUES/CHALLENGES	PROSPECTS FOR MAJOR ADVANCES (Short Term 1-5 Yrs; Med. Term 6-10 Yrs; Long Term 10 Yrs. Plus)
A. Pavement Data 1. Needs and Cost-Effectiveness (comprehensive protocols/guidelines for types of data required, frequency of collection, level (strategic, network or project), use (MEPDG, overall asset management, etc.)	• Responding to advancements in technology • Consistency over time • Amount (s) and types required for different uses • Value of and compatibility with historical data • Role of standardization and comparison across agencies • In-house or outsourcing data collection? • Commitment to and amount of resources required • Coordination with other data collection (traffic, etc.) • Optimization of data collection	• Needs will remain short to long term • More comprehensive guidelines likely in short term • Advances will be constrained by cost concerns short to long term • Widespread standardization not likely in short to medium term • B/C analysis for pavement data will become more established
2.Collection Technologies (precision required, automation of condition measurement, sensors, image quality, speed, referencing, integrated collection capabilities, equipment reliability and robustness)	• Implementation of high speed deflection (eg. Rolling Wheel Deflectometer) • Evaluation of new/improved equipment • Equipment costs, reliability and service life • Degree of integration capabilities required in a vehicle vs. use/optimization of data collection • Agency procurement of equipment vs. contract/outsourcing	• Cost may delay under spread use of high speed deflection in short to medium term • Competition will continue to drive advances short to long term • Image quality will continue to improve (eg. 3D photogrammetry) short to long term
3.Quality Assurance (validity, consistency, accuracy, completeness, management of data quality, audits, effect of collection method, automation of quality checks, QC and QA plans	• Level of accuracy needed for various data elements? • Volume of low-quality data vs less but higher quality data? • Technical expertise required to develop QC/QA plans • Impact of staff turnover (vendors and clients)? • Impact of data quality on engineering and management decisions?	• QA procedures in LTPP can be used advantageously for short to long term • Prospects for impact of quality level of data on pavement design, maintenance, preservation, etc. likely to be better established in medium term

Table 2 Continued		
FORWARD LOOKING OPPORTUNITY AREAS	EXAMPLE ISSUES/CHALLENGES	PROSPECTS FOR MAJOR ADVANCES (Short Term 1-5 Yrs; Med. Term 6-10 Yrs; Long Term 10 Yrs. Plus)
4.Storage and Integration (storage needs and capacity, methods, file sharing, security, access, updates, queries/retrieval, tying “silos” together, integration mechanisms (reference location, asset value, risk exposure, etc.), cost)	• Limits to storage capacity, offsite backup, purging old and/or redundant data • Reluctance to share information/preservation of “silos”? • Distribution, format and level of reports • Sufficiency of available technology and agency resources to meet storage and integration demands	• Benefits from well designed and managed storage systems and integration platform can be substantial in the short term • A constraint on storage capacity; however, is already a short term problem
B. Pavement Management 1.Structural Design and LCCA (input variables, type of facility, design method, component models, design options, LCCA method, constructability and maintainability)	• Probabilistic vs deterministic approach • Adoption of the MEPDG method, or …..? • Defining and incorporating sustainability and “green” aspects • In-house vs outsourced design (within a P3) • Communication of finalized design to other areas (construction, maintenance, etc.)	• More probalistic short term • Extensive calibration on MEPDG short term • Comprehensive attention to sustainability and “green” roads short to medium term • More P3’s short to long term
2.Performance Modeling (Direct part of evaluating design options, models), predictions (IRI vs Age, and/or…..), reliability, periodic updating, accuracy, etc.)	• Probalistic vs deterministic basis • Impact of new materials on predictions (warm mixes, etc.) • Groups/families vs individual sections • Calibrating MEPDG performance models • Use of performance models in predicting remaining service life (RSL) – functional and structural	• Continual move to probabilistic short to long term • Continued work on improved accuracy of models, and in MEPDG calibration, short to long term • Advances in RSL protection capability short to medium term
3.Treatment Selection (Fundamental component of a PMS, selection process for network and project, interface with other project elements, sensitivity to timing, safety, constructability and future rehabilitation)	• Flexibility in selection vs change upon implementation • Clarifying preservation vs preventative vs rehabilitative vs maintenance treatments • Estimating treatment costs in rapidly changing prices • Types and extent of information needed for selection	• Better, more comprehensive models/processes likely over long term • Integration of preservation and preventive treatments into PMS likely in short term • More emphasis on long term impacts of treatments likely over short to long term

Table 2 Continued

FORWARD LOOKING OPPORTUNITY AREAS	EXAMPLE ISSUES/CHALLENGES	PROSPECTS FOR MAJOR ADVANCES (Short Term 1-5 Yrs; Med. Term 6-10 Yrs; Long Term 10 Yrs. Plus)
4.Quantifying Benefits (Cost side of people, equipment, data collection, etc. represents the investment; impacts on decisions)	• What benefits and how to quantify? • Demonstrating changes in network condition vis a vis cost side • How to communicate benefits and to whom?	• Increasing demand likely from stakeholders to quantify benefits, short to long term • Improved communication tools also likely, short to long term
5.Decision Support (information needed at all levels for policy, strategic network and project level decisions; optimization approach; feedback)	• Incorporating risk exposure into the decision process • Balancing practicalities with recommendations • Incorporating user costs and benefits? • Transparency of the decision process	• Increasing use of risk analyses in decisions, short to long term • Increased requirement from senior levels to demonstrate value of PMS in decision support, short term
C. Institutional Improvements 1.Organizational Structure (Centralized vs regional decisions; simple (small) vs comprehensive (large); use of performance indicators)	• Impact of funding (amount, sources) on organizational structure • Capability of adapting to change (downsizing, asset management, retirements, information, politics, technology, etc.) • Ability to compete for pavement dollars	• Many types of changes will occur, even in short term, and adaption will be crucial to survival of pavement management • Continued erosion of institutional knowledge likely in short to medium term
2.Loction of PMS and AMS (Distinct or combined offices for pavement management and asset management; communication channels	• PMS as a "silo" or component subsystem of AMS? • Rationale for PMS in traditional location (materials, planning, maintenance, etc.) • Pavement preservation in the PMS, or separate budget?	• Smooth interpretation of PMS, BMS, etc. into AMS likely to be a struggle over short to medium term • Risk of losing distinct benefit and features of PMS, short term
3.Technology (State-of-the-art technologies today, and periodically upgraded, for data acquisition and processing, sensors, maintenance, etc.	• Developing and maintaining in-house expertise on a fast moving world of technology • Assessing capabilities and limitations of new technologies • Investment in new or improved technologies	• Effective acquisition, understanding and use of new/improved technologies will continue as a long term need

Table 2 Continued		
FORWARD LOOKING OPPORTUNITY AREAS	EXAMPLE ISSUES/CHALLENGES	PROSPECTS FOR MAJOR ADVANCES (Short Term 1-5 Yrs; Med. Term 6-10 Yrs; Long Term 10 Yrs. Plus)
4.Skills (Experience, teaching and training base; periodic upgrades; technical plus administrative and other skills)	• Determining what skills the "leaders of tomorrow" will need (see TAC Briefing Note of Nov., 2009, Ref. 8) • In-house skills/knowledge requirements vis a vis outsourced/purchased skills • Losses through retirements and resignations	• Maintaining the continuing skill sets requirements for effective PMS and AMS will continue at a long term priority need
5.Public-Private-Partnerships (Use ranges from maintenance out-sourcing to finance, design, build and operate)	• Achieving a true partnership with measurable key Performance Indicators on warranties, source delivery, allocation of risk, etc. • Achieving positive benefits for all stakeholders	• Adoption of P3"s in PMS and AMS will be a growing trend over the long term (See Ref. 6)

TOWARD A CANADIAN "MODEL" FOR TACKLING THE OPPORTUNITIES

Tackling the opportunities for advancing pavement engineering and management through forward looking innovations is really a joint responsibility of the public and private sectors and academia. Some recent and/or current approaches with notable records of achievements include the following, not in any order of importance:

- Creation of Canada Research Chairs and Industrial Research Chairs, federally funded for the former and jointly funded in partnership with industry for the latter, a number of which have been awarded to pavement researchers (eg., the Husky Chair at the University of Calgary, the two Canada Research Chairs in Pavements and Infrastructure at the University of Waterloo, the NSERC Industrial Research Chair on Heavy Loads/Weather/Pavement Interaction at Université Laval), and the D.C. Campbell Chair in Highway Construction and Pavement Research at the University of New Brunswick.
- Collaborative Research and Development (CRD) projects as joint (50/50) ventures between NSERC and industry, for relatively short term R&D initiatives and which contribute substantially to training of undergraduate and graduate students.
- Centres and Institutes, usually with public and private support/partners (eg., the Saskatchewan Centre of Excellence for Transportation and Infrastructure, established in 2002 as a strategic partnership between the Saskatchewan Ministry of Highways and Infrastructure, the University of Saskatchewan and private industry; the University of Waterloo's Centre for Pavement and Transportation Technology, CPATT, formed in 2002 with Canada Foundation for Innovation, Ontario Innovation Trust, Ontario Research and Development Challenge Fund and various public and private partners support; Centre for Geosynthetics Research Information and Development, Carleton University, with public and private sector support)
- The Transportation Association of Canada Foundation which awards annually some $150,000 in postgraduate and undergraduate scholarships. This program, initiated in 2004 upon formation of the Foundation, (which was the successor to a long standing but more modest program of TAC postgraduate scholarships) has had a profound and substantive effect on advancing pavement and other transportation technology
- The Natural Sciences and Engineering Council's Discovery Grants which provide about $500,000 annually to pavement researchers in Canada. It should be noted that this is a competitive program involving all fields of engineering and in order to receive support pavement researchers need to be highly innovative and forward looking in their proposals
- Various provincially supported programs, such as Ontario's Highway Infrastructure Innovation Funding Program This provides about $500,000 annually, and pavement research competes with bridges, traffic, planning, etc. Nevertheless, the program has had significant impact on advancing the state of pavement technology.

The foregoing are examples of individual models, but beg the question of whether a comprehensive and coordinated strategic model is possible to tackle the array of opportunities: eg., perhaps like the National Cooperative Highway Research Program (NCHRP) in the United States. This is administered by the Transportation Research Board (TRB), and supported primarily by State funding. In the overall process, problem statements are generated by various TRB Committees, reviewed by AASHTO Committees, and if the priority is high enough for a proposal project and the funding is programmed for it, then a Request for Proposals (RFP) is generated and academic, consulting, research and other organizations can submit proposals. NCHRP uses panels of experts to oversee projects, with operational monitoring by a project manager.

A parallel and complementary model to NCHRP is the FHWA program which currently has over 40 projects underway in the 10 pavement related focus areas previously identified in the Introduction. See Ref. (1), also http://www.fhwa.dot.gov/pavement/falcon/.

The NCHRP model is supplemented by individual states, some local agencies, and some national private sector supported organizations which fund targeted areas and/or academically based centres. Many examples exist, such as the Texas Transportation Institute, and the National Centre for Asphalt Technology (NCAT) in Auburn Alabama, the latter being primarily supported by the National Asphalt Paving Association. Similar Canadian examples would be the previously noted CPATT in Ontario and the Saskatchewan Centre of Excellence for Transportation and Infrastructure.

On a national basis, the best example model would be the Transportation Association of Canada's projects which are supported by pooled funds. The process involves problem statements and cost estimates generated by TAC Committees, approval by a Council to which the Committee reports, solicitation for support by the TAC member constituency (et., Provinces and Municipalities), formation of a Project Steering Committee and issuance of an RFP when the level of support has come up to the cost estimate, and finally selection of a consultant to do the project. Academically based proposers, as well as private sector firms are eligible. An excellent example is the $300,000 plus current project in updating the 1997 Pavement Design and Management guide, which involves extensive support by provincial and municipal agencies, and a national project team from academia and consulting firms.

A comprehensive and coordinated model for tackling the array of opportunities is conceptually possible and indeed exists to some degree, in view of the excellent individual models previously noted and largely in terms of the (mostly informal but effective) alliances formed between researchers and organizations across the county. The Transportation Association of Canada's Standing committees on Pavements and on Soils and Materials, as well as the TAC Foundation, play a key role in facilitating these alliances. But considering the political, geographic and social environment that exists in Canada (eg., no equivalent of the US' FHWA, one tenth of the population, provincial and municipal agencies with different agendas and priorities, etc.), the existing model of mostly informal alliances, and the strong coordinating role through TAC, is perhaps best suited to advancing pavement technology in this county.

CONCLUSIONS

Long term sustainability and advancements in pavement technology depend on innovations and a forward looking approach. This requires recognition of the elements that characterize innovation, and the underlying driving forces and the contributing factors.

As well, there are motivating factors, and road blocks, that are important to innovations. The role of strategic planning and measurable performance indicators in research programs is also important.

A number of forward looking opportunities have been suggested in the paper and they can be categorized as: (A) Pavement Data, (B) Pavement Management and (C) Institutional Improvements. These opportunities have been related to example issues and challenges, and to short, medium and long term future prospects.

Finally, the paper suggests that the public and private sectors and academia can jointly share responsibility in a “model” for tackling the opportunities and advancing pavement technology.

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