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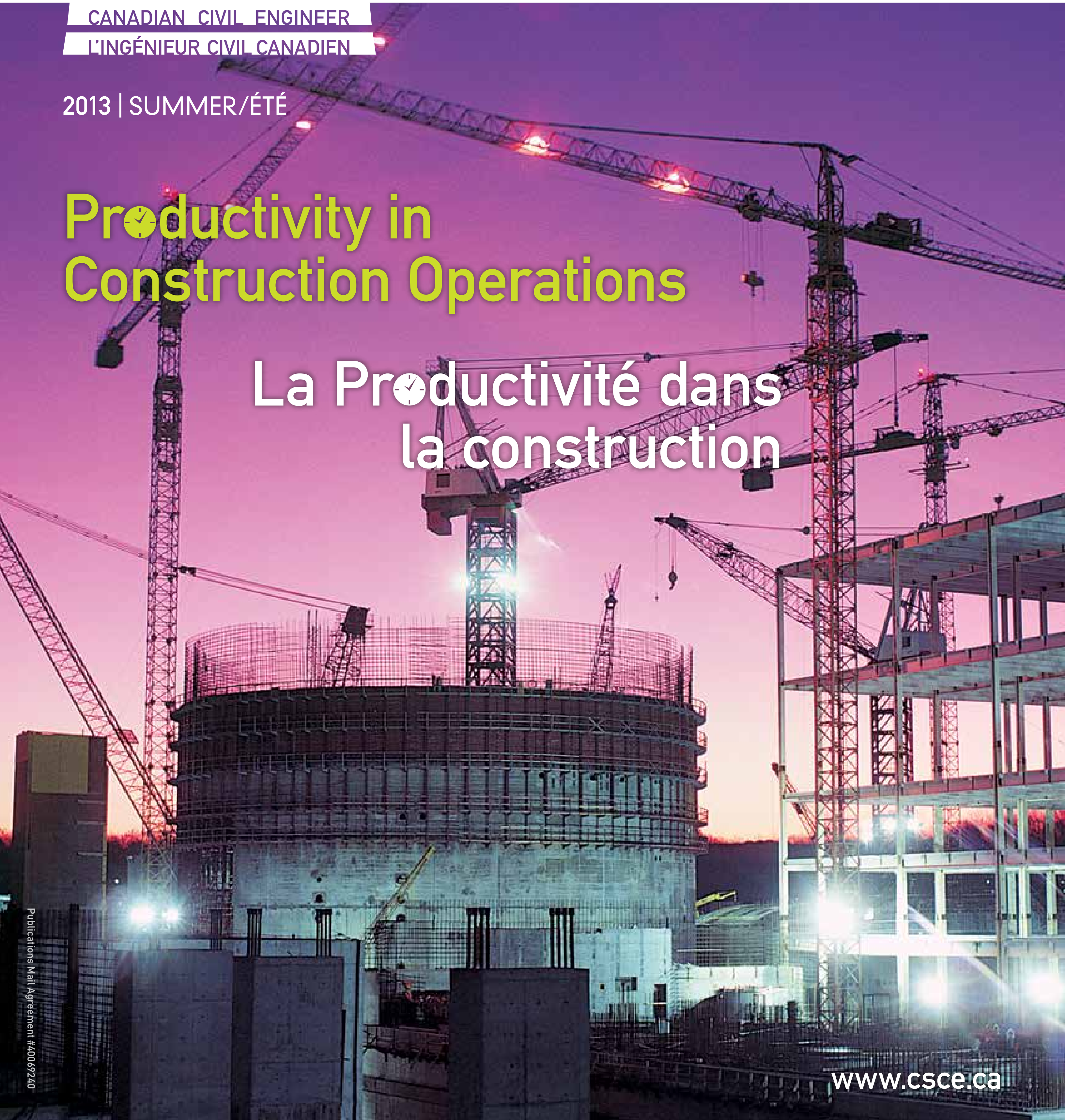
CANADIAN CIVIL ENGINEER

L'INGÉNIEUR CIVIL CANADIEN

2013 | SUMMER/ÉTÉ

Productivity in Construction Operations

La Productivité dans la construction



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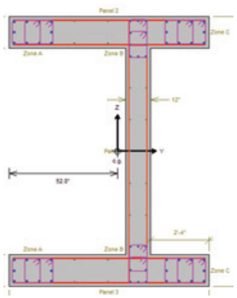

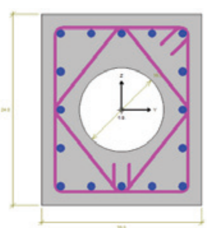

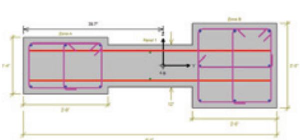

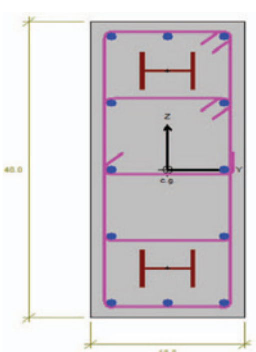

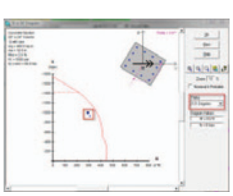

CANADIAN CIVIL ENGINEER
L'INGÉNIEUR CIVIL CANADIEN

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CANADIAN CIVIL ENGINEER
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National Asset Management Governance Framework

Recent environmental events in Calgary and Toronto, symptomatic of the increasingly regular climatic extremes being observed around the world, have highlighted the limitations of existing systems and exacerbated the challenges associated with the continuing deterioration of the core infrastructure on which Canadian communities and residents depend. The ability to address these infrastructure challenges requires a national infrastructure action plan that engages infrastructure stakeholders with a common consolidated national vision. Who are these infrastructure stakeholders and what is this vision?

In 2003 the Civil Infrastructure Systems Technology Road Map (CIS-TRM), a national consensus document, was published by four national organizations, including the Canadian Society for Civil Engineering. The CIS-TRM was a "call to action" in the backdrop of the need for a national infrastructure action plan. In the 10 years since this document was published there have been notable advancements in the development of some of the goals and objectives identified in the CIS-TRM. We have not yet, however, achieved the goal of a national infrastructure action plan with a consolidated approach to infrastructure management practices, processes and policies.

In order to be successful in the development of such a national action plan there needs to be a clear understanding that no singular individual, organization or government agency can meet this challenge alone. It will require a consolidated effort of the entire infrastructure stakeholder group working together on a common nationally adopted vision.

One of the follow-up activities of the CIS-TRM was the development of a National Asset Management Working Group (NAMWG) co-chaired by CSCE. NAMWG comprised a broad range of private and public sector representatives of 12 organizations. In 2009 NAMWG published a document titled "An Asset Management Governance Framework for Canada."

This "governance framework" defines asset management in terms of sustainable communities, presents principles for the sustainable management of infrastructure, and identifies a holistic view of those who represent infrastructure stakeholders in Canada. It offers the following consensus statement in terms of a national vision for the management of Canada's civil infrastructure systems:

VISION STATEMENT (National Asset Management Working Group)

In 2020, through collaboration of all orders of government, communities in Canada will have sustainable municipal infrastructure with the levels of service that support the community's health, safety, economic prosperity and quality of life.

Specifically, Canadian communities will:

• Make sound municipal infrastructure decisions based on full lifecycle analysis that are socially, environmentally and economically sustainable.

- Have eliminated the current infrastructure and deferred maintenance deficits and have access to sustainable funding mechanisms.
- Have improved overall resilience and adaptability of municipal infrastructure to the impacts of climate change.
- Be recognized as leaders in innovative infrastructure technology and practice.

The recently adopted vision for CSCE is a call to action for every member of the Society. In terms of Strategic Direction 3, Leadership in Sustainable Infrastructure, CSCE will influence how public infrastructure in Canada is planned, designed, constructed and maintained.

CSCE is poised to be a leader, in cooperation with other national organizations, in the development of a national infrastructure action plan. As civil engineers, regardless of our specific role in this professional career path, we have an obligation and a responsibility to be part of this activity. It is our time and our place to provide this leadership for Canadian society.

Reg Andres, P.Eng., FCSCE is vice-president of R.V. Anderson Associates Limited, Toronto. ■

Cadre national de référence pour la gestion de l'actif

Les récentes manifestations de la nature survenues à Calgary et Toronto, très symptomatiques des extrêmes observés de plus en plus fréquemment à travers le monde, soulignent les limites des systèmes existants et exacerbent les défis reliés à la détérioration constante des infrastructures de base dont dépendent les collectivités et les résidents du pays. La capacité de relever ces défis en matière d'infrastructure exige un plan d'action national impliquant tous les intéressés en fonction d'un plan d'ensemble au niveau national. Qui sont ces intéressés et que doit être ce plan d'ensemble ?

En 2003, la Carte routière pour la technologie des infrastructures civiles (CIS-TRM), un document national qui a fait consensus, a été publiée par quatre organismes nationaux, dont la Société canadienne de génie civil. Ce document était un appel à la mobilisation, dans le cadre d'un nécessaire plan d'action national en matière d'infrastructures. Au cours des 10 années qui ont suivi la publication de ce document, il y a eu de remarquables progrès dans la définition de certains objectifs définis dans le document. Nous n'avons cependant pas encore réussi à créer un plan d'action national en matière d'infrastructures, avec une démarche unifiée en matière de pratiques, de procédures et de politiques de gestion des infrastructures.

Pour réussir à élaborer un tel plan d'action, il faut bien comprendre qu'aucune personne, organisation ou entité gouvernementale n'est en mesure de relever seul ce défi. Cela exige un effort commun de tous les groupements intéressés aux infrastructures, oeuvrant de concert en fonction d'un plan national adopté par tous.

L'un des suivis assurés par l'équipe de travail du CIS-TRM a été la création d'un Grouper de travail national sur la gestion de l'actif, coprésidé par la SCGC. Le Groupe de travail comportait un vaste éventail de représentants des secteurs public et privé incluant 12 organismes. En 2009, le groupe de travail a publié un document intitulé « An Asset Management Governance Framework for Canada ».

Ce « cadre de gouvernance » définit la gestion d'actif en termes de communautés durables, expose les principes de gestion durable des infrastructures, et définit une approche globale pour ceux qui représentent les personnes intéressées aux infrastructures du Canada. Il présente cet énoncé unanimement accepté en termes de plan national pour la gestion des infrastructures civiles au Canada.

ÉNONCÉ DU PLAN (Groupe de travail national sur la gestion de l'actif)

En 2020,grâce à la collaboration de tous les niveaux de gouvernement au Canada, les collectivités auront des infrastructures municipales durables avec des niveaux de services propres à assurer la santé, la sécurité, la prospérité et la qualité de vie des citoyens.

Plus précisément, les collectivités canadiennes auront :

- Pris de bonnes décisions en matière d'infrastructures municipales à partir d'une analyse du cycle de vie basé sur une durabilité sociale, environnementale et économique.
- Éliminé les infrastructures existantes, reporté les déficits d'entretien et eu accès à des mécanismes de financement durable.
- Amélioré la résilience générale et l'adaptabilité des infrastructures municipales aux impacts des changements climatiques, et
- Été reconnus comme leaders ne matière de technologie et de pratique d'infrastructures novatrices.

Le plan récemment adopté par la SCGC consiste en un appel à tous les membres de la SCGC en vertu de l'orientation stratégique no 3, qui porte sur le leadership en matière d'infrastructures durables : la SCGC influencera la façon dont les infrastructures publiques au Canada seront planifiées, conçues, construites et entretenues.

La SCGC est disposée à agir comme leader national, en collaboration avec d'autres organismes nationaux, pour l'élaboration d'un plan d'action national en matière d'infrastructures. À titre d'ingénieurs civils, peu importe notre rôle précis en fonction de notre plan de carrière, nous avons l'obligation et la responsabilité de faire partie de cette activité. C'est maintenant à nous d'assurer ce leadership au sein de la société canadienne. ■

By Harold Retzlaff, P.Eng., FCSCE
VICE PRESIDENT, PRAIRIE REGION, CSCE

Building stronger ties with our engineering students

The CSCE South Saskatchewan Section was excited to host its first Student Competition, Popsicle Bridge Building. The event took place on March 21, 2013, and was hosted by the University of Regina, Faculty of Engineering and Applied Science, Environmental Systems Program.

Dr. Kelvin Ng, Faculty Liaison, conducted the bridge loading test, and Section members Geoff Sarazin, Brent Miller and Harold Retzlaff were the competition judges.

The student participation for the event was very good, with 10 teams registering. Each team had a maximum of four team members.

The top three teams with the best performing bridge design were awarded a cash prize. The event and prizes were sponsored by the University of Regina, Faculty of Engineering and Applied Science, the South Saskatchewan CSCE Section and Associated Engineering.

The Section has been working for a number of years to build a stronger link with the engineering students at the University of Regina. This has been a challenge in that the engineering program at the university is co-op, wherein the students intersperse three co-op work terms into their course work.

The Section hopes that this competition will become an annual event. In light of several participating students commenting: "Expect more entries next year!" we are eagerly looking forward to next year and beyond. ■

Resserrer les liens avec nos étudiants en génie

La section de Saskatchewan Sud de la SCGC était ravie d'accueillir son premier concours étudiant, un concours de construction de ponts en bâtons de « popsicle ». L'activité a eu lieu le 21 mars 2013, sous les auspices du programme des systèmes environnementaux de la faculté de génie et de science appliquée de l'Université de Regina.

Le professeur Kelvin Ng, agent de liaison avec la faculté, a dirigé les tests de chargement des ponts, et les membres Geoff Sarazin, Brent Miller et Harold Retzlaff ont agit comme juges du concours.

Dix équipes s'étaient inscrites, assurant une excellente participation. Chaque équipe avait droit à un maximum de quatre membres.

Les trois meilleures équipes ayant présenté les meilleurs ponts ont mérité un prix en argent. L'activité et les prix étaient payés par la faculté de génie et de science appliquée de l'Université de Regina, la section de Saskatchewan Sud de la SCGC, et « Associated Engineering ».

La section s'emploie depuis des années à resserrer les liens avec les étudiants en génie de l'Université de Regina. Il s'agit d'un défi particulier, compte tenu du programme coopératif de génie en cours à l'université en organisé en coopérative, ce qui fait que les étudiants sont répartis en trois équipes coopératives pendant leurs études.

La section espère que ce concours deviendra une activité annuelle. Plusieurs participants ont émis le commentaire qu'il y aurait beaucoup plus d'équipes inscrites l'an prochain. ■

Dr. Kelvin Ng of the University of Regina conducting the bridge loading test at the CSCE South Saskatchewan Section's first student popsicle bridge building competition. / Le professeur Kelvin Ng de l'Université de Regina, effectuant les tests de charge des ponts lors du premier concours de ponts en bâtons de popsicle organisé par la section de Saskatchewan Sud de la SCGC.

By Nigel Parker, EIT, M.Eng, LEED AP BD+C, AMCSCE
CHAIR, CSCE YOUNG PROFESSIONALS COMMITTEE

YPs compete in "Amazing Race" at CSCE Annual Conference

This year's Young Professionals Program at the CSCE 2013 Annual Conference in Montreal held May 29 - June 1 included a wide variety of professional development and social networking opportunities.

Professional development sessions included "The Infinite Power of Soft Skills" presented by Eric Sicotte from Sicotte Recruitment in Montreal, and a workshop on Project Management presented by Milt Walker from Walker Projects in Regina. We also hosted a Speed Mentoring event where several industry leaders shared their experience and knowledge.

Social activities included the President's Reception for Young Professionals and Students, an "Amazing Race: Montreal Edition," dinners out at various restaurants in Centre-Ville, pub nights, and even bowling!

A group of YPs with keynote speaker, Olympian Chantal Petitclerc (second row, at right) at the CSCE Annual Conference in Montreal. / Un groupe de jeunes professionnels en compagnie de la conférencière invitée, l'athlète olympique Chantal Petitclerc, au congrès annuel de la SCGC, à Montréal. Photo: Carl Wong.

A big thank you to Katelyn Freçon, the YP conference coordinator for all of her efforts in making these things happen. The YP Committee is already hard at work to make the CSCE 2014 YP program better than ever. Please get in touch if you'd like to be involved. *nparker@rjc.ca*

The head table at the Student Awards Luncheon at the CSCE conference including YP Committee members and CSCE presidents, past, present, and future. / La table d'honneur lors du banquet des prix étudiants regroupait les membres du comité des jeunes professionnels et les présidents (actuel, ancien et nouveau) de la SCGC.

Les JP en compétition au congrès annuel de la SCGC

Cette année, le programme des jeunes professionnels organisé dans le cadre du congrès annuel de Montréal de la SCGC tenu du 29 mai au 1er juin comportait de multiples occasions de perfectionnement et de réseautage.

Les sessions de perfectionnement comportaient notamment l'exposé intitulé « The Infinite Power of Soft Skills », présenté par Eric Sicotte, de « Sicotte Recruitment », à Montréal, et un atelier sur la gestion de projet présenté par Milt Walker, de Walker Projects, de Regina. Nous avons également organisé des activités de mentorat instantané au cours desquelles plusieurs leaders de l'industrie ont mis en commun leur expérience et leurs connaissances.

Les activités sociales comportaient la réception du président à l'intention des jeunes professionnels et des étudiants, l'activité « Amazing Race: Montreal Edition », dans divers restaurants du Centre-Ville, des soirées au pub, et même des parties de quilles !

Un grand merci à Katelyn Freçon, coordonnatrice des JP pour le congrès, pour son travail d'organisation. Le comité des JP s'emploie déjà à préparer un programme supérieur pour 2014. Si vous désirez participer, faites-nous parvenir un courriel: *nparker@rjc.ca*

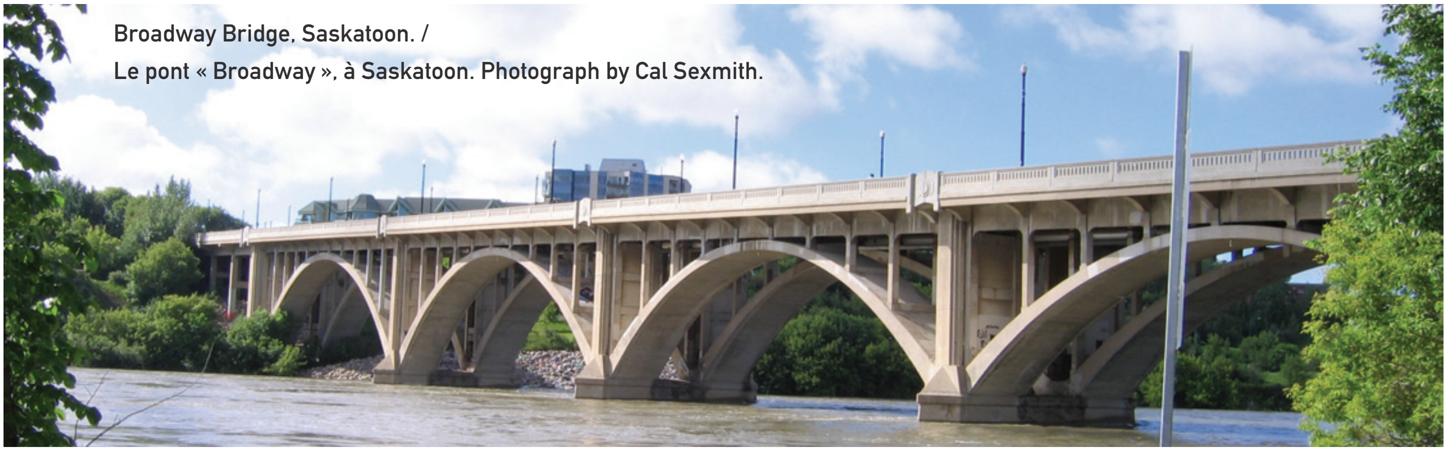
CORRECTION

Wrong bridge photo shown

The photograph on the cover and in the article on page 28-29 in the May 2013 issue of CIVIL magazine incorrectly showed the University Bridge in Saskatoon. The article by Calvin Sexsmith, FCSCE, discussed the Broadway Bridge, also in Saskatoon (see below). Both bridges in the city are concrete arch structures. We regret the error.

Erreur sur la photo du pont

La photographie en couverture et dans le cadre de l'article sur les pages 28-29 du numéro de mai 2013 de la revue CIVIL représentait, par erreur, le pont « University », à Saskatoon. L'article de Calvin Sexsmith, FSCGC, portait sur le pont « Broadway », également situé à Saskatoon (voir ci-dessous). Il s'agit de deux ponts à arches en béton. Mille excuses pour cette erreur.



Broadway Bridge, Saskatoon. /
Le pont « Broadway », à Saskatoon. Photograph by Cal Sexmith.

First Capstone Competition held at CSCE Annual Conference

By Amie Therrien, P.Eng., M.Eng., MCSCE
STUDENT AND YP PROGRAM COORDINATOR, CSCE/COORDONNATRICES DES PROGRAMMES POUR LES ÉTUDIANTS ET LES JP, SCGC

The student program at the CSCE 2013 Annual Conference in Montreal introduced the first Capstone Competition, with teams from 14 universities presenting their projects. Congratulations to the first place team from Carleton University.

Another new initiative this year was the Student Leaders Workshop, where CSCE student chapter representatives from Calgary to St. John's got together to share information and to learn more about the CSCE.

The Best Student Paper Competition also took place. There were almost 300 papers and presentations to be judged. Congratulations to Taofiq Al-Faesly from the University of Ottawa who won first place. Visit csce.ca/news for a list of the other winners.

Congratulations also go out to the CSCE student chapter at Western University, whose impressive schedule of social and technical activities throughout the year earned them the CSCE President's Best Student Chapter Award.

We will be working hard to increase the programming for students for the 2014 conference in Halifax and throughout the year. *Amie Therrien can be reached at yp@csce.ca*

Gosego Motakwa and Ben Pascolo-Neveu (centre and right) from Carleton University receive the Capstone Competition award. Gosego Motakwa et Ben Pascolo-Neveu, de l'Université Carleton, reçoivent eur prix après avoir gagné le premier concours annuel « Capstone ».

Premier concours « Capstone » de la SCGC

Le programme étudiant lors du congrès annuel de la SCGC de 2013, tenu à Montréal, comportait la création du premier concours annuel « Capstone » mettant aux prises des équipes de 14 universités canadiennes. Félicitations aux grands gagnants, l'équipe de l'Université Carleton.

Autre nouvelle initiative cette année : l'atelier des leaders étudiants, où des représentants des sections étudiantes de Calgary à St. John's se sont rencontrés pour mettre en commun leurs informations et en apprendre davantage sur la SCGC.

Le concours de la meilleure communication étudiante s'est déroulé dans le cadre du congrès. Il y avait presque 300 communications et exposés à juger. Félicitations à Taofiq Al-Faesly, de l'Université d'Ottawa, qui a remporté le concours. Consultez la liste des autres gagnants à l'adresse csce.ca/news .

Félicitations également à la section étudiante de la SCGC de l'Université Western, dont l'impressionnant programme social et technique pendant toute l'année leur a valu le prix du président attribué à la meilleure section étudiante.

Au cours des prochains mois, nous nous emploierons à enrichir la programmation pour les étudiants au congrès de 2014, à Halifax, ainsi que pendant toute l'année. N'hésitez pas à nous rejoindre si vous avez des suggestions à faire. *Vous pouvez rejoindre Amie Therrien à l'adresse yp@csce.ca*

Calgary West LRT

Test train at 45th Street Station.

Clearly defined processes helped ensure that the latest extension to Calgary's light rail transit system was delivered within its tight schedule.

By Russel Delmar, P.Eng., PMP
Hatch Mott MacDonald Ltd.

Calgary's West Light Rail Transit project (WLRT) is the most recent extension of a light rail system that originally commenced operation in 1981. This extension to serve communities in the city's southwest was approved by the City of Calgary in November 2007.

The alignment of the WLRT line features a combination of elevated, tunneled, trenched and at-grade guideways and stations. By its very nature, delivery of a new LRT line requires the application of unique planning, engineering, project management and commissioning processes. It also necessitates the formation of a multi-disciplinary project management, engineering and architectural design team to deliver the highly complex work scope.

Clearly defined project processes were required to ensure that the WLRT was successfully delivered within the tight schedule. These included:

Fast-track delivery. To achieve the December 2012 completion date, a fast-track design-build project delivery strategy was implemented. Its success depended on a number of factors. A clear definition of the scope of work was key to allow for accurate costing, detail design and scheduling by the design-build contractor. The clear scope definition was achieved by preparing a request for proposal package that defined the work via a series of concept drawings and a combination of both prescriptive specifications for owner "must have" requirements, and performance specifications which allowed for innovation by the contractor.

Integrated project team. The city created a separate WLRT project office to direct the project. This group was supported by and integrated with Hatch Mott MacDonald (HMM) who served as the owner's engineer with their team of subconsultant specialists. The integrated project team approach was a first for the City of Calgary and provided significant overall project efficiencies.

Accelerated preliminary design. The HMM team completed all of the key procurement phase deliverables on time, within a nine-month period. These included the following: public engagement and routing alternatives; preliminary design drawings; prescriptive and performance specifications; preliminary schedule and construction cost estimates; LRT design guidelines; RFP documents; and proponent submission evaluations.

Segregation of the WLRT from the existing Operations and Control Centre. Because a significant risk existed with integrating the new operations into the existing Operations and Control Centre (OCC), the project team designed a separate OCC integration plan to be implemented progressively in parallel with testing and commissioning of the project.

Photos courtesy: FTG

CTrain on elevated guideway.

1	Grade Separated Interchange High School Relocated (Ernest Manning High School)
1.8	kilometers of Elevated Guideway
2	Park n' Ride Terminals Bus Terminals Utility Buildings
2.9	kilometers of Tunnel/Trench Rail
3	New Road Bridges (69th Street, 45th Street & 42nd Street) Pedestrian Bridges (Sunalta Station, 24th Street SW & 69th Street Station)
3.3	kilometers of At-Grade Rail
4	Storey Commercial Building
6	LRT Stations
8	kilometers of Double Track Rail
50	Properties Acquired
62	months = project duration
115	Public Meetings
3,250	tonnes of CO_2 Emissions to be Reduced
7,300	Less Vehicles on Calgary's Roads each day
44,000	Forecasted Daily Passengers
3.1 Million	Construction Manhours
$1.4 Billon	Estimated Project Cost

Public and stakeholder engagement. The public engagement process was based on the city's "Engage!" policy and framework. Community advocates and community advisory committees were established to have input into key project elements. Also city departments were engaged to identify project requirements, addressing their needs during both construction and operation of the new line.

Design-build contractor procurement. At the time of procurement, the project team was challenged with creating a competitive bidding process and attracting qualified proponents in a busy local construction market. Initiatives to address this challenge included issuing bulletins, retaining a Fairness Advisor to ensure fairness and transparency in the procurement process, and creating a new form of design-build agreement for the city.

Quality management. A key innovation in the design-build delivery of the project was the development of a new design-build agreement and procurement process that is expected to serve as the city's model for future design-build projects. The new agreement, as well as the project management process that included a structured quality audit process carried out by the owner's engineer team, resulted in the quality end product that the city desired.

Partnering for success. A major contributor to the success of the project lay with the willingness of all the parties to partner for the success of the project. Contracted parties recognized that partnering, communication and alignment were crucial to the delivery of such a complex project within an aggressive schedule.

Benefits to society

The major benefits to society resulting from the WLRT project include:

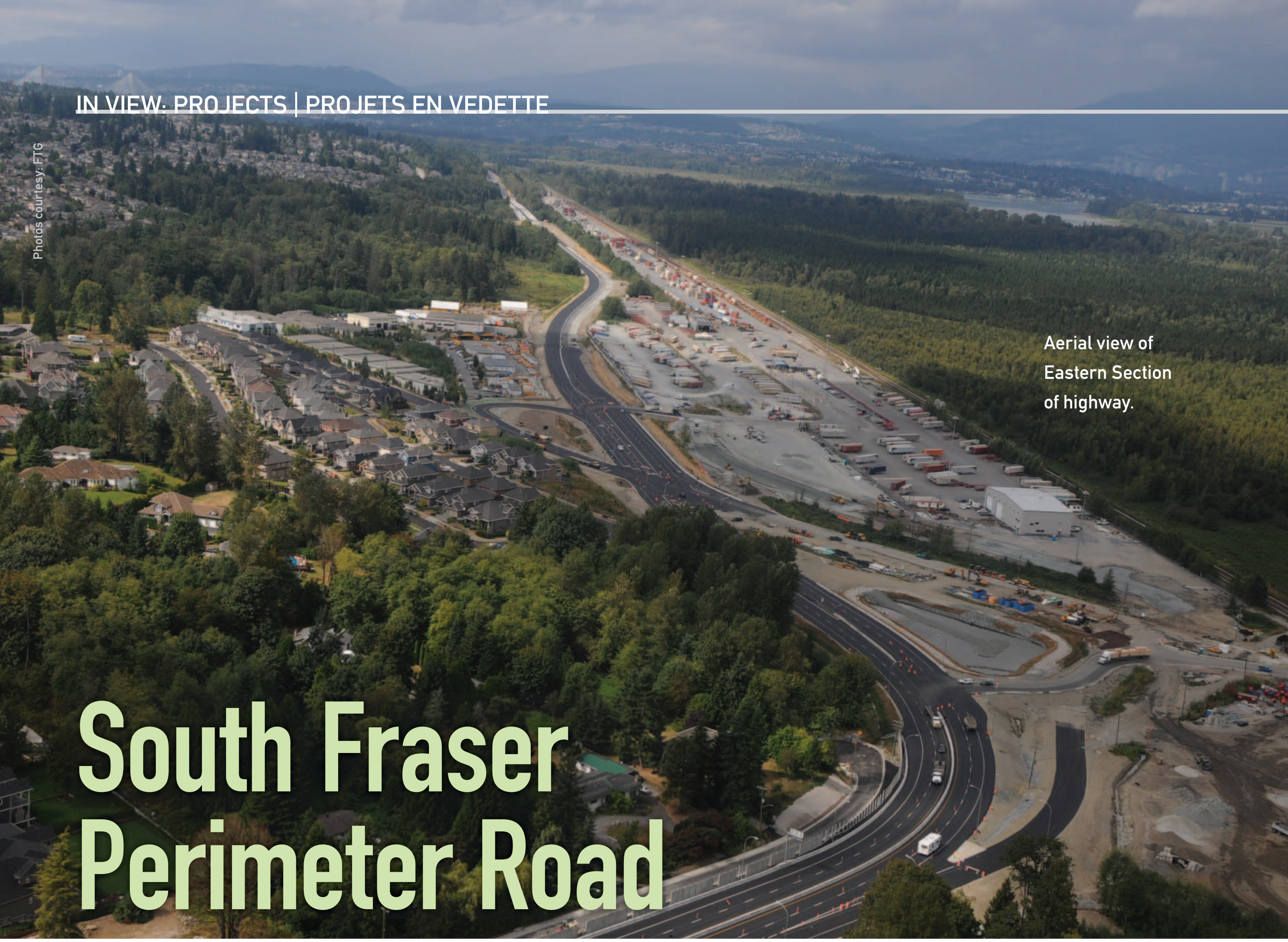
- Diversion of 7,300 automobile trips per day from Calgary roads to public transit, thereby reducing carbon emissions.

Photos courtesy: HMM

Elevated guideway construction.

- Provision of a rapid, convenient, economical and safe mode of public transportation for approximately 44,000 people per day from the western quadrant to the downtown core of the city.
- Refurbishment of a significant portion of the infrastructure (roadways, utilities, landscaping, etc.).
- Refurbishment of the Westbrook mall area; development in the area will provide added local services to the public.
- LEED Gold-accredited transit oriented development in the form of a four-storey commercial building over the Westbrook Station.
- Redevelopment of a new high school in the west Calgary area. ■

OWNER-CLIENT: City of Calgary
PRIME CONSULTANT/OWNER'S ENGINEER: Hatch Mott MacDonald (Russel Delmar, P.Eng., Nathan Higgins, P.Eng., Paul Wilson, P.Eng.)
OTHER KEY PLAYERS: GEC (architecture), Focus Corp. (roadways, survey, utilities); Associated Engineering (traffic management); AECOM (environmental, mechanical/electrical monitoring); Patching Assoc. (noise assessment); Thurber (geotechnical); Ground3 (landscape); WorleyParsons (environmental studies); Klohn-Crippen (geotechnical studies);
CONTRACTOR: SNC-Lavalin



Photos courtesy: FTG

Aerial view of Eastern Section of highway.

South Fraser Perimeter Road

To meet a tight schedule, the engineers of a new highway between Deltaport and Surrey, B.C. found innovative solutions for the alignment and geotechnical design.

By Cozmin Radu, MSc, P.Eng.
STANTEC

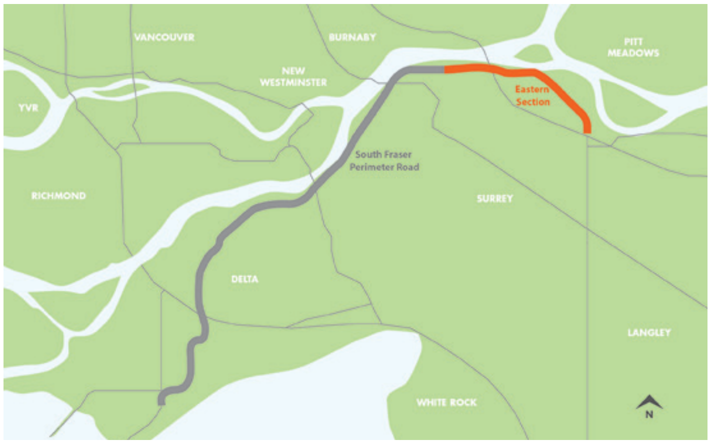
With 130 million tonnes of cargo changing hands at Port Metro Vancouver every year, the level of heavy truck traffic leads to congestion, noise and infrastructure breakdown in the greater Vancouver area. Much of this traffic is centred in the suburb of Delta, where Deltaport handles the largest container ships coming to Canada's west coast.

The solution to heavy haulers clogging commuter routes is the South Fraser Perimeter Road (SFPR), a four-lane highway stretching 40 kilometres along the south side of the Fraser River from Deltaport to Surrey, B.C.

The Government of British Columbia, the Fraser Transportation Group Partnership, and Design-Builder FTG Constructors partnered with Stantec to design a cost-effective infrastructure solution to remove the cargo traffic from commuter roads. The project had to minimize its environmental impacts and improve local communities. The project is being delivered through a public-private partnership between the B.C. Ministry of Transportation and Infrastructure and the Fraser Transportation Group Partnership. It is part of B.C.'s Gateway Program that was started in 2006 to improve the movement of people, goods and transit through Metro Vancouver.

For the entire SFPR project Stantec is leading the multi-disciplinary design team, providing project management, transportation engineering, environmental services, landscape design, municipal engineering, structural engineering, traffic engineering, electrical engineering, and water resources engineering.

The opening date of the first phase of the SFPR was driven by the opening of the new Port Mann Bridge in order to provide commuters with a free alternative to the toll bridge. The substantial completion date for the 7-kilometre Eastern Section of the highway was Novem-



Area route map.

ber 30, 2012, one month ahead of the bridge opening. This portion of the highway runs from 136th Street to the Port Mann Bridge and onward to connect to Highway 1.

Faced with an aggressive schedule (first construction drawings were due less than nine months from the contract award), the design team had to tackle a variety of challenges in a tight timeline. The challenges included a limited right of way, unstable ground conditions and an ecologically sensitive location, along with a variety of stakeholders and community concerns.

"The skills, local experience and expertise of the design team with projects of this scale and complexity was critical to developing the solutions to the various constraints and challenges we faced during the design and construction of the SFPR," says Sarrah Busby, Stantec's project manager. "The ability to quickly call on a wide range of local specialists within our team allowed us to meet the aggressive schedule."

Despite the tight deadline, the design team found many creative solutions. These allowed the project to progress on an accelerated schedule that would see approximately one million cubic metres of earthworks, concrete work and pavement structure completed.

Design innovation in the selection of the road horizontal and vertical alignment and geotechnical design played a crucial role in the successful completion of the Eastern Section one month ahead of the original schedule.

Innovations to save time

Time and cost savings were found when addressing the geotechnical challenges of the site. Where the schedule would not allow for the longer preload durations, the team identified comparable alternatives. A short duration preload treatment followed by final construction of the embankments using lightweight fills was chosen for select areas. Lightweight fills included red vesicular basalt pumice and expanded polystyrene (EPS).

In areas where the depth to the bottom of the compressible soils was less than 4 metres, excavation and immediate replacement with compacted granular fill was used. This technique resulted in significant savings in the construction schedule. As the excavated materials were suitable for landscaping purpose and a landscaped disposal site was nearby, the cost of truck hauling the waste was also minimized.

Unstable slopes, poor soils, and right of way constraints along the route resulted in several kilometres of retaining walls being constructed. The retaining walls are up to 10 metres high and amount to 6,500 square metres.

An MSE wall system that can tolerate post-construction settlement was used to manage the alignment within these constraints and to minimize the environmental impacts. Unstable hill slopes along the route also had to be improved with new or upgraded drainage systems, often using drilled-in horizontal drains. The drilled-in drains were further optimized by the use of well graded rock fill on the cut slopes to improve drainage.

More than 500 individual environmental permits were required for the Eastern Section of the SFPR, creating a major threat to the aggressive deadline. The design team streamlined the process by creating a permitting database to efficiently manage the process.

Work on the remainder of the road is ongoing, but with the Eastern Section completed the project is well on its way to returning residential roads to quieter community connectors, while maintaining Vancouver as the economic hub of Canada's west coast. ■

(Above) Approaching the new Port Mann Bridge. (Below) Owing to unstable slopes, poor soils and constrained rights of way, several kilometres of retaining walls were built, up to 10 metres in height.

Photos courtesy: Stantec

PROJECT: South Fraser Perimeter Road
OWNER: British Columbia Ministry of Transportation & Infrastructure
CONCESSIONAIRE: Fraser Transportation Group Partnership
CLIENT: FTG Constructors
PRIME CONSULTANT: Stantec (Cozmin Radu, P.Eng., Bob Kelly, P.Eng., Garry Romanetz P.Eng.)
OTHER KEY PLAYERS: exp Services (geotechnical engineering); Urban Systems (road design Western Segment); Buckland & Taylor (structure design)

Photo: iStock

Training Graduate Students in Sustainable Civil Engineering in Canada

By Catherine N. Mulligan, Ph.D, Eng.,
FORMER CHAIR, CSCE SUSTAINABLE DEVELOPMENT COMMITTEE

Since civil engineers are important builders and problem solvers in Canadian industry and society, it stands to reason that engineering education is an excellent platform for imparting additional skills. Multi- and interdisciplinary approaches are necessary to address the complex social, economic and technological challenges Canada faces. A results-oriented analytical approach to problem-solving should be an integral part of the rigorous training that civil engineers receive.

There also exists a measurable trend towards multidisciplinary education in all fields of engineering: de Graaff and Ravesteijn describe the crucial need for the "complete engineer," an individual who not only has technical-scientific skills, but also has an understanding of the interplay between technology and society, organizational and management skills, as well as social and communications skills (De Graaff and Ravesteijn, 2001).

A movement towards encouraging the idea of sustainability coincides with the decision of the Canadian Engineering Accreditation Board (CEAB) to implement an outcome-based accreditation process at the university undergraduate level: it has been shown that "global engineering outcomes present a smaller set of more detailed statements (than CEAB's original outcomes) which have complete coverage with the CEAB requirements" (De Graaff and Ravesteijn, 2001).

Undergraduate and graduate-level university students, as well as post-doctoral fellows, need training that incorporate a number of perspectives in evaluating environmental conditions and solving problems. The Johannesburg World Summit on Sustainable Development (WSSD, 2002) identified five priority themes that strongly influenced the direction that university-level training is presently adopting. These five thematic areas are: (a) water and sanitation, (b) energy, (c) health, (d) agriculture, and (e) biodiversity. They are referred to collectively by the acronym WEHAB.

Combining a technical engineering discipline with courses in policy, economics, or social sciences (Figure 1) will allow for more effective policy design, keener political decision-making, and an informed civil society in Canada and worldwide (De Graaff and Ravesteijn, 2001). Formalized training in interdisciplinary approaches to problem-solving is not just an added bonus to engineers but is an increasingly required skill. Furthermore, the complex nature of environmental systems invites a multi-axial approach to solving environmental problems in engineering, economics and policy. Finally, de Graaff and Ravesteijn point to engineers as serving a role in bridging the gulf between technology and society; the role of engineers in interpreting and disseminating environmental knowledge will become critical.

This trend towards interdisciplinarity in engineering education is reflected by an increasing number of interdisciplinary sustainability initiatives at universities and research institutions in Canada and beyond. Although there have been significant strides in undergraduate education due to CEAB requirements, graduate level training in sustainability has not advanced as significantly. There are some excellent examples, however, as research and graduate level training in this field is essential.

In Canada, a prime example is the University of Victoria that has been the recipient of NSERC CREATE funding for its Training Program in Interdisciplinary Climate Science (NSERC 2011). Another example is the École Polytechnique (2013) in Montreal, which has a graduate diploma in sustainable development. This diploma can be combined with other Masters degrees in modules for five options. The one for civil engineering includes an option in environment. At the University of B.C., within the civil engineering program, Sustainable Infrastructure Systems Engineering is a multi-disciplinary research division focusing on sustainable futures through engineering innovation with research in Sustainable Transportation Systems and Project and Construction Management (UBC, 2013).

The School of Public Policy and Administration at Carleton University (2013) is leading teaching and research in public administration and public policy. Courses on sustainable development are offered within the "Innovation, Science and Environment" concentration of its existing MA in Public Policy and a Graduate Diploma in Sustainable Development. Carleton offers Masters programs (MA, M.A.Sc. and MEng) in sustainable energy, both in engineering and public policy, and McMaster University (2013) offers two Masters related to sustainability: a Master in Engineering and Public Policy and a Master of Engineering Design in Sustainable Infrastructure.

The Department of Civil Engineering of the University of Toronto (2013) has created a Master of Engineering in Cities Engineering and Management (MEngCEM). It also has a specialization in Sustainable Urban Systems with the Master of Engineering. In addition, its Master and Ph.D. within the Environmental Engineering Program are designed to encourage interdisciplinary studies in environmental engineering. The Division of Environmental Engineering and Energy Systems administers and coordinates the program in conjunction with the four departments (Chemical Engineering, Civil Engineering, Materials Science and Engineering, and Mechanical and Industrial Engineering) and the Centre for Environment. The University of Toronto has applied an interdisciplinary approach to identifying the role of engineers in solving complex global problems – including those related to sustainable development – at the Centre for Global Engineering (CGEN, 2013).

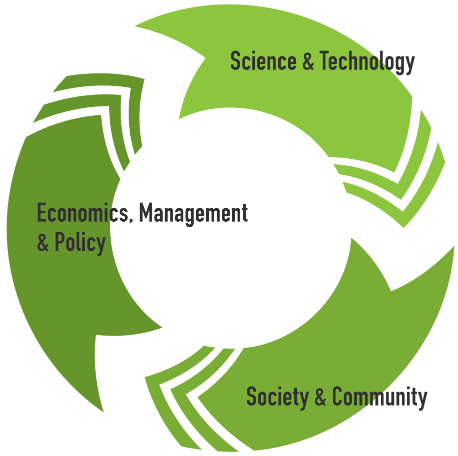


Figure 1. Interdisciplinary aspects of sustainability training

"This trend towards interdisciplinarity in engineering education is reflected by an increasing number of interdisciplinary sustainability initiatives at universities and research institutions"

The Collaborative Masters Program in Applied Sustainability (CMAS) of Queen's University began in September 2010. Building on the applied sustainability strategic theme, the objective of the CMAS program is to expose students to the implementation of sustainable engineering solutions within the context of broader sustainability theory. Six engineering programs, including civil engineering, enable engineering students to advance their technical education with complementary public policy to solve multidisciplinary sustainability problems. Four research concentrations are available, including Applied Sustainability and Energy Technology, Applied Sustainability and Fresh Water Systems, Applied Sustainability and Resource Management, and Applied Sustainability and Policy Studies.

In light of the above, Concordia University established an interdisciplinary Concordia Institute for Water, Energy, and Sustainable Systems in 2012 (CIWESS, 2013) that will provide a unique location to develop interdisciplinary undergraduate and graduate programs, particularly Masters and Ph.D. programs in water and energy-focused sustainable engineering. The long-term objectives of the NSERC CREATE-funded program are to train highly-qualified personnel to design systems, solutions and technologies in a multidisciplinary manner that will reduce our environmental impact with emphasis on water, energy, and resource conservation. Via internships and projects in collaboration with industry, the students acquire practical experience and multidisciplinary training in various fields, including alternative energy sources, sustainable water management, ecological economics, global resources, infrastructure development, sustainable land use, green industrial engineering and materials, natural resource conservation, environmental laws and policies, sustainable design, and ecosystem management.

In conclusion, universities have a crucial role to play in developing a socially just, ecologically aware, and economically responsible society. Universities are responsible for setting curriculum standards and training, and they have a moral responsibility to educate their graduates with the knowledge, skills, and values to effectively develop a thriving civil society. Civil engineers have the obligation to develop and implement design, construction, and management techniques that minimize harm to the environment and minimize energy use. Engineers must also be able to work in multidisciplinary teams that incorporate perspectives from public policy, economics, and social responsibility. These demands place a unique burden on engineering educators to design programs that will train future civil engineers for contemporary challenges. The efforts that have been initiated will need to continue and expand. ■

Catherine Mulligan, Ph.D, Eng. is director of the Concordia Institute for Water, Energy and Sustainability in Montreal.

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Why a Holistic View of Sustainability is Key

Michael McSweeney, president and CEO
CEMENT ASSOCIATION OF CANADA

By 2050, more than 70% of the world's population will live in urban settings. As engineers, city planners, architects and politicians rethink how we plan, build and live for a sustainable future, it's critical that we get this sustainable transformation of our cities right.

Climate change is an issue that is having a dramatic impact on how we build. The design of our infrastructure is of critical importance since buildings account for over one third of all man-made greenhouse gases (GHGs). Research from institutions such as MIT and UBC shows that when all phases of a building project are considered, the raw materials used in construction, through to the eventual demolition of the building at the end of its useful life – some 90% of GHG emissions come from a building's operation (heating, cooling, lighting and so on).

Operational energy efficiency is where concrete shines; concrete's ability to store heat and energy makes buildings easier and more affordable to cool in the summer and heat in the winter. A shining example of this is the award-winning, LEED Platinum Manitoba Hydro Place, which capitalizes on concrete's thermal mass to achieve energy efficiencies upwards of 70% over conventional buildings. This efficiency far eclipses the GHGs generated during the building's construction, including those emitted to make the concrete.

The engineering community is at the forefront of raising awareness of the necessity to construct more climate-resilient infrastructure. While we are made aware almost daily of the potential dangers related to climate change in the U.S., we also know Canada is not immune to these risks and impacts. Concrete has always been a material of choice when it comes to safety and is used under the harshest environmental conditions. It will serve us well as we think about building for tomorrow.

At the end of the day, resilient, sustainable construction is more complex than choosing one material over another. There is tremendous innovation across the whole building industry, and to realize this potential we must let a holistic and long-term view be our guide. ■

Manitoba Hydro Place, Winnipeg

Photo courtesy: CAC

Productivity in Construction Operations

The technical editor introduces four articles that deal with different approaches for improving the efficiency, performance and productivity of construction projects.

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Performance and productivity improvements are key focus areas in any nation's construction industry since it makes a substantial contribution to a country's economy. With the rising costs of building materials and a shortage of skilled labour, along with added complexities, construction companies are looking for ways to increase efficiencies throughout their operations.

Construction productivity is a complex issue involving the interaction of labour, capital, materials and equipment. Finding innovative solutions in terms of labour, management and technological issues will save billions of dollars and make construction a professional and attractive business.

The four technical articles in this edition discuss four different approaches for improving the efficiency, performance and productivity of construction projects. One paper deals with an innovative methodology for large construction/infrastructure rehabilitation projects that involve complex economic decisions for allocating limited budgets among many assets. The second paper suggests a business model for architectural, engineering and construction companies based on using knowledge management and business analytics to capitalize on emerging market opportunities. State-of-the-art of life cycle approaches (LCA) in the construction and management of built assets, including recent developments in LCA-based tools, are introduced in the third paper. The concept and successful implementation of a "construction productivity improvement officer," a person dedicated to plan, implement, monitor and evaluate all the productivity-related activities in a construction project, are explained in the fourth paper. ■

La productivité dans la construction

Le rédacteur technique décrit les quatre articles suivants et la façon dont ils traitent de diverses démarches en vue d'améliorer l'efficacité, la performance et la productivité dans les chantiers de construction.

La performance et l'amélioration de la productivité en matière de construction sont au cœur de l'industrie de la construction dans tous les pays, dans la mesure où ce secteur représente une partie importante de l'économie. Avec la hausse du prix des matériaux et la rareté d'une main d'œuvre qualifiée, les entreprises de construction cherchent des façons d'améliorer leur efficacité dans tous les domaines.

La productivité dans la construction est un problème complexe impliquant l'interaction de la main d'œuvre, du capital, des matériaux et des équipements. Découvrir des solutions novatrices en matière de main d'œuvre, de gestion, de problèmes technologiques épargnera des milliards de dollars et fera de la construction une affaire intéressante pour les professionnels.

Les quatre articles de ce numéro traitent de quatre démarches différentes pour améliorer l'efficacité, la performance et la productivité des chantiers. L'un des articles traite d'une méthodologie novatrice pour les grands chantiers de construction/ réhabilitation des infrastructures impliquant des décisions économiques complexes d'allocation de budgets limités destinés à plusieurs ouvrages. Le deuxième article expose un modèle d'affaires pour les entreprises d'architecture, de génie et de construction reposant sur les connaissances en gestion et l'analyse afin de profiter des occasions que présentent les marchés émergents. Les analyses modernes du cycle de vie dans la construction et la gestion du bâti, incluant les derniers développements en matière d'outils pour le calcul du cycle de vie, font l'objet du troisième article. La notion et la mise en œuvre réussie du poste « d'agent d'amélioration de la productivité en construction » (une personne qui se consacre à la planification, la mise en œuvre, la surveillance et l'évaluation de la productivité dans la construction fait l'objet du quatrième article. ■

A Loss-Aversion Approach to Optimize Infrastructure Spending

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In the newly emerging field of behavioural economics, loss-aversion refers to people's tendency to strongly prefer avoiding loss rather than acquiring gain. This paper examines the applicability of the loss-aversion perspective in the construction domain, particularly infrastructure rehabilitation projects that involve complex economic decisions of allocating a limited rehabilitation budget among many assets.

Using a pavement case study, extensive optimization experiments were carried out to compare the traditional approach of maximizing the gain from a limited rehabilitation budget with two loss-aversion approaches. The results show that incorporating behavioural economics makes the decisions more reflective of the preferences of all stakeholders.

Introduction

Private and public organizations are concerned with making good economic decisions regarding new construction and rehabilitation projects. Due to the fast deterioration of infrastructure, rehabilitation planning is gaining the increasing attention of government, asset management firms and construction companies. Rehabilitation planning, in essence, is a large process that aims at efficiently distributing a limited rehabilitation budget among a large number of competing assets.

To optimize rehabilitation decisions, several research efforts in the literature have introduced optimization models in different asset domains, including pavements (e.g. De la Garza et al, 2011); water/sewer networks (e.g. Halfawy, 2008); bridges (e.g. Elbehairy et al., 2006); and buildings (e.g. Hegazy and Elhakeem, 2011). While these efforts are useful, none of them consider the decision makers' and users' behavioural preferences in the decision making process. The latter behavioural aspects have been extensively studied under the umbrella of "behavioural economics."

Behavioural economics is the integration of psychological phenomena and behavioural aspects with economic reasoning (Humphrey, 1999). It takes into account psychological feelings along with the monetary gains and losses to better reflect the preferences of consumers/decision makers, and thus has a great potential for application in the construction/infrastructure domains.

Psychological experiments have revealed that decision makers are not fully rational; rather, they follow their own "bounded rationality" which is characterized by systematic patterns of affection and cognition (Selten, 1998, Bolton and Ockenfels, 2012). In the literature, various researchers (e.g. Gordon, 2011, Dawnay and Shah, 2005, etc.) discussed several behavioural aspects that can influence decision making. Among the most important concepts, Tversky and Kahneman (1986) used a survey to show that when a problem was defined in terms of gain, respondents' choices were very different from when the same problem was defined in terms of loss. This paper, therefore, examines the gain versus loss perspectives of behavioural economics on infrastructure fund-allocation decisions.

Case study: road pavements

The case study is a pavement network which was part of an asset management challenge posted at the 7th International Conference on Managing Pavements (ICMPA, 2007). The pavement network consists of a total of 1,293 road sections of two types: interurban and rural roads. The available budget per year is assumed to be $8 million with an annual interest rate of 6%. The information given on each road section includes: length, width, AADT, year of construction, and surface condition assessments (International Roughness Index, IRI, and others). Other general information was also given regarding the annual rate of increase of IRI, the maximum allowed IRI values, the unit cost of various treatment types, and IRI values before and after treatment. The condition of a given pavement is measured in terms of its IRI as a single parameter that represents pavement performance, where the lower the value the better the condition.

Optimization model

To optimize fund-allocation decisions, the Multiple Optimization and Segmentation Technique (MOST) of Hegazy and Elhakeem (2011) has been utilized in this paper due to its ability to handle large-scale problems. In the MOST technique, project-level decisions (one asset at a time) are first optimized through small individual optimizations to determine the best rehabilitation method associated with any year in the planning horizon. The results of all project-level optimizations are then saved in a group of look-up tables which are readily used in network-level optimization.

In MOST, network-level optimization determines for each asset its optimum rehabilitation year. The analysis uses a planning horizon of 5 years. Therefore, each asset can be selected in year 1, 2…, 5, or zero (no action). The model's variables, constraints, and objective function are as follows:

Decision Variables

(Matrix of rehabilitation timing decisions)

$$\begin{bmatrix} X_{11} & X_{12} & X_{13} & X_{14} & X_{15} \\ X_{21} & X_{22} & X_{23} & X_{24} & X_{25} \\ \cdot & \cdot & \cdot & \cdot & \cdot \\ \cdot & \cdot & Xij & \cdot & \cdot \\ \cdot & \cdot & \cdot & \cdot & \cdot \\ X_{i1} & X_{i2} & X_{i3} & X_{i4} & X_{i5} \end{bmatrix}$$

Where, if Xij=1, then asset i is selected in year j, otherwise not selected in year j.

Constraints: *The total rehabilitation cost (TCj), which is the sum of all assets' rehabilitation costs (RCij) in any year j, should not exceed the available budget for that year, as shown in Equation 2.*

$$TCj=\sum_i [(RC]_{ij}*X_{ij}) \leq B_j$$

Objective function: *To compare the gain versus loss perspectives, different experiments were performed with different objective functions of either minimizing the disutility (loss) or maximizing the utility (gain) associated with rehabilitation decisions.*

Loss-aversion models

In this formulation, the objective function is set to minimize the loss associated with any rehabilitation decision. Generally, loss can be represented in different ways; however, in this paper, loss has been represented in two ways, as shown in Figure 1: (1) sum of IRI losses due to delayed repairs, and (2) sum of users' vehicle operating costs (VOC).

Figure 1 shows an example road section that, it has been decided, is to be rehabilitated at year 3 (i.e. lost the opportunity to be rehabilitated at year 1 and 2). Figure 1(a) shows two IRI deterioration curves, one in the case of rehabilitation at year 1, the other with rehabilitation at year 3. The shaded area represents the lost opportunity due to the rehabilitation decision, which is quantitatively calculated as a value of 40. The overall network loss is then the sum of losses associated with all asset repair decisions. As an alternative to this loss representation, Figure 1(b) shows loss in terms of VOC which is calculated from the given case study data. In this case, the overall network loss is the sum of the VOCs associated with all asset repair decisions. In either formulation, the objective function is to minimize the network overall loss or disutility (DUN) which is weighted by the relative importance factor (0–100) of each asset category (e.g. interurban versus rural).

Gain maximization models

In this model, the objective function is to maximize the utility (gain) associated with any rehabilitation decision. The utilities were defined in terms of the IRI improvement due to rehabilitation at a given year compared to a no-repair decision (Figure 2). The figure shows two IRI deterioration curves, one in case of repair at year 3, while the other curve is in case of no repair. The shaded area represents the gain due to the repair decision, which is calculated as a value of 75. The overall network gain (UN) is the sum of utilities associated with rehabilitation decisions and the objective function is to maximize this network overall gain.

To implement the above models, this research uses an advanced mathematical optimization tool, General Algebraic Modeling System (GAMS) with its powerful CPLEX solver (IBM-ILOG, 2009) that is suitable for modelling large-scale optimization problems.

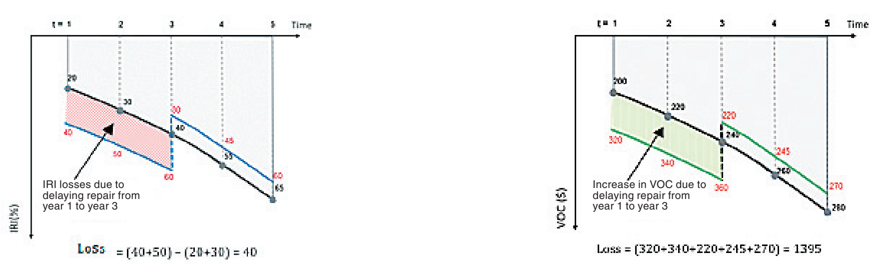
Optimization experiments and results

Based on the case study formulations, project-level analysis was first carried out using the MOST technique to determine the pool of best rehabilitation types for each asset at each decision year. Afterwards, the case study data was exported to GAMS to conduct the network-level optimization for the two loss-averse models and the gain model. After optimization, the optimum rehabilitation year for each road section in each experiment was determined. The overall network condition, in terms of the average IRI values of all assets in all years, has im-

Figure 1: Schematic of two loss formulations

(a) LOSS-1: IRI losses due to delayed rehabilitation

(b) LOSS-2: Users' vehicle operating costs (VOC)

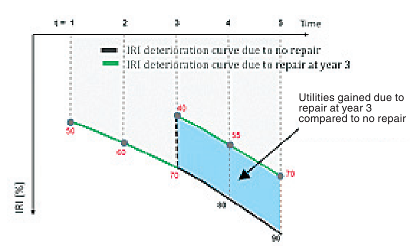


— IRI deterioration curve due to repair at year 1
— IRI deterioration curve due to repair at year 3

— VOC deterioration curve due to repair at year 1
— VOC deterioration curve due to repair at year 3

Figure 2: Schematic of utility (gain) information

GAIN-1: Utility due to repair



— IRI deterioration curve due to no repair
— IRI deterioration curve due to repair at year 3

proved compared to the original value (1.7 without any repair), using a budget limit of $8 million/year. The comparison of results is shown in Table 1.

Table 1: Comparison among optimization results

POINT OF COMPARISON	GAIN-1	LOSS-1	LOSS-2
Objective Function	Max. IRI	Min. IRI	Min. VOC
Overall Condition (in terms of IRI)	1.4512	1.4517	1.5969
No. of roads selected for rehab.	702	683	281
Total Area Repaired (m^2)	992,529	1,017,365	836,899
Total Length Repaired (m)	543,290	540,800	467,640
No. of roads with area >10000 m^2	2	2	20
No. of roads with area within 5000 and 10000 m^2	17	22	25
No. of roads with area within 2000 and 5000 m^2	119	123	63
No. of roads with area within 1000 and 2000 m^2	225	218	64
No. of roads with area < 1000 m^2	339	318	109

From Table 1, the following observations could be made:

- All experiments provided good solutions that represent different mechanisms for infrastructure fund-allocation, thus giving the decision maker credible options to choose from.
- The Gain-1 model provided the best overall network condition. Loss-1, however, is better than Gain-1 with respect to the total road area repaired (row 5). Both methods are very close in the method of selecting the roads for rehabilitation, where the funds are allocated more to small-size road sections (rows 10, 11), thus being able to fund many roads.
- Loss-2 allocated funds differently from Loss-1. It allocates more funds to much larger sections (rows 7, 8), hence, this model ended up consuming the budget on much fewer roads (total is 281).

Comparing the results of Gain-1 and Loss-1 experiments shows that the results are comparable. This is so because the two experiments use IRI to directly represent either gain or loss to the authority that owns the assets. The Loss-2 experiment, on the other hand, showed a different result by considering a social loss aspect for the users rather than for the authorities. This proves that incorporating the behavioural aspects of stakeholders changes the fund-allocation results and that the traditional utility maximization can lead to an unrealistic economic analysis.

Conclusions

Funding for construction and infrastructure projects is, in essence, an economic decision that is often made by economists and politicians who are more concerned about economics than about the performance issues that concern engineers and asset managers. This research, therefore, shed some light on integrating the two worlds of behavioural economics and construction/infrastructure asset management. This integration is part of ongoing research by the authors to benefit from the wealth of well-established theories in the behavioural economic and the microeconomic domains to provide rational economic reasoning behind construction/infrastructure decisions. ■

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Selling AEC Knowledge Over the Cloud

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The increased amount of knowledge acquired over time within the construction industry has created an opportunity for improving the industry's operations. Companies need to implement efficient knowledge management practices and use new emerging analytical tools to capitalize on this opportunity.

Thanks to the advancement in cloud computing and information technology, online knowledge management and data analytics can now be offered online. The opportunity to sell knowledge online is enabled by three main factors.

First, the role of data in conducting business processes has increased. The market has changed – clients are looking to get more added value for their projects and operations. Most of the project data involved is electronic; as a result, online data management is a perfect match for analyzing this emerging "big data" and transforming it into added value analytics.

The second enabling factor is the advancement of models and algorithms used in the construction industry, such as simulation models, BIM (building information models), business process models, and supply chain models. These new tools contain a comprehensive view of the whole business or project; they capture not only the graphical aspects of the project, but also intelligence information that has great potential to improve the performance of a project or a business.

The third enabler is the need of construction firms for customized software services that assist their business needs. These software systems gather an overwhelming amount of information that, if analyzed, could produce insightful information, patterns, and trends to help improve business operations and construction supply chains. AEC (Architectural, Engineering and Construction) companies need to reconsider their business models to capitalize on the emerging market opportunities.

In this article, we propose three business models based on knowledge management and business analytics: Business Management and Intelligence, Design Optimization and Innovation, and Software Customization and Real Time Analytics. Each of the proposed business models aims to capitalize on the value hidden in certain types of construction industry data, including market data, design data and software data. The objective is to transform these meaningless data into meaningful knowledge through applying analytical activities and information technologies tools to help exploit the value within "big data."

Business models as a map for change

Business models have emerged as a powerful tool that assists companies with re-engineering their operations and business processes. A business model is simply a map that defines the value, operations and financials of a business. It identifies the main components of any business, such as financial streams, logistical streams, customer segments, and the added value proposed to customers.

In order for companies to concentrate more on added value services and customer needs, they must modify their business models to cope with the changing environment. The analysis of business models has emerged recently as one of the most powerful tools for an organization to reinvent itself, mainly due to the increased penetration of information technology and the spread of trans-national business ventures. A survey showed that 70% of CEOs emphasize the importance of integrating technologies and business strategies, and that 30% of their innovation activities focus on developing and modifying their business models (IBM, 2006). The main objective of redeveloping a business model is to formulate a vision and approach for a company to reinvent its value proposition and its offerings to customers.

E-business vs. selling online knowledge

There is a significant difference between online knowledge selling and e-business. E-business transfers the same business processes from the traditional face-to-face methods to a virtual platform. This has been manifested in the AEC industry mainly through online procurement systems and e-bidding. Owners, contractors, and suppliers can now access an elaborate online marketplace to trade and buy goods and services. Instead of submitting bids in paper format, contractors can now submit bids via web sites. In many cases, other transactions such as billing and field reports are also done online. Effectively, the change was from bricks and mortar (physical) to clicks and mortar (electronic) business channels (Linder and Cantrell, 2000).

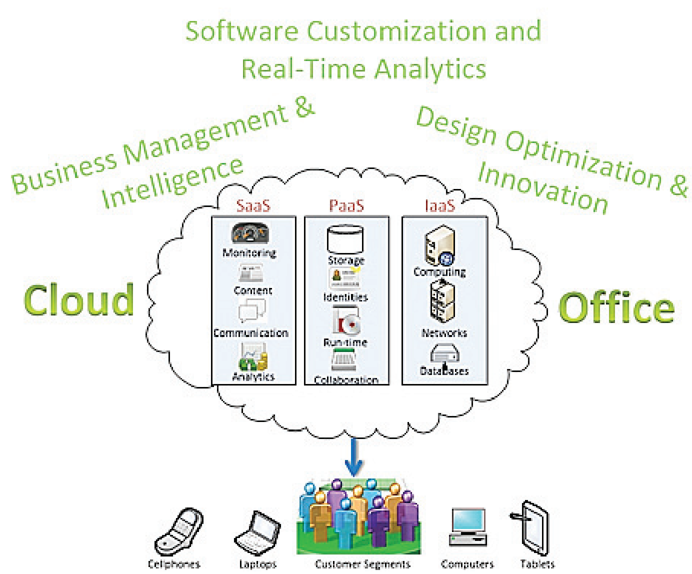
In addition, online knowledge selling differs from e-business in that it provides customers with added value wisdom and intelligence about relevant data within their business processes. Data analytics is one of the top emerging tools in many industries; it changes the way that companies do business through delivering improved operations and a competitive advantage (Mckinsey, 2013). Data analytics allow firms to concentrate more on the big decisions, enabling better optimization and leading to more revenues and business opportunities (Court, 2012). Unlike e-business, knowledge services not only take advantage of online business transactions, but they also offer added value in the form of wisdom about the business processes and operations. Thanks to the advancement in cloud computing and information technology, online knowledge management and data analytics can now be offered online beyond the limited application of e-business.

Cloud computing as a business channel

Cloud computing is the main enabler of the proposed business models. It acts as the main channel delivering the value to the customers. Cloud computing is an emerging technology that has created an opportunity for a business model that provides on-demand computational services through accessing a shared pool of customized computational resources (software or hardware) offered to users in a convenient way (Chang et al, 2010). Cloud computing technology lowers the cost of technological infrastructure for small and medium firms that would want to benefit from computing-intensive business analytics. Cloud services offered are divided into SAAS (Software As A Service), IAAS (Infrastructure As A Service), and PAAS (Platform As A Service) (Marston et al, 2011).

- Infrastructure As A Service stores and manages all project information. It provides a secure environment for data sharing across all project stakeholders. This streamlines the updates to any project activities, enhancing decision-making and conflict resolution. The idea is not only to offer storage, but also to offer knowledge management and data mining tools that contribute to business analytics and information intelligence.
- Software As A Service offers customizable web based software and applications tailored to the customer needs. These web-based applications offer project stakeholders problem-solving and communication tools. The applications create reports and generate intelligence to measure the progress of various business activities and generate recommendations for decision makers.
- Platform As A Service offers web-based platforms that can enhance collaboration and interoperability between different stakeholders. This will optimize interaction during different project activities such as design and procurement. A good example of PAAS is Google Docs, which offers an online platform where people can work on their documents collaboratively and simultaneously.

Running a cloud-based office depends on three main enablers: first, software applications to monitor the business, analyze data, and enhance collaboration and communication between different business parties. Second, platforms which identify all business stakeholders and coordinate their activities, in addition to managing knowledge related to all business activities and processes. Third, cloud infrastructure capabilities such as computing power, networks, and data storage tools. These cloud services are used to deliver the final value to customers where they can conveniently access it on their computers or any mobile devices.



Proposed business models

The business models proposed in this article act as additions to the traditional models currently implemented by AEC firms. The added value we propose depends on exploiting wisdom and intelligence out of the dissipated knowledge in the construction market. The combination of cloud-based channels and traditional channels will ensure better coordination between the market stakeholders, as well as produce insightful analysis of different market data that assist in decision making and provide better insights about the business processes.

Business Management & Intelligence Model: In this model, an AEC firm (or a consultant) is to use its knowledge of the

AEC domain, industry structure, and related information to advise customers (such as owners and contractors) about how to configure a project. This model includes setting the scope and scale of the project, selecting partners (especially in international ventures), analyzing risks, evaluating alternative finance schemes, and selecting and developing contractual relationships. The consultants can help contractors and suppliers in bid development, compliance issues, risk assessment, and formalizing suitable contractual agreements. For smaller contractors and suppliers in developing countries who want to work in internationally-funded projects, registering with a consultant who is doing such analytics can, on one side, open business opportunities for them, and on the other side, protect them from engaging in unclear deals with unknown owners and/or financiers.

Traditionally, business intelligence was achieved through discussions between customers and senior/experienced members of the consulting firm, whereby they entered a rational debate and discussion about these issues; they developed recommendations based on benchmarking previous cases and analyzing the context of the project, along with formalizing the needs of the customer. Thanks to advances in data analytics, a good part of this work can be conducted by using advanced algorithms for analyzing "big data." A study showed that if companies unlock the value within their data through applying data analytics activities, they can see 5 to 6% higher productivity and market gains than those of traditional competitors (Biesdorf, Court and Willmott, 2013). After the initiation of a project, consultants can also track and analyze project performance data and advise customers about productivity levels and areas of low performance to improve the project's performance.

Design Optimization and Innovation Model: This business model offers specialized and value-added design services to customers. For example, many small design firms do not have abilities to use BIM in their designs; a consultant can offer the service of transferring non-BIM (or even 2D designs) into BIM-compliant designs. BIM-based designs are by nature multi-stakeholder, which complicates the management of design processes and data flow. There is an opportunity for offering services to manage the flow of data and the design changes in such a complex environment. BIM models could also be used to optimize designs through checking for errors or mismatches, in addition to optimizing the whole design to be more efficient. The design could also be cross-referenced and linked with best practices, which guarantees more efficiency and optimized designs for the client. The services proposed include design tailoring. A specialized consultant can exploit the value within a BIM-based design through developing a set of algorithms to study the optimality of that design or its compliance with different codes, or to tailor the model to enhance its LEED or energy credentials. In summary, the model offers customized design services to the customer through coordinating, optimizing and certifying the design process.

Software Customization and Real-Time Data Analytics: This business model addresses two related domains. The first focuses on customizing software systems to meet the needs of a specific firm. Most AEC companies use software systems to manage their internal or external operations. In many cases, these software systems do not match the work needs of customers. A knowledge-savvy AEC company can work in the area of developing special applications or plug-ins to help customize software systems to the needs of the user. The usage of this software could be scaled up or down according to customer needs to ensure the least IT expenses.

The second angle of this business model relates to the increasing role of smart facilities in the AEC industry. These facilities range from smart buildings, to smart bridges, to smart signals. A wealth of data is generated from these facilities; however, they are typically under-used. A knowledge-savvy firm can develop means to collect real-time data from these facilities and conduct relevant analytics to measure performance and suggest enhancements. There is a business potential in analyzing the data gathered from these software systems to produce added value wisdom to the customer about their business processes and supply chain management. The wisdom produced from this data analytics process will enhance the operations of the supply chain or facility and offer the client decision making tools that can enhance its business operations.

Conclusion

There is a huge opportunity rendered by the increased role of knowledge management within the emerging knowledge economy. The value within the "big data" can be exploited using business analytics and information technologies such as cloud computing that acts as an efficient channel for delivering added value services to the client. Construction firms must re-consider their business models to efficiently cope with the dynamic business environment. Three business models for selling online consulting knowledge have been presented that help construction companies improve their performance and also generate business opportunities. ■

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Cultivating Life Cycle Thinking in the Construction and Management of Civil Infrastructure Systems

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Civil infrastructure systems consist of built assets such as buildings, water and energy systems, transportation infrastructure, and public utilities. These systems interact with the natural environment all over their life cycle. Their construction and operation significantly contribute to resource depletion, energy consumption, waste generation, greenhouse gas emissions and climate change. Such impacts have long-term effects on the natural environment, human health and well-being, as well as on economic competitiveness. These global pressures have been steering the adoption of cost-effective construction and operation systems, and encouraging the incorporation of environmental and socio-economic performance into asset management processes.

In practice, construction and asset management strategies mainly rely on cost-benefit analysis with limited attention given to triple bottom line (TBL) sustainability criteria, including environmental, social and economic issues. In recent years, however, sustainability assessment in the context of construction and asset management has gained global popularity. Life cycle assessment (LCA) has been proposed to integrate environmental concerns such as climate change and resource depletion in decision making (Reza et al. 2011; ISO 14040 2006). This article aims to discuss state-of-the-art of life cycle approaches in the construction and management of built assets. In addition, some recent developments in LCA-based tools are briefly discussed.

LCA provides a methodological framework for evaluating environmental performance over the life cycle of a product, process, or an activity. A comprehensive effort has been made towards the standardization of LCA by the International Standardization Office (ISO 14040 2006). LCA considers the environmental impacts of a product (e.g. a construction project, building, or road) in various categories, such as resource depletion, climate change, acidification, eutrophication, ozone depletion, tropospheric ozone (smog) creation, and toxicological stress on human health and ecosystems. LCA's "cradle-to-grave" approach, which follows a systemic and rigorous step-by-step procedure, makes it unique among other performance assessment tools (Finnveden et al. 2009). The LCA framework considers all phases of a product's life that have environmental impacts, including raw materials acquisition, product manufacture, transportation, installation, operation and maintenance, and ultimately recycling and waste management (Lippiatt 2000). LCA has a wide application in diverse areas, including the construction and infrastructure industry.

Although LCA has become a recognized approach for assessing comparative environmental performance, many scientific methods of LCA are still under development (such as the ultimate impacts on human and ecosystem health). It has been argued that LCA remains fundamentally at the trial stage and has not yet been integrated within practice (Finnveden et al. 2009). Nevertheless, life cycle thinking has gained increasing attention recently and has evolved as a viable approach, i.e. as a life cycle sustainability assessment (LCSA) approach.

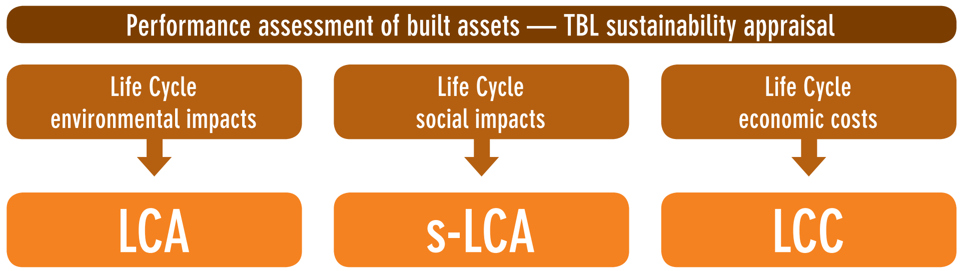
The LCSA approach is under continuous development to provide a technical basis for assessing the environmental performance and associated socio-economic costs related to the design, construction, operation and disposal of built assets and infrastructure systems. The LCSA approach not only includes impacts on the natural environment, but also has the capability to evaluate and integrate socio-economic factors. Life cycle costing (LCC) estimates the overall cost of different design options, whereas social life cycle assessment (s-LCA) evaluates social impacts on stakeholders such as workers, consumers, and local communities. Figure 1 provides a basic framework for LCSA with a focus on the TBL impacts of built assets and infrastructure systems.

LCSA for construction and asset management is a complex process. Several studies have identified framework deficiencies and provided suggestions to improve the evaluation process (Reza et al, 2013). The gaps and inconsistencies include issues related to functional units, system boundaries, goal and scope, and data availability (Santero et al, 2011). In many cases, the definition of a "system boundary" for a built asset or an infrastructure system is complicated due to lack of transparency. The definition, in general, ignores a building's service life, maintenance, and rehabilitation activities and relies on subjective weighing schemes. There is a pressing need for a transparent and comprehensive LCSA approach for construction and asset management that can guide stakeholders to reliably evaluate the TBL impacts of construction, operation and maintenance.

Research initiatives at UBC

The life cycle management (LCM) research program at the University of British Co-

Figure 1: Life cycle sustainability assessment (LCSA) approach for built assets and infrastructure systems



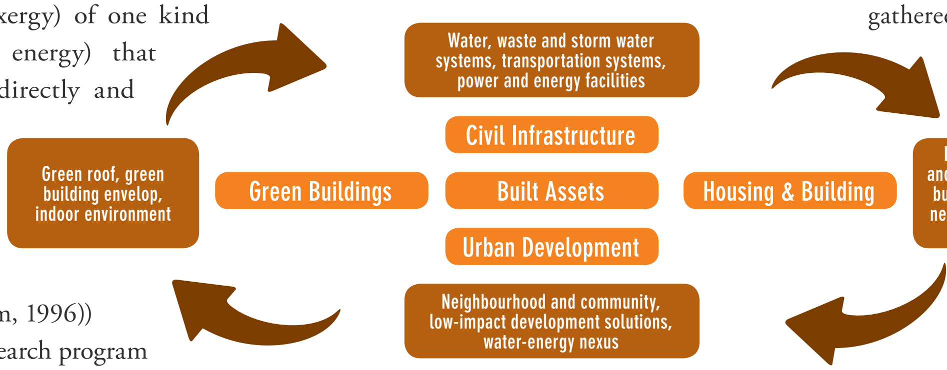
lumbia (UBC) has been actively engaged in developing novel and pragmatic approaches for sustainability and environmental performance assessment. The newly developed LCM laboratory at UBC is equipped with state-of-the-art hardware and software to conduct both micro and macro level life cycle assessments for engineering products and services. The lab has facilities to observe any engineering operation/process through high resolution wireless cameras and to analyze the collected data using state-of-the-art life cycle databases. In addition to LCA software, the lab is equipped with building information modeling (BIM), human health risk assessment, and statistical data analysis software.

The LCM research program is currently involved in both basic and applied research related to emergy-based LCA, uncertainty evaluation in LCA, water and carbon footprint assessment, s-LCA, and risk-based LCA. (By definition, emergy is “the available energy (exergy) of one kind (usually solar energy) that was used up directly and indirectly to generate a resource, product, services or activity.” (Odum, 1996))

The LCM research program has developed many innovative methods and systematic processes that can assist asset managers and urban planners in making informed policy decisions. This research program is committed to advancing life cycle research and practice by cross-fertilizing disciplines and professions, and popularizing a sustainability paradigm. Figure 2 outlines major research initiatives at UBC’s LCM laboratory.

In recent research, an Emergy-based Life Cycle Assessment (Em-LCA) framework was developed to integrate emergy synthesis, LCA, LCC, and s-LCA, for sustainability appraisals of different building and infrastructure systems. The Em-LCA framework was applied to paved roads and building systems. A cradle-to-grave LCA approach was followed in these case studies (Reza et al, 2013). The Em-LCA framework was implemented to classify life cycle inflows/outflows and to deliver a quantitative characterization of the associated impacts of the selected building and infrastructure systems. Further, the Em-LCA results were integrated into several sustainability performance indicators.

Figure 2.: Research initiatives at UBC’s LCM laboratory



The results of the case studies were used as a basis to create a decision support tool to estimate the life cycle sustainability performance of different design alternatives. The decision support tool has enabled the incorporation of TBL sustainability objectives in decision making for construction and asset management. The Em-LCA can be applied during the project design phase as an advanced LCSA approach to select the most sustainable and technically applicable construction and asset management solutions.

In a similar project, a new green building rating system, “Em-Green,” was developed. This sustainability evaluation system is a user-friendly framework for the building and construction industry in Canada. Em-Green aims to obviate the deficiency of existing building rating systems by covering all building life cycle stages by considering local construction practices in Canada. This framework incorporates a spatial-based, green building framework for sustainable decision making that consists of various modules, including: emergy synthesis, LCA, LCC, and macro-level water and energy models. Using multi-criteria decision analysis (MCDA) methods, these modules are gathered in a GIS-based model to assist in sustainable decision making for green buildings by offering local solutions (Hossaini Fard, 2012).

The green building group in the LCM lab is working on developing an asset management framework for green building products such as green roofs and green walls. They integrated LCSA with advanced MCDA techniques to evaluate the “greenness” of building products. This green building evaluation framework aims to minimize uncertainties in LCA-based decision making. Detailed LCSA analysis proved that the current green roof technologies are not sustainable over their life cycle (Bianchini and Hewage, 2011). The team has studied the potential use of construction and demolition waste in green roofs with encouraging results.

The urban development group in the LCM lab is studying the water-energy nexus for sustainable neighborhoods. During the past 10 years, the "water-energy nexus" has emerged as an important way forward to sustainable policy development (Scott et al, 2011). Since water and energy resource use are interdependent, there is a need for integration in policy and research (Maas, 2010). Some potentially valuable approaches include conservation practices that incorporate resource recovery from water facilities. Emerging concepts such as radiant, geo-thermal, and steam-based heating systems were analyzed over their life cycle.

In conclusion, the construction industry should strive to improve its sustainability performance. Accordingly, construction and asset management must be supported by LCSA frameworks for accurate and reliable sustainability performance assessments. There is an urgent need to cultivate life cycle thinking among asset and construction managers and custodians of public infrastructure systems in Canada to make more informed policy decisions that support not only the present, but also the future generations. ■

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The Construction Productivity Improvement Officer: A Case Study Approach

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Success in the dynamic and growing construction industry has been heavily dependent upon the effectiveness of project management (PM) practices, tools and techniques that go hand in hand with the operational aspects. More effective, more successful and stronger PM tools and techniques have been in demand for decades and a great deal of intellectual ability, time and money has been spent on exploring the opportunities for better performances. Many researchers have reiterated that the industry needs more scrutiny of industry and market trends, and needs to exploit these when the opportunity becomes available. Boussabaine and Duff (1996) have stated that the factors that actually affect productivity at the site level continue to be topics of considerable research and the subject with the most impact. The nature of the problem, however, has been identified as multifaceted. One significant area the researchers have focused on is ways and means of productivity improvement. The concept of a Construction Productivity Improvement Officer (CPIO), a person dedicated to planning, implementing, monitoring, and evaluating all the construction productivity-related activities in a project was introduced by Ranasinghe and Ruwanpura (2011), under productivity improvement research funded by the Natural Sciences and Engineering Research Council and construction industry partners in Alberta.

Background

According to the revelations of many productivity performance, time motion or tool time studies, general worker time spent on a direct work related task, which is commonly called direct tool time, lies between 40-60% of the total time spent on the task by an individual worker. Around 40-60% of the total worker time has been spent on either the supporting tasks or totally non-productive work tasks (Choy and Ruwanpura, 2005, AACE International Recommended Practice No. 25R-03, 2004). Thomas et al (2004) and McTague, B. and Jergeas, G. (2003) also had concluded through their productivity studies that only one-third to one-half of the worker's time was spent on direct work activity. The core idea of this research was to introduce some sustainable ways and means to reduce this non-productive time and to make that time positively contribute towards improved productivity.

The concept of CPIO and its associated tools, techniques and models were introduced based on a series of comprehensive pilot studies conducted on construction sites involving scrutinizing selected construction activities, by way of close monitoring, tool time recording and analyzing, and performance (input/output) investigations. It was evident from these pilot tests that there was a huge potential for productivity improvement and that the management of these sites could benefit from improved productivity at almost all the construction sites researchers investigated. Researchers have quantified and priced the marginal tool time improvement of these selected activities and have identified myriad reasons leading to unproductive time. The whole idea behind the introduction of CPIO was to identify these potential tool time losses along with the underlying reasons, and to collaboratively plan to reduce these losses and divert the increased tool time towards productive output.

The following productivity-related issues have been identified from the preliminary pilot investigations:

Table 1: Models of implementation of CPIO

#	MODE OF OPERATION	MAIN CHARACTERISTICS
1	Single site full capacity implementation	One CPIO per site, start from the planning stage, stationed in the site, covers the entire project site and all the operations
2	Multi-site full capacity implementation	A single CPIO for more than one project at a time. Possible staggered implementation, when the crucial work in a site is done.
3	Single site-team implementation	For a large site, a CPIO and a team will be appointed. Do productivity improvement covering entire operation. Implement based on the initial feasibility analysis.
4	Multi-site reduced scope implementation	Single CPIO in a site. Select the most appropriate tools and techniques, do only in selected critical activities.
5	Concepts only implementation	There is no additional person for CPIO role. CPIO tasks assigned to a single or multiple persons at the site. Selected tools and techniques will be implemented.
6	Collaborative CPIO operation	CPIO cost is shared between the owner and the contractor, ideal for specific contracting types such as cost plus contracts and partnering.

- Lack of accountability to productivity improvement tasks;
- Absence of productivity plan indicating the productivity targets and suggested operations;
- Lack of company top management awareness, commitment and initiation in on-site productivity improvement;
- Poor recognition of the impact of productivity improvement on project profitability;
- Lack of pre-planning for the potential on-site productivity issues;
- No continuous tracking of overall and activity-specific productivity performances;
- No records or documentation of project and activity productivity levels at the site;
- No active participation of the relevant trade partners in activity productivity performance evaluation efforts;
- Absence of integration mechanism for productivity improvement and loss prevention;
- No productivity conscious PM planning empowered by CPIO;
- Lack of activity-specific productivity performance forecasting and preparation approach;
- Absence of a formal measure to involve operational staff at the sites on active and collective decision making.

With these insights on the real project sites, idea of CPIO was basically introduced to address the following key areas:

- Advance planning for productivity; Bringing accountability for productivity;
- Introducing continuous and close monitoring of productivity performances;
- Identifying potential performance inhibitors and planning for corrective measures;
- Continuous improvement; Integrating productivity improvement with the other tasks.

Proposed CPIO working models

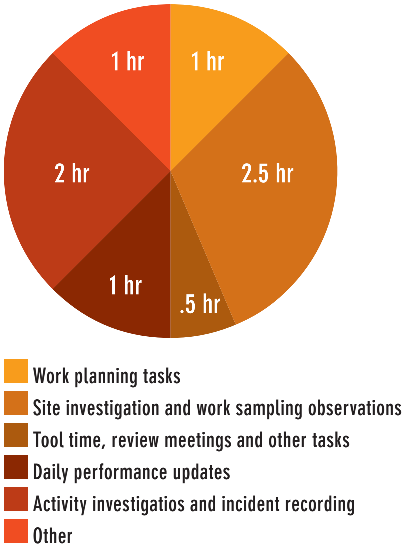
It was expected at this proposed level of the new CPIO concept, for the industry to have a reserved perception about the implementation and the costs and benefits of the system. Researchers suggested a multitude of potential implementation models (Table 1) considering differences in contracting methods, differing levels of expected adoptability, type and stage of the project, and risk averseness of the companies.

Based on the pilot implementation work, researchers suggest the daily tasks and the time allocation for a CPIO, assuming a single CPIO application for an average site. These time allocations shown in Table 2 and Figure 1, can vary depending on the productivity improvement scope, stage of the construc-

Table 2. Frequent CPIO activities and proposed time allocations

TASK	DURATION, HOURS	FREQUENCY
Work planning tasks	1	Daily
Site investigation and work sampling observations	2.5	Daily
Tool time and review meetings and other tasks	0.5	Daily
Daily performance updates	1	Daily
Activity investigations and incident recording	2	Daily
Other unplanned	1	Daily
Tool time and work process reporting	4-6	Weekly/monthly
Weekly and monthly progress meetings	2-3	Weekly/Monthly

Figure 1. Proposed time allocation for CPIO daily tasks



tion and the CPIO mode of operation and the work shift.

Challenges and risks

Ranasinghe and Ruwanpura (2012) have introduced the following as the identified barriers to the implementation of the CPIO role:

- Lack of acceptance due to the current construction management setup;
- Lengthy adoption time to realize the real benefits of the CPIO;
- Additional cost requirement to implement the CPIO position;
- Cross-functional misalignment with other areas of operation (e.g. quality, safety and health);
- Finding the ideal candidate for the position of CPIO;
- Lack of supporting practical evidence of CPIO implementation works to convince the project parties on adopting the concept.

Based on the identified risks, a risk management plan as depicted in the Table 3 has been introduced as one of the preliminary tasks go along with the CPIO implementation work.

CPIO implementation case studies

Realistic implementation challenges of a CPIO as had been explored in the research and pilot study phase have been tested by the researchers with three case studies. A great deal of time was invested on each case to identify the feasible implementation model for a CPIO to suit the specific expectations of the main stakeholders.

Case Study 1: CPIO implementation in a building construction site in San Francisco (over 9 months).

The research team had detailed discussions with the management and operational staff of a construction site before implementation. Prior to real CPIO implementation at the site, the research team was remotely investigating some selected activities for 2-3 months in order to identify the characteristics of the CPIO implementation work based on Method 1 (Table 1) with a reduced scope of work. Tool time improvement was recorded between 11-15%.

Case Study 2: Pre-planning and feasibility study for a CPIO implementation for a steel fabrication facility for a construction company in Alberta.

All the tools, techniques and templates were developed with the collaboration of the client's operational staff. Management and the operational staff were in agreement with the lack of productivity planning and close monitoring in their routine operations confirming the value of CPIO. However some logistical issues prevented the CPIO implementation work. Preliminary discussions addressed many associated risks of CPIO implementation work and all was geared towards a successful implementation.

Case Study 3: Pre-implementation study and CPIO implementation for a mechanical contractor in Manitoba.

Table 3. Risk management plan

DESCRIPTION	NATURE OF IMPACT	MITIGATION STRATEGY	RESPONSIBILITY
Conflicts of interest between CPIO and other staff	Poor cooperation for CPIO from the other staff	Clear role definition and division of responsibility prior to implementation	Construction Project Manager (CPM), with the contractor's human resources (HR) team
Poor buy-in from other staff for the CPIO concept, leading to de-motivation of the staff	Poor cooperation and friction between CPIO and other staff and also poor performance	An advanced and detailed orientation of the staff about the CPIO and the commitment from top management	CPM with higher management
Insufficient power and control vested in the CPIO position	Inability to implement, coordinate, and alter the productivity improvement tasks	Clearly defined tasks and hierarchical structure, including the CPIO position	CPM with contractor's HR team
Difficulty in finding a qualified person	The CPIO concept will tend to fail	Offering attractive perks and having a thorough screening process	Contractor's HR team
Conflicts in division of responsibility and unclear roles and responsibilities between CPIO and other staff	Overlapping duties and responsibilities may create issues and friction between CPIO and staff	Clearly defined job descriptions for the site staff indicating the operations with staff	CPM with contractor's HR team
Unclear site communication structure with the inclusion of the CPIO in management process	Difficulties in getting staff support for productivity improvement initiatives	Clearly defined site communication structure indicating authority and lines of command	CPM
High expectation from the stakeholders for the immediate tangible outputs from the CPIO	Loss of confidence in the CPIO concept, proposed deliverables and improvements to the project	Clear objectives, goals and limitations of CPIO implementation communicated to the stakeholders	CPM and contractor's project management team
Unclear access, authority and dissemination of the information generated by the CPIO	Conflicts between client, contractor, engineer and sub-trades for the access and usage of the findings by the CPIO	Prior discussions and agreement of the CPIO implementation model with the relevant partners	CPM with the owner, engineer, sub-trades

A pilot test was performed after the initial discussions and awareness sessions, in order to make sure the planned CPIO implementation was feasible and to evaluate the implementation model and extent. Data collection templates, the CPIO job description, and extent of implementation were all developed collaboratively with the management, making sure the customer objectives were precisely achieved.

The possibility of CPIO implementation work complementing the ongoing Earned Value Management work within the company was also taken into consideration prior to CPIO implementation. The impact of the CPIO has been successfully recorded and is ongoing.

Conclusions and recommendations

From the outcome of the case studies it is evident that the pre-implementation planning for a CPIO plays a crucial role in defining the success of the whole implementation process. The extent of the implementation and the broader utilization of the full potential of a CPIO was completely dependent on the top management commitment to, and patronage of, the whole process. The CPIO role can vary, from being just an observer to having complete control over the productivity affairs of the construction site through the full project life cycle.

A series of discussions, which the research team conducted with the higher management who sponsored and provided patronage toward the whole CPIO implementation process and the operational staff who were affected by the installation of this new CPIO role, facilitated the smooth implementation of the CPIO on these sites and helped to plan for most of the challenges anticipated from this implementation.

Even though the researchers have developed many tools, techniques and data collection templates as part of the CPIO tool box, the selection of the most appropriate set of tools for each implementation job, upon careful investigation of the project requirements and the extent of implementation required, positively impacts the intended results. CPIO implementation also brought promising results when followed by a tailor-made implementation approach developed with detailed pre-implementation discussions and pilot studies. The concept of a CPIO and the basic high-level implementation framework stays the same, while the approach, tools and techniques bring best results when customized and tailor-made based on the ground situation.

As the role of CPIO necessarily entails the continuous evaluation of crew performance, some natural friction between the crews and the CPIO is anticipated. Readiness of the workforce prior to CPIO implementation eliminates some potential inhibitors for successful implementation. Researchers experienced that the best results would be expected when the CPIO is introduced at the initial stages of the project with a limited scope and then has the scope extended as the project progresses. ■

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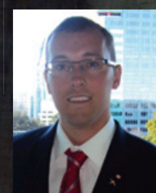

Award Winner

Mr. Philippe St-Germain

Mr. Philippe St-Germain of the University of Ottawa, Department of Civil Engineering, for his thesis entitled: "Numerical Modeling of Tsunami-Induced Forces on Free-Standing Structures using the SPH Method" under the supervision of Dr. Ioan Nistor and Dr. Ronald Townsend.

Award Winner

Ms. Sandra Proulx-McInnis

Ms. Sandra Proulx-McInnis of the Le Centre Eau Terre Environnement (Université du Québec, Institut National de la Recherche Scientifique) for her thesis entitled "Caractérisations hydrologique, topographique et géomorphologique d'un bassin versant incluant une tourbière minérotrophe fortement aqualysée, Baie-de-James, Québec" under the supervision of André St-Hilaire.

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Lauréate

Mme Sandra Proulx-McInnis du Centre Eau Terre Environnement (Université du Québec, Institut National de la Recherche Scientifique) pour sa thèse intitulée "Caractérisations hydrologique, topographique et géomorphologique d'un bassin versant incluant une tourbière minérotrophe fortement aqualysée, Baie-de-James, Québec" sous la supervision d'André St-Hilaire.

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