SEEDS International Conference

Developing a Sustainable Urban Environment through Teaching Asset Management at a Postgraduate Level

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Keywords: Sustainability, Education, Asset Management, Urban Environment, Building Information Modelling,

Abstract

More than half of the world's population live in cities, with this proportion expected to grow over time. Cities and other urban areas tend to be significant consumers of natural resources and producers of greenhouse gases. The effective sustainable management of their assets is therefore critical in ensuring that they achieve and maintain a positive living environment that provides safety and security for their citizens while achieving sustainable management goals. A significant contributor to the achievement of this goal is a modern and sustainable asset management process that facilitates well planned and managed roads and other infrastructure, such as water supply, sewerage and communication systems.

Developing, managing and maintaining a sustainable urban environment is underpinned by comprehensive asset management systems, supported by other processes, such as risk management, management of engineering projects and taking a strategic approach to managing assets on a life cycle basis. The use of advanced approaches, such as building information modelling (BIM), geographical information systems (GIS), improved asset planning and design, and automated data collection supports these systems.

The effective education of engineers and other professionals in advanced asset management is considered to have a major role in developing the strategic asset management leaders who can implement these advanced processes. To meet this requirement, the University of Southern Queensland has developed and updated on an ongoing basis a postgraduate engineering management course in asset management, along with related courses in areas like risk management and project management. These courses take a strategic approach to developing their students and are integrated where possible with relevant standards and systems. Initiatives to incorporate modern asset development and management approaches through utilising them to educate strategic asset managers of the future are discussed.

INTRODUCTION

The Population Division of the Department of Economic and Social Affairs of the United Nations has estimated that globally, more people live in urban areas than in rural areas, with 55 per cent of the world's population residing in urban areas in 2018. This proportion is projected to be 68 per cent by 2050 (United Nations, 2019). It has been estimated that cities responsible for 75 percent of global carbon dioxide (CO_2) and other greenhouse gas (GHG) emissions. Key aspects of urban life, such as transportation and buildings are considered to be major sources of these emissions (United Nations Environment Programme 2020).

While producing significant percentages of GHG emissions, cities and other urban areas also have the potential to be affected by climate change and its consequences like global warming, which in turn is associated with rising sea levels, extreme weather events and the potential to facilitate the incidence of tropical diseases, all of which have the potential to significantly impact on the urban living environment, including services, housing, infrastructure, work conditions, living conditions, safety, security and health. Thus it is important that cities, including the key building and construction sector undertake initiatives to minimise the impact of climate change and improve their resilience to the effects of this impact. It is been stated that such success is likely to be possible only through a coordinated approach to fight climate change, an approach that is being taken by many cities through initiatives like using renewable energy sources, cleaner production and limiting industrial emissions (United Nations Environment Programme 2020).

One process for achieving a sustainable urban environment is to use a strategically focused life cycle asset management approach, based on theoretical and practical principles, in conjunction with good project and risk management to the ongoing planning, development and management of the city's transportation, building, infrastructure and other assets that are significant sources of the operational and embodied energy that produce GHG emissions in the city. The objective of the discussion in this paper is to discuss an approach to achieving this goal, using the following process, which is further developed and illustrated in Figure 1.

- Review the issues in urban sustainability management
- Discuss the role of asset management in facilitating urban sustainability
- Using the example of existing study courses, discuss how this role can be facilitated by postgraduate education in sustainable asset management, supported by other courses
- Discuss the effectiveness of these courses in facilitating urban sustainability and develop conclusions.

ISSUES IN URBAN SUSTAINABILITY MANAGEMENT

The issues in urban sustainability are underscored by a study of 79 cities, undertaken by the C40 Cities Climate Leadership Group in conjunction with the University of Leeds, the University of New South Wales (Australia) and Arup, which found that over 70 per cent of greenhouse gas (GHG) emissions come from utilities and housing, capital, transportation, food supply and government services. These emissions included the supply of goods and services outside city boundaries (such as power, externally manufactured goods and water supplies), which while originating outside cities form a significant component of their requirements (C40 Cities 2018).

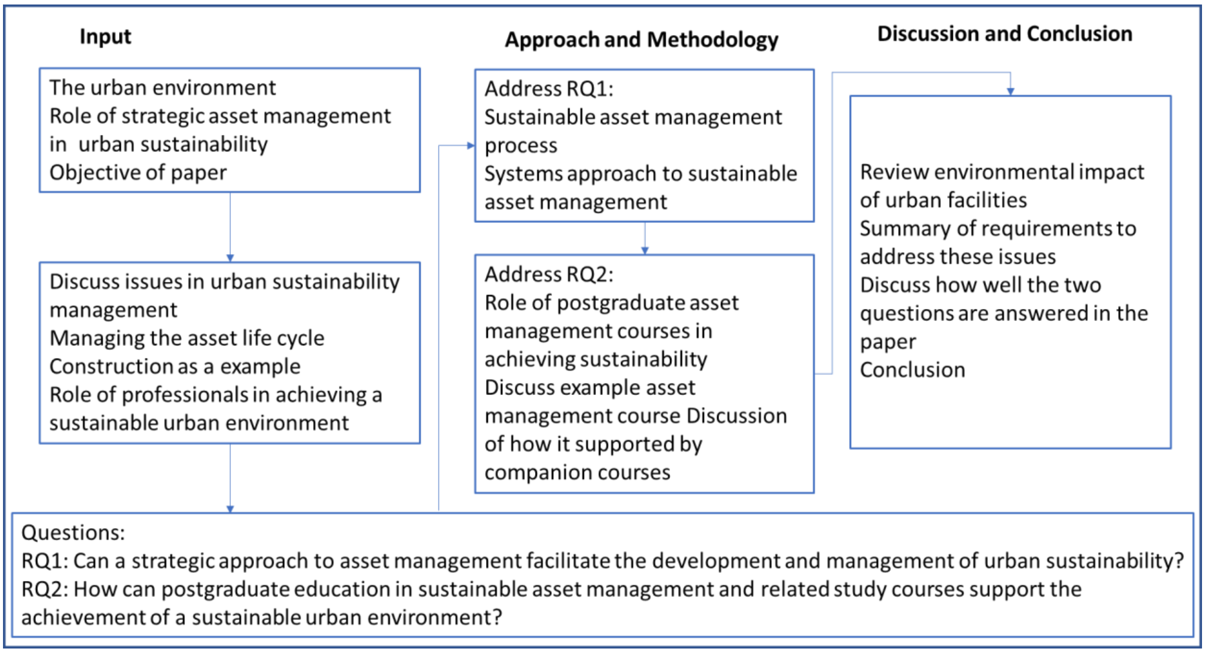

Figure 1. Conceptual Framework of Paper

These issues occur throughout the asset lifecycle, which can be divided into the phases of planning, design, construction, operation (including maintenance) and retirement. Planning and design are important, as decisions made in them impact on the subsequent phases of the lifecycle. Managing the carbon footprint of the city will also require addressing the 17 sustainable development goals of the United Nations, which from an urban point of view include social aspects (for example, poverty, hunger, health, education, safe and secure cities); resources (for example, water, energy, sustainable consumption and production), resilience, climate change and sustainable ecosystems (United Nations, 2015). It will also require coordinated activities by professional engineers, asset managers and other built environment professionals. For example, while professional engineers are responsible for planning, designing, delivering and maintaining significant public and private works, they are also expected to undertake sustainable engineering practices and adhere to sustainable management principles (Engineers Australia, 2014), a requirement that is reinforced in the Engineers Australia Code of Ethics and Guidelines on Professional Conduct (2019). Such requirements would be expected to guide the actions of engineers and other professionals in minimising the impact of urban development and management on the world's carbon footprint.

The asset lifecycle components in which emissions occur are primarily construction and operation, including asset retirement. As an example, construction is a significant contributor to the carbon footprint of cities. It has been estimated that building construction and operations (including the manufacture of materials and products for buildings construction, such as steel, cement and glass) accounted for 36% of global final energy use and nearly 40% of energy-related carbon dioxide (CO_2) emissions in 2017 (International Energy Agency and the United Nations Environment Programme, 2018). The World Green Building Council has similarly stated that buildings account for 39% of energy-related global CO_2 emissions, of which 28% comes from operational carbon and 11% arises from the energy used to produce building and construction materials, which is usually referred to as embodied carbon (World Building Council, 2019). A further perspective on the energy produced by the construction sector is an Australian study that used a two-region globally closed model of Australia and the Rest of the World found that from 2009 to 2013 the embodied energy component of the construction sector was a total of 20% of Australia's carbon footprint, consisting of 1.9% of direct GHG emissions and 18.1% of embodied energy, which was mainly attributed to electricity, gas and water; materials and construction services (Yu et al., 2017).

These examples show that it is important to achieve a sustainable urban environment that minimises the percentage of greenhouse gas emissions and its impacts on the carbon footprint. At the moment, this percentage is high, both in cities as a whole and in the development and management of their buildings and infrastructure, which are activities in which engineers and other built environment professionals have a significant role. While the process of achieving a sustainable urban environment has commenced, there is much to be achieved. Doing so requires sustainability focused, life cycle oriented built environment management that spans all life cycle activities, such as planning, design, construction, operation, maintenance and retirement. This process will require sustainable management of the design, construction and operation of the built environment, and include activities like recycling materials, strategic use of information systems, and the minimisation of waste in the construction and operation of assets. Through good planning and ongoing management, this approach assists city government and other parties to maximise sustainable management of the urban built environment, such as power generation, roads and transportation, water and sewerage management and greening of the urban environment itself. As engineering and other built environment professionals would be expected to have a leading role in developing a sustainable urban environment, their education in its development and implementation is expected to be a significant component of this process.

Therefore, there are two questions required to be addressed. They are:

- RQ1: Can a strategic approach to asset management facilitate the development and management of urban sustainability?
- RQ2: How can postgraduate education in sustainable asset management and related study courses support the achievement of a sustainable urban environment?

THE ROLE OF ASSET MANAGEMENT IN FACILITATING URBAN SUSTAINABILITY

The sustainable asset management process

In order to address the first question (RQ1), the first step is to consider the management of environmental factors in the urban environment. Addressing this step requires an understanding of the terms "asset" and "asset management", followed by consideration of the lifecycle of urban assets and whether using a sustainable asset management approach is a suitable process for managing these factors.

While there are a number of definitions of assets, a good definition is that from the International Asset management – Overview, Principles and Terminology Standard (ISO5500:2014), in which an asset can be defined as an "item, thing or entity that has potential or actual value to an organisation." In turn, the term "asset management" can be defined as a "coordinated activity of an organisation to realise value from assets" (International Organization for Standardization, 2014a). These definitions indicate that assets and their management have an economic value. They also demonstrate that such management of assets requires to be undertaken in a way that maximises their life cycle performance.

From a strategic point of view, effective asset management requires the recognition of a range of stakeholders – owners, managers, users and external stakeholders, who may be impacted by the asset although they may not use it. From a management point of view, assets should achieve a number of outcome oriented goals in areas like provision of adequate level of service at the required level of demand, meeting serviceability and life cycle performance goals, having optimum service lives and achieving maximum life cycle benefit and lowest life cycle cost subject to other requirements (University of Southern Queensland, 2020a).

Managing the emissions produced by the construction phase, for example, requires the use of sustainable construction processes. One approach is to consider the use of alternative materials in the construction process that are energy efficient to develop and install, and that where possible are recyclable. For example, advanced materials like fibre composites, green cement and concrete, use of recycled materials in road surfacing and other innovations are improving the sustainability of the construction process from the material aspect. Other issues in managing construction phase emissions include managing energy usage and the negative impact on environmental pollution from the component activities of construction and refurbishment. Low at al. (cited in Medineckiene, Turskis & Zavadskas, 2010) identified five aspects (energy efficiency, water efficiency, environmental protection, indoor environmental quality, and other green features that focus on the adoption of green practices and new technologies with potential environmental benefit) as areas of environmental impact of the construction process. Managing these issues requires assessing the combination of variables affecting matters like building (or infrastructure) production impact on the environment, and financial and social conditions, through using approaches like multicriteria analysis (Medineckiene, Turskis & Zavadskas, 2010). Sustainable management of the other phases of the asset like cycle will similarly require consideration of their component activities.

Systems Approach to Sustainable Asset Management

To facilitate the delivery of sustainable asset management, assets are best managed by an asset management system, which can be considered a set of interrelated and interacting elements of an organisation, with the function of establishing the organisational asset management policy and objectives, and the processes needed to achieve them (International Organization for Standardization, 2014a), accompanied by a strategic asset management plan. Such an asset management system would normally have the components of leadership, planning, support (of the system), operation, performance evaluation and improvement (International Organization for Standardization, 2014b).

An asset management system would be expected to be underpinned by an asset management information system, supported by an asset register (or inventory), and contain a number of sub-systems, such as financial management, maintenance management, operations management and decision support. Information technology tools like building information modelling (BIM), geographic information systems (GIS), and tools like the use of radio frequency identification (RFID) for identification and tracking, along with managing big data, can further aid sustainable life cycle management through facilitating construction and demolition waste management (Kabirafir et al., 2020).

As an example of these technologies, BIM initially commenced as a three-dimensional model (3D), which can express visually and in other ways the three primary spatial dimensions of width, height and depth. It has subsequently added additional dimensions of 4D (planning) and 5D (costing), and has further developed additional dimensions, including sustainability and facilities management (Charef, Alaka & Emmitt, 2018). These last two dimensions make BIM of particular interest with respect to sustainable asset management, as it is not only able to record detailed information in digital form about buildings and infrastructure components and their functional parts (Xu at al., 2014), but has the potential to be a useful tool to optimize the environmental performance of building elements and buildings (Habibi, 2017). Chong et al. (2017) noted that the research trend of BIM for sustainability was apparent in the design, construction, use of products and materials, and energy efficiency. Zhang et al. (2016) suggested that the use of BIM in the architectural, engineering and construction industry is helpful for environmental sustainability monitoring and management over a building's full life cycle, and could be used at the conceptual design stage to build sustainability into the design solution and allow sustainability to become a key component of the design, construction, and delivery of a building.

At the same time, the use of BIM in its current form has limitations. Charef, Alaka & Emmitt (2018) undertook a systematic review and online survey of architectural, engineering and construction stakeholders across Europe. They found that while there was agreement about the first five dimensions (up to cost) of the BIM model, there was some confusion among the practitioners using the 6th and 7th dimensions (6D and 7D) of BIM (sustainability and facilities management). Lu et al. (2017) reviewed the use of BIM for green buildings However, the use of BIM for facility management (FM) during the operation phase is still limited and found that there was weak interoperability among various green BIM applications, limited capability of BIM applications supporting the construction and operation phases of projects, lack of industry standards, low industrial acceptance of green BIM applications, low accuracy of BIM-based prediction models and a lack of appropriate project delivery methods. Thus, while technologies like BIM have considerable potential for application to the sustainable development and management of urban buildings and infrastructure, there are a number of issues that need to be resolved before they can be fully used by practitioners.

In summary, a strategic approach to asset management, using a well-structured and managed lifecycle approach supported by good systems, is able to strongly facilitate and contribute to the development and management of urban sustainability. This contribution is achieved through planning and design that consider sustainability, a sustainable approach to construction, use of sustainable and recyclable materials, use of good processes underpinned by an asset management system aligned with corporate objectives and supported by good information systems, a focus on minimising the use of energy, and an understanding and consideration of sustainable management goals.

POSTGRADUATE EDUCATION IN SUSTAINABLE ASSET MANAGEMENT

A strong understanding of sustainability focused asset management principles by engineers and other professionals practising in this field is essential for effective sustainable outcomes to the asset management principles. Therefore, to address the second question (RQ2) on how postgraduate education in sustainable asset management and related study courses can support the achievement of a sustainable urban environment, it is necessary to consider how such education develops the knowledge and skills required by professionals in engineering and the built environment in asset management.

One course offered in this field is the postgraduate course Asset Management in an Engineering Environment (University of Southern Queensland, 2020a), which is part of the Master of Engineering Science and other engineering and other built environment postgraduate coursework programs offered by the University of Southern Queensland. This course, which utilises the principles of good teaching principles like student centred learning (Biggs, 1999) and authentic assessment (Gulikers, Bastiaens and Kirschner, 2004), adopts a strategic life-cycle approach to managing engineering assets and has a strong sustainability emphasis. Following an introduction to asset management, this course initially discusses the strategic asset management principles of the strategic asset management framework, the asset life cycle and asset management economics, before focusing on the application of these principles to asset management operations and maintenance, integrated asset management and asset management systems. It concludes with a discussion of current and emerging issues in asset management. The course has a strong stakeholder oriented sustainable asset management focus, which is illustrated in Figure 2.

Figure 2 emphasises the interaction between physical infrastructure assets, which are founded on the natural environment, and are linked with the economic and social environments; and the various communities of stakeholders in the assets (owners and managers, the community of asset users and the external community, which are people or organisations served indirectly by the asset or are affected by the asset). Balancing these requirements results in the asset being required to meet the three environmental, economic and social components of sustainability. This sustainable asset management theme is maintained throughout the course.

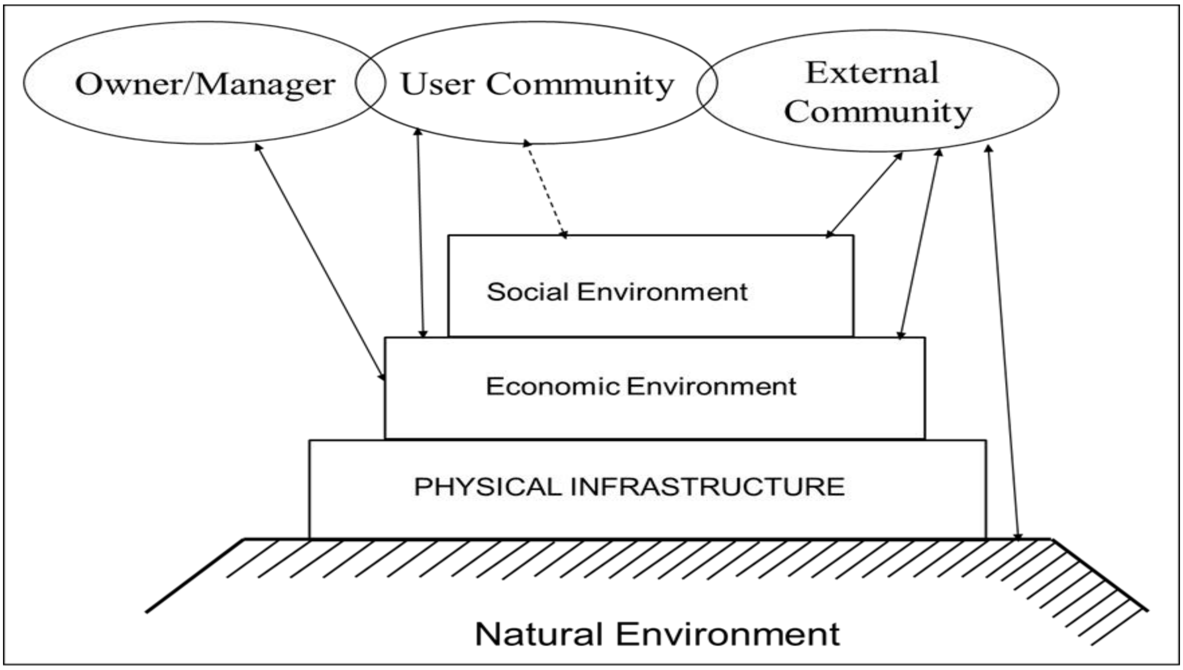

Figure 2. Interaction of Communities and their Environments – Asset Management in an Engineering Environment. Source: University of Southern Queensland 2020a.

This course, which was first offered in 2004 as an online course only, is taught in a blended learning mode, and is studied both at the Toowoomba (Queensland, Australia) campus of the University and online. It is normally assessed by a single assignment worth 50% of marks, and an examination worth 50% of marks. In 2020, 67 learners were enrolled in this course, of which 44 studied online and the balance of 23 studied on campus. The main question in the assignment asks learners to assume the role of an asset manager who has been tasked to manage a middle level engineering asset that has several issues, and are required to develop a plan to rectify this position. The other questions are normally in asset depreciation and the use of engineering economics principles. The examination asks learners to apply principles learnt in the whole course to example engineering applications nominated by them.

While generally learner feedback at the end of the course has been quite positive, there have also been some less positive comments, including about relevance of the course to particular engineering and built environment disciplines such as surveying, and concerns from time to time about the currency of some of the material taught in the course. A possible weakness of the course is that, being strategic in nature, it does not deal with asset operations and maintenance in the detail required by practitioners. To address these concerns, the course is regularly reviewed and updated to include current professional issues and advances in asset management, including information systems. Recent initiatives have included strengthening the use of asset management standards and incorporating sections on BIM and GIS. These sections are expected to be expanded over time. In particular, it is has been stated that that there is a growing need for universities to provide their graduates with appropriate BIM-related skills in architecture, civil engineering, building construction, and construction project management programs, including both teaching and practising the collaboration and integration required for successful implementation (Forsythe et al., 2013). Future expected developments of this course include a stronger emphasis on sustainable and recyclable materials, and on energy management. Other initiatives have included making the course relevant to a wide range of engineering and built environment initiatives, such as including an example relating to an electricity power distribution network.

The focus of this course on sustainable engineering and built environment has been strengthened by the development and delivery of companion courses. One of these courses is Management of Technological Risk (University of Southern Queensland, 2020b), which teaches risk management in accordance with the ISO 31000:2018 Risk Management Guidelines (international Organization for Standardization, 2018), and then applies the principles taught to the management of project risk and process risk. This course assists asset managers and other engineering and built environment practitioners to understand and manage the risks associated with good asset management principles. A further course, Advanced Engineering Project Management (University of Southern Queensland, 2020c), which includes a specific section dealing with sustainability in project management, teaches the management of engineering projects at a project and program level, which is a valuable skill for implementing sustainable asset management principles, including the sustainable management of construction activities.

The above discussion has answered the second question with respect to how postgraduate education in sustainable asset management and related study courses can support a sustainable urban environment. Such support can be provided through a strategically focused postgraduate asset management course with a strong sustainability orientation that is supported by companion courses in related areas like risk management, project management and other related areas, all of which are regularly updated.

DISCUSSION AND CONCLUSION

Urban facilities consume significant natural resources, are significant emitters of greenhouse gases, and have other impacts on the natural environment. The built environment, and in particular its construction and operational life cycle phases, is a major source of these emissions as well as contributing to other negative impacts on the environment such as waste and pollution. Addressing these issues from a sustainable urban environment point of view will require the achievement of relevant global sustainable development goals for the assets that comprise the buildings and infrastructure of cities, using a strategic asset management approach. It would also require coordinated activities by engineers, asset managers and other built environment professionals responsible for their management. These professionals, many of whom are required by their professional organisations to practice sustainability, would be expected to have the knowledge and skills to effectively achieve the objectives of sustainable urban development and management. Two questions, one on whether a strategic approach to asset management can facilitate the development and management of urban sustainability (RQ1) and the other on how postgraduate education in sustainable asset management and related courses can support the achievement of a sustainable urban environment (RQ2), have been accordingly been proposed to provide a framework for addressing the development of the necessary skills to achieve this goal.

The first question (RQ1) has been addressed through developing an understanding of the strategic asset management process, the standards that support it, stakeholder management and its requirements, including construction and the use of advanced asset management systems. While it is recognised that further development of the strategic asset management process is required, the role of strategic and forward thinking asset management in developing a sustainable approach to asset management has been confirmed. This process is contingent on ensuring that this process is current and addresses key issues. For example, the uncertainty about what the sixth and seventh dimensions of BIM (sustainability and asset management) represent requires resolution, as both dimensions are significant for sustainable asset management.

To address the second question (RQ2), a postgraduate course in asset management in an engineering environment, along with supporting courses in risk management and project management, has been reviewed from the point of view of how well it deals with sustainable whole of life asset management. While enhancements to this course in areas like application to a wider range of engineering disciplines and the further development of course material on information systems like BIM and GIS is required, it is concluded that a strategically focused postgraduate engineering asset management course with a strong sustainability focus can, with the support of suitable companion courses, provide the necessary theoretical underpinning to enable engineers and other built environment professionals to effectively develop and manage a safe and sustainable urban environment. Complementing this course and its companion courses in the future with a broader sustainable engineering and management course that addresses global sustainable development goals would further enhance its contribution to a sustainable and liveable urban environment.

In conclusion, the development, maintenance and ongoing management of a sustainable urban environment, with a view to reducing its carbon footprint, minimising its waste, and increasing its liveability, is essential. Strategic, whole of life asset management of this environment, along with development of engineers and other built environment professionals through postgraduate education in sustainable asset management, complemented by appropriate companion courses, are considered key components of this process. Ongoing enhancement of these courses and the future addition of a broader sustainable engineering and management course would be expected to further enhance the education and development of professionals charged with the development and management of a sustainable urban environment.

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