Development of Sustainability Professionals from a Geomatics Context : Experiences at the University of Calgary

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SUMMARY

It is becoming increasingly recognized that the sustainable development of infrastructure is critical for the long-term well-functioning of societies. With this increased recognition has come the expansion of professional opportunities in sustainability-related fields such as infrastructure asset management. In this paper, the potential for geomatics professionals to be leaders in these fields is presented, as sustainability consulting requires expertise drawn from geomatics related fields such as of cadastral/land management, monitoring, remote sensing, stakeholder engagement, and public policy development.

Additionally, this paper outlines developments within the Department of Geomatics Engineering at the University of Calgary in creating educational content that allows geomatics students and working professionals to develop skills in the rapidly expanding field of sustainability consulting. This includes the provision of certification opportunities with several internationally recognized asset management and sustainability bodies such as the World Partners in Asset Management and The Institute for Sustainable Infrastructure. An overview of course content and its intersections with geomatics fundamentals is provided.

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1. INTRODUCTION TO SUSTAINABILITY

Economic development is a key part of robust societies – availability of goods and services is necessary for a community to function, and individuals generally benefit from the ability to provide the same.

However, societies are becoming increasingly aware that unrestrained development puts strains on the environment, depletes resources and creates the potential for increased social disparity. At the same time, it is also being recognized that observed and anticipated changes in climate will affect local carrying capacities, as well as placing stresses on supporting infrastructure (including land, which can be considered the basis of all infrastructure).

The need for this balance is not necessarily a new concept – in 1987, the United Nations defined “sustainable development” as “development that meets the needs of the present without compromising the ability of future generations to meet their own needs.” (Brundtland, 1987). This was an evolution from the narrower focus of *environmentalism*, as *sustainability* generally considers four distinct dimensions including:

- Economic - opportunities for growth and improvement in peoples’ material quality of life and availability of services
- Environmental - recognition that all life depends on the proper functioning of complex natural systems and that minimization of impacts on these systems is desirable
- Social - balancing the needs of the individual with the needs of the community, including considering issues such as safety, equity and access to services
- Governance - ensuring that decision making by governments and organizations are transparent, accountable and properly include the considerations of impacted stakeholders

Within this context, the nature of activities considered “sustainable” can differ significantly while at the same time having impacts that span dimensions. For example, a company’s minimization of energy consumption would be a classic demonstration of sustainability from an environmental perspective, but may also result in long-term economic savings through reduced operating costs. Similarly, a company’s efforts to increase diversity on its corporate board of directors would be considered sustainable from a social and governance perspective.

However, due to the multi-dimensional impacts of activities, activities considered sustainable in one dimension may have impacts that actually have a negative impact in another. For example, a company might reduce its energy consumption though process efficiencies which result in reduced requirement for labour, which would have negative social impacts. In addition, the economic benefits may differ depending on the stakeholder considered (the individuals working at the company versus the company's owners).

The importance of the multi-dimensional nature of sustainable development was further highlighted by the United Nations in 2015, with the establishment of seventeen distinct, but interlinked, Sustainable Development Goals (SGDs) (UNGA, 2015). These goals are wide ranging, from a goal of ensuring "clean water and sanitation" (SDG 6) to "fostering peace, justice and strong institutions" (SDG 16). Interestingly, while SDG 9 directly relates to "industry, innovation and infrastructure," the United Nations estimates that infrastructure such as roads, water systems and utility networks directly influences 92% of all SDG goals (Thacker et al, 2018).

In stride with this heightened awareness of the fundamental importance of well-functioning infrastructure has been an increase in interest in rigorous, data-driven processes to optimally manage such assets. This has led to considerable growth in the related sub-field of Infrastructure Asset Management (IAM) – an area in which surveyors have a considerable role to play and in which the University of Calgary has been focusing on developing educational opportunities for new geomatics graduates.

1.1 Infrastructure Asset Management

Put simply, IAM seeks to balance the whole-lifecycle cost of maintaining and operating infrastructure against risks that might impact service delivery and the level-of-service desired by end-users. In this way, end-users get reliable services that they actually need while minimizing long-term costs. More broadly, ISO 55 000 defines asset management as "the coordinated activity of an organization to realize value from assets." (ISO, 2014).

The practice of IAM combines data on infrastructure usage and condition to predict the risk of asset failure and its remaining lifespan. As well, IAM involves considering various maintenance scenarios, their costs and respective impacts on asset condition to optimize the maintenance plan and the timing of eventual asset replacements. Importantly, IAM goes beyond simply considering the initial acquisition costs of infrastructure to incorporating likely operations and maintenance costs over the entire period the service will be provided.

Stated differently, infrastructure asset management is a system of processes, software and data that let us make smarter decisions on how to develop, maintain and operate infrastructure by answering the following questions :

1. What assets does a community own?
2. What services do the assets support now and in the foreseeable future?
3. What condition are the assets in and how do they degrade over time?
4. What are the risks if an asset fails?

5. What are the total costs of acquiring, operating, maintaining and disposing of the assets in a certain way?

As an example, consider the transportation network of a hypothetical town, consisting of paved and unpaved roads of varying widths. In this town, roads are improved reactively based on congestion, and maintenance of a given road is only implemented once the community complains about significant potholing or rutting of the road, leading to temporary closure of the road. No significant forward-looking estimation of repair costs is considered, and instead maintenance and operations occur within the envelope of available funding. The result of this is likely to be increased cost due to planning inefficiencies, periods where no road access is available due to unforeseen closures and generally poor road condition.

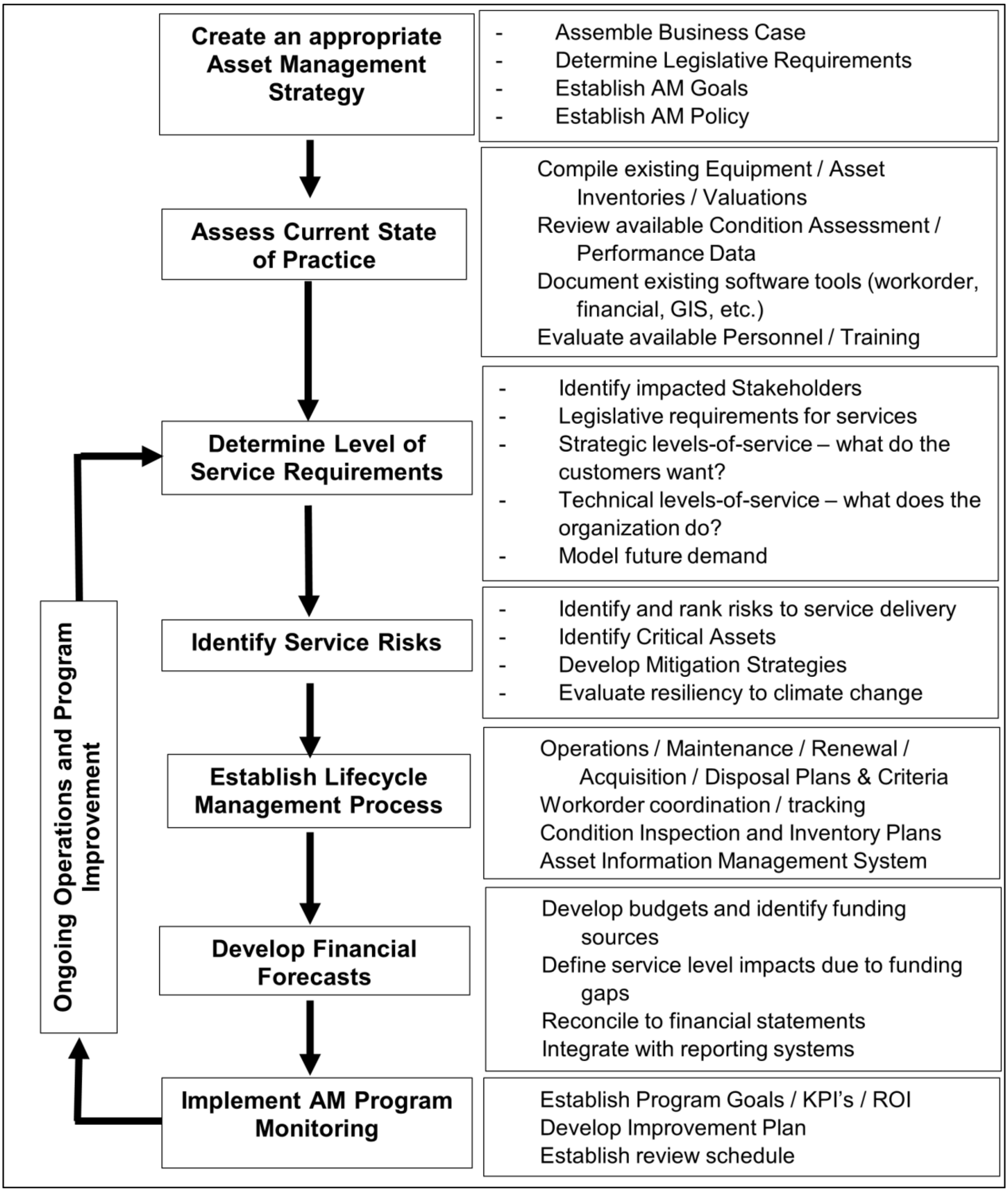
On the other hand, if a robust IAM practice is implemented, one would start by explicitly establishing an overall goal of optimizing the overall lifecycle costs of the road construction and maintenance while minimizing the risk of unexpected failures for the majority of community members. Achievement of this goal would involve an asset management plan that would likely feature the following :

- Inventory of current road network, including location, road type and daily traffic count
- Assessment of population density and traffic patterns with forecasting preferably 20 years into the future based on expected growth of the community
- Establishment of road functionality level-of-service criteria based on usage (e.g. paved multi-lane roads for high-traffic areas, gravel roads for low-density areas)
- Acceptance of minimum road quality level-of-service criteria (e.g. ride comfort rating) based on consultation with residents
- Development of expected deterioration curves per road-type, allowing for prediction of road condition based on age and usage
- Implementation of regular condition inspection of roadways to allow verification of deterioration models and to calibrate remaining expected road life
- Development of multiple pavement maintenance options, including cost estimates, impacts of road lifetime extension, and disruption of access

With these elements in place, data from actual road usage and condition would then be combined with various preventative maintenance scenarios to iteratively develop long term budgets and schedules for road maintenance and improvement. In this way, unexpected risks of road failure and closure would be minimized, overall road condition would remain acceptable, and costs optimized through the ability to schedule and plan for work in advance.

This overall process is shown diagrammatically in Figure 1. The framework shown has been used by the author in practice on several asset management projects (Radovanovic, 2021) and is based on recommendations from the International Infrastructure Maintenance Manual (IPWEA, 2020).

Figure 1 : Generalized Infrastructure Asset Management Process



A key element in IAM is the identification of appropriate level-of-service for an end-user. For example, not every town needs 8 lane concrete freeways, while unpaved roads may not be suitable for high volume traffic areas. Careful identification of current and future demand allows the proper selection of assets and their design capacities. As a result, a key connection between asset management and sustainability is the concept that avoiding the construction of unnecessary infrastructure is generally one of the most sustainable approaches a community can take.

Additionally, sustainability and IAM are connected through the impact of climate change on infrastructure. Weather plays a significant role in the operation of infrastructure, as assets are designed with average climactic conditions in mind, and a certain amount of resiliency against extreme events factored in. However, as climate change drives average conditions away from a historical normal, there is a significant increase in the number of events that would have previously been considered extreme. This increased exposure to extreme weather events (and in particular, exposure to increasing magnitudes of extreme conditions) can prematurely degrade infrastructure or cause it to fail altogether. Since evaluation of potential risks to asset failure is central to proper IAM, consideration of long-term climate impacts is a key feature of any asset management plan.

2. LINKAGE BETWEEN SUSTAINABILITY AND GEOMATICS

It is well known that effective cadastral management is foundational to good land administration, which in turn supports economic development in communities (De Soto, 1993; Trewin, 1997; Enemark, 2010). Surveyors play a central role in cadastral management through a variety of activities such as

- Delineating, establishing, maintaining and interpreting boundary information
- Collection of survey information such as relative positions, elevations and coordinates to allow the geospatial description of boundaries
- Establishing geodetic control networks which allow for consistent georeferencing of coordinate information
- Preparation of plans, maps and documents (both physical and digital) that allow transmission of information with regards to boundaries

However, the above list of activities, while itself non-exhaustive, also fails to acknowledge the broader *advisory and consulting* nature of the roles that surveyors plan in infrastructure development. Although “geomatics” by definition focuses on the collection and processing of geographic data, the *practice* of surveying has always been a broader endeavour. For example, surveyors often become very familiar with local processes and requirements for land development activities and can provide a useful service to developers by advising on timelines to be expected, approvals that will be required and the likelihood of success of various development proposals. In this way, the fields of surveying and planning begin to overlap, but this is common at the boundaries of many consulting professions – consider the role of financial analysis within the accounting and engineering fields.

As discussed previously, in the case of "sustainability," there is no singular definition of a unique technical practice area – rather, it is comprised of a multitude of individual practices ranging from accounting of an organization's carbon emissions to the efficient physical operation of recycling facilities.

Overall, it should be evident that sustainability in general (and IAM in particular), relies heavily on sources of high quality geospatial data to support decision making, which is a core function of surveyors. However, the potential role of surveyors in IAM and sustainability extends beyond the narrow field of data collection, as surveyors also hold key competencies in the areas of data quality assurance, data analysis and visualization, stakeholder engagement and strategic planning. As discussed in Radovanovic and Sikkes (2021), a key opportunity for surveyors is to realize these additional skillsets and to apply them to this emerging field.

2.1 Data Collection, Validation and Quality Assurance

Good quality data provides the support for many types of sustainability-related decision making and is the natural focus of geomatics practitioners. Typical types of data related to IAM and sustainability are shown in Table 1, and many will be familiar with the sensors used to collect information required. As such, collection of these types of data provides a straight-forward entry point for surveyors into the IAM industry.

If surveyors understand the intended end use of data within an asset management system (and in particular, the actual questions that the system itself seeks to answer), then they are better positioned to provide input into data collection specifications and to recommend collection design and appropriate sensor selection. In this way, the surveyor enters an advisory role at project initiation, as opposed to playing the part of a commodity data collector.

Unfortunately, as will be familiar to most readers of this paper, there exists a serious discrepancy in the general public's understanding of the difference between "data" and "verifiably good data." This is no different in the sustainability and IAM worlds, where data is often assumed to be of infinite precision and accuracy once it is entered into a database.

Nevertheless, since many sustainability and IAM studies require extrapolation of current conditions to future states, understanding the quality of data is critical to develop appropriate sensitivity analyses and error estimates. Proper assessments of these qualities becomes significant when triaging risks to identify the most critical risks to mitigate under limited budgets.

An additional interesting opportunity for surveyors within IAM is the validation and verification of 3rd party data. Asset management often involves the aggregation of asset information from multiple different sources – for example, road alignments may be derived from an open source linework repository, while underlying utilities might be determined from field locates. The geospatial quality and consistency of such data can vary considerably, and supporting metadata is often sparse. In such situations, surveyors have significant domain expertise in the likely methods that were used to collect such data and the possible pit-falls involved in their use. This expertise can be further leveraged by assisting organizations in the development of geospatial standards relevant to the collection of asset inventory data to ensure consistent georeferencing practices, capture methodologies and accuracy standards.

Table 1 : Sample of measurement types and sensors used in Infrastructure Asset Management (based on Radovanovic and Sikkes, 2021).

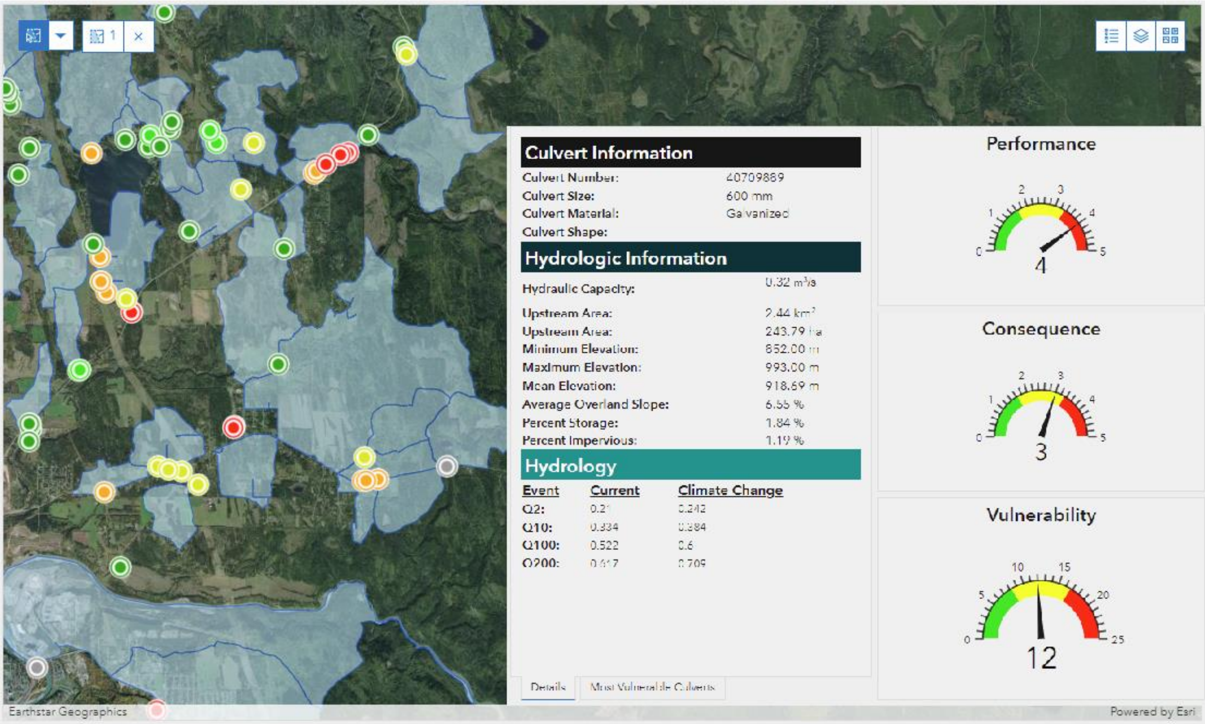
Asset Type	Level Of Service	Measurement Type	Sensors Used
Roads	Pavement Condition	Depth of potholes, extent of cracking	Mobile Laser Scanners, Laser Profilometers, GPS-enabled observational surveys
Roads	Traffic Capacity	# vehicles / hour	Traffic counts with tablet-based collector applications, video recording systems
Sewer networks	Pipe condition	# blockages / 100 m	In-pipe video cameras, underground utility location
Stormwater	Catchment volumes	Flood modelling based on digital elevation models	Aerial LiDAR, topographic surveys
Parks and Recreation	Accessibility	# facilities with accessibility restrictions and locations	On-site surveys and assessments w/ GPS and Digital Imagery collection
Powerlines	Vegetation Clearance	Obstructions within ‘x’ m of line	UAVs, aerial and ground-based laser scanners
Powerlines	Wildfire Risk	Vegetation type, height and soil dryness	Aerial LiDAR, Near Infrared and Visible Imagery
Utility Networks	Minimization of inadvertent line strike	Location, depth of cover, network connectivity	Line locators, Ground-penetrating radar

2.2 Data Visualization

By its nature, IAM results in large volumes of data in the form of asset inventories, their locations, their interconnectivity, their condition and usage levels. While a certain amount of analysis can be completed by inspecting data tabularly, most asset management information systems (AMIS) rely on a geographical information system (GIS) to display information on assets graphically.

Such data representations are used by analysts to view geospatial correlations of asset conditions or usage patterns. For example, an analyst can quickly identify the impacts of a road closure or use a GIS interface to select all the fire hydrants within a particular neighbourhood. Additionally, GIS developers can create customized dashboards to support ongoing evaluation of asset performance, or design specialized data collection forms for condition inspections. Figure 2 shows an example of a customized dashboard created by McElhanney Ltd. to support culvert risk assessment, which prioritizes culverts for condition inspection based on existing culvert inventories and watershed modelling under extreme rain events. The resulting condition inspections for vulnerable culverts are completed in the field via a custom survey collector app, which then in turns updates the underlying culvert inventory database.

Figure 2 : Sample Culvert Asset Management Dashboard (by McElhanney Ltd.)



2.3 Stakeholder Engagement

Defining appropriate service levels requires input from end-users in terms of the values and priorities. Similarly, evaluation of risk requires considerable consultation with stakeholders in terms of what perceived outcomes of a risk may be, and what their relative severity may be. These discussions often involve multiple parties, who may have their own self-interests that do not necessarily align with others. In such situations, impartial facilitation of discussion is critical to achieve acceptable compromises. As historical arbitrators of boundary locations, surveyors have developed a reputation for integrity and impartiality, which makes them particularly well suited to the engagement activities intrinsic to most sustainability-related decision making.

2.4 Policy and Capacity Development

As an increasing number of organizations seek to adopt asset management practices, there is a rising demand for professionals who can aid in establishing the frameworks and systems required. This generally involves formulating policies for implementing asset management practices and providing expert guidance on data collection methods, software implementation, and other related matters. These processes are then generally compiled into formalized asset management plans which document how the system will operate over time, responsibilities of involved parties, and mechanisms for evaluation of the performance of the assets and the management system.

Success in deploying asset management systems also requires education of the organizations that are undertaking these practices – this has led to an increase in the range of competency and capacity building tools such as maturity or gap assessments, workshops on asset management fundamentals, and the creation of asset management toolkits and templates. For example, in recognition of the importance of IAM to support its sustainability objectives, the United Nations recently published a handbook on Infrastructure Asset Management for local and national governments (Hanif et al, 2021). Incidentally, within this handbook, the fundamental value of land as an asset to be managed is highlighted.

Intrinsic to their role in cadastral management and land-use planning, surveyors are often involved in government policy and planning work, which puts them in a good position to assist communities in the development of these closely related initiatives.

3. SUSTAINABILITY EDUCATION DEVELOPMENTS AT THE UNIVERSITY OF CALGARY

At the University of Calgary, there has been a growing realization that there is a need for expanded education around sustainability within science and engineering faculties. As a result, there has been an increase in the number of sustainability-related courses being offered across departments, such as courses on environmental engineering, urban planning, and energy lifecycle management at both the undergraduate and graduate levels.

Furthermore, the Schulich School of Engineering has recently developed an undergraduate specialization in “Sustainable Systems Engineering,” (SuSE) which is described as a “technical, transdisciplinary field focusing on how to design, integrate, and manage complex systems over their life cycles, with a goal of environmental, economic, and social sustainability’ (University of Calgary, 2023). In addition to the traditional engineering fundamentals courses taken by all students across departments, students within the SuSE specialization build their course selections around a set of topics including topics such as data analytics, renewable energy systems, sustainability economics and systems modelling. Interestingly, students are required to take both a course on probability and statistics course, as well as one on geospatial analysis, which are also required courses within the Geomatics Engineering specialization.

Within this broader trend of increased sustainability education opportunities, the Department of Geomatics Engineering has expanded its sustainability-related course selections. For example, an environmental modelling course (ENGO 583) has been introduced which provides an introduction to the creation of environmental numerical models and how they can be applied.

Significantly, the Department of Geomatics Engineering has also created two graduate-level courses on Infrastructure Asset Management (ENGO 603/605) which are known jointly as the Asset Management for Sustainable Infrastructure (AMSI) series. These courses intended to provide students with an understanding of the fundamentals of establishing an asset management system, as well as exposing them to concepts in public policy development and financial reporting – a complete listing of course topics is provided in Table 2.

Table 2 : Course Topics provided in the Asset Management for Sustainable Infrastructure course series

Fundamentals of Asset Management and Sustainability	**Advanced Topics in Asset Management – Strategy and Financial**
• Rationale of Asset Management • Role of Organizations in Service Delivery • Stakeholder Engagement • Risk Management • Asset Information Management Systems • Condition Assessment Systems • Lifecycle Cost Modelling and Optimization	• Organizational Policy and Strategy Development • International Standards in Asset Management • Canadian Requirements for Public Asset Management • Asset Management Maturity Evaluation • Infrastructure Funding Models • Alignment of Financial Reporting and Asset Management • Sustainability and Climate Resilience in Asset Management

Upon completion of the AMSI course series, students will have met the educational requirements for registration as a Certified Senior Principal in Asset Management (CSAM) with the World Partners in Asset Management (WPiAM). This course series is the first such university-level series to be so recognized by WPiAM, and as a result the series has begun to draw interest from industry as a source of qualified graduates in the infrastructure asset management field. Students taking this course series also are able to partake in significantly discounted education and credentialling opportunities as “Envision Sustainability Professionals” (ENV Sp.) through the Institute of Sustainable Infrastructure, which focuses on application of the Envision sustainability evaluation framework to infrastructure development projects.

The AMSI course series is available via a hybrid on-line/in-person/asynchronous model and tends to attract students and working professionals from both geomatics and civil engineering backgrounds. Since the creation of the series in 2022, thirty-eight students have completed the initial course, with nineteen completing the complete series. It is planned that up to thirty students per year will complete the series starting in the Fall 2023 semester, which will dramatically increase the number of students with some asset management exposure entering industry.

4. CONCLUSIONS

The field of sustainability consulting is gaining growing recognition internationally as communities seek to ensure that development occurs in a way that balances economic gains against factors such as impacts to the environment and social equity. With infrastructure playing a key role in supporting community activities, there has been a corresponding increase in the awareness of the need to systematically plan for infrastructure development and long-term operations and maintenance against community needs both present and future. Supporting this planning requires considerable data on the nature and condition of infrastructure, which surveyors are well placed to collect and mange.

However, beyond the collection of data, there exists considerable professional and advisory work to be done in the design and roll-out of such infrastructure asset management systems. To the author, this seems very analogous to the type of work historically done around the world by surveyors in developing cadastral systems and geodetic reference systems. It is noteworthy that a framework for unambiguous land ownership is often viewed as core enabler of community development , and therefore it is reasonable to expect surveyors, with their expertise in creating just, unbiased, and durable systems for recognizing land assets, to contribute to the establishment of comparable frameworks for managing infrastructure.

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BIOGRAPHICAL NOTES

Dr. Robert Radovanovic is an Adjunct Associate Professor with the Schulich School of Engineering at the University of Calgary, and a Regional Vice President at McElhanney Ltd. His specialization includes leveraging spatial data from sources such as laser scanners, unmanned aerial vehicles and geographic information systems to develop infrastructure asset inventories, monitor performance and assess risk resiliency. He is also active in the development of standards and policies with regards to the sustainable management of infrastructure and is a deputy convenor of the ISO/TC 251 Working group WG8 on developing competency/capacity standards related to ISO 55 000 (Asset Management). At the University of Calgary, Robert is currently developing curriculum content around educating students in the fundamentals of asset management, and how it ties into long-term sustainable outcomes for communities.

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