Considering Emerging Areas of Engineering Practice

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Introduction

In response to growth in emerging areas of practice, the Board of Engineers Canada has made supporting regulation for emerging areas of engineering practice a strategic priority. As part of this strategy, in 2023 the Canadian Engineering Qualifications Board (CEQB) was tasked with the development of overall guidance on the identification, assessment, and regulation of emerging areas. To help advance this priority, Engineers Canada prepared an Engineers Canada Paper (the "Paper", this document) on the regulation of emerging engineering areas of engineering practice. The Paper will provide guidance to Canada's engineering regulators (the "Regulators") on how to identify and engage with emerging areas in a manner that balances the protection of the public with the benefits that new engineering products and services bring to society.

Motivation

Advancements in science and technology provide benefit by contributing solutions to pressing societal issues, such as climate change, equity and fairness, health and disease, and economic instability. By virtue of their technical training and experience, and their position in society as regulated professionals, engineers are well positioned to research, develop, and operationalize these advances. However, these advances often require practitioners to employ novel and specialized knowledge, which might differ from established practices. Departures from established practices entails different, and perhaps unknown, risks which must be managed to fully realize the potential of advances to science and technology and to protect the public from imbalanced or inappropriate risk v. benefit trade-offs.

Canada's engineering regulators, empowered by legislative mandates from provincial and territorial governments, have an important role in managing risk associated with engineering practice. In this role, regulators must keep abreast of advances in engineering practice which are primarily led by industry while simultaneously applying an appropriate regulatory "touch" (force, timing, etc.) to manage risk without stifling innovation or growth. This, it turns out, is a remarkably difficult task, especially for novel or "emerging" areas of engineering practice. A forceful regulatory action applied when an area of practice is still in its infancy might deter uptake of professional registration/practice in the area by pushing practitioners to jurisdictions without regulatory hurdles. Conversely, the absence of, or weak, regulatory actions results could increase undue risk to the public in either the short- or long-term due to practice by unqualified persons or a weak professional practice community in the area.

To manage risk with appropriate support for innovation and growth in emerging areas of engineering practice, a framework for Engineers Canada and Regulators is necessary.

Purpose

The purpose of this Paper is to equip Canada's engineering Regulators with a pan-Canadian, agile, and risk-oriented framework that provides an appropriate level of flexibility and discretion when identifying and engaging with emerging areas of engineering practice and emerging engineering disciplines. The framework consists of a set of principles, a conceptual model (called the Emerging Field Regulation Model, EFRM) and guidance for operationalizing the principles and model for Regulators. EFRM also has a temporal aspect that accounts for the evolution of emerging areas of practice.

This Paper is focused on providing Regulators tools to make decisions about, and engage with, emerging areas of engineering practice. It does not take a position on whether Regulators should do more (or less) to regulate in a specific area. Instead, it proposes a framework and model to guide Regulators across jurisdictions in their response to emerging areas of practice and disciplines with the overall goal of facilitating a systematic and consistent approach to the regulation.

Role of Engineers Canada

One of the core purposes of Engineers Canada is to monitor, research, and advise its members, (the Canadian engineering Regulators) on changes and advances that impact the Canadian regulatory environment and the engineering profession. Another mandate of Engineers Canada is to provide services and tools that enable the assessment of engineering qualifications and foster excellence in engineering practice and regulation, while managing risks and opportunities associated with mobility of work and practitioners internationally. As such, two key functions provided by Engineers Canada are the accreditation of engineering degree programs and the development of guidelines for qualifying engineering applicants for licensure.

Engineers Canada has identified the need to support its members with the regulation of emerging areas as a priority in its current strategic plan. To this date, Engineers Canada has responded to this priority by developing tools and guidelines to support assessment of engineering applicants in specific emerging areas. However, an overarching framework of fundamental principles to guide the identification, definition, assessment, and regulation of emerging areas of engineering practice and engineering disciplines has not been available. The focus of this directional and forward-looking guidance is to establish this framework for use by Regulators, if they so choose.

Role of Engineering Regulators

Canada's 12 engineering Regulators have been entrusted by their jurisdictional governance to self-regulate the engineering profession with a mandate to safeguard the public interest and the environment. Responsibilities of Regulators include issuing licenses to persons qualified to practice professional engineering, establishing standards of professional practice, and enforcing jurisdiction specific legislation and regulations.

While there are differences across the jurisdictional regulatory systems, all regulators agree that partnership and collaboration is foundational to effective regulation. This agreement has recently been affirmed by signing a National Statement of Collaboration [1]. This statement identifies several roles and responsibilities for engineering regulators with relevance regarding the regulation of emerging areas of engineering practice. One role of particular importance is to assess the impact of any changes to legislation, regulations, by-laws, policies, programs, or practices and advocate for collaboration within their jurisdiction when making changes.

How to Use this Guidance

This Paper, and the guidance therein, has been prepared as forward-looking document with an intent to provoke discussion about emerging areas of engineering practice. It is recognized that the guidance does not necessarily align "one to one" with current practices performed by Regulators.

Canada's Engineering Regulators and Engineers Canada are the main audience of this document, with two main uses in mind:

1. Help Regulators prepare for the emergence of new engineering practices areas and disciplines and, to some extent, nurture its evolution, particularly so that engineering regulation is not "left behind" as science and technology advances.
2. Help Regulators and other interest holders who interact with Regulators select "right touch" regulatory activities while keeping in mind the level of maturity and risk associated with engineering practice in emerging areas, for the purpose of protecting the public.

Comparison to Regulation in Other Professions and Sectors

Compared to regulators in other sectors and professions, the regulation of engineering practice can be considered particularly challenging since its definition covers such a broad scope of areas. Despite, and indeed because of this comparison, it is worthwhile to note that some other regulators use and enforce scope-of-practice regulations in addition to entrusting licensees with aligning their scope of practice with their competencies. Examples of regulated sectors that use scope-of-practice enforcement are health care professionals and the legal profession. Scope-of-practice enforcements allow these regulators to create specific carved-out provisions for new and emerging areas of practice, such as tele-health care or the prescribing of medications by pharmacists, without the need to qualify professionals working in these areas for general practice. Presently, engineering Regulators in Canada do not generally use scope-of-practice regulations.

Definitions

This section motivates and defines essential terminology that is used throughout the Paper and that are expected to be useful for Regulators applying this guidance, either by directly adopting these definitions or tailoring them to meet the needs of their jurisdiction(s).

Practice of Engineering

It is acknowledged that Canadian regulators rely on different definitions for what constitutes engineering. While this Paper refers to a joint definition from Engineers Canada, this does not limit the consideration of individual regulators to use their own definitions. It is believed that the definitions used by the different Regulators are sufficiently aligned to allow meaningful use of this guidance document across Canada.

Engineers Canada defines the "practice of engineering" as any act of planning, designing, composing, evaluating, advising, reporting, directing or supervising, or managing any of the foregoing, that requires the application of engineering principles and that concerns the safeguarding of life, health, property, economic interests, the public welfare or the environment [2].

Engineering Disciplines and Areas of Practice

Engineering is a broad concept, as evidenced by the definition of the “practice of engineering” above. Regulators differentiate between different disciplines and areas of engineering practice to allow for more focused considerations. The terms “discipline” and “practice area” (or simply “area”) are sometimes used without a clear demarcation. For example, Engineers Canada strategic plan prioritizes support of regulation of emerging *areas*, while the initial request for proposal for this project refers to the regulation of emerging *disciplines*. It is useful to provide clarification about this terminology.

There is consensus that the notion of a *discipline* is broader than that of a *practice area*. The fundamental root of the term *discipline* is about *learning* while the root of the term *practice* is about *applying* or *performing* an activity.

For this Paper, an “engineering discipline” is defined as a specific branch of engineering *studies* that focus on a distinct body of knowledge of technical and scientific principles addressing specific categories of problems. Examples of engineering disciplines include civil engineering, mechanical engineering, electrical engineering, and software engineering. While not universally true, engineering disciplines typically align with undergraduate degree programs offered by higher education institutions in Canada (e.g., Bachelor of Engineering - Mechanical).

Engineering disciplines are fundamental to support specific application areas of engineering practice in industry. An “area of practice” is a specialized field of *applying* engineering principles to specific technical problems (e.g., robotics control and automation). An area of practice may be interdisciplinary in that it may be supported by different engineering disciplines. For example, practice in robotics control and automation depends on the application of engineering principles from the disciplines of mechanical, electrical, computer, and software engineering.

Industry of Practice

Engineers practice in various industries, e.g., health care, transportation, energy generation, manufacturing, etc. Some Regulators also categorize “industries of practice” in addition to areas of practice. From a pragmatic regulatory perspective this makes sense since an understanding of the industry plays a role when assessing and mitigating risk to the public and the environment. For example, an area of practice in “robotics” may be considered more critical in terms of risk to harm to humans (patients, health care providers) in the healthcare industry than in the home cleaning industry.

Emergence

Considering the engineering practice pyramid model shown in Figure 1, the emergence of a new engineering discipline normally occurs “top-down”. That is, the emergence of a discipline is driven by a societal or industry need, which leads to advances in knowledge about how to address problems related to that need. For instance, the societal need to adapt to a changing climate entails many problems in specific industrial contexts (e.g., zero-carbon energy production, storage, and transmission).

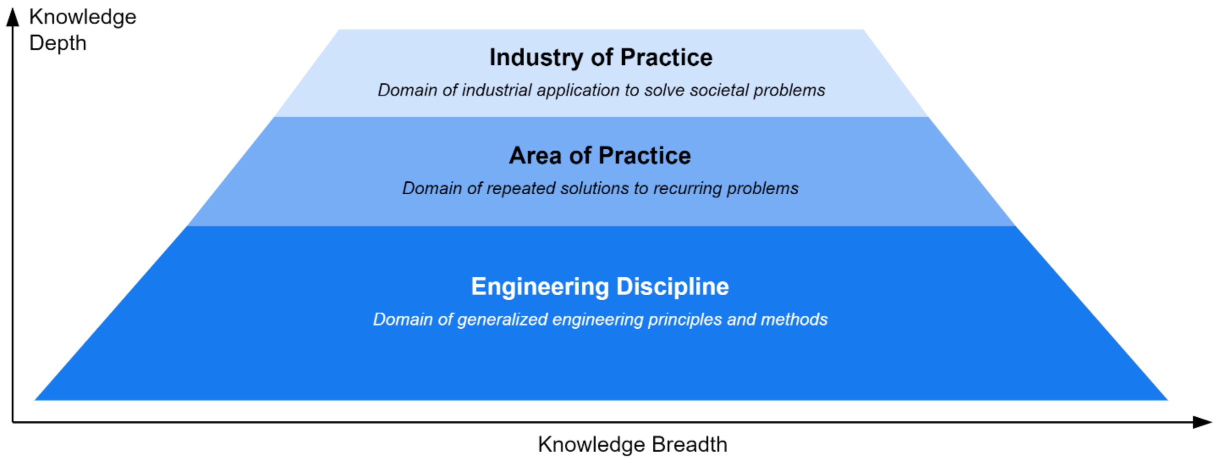

Figure 1 - Engineering practice pyramid model. Distinguishes the concepts discipline, area of practice, and industry of practice.

As industry-specific problems are solved, knowledge about how to solve them in more general contexts is developed contributing to a broader area of engineering practice. It is possible that, if the underlying industry problem(s) are adequately addressed, an area of practice will not broaden into an entire discipline. The area might continue to develop new knowledge specific to the problem(s) it aims to address, but the demand for the application of that knowledge by society might be limited.

Conversely, if there is increased demand for the knowledge held by an area of engineering practice, it might further develop into an engineering discipline. For example, to meet increased demand, higher education institutions might establish training programs intended to train many practitioners in an area of practice. The speed at which emerging areas of practice lead to the emergence of new disciplines depends on three main factors:

1. How well an area of practice is supported by the fundamental knowledge, principles and methods taught in established disciplines, i.e., the gap between school-taught knowledge and knowledge learned after graduation.
2. How much an area of practice's scope or application area differs from those of established areas of practice or disciplines.
3. The scale of demand for practitioners working in an emerging area.

Though there is often overlap in knowledge between engineering and scientific fields, it is important to distinguish between the emergence of disciplines in these fields. In the sciences, new areas of study and disciplines are driven by research advances, a "bottom up" process that has been referred to as "scientific fission" of a discipline [3]. That is, scientific study (as a pursuit of knowledge) is not necessarily driven by industrial or societal needs. Whereas, as described above, emergence of engineering areas is based on societal and industrial need.

Additional Terminology

The purpose of this Paper is to introduce a framework for managing risk as a collection of industry-specific activities (the top of the pyramid) matures to potentially become a full engineering discipline (the bottom of the pyramid). It is convenient to have terminology to refer to the collection of practices, knowledge, conventions etc. that is maturing, regardless of its explicit phase of maturity. So, in addition to the terminology introduced below, throughout this Paper the term “engineering area” is used to refer broadly to an emerging area of engineering practice or discipline without making a statement about its maturity. That is, an “engineering area” could be in its infancy, only applicable to a handful industry practitioners or could refer to a whole discipline.

Principles

A review of the literature on regulating emerging areas and consultations with workshop participants and interest holders have highlighted the importance of three principal considerations in this initiative. These principles are the basis of the framework proposed later in this Paper.

Risk Proportionality

A fundamental aspect of right-touch regulation is that regulatory force should be proportionate to the risks posed to the public and society's attitude towards tolerating such risks. Regulators are accountable to the public and must justify their decisions for public scrutiny.

Risks may be short-term or long-term. Short-term risks are often better understood when it comes to emerging areas but both kinds of risks must be considered. Risks may be unknown, including known unknowns (e.g., “we don't know how this new method of engineering biodegradable medical devices will affect the patient's body long-term”) and unknown unknowns (e.g., “we are not yet able to imagine all possible risks this kind of artificial intelligence will have on the world”).

Risk is regarded as a composition of severity (impact, damage, harm, consequence, etc.) of a negative event and the likelihood (incidence, exposure, etc.) of the event occurring. When considering risk proportionality for engineering areas, both the severity and likelihood should be considered by Regulators.

Knowledge Focus

Emerging engineering areas often grapple with uncertain knowledge. There may be uncertainty about the scope of an emerging practice area (e.g., what does an “AI engineer” do?), the technical and scientific principles that should be applied (e.g., how do we prove the correctness of an intelligent system?), and the linkage to one or more broader engineering disciplines (e.g., which engineering disciplines provide the basis for practice in “AI engineering”?).

It is important to recognize emerging engineering areas, and their associated knowledge, do not develop in isolation. Rather, they develop in a societal and industrial context that influences the growth of knowledge in the area. Existing engineering areas and domains of scientific knowledge are also likely to influence, or be the genesis of, an emerging area. For instance, emerging area might combine knowledge from several engineering areas, scientific fields, and the legal profession to develop innovate solutions to a novel problem encountered in an industrial context. The result is new knowledge about how to address a specific type of problem, which forms the basis of the new engineering area.

Time Progression

Emergence is a process over time. Therefore, considering temporal progression is important when developing guidance on regulating emerging engineering areas. Time interacts with the two other principal considerations discussed above. This interaction is particularly challenging when considering the regulation of emerging disciplines. On one hand, regulation of emerging engineering areas in their early stages is difficult because not enough is known about the risks and impacts of the area. On the other hand, regulating an emerging engineering area late might be expensive and appear overly drastic and impractical. Therefore, the form of regulatory touch should progress over time and as the pertinent knowledge solidifies, e.g., from education and awareness to enforcement.

Emerging Field Regulation Model (EFRM)

This Paper proposes a model to guide Regulators in their efforts to regulate emerging disciplines and areas of practice. This conceptual model, referred to as the Emerging Field Regulation Model (EFRM), has four parts and is shown in Figure 2 with definitions of the concepts depicted therein following in the sub-sections below.

Broadly, EFRM contains two nested feedback loops. The “inner” loop uses maturity and risk indicators to inform which regulatory actions are applicable to an emerging engineering area. The “outer” loop provides a higher-order process monitoring and improvement.

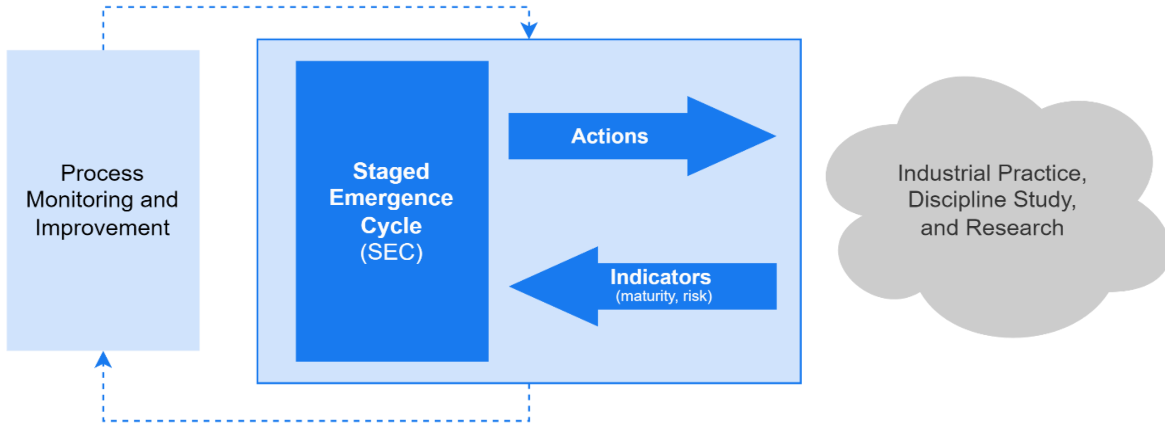

Figure 2 – Overview of the Emerging Field Regulation Model (EFRM).

The *Staged Emergence Cycle* (SEC) is a maturity model characterizing the emergence of an engineering area over time and relating time with two of the principal considerations introduced above (knowledge and risk). The *Indicators* provides a collection of measures that can be put in place by Regulators to monitor and assess the state of emerging areas in terms of both maturity and risk. Example indicators might be industry positions/roles (titles), educational offerings in emerging areas, or incident report databases. The *Actions* describes a collection of actions and tools that can be used by Regulators to control risk arising from practice in emerging areas. These include awareness and education initiatives, development of advisories and guidelines, and enforcement actions. Finally, *Process Improvement* provides guidance on how Regulators can continually assess and improve their capability and maturity with respect to regulating emergent areas. Each of these elements of EFRM are discussed in detail below.

Staged Emergence Cycle (SEC)

The Staged Emergence Cycle (SEC) is a conceptual model that characterizes the emergence of an engineering area in three stages. The stages in the SEC reflect the emergence model described by the engineering practice pyramid shown in Figure 1, which is based on the notion that the emergence of an engineering area is driven by industrial and societal need(s).

Given an emerging engineering area, the stages of the SEC are:

- **Stage 1 (Industry Recognition)** - The engineering area is recognized within specific industries as solving a specific set of industrial applications that require consideration for the safeguarding life, health, property, economic interests, public welfare, or the environment. The collection of engineering activities that are performed by practitioners to address industrial problems are recognized by a specific name (e.g., "XYZ Engineering") within the industry.

- **Stage 2 (Practice Recognition)** - The engineering area is recognized as having knowledge that is transferable between application areas and/or industrial verticals such that a *practice* (scope, competencies, methods, tools, technical standards, conventions, etc.) emerge. There is broad agreement among practitioners working in the area on what constitutes appropriate (or inappropriate) professional practice in the engineering area. The engineering area might draw on knowledge from one or more established engineering disciplines.
- **Stage 3 (Discipline Recognition)** - A widely accepted body of knowledge (e.g., the Software Engineering Body of Knowledge (SWEBOK) [4]) about the engineering area is recognized and is used as the basis for holistic education and training programs (e.g., accredited undergraduate programs) intended to equip practitioners with knowledge and skills in the engineering area.

The consideration of discrete stages in the SEC is of course an abstraction of what in reality is a continuous process of accumulating knowledge and recognition of a maturing engineering area. However, this abstraction can be helpful for regulators when deciding on how to approach the regulation of a growing field. To this end, the stages of the SEC may be viewed as "thresholds" that the engineering area surpasses as part of its emergence.

Though not formally described as part of the SEC, prior to reaching *Stage 1 (Industry Recognition)*, an engineering area must undergo a period of "genesis" (perhaps a "Stage 0") where industrial problems are identified and solved in a consistent and repeatable way (potentially many times) to establish a basis for the engineering area.

Indicators

In accordance with the principles laid out above, the regulation of emerging disciplines should be sensitive to *knowledge* (i.e., how much is understood and recognized as a generalizable body of knowledge) and *risk* (i.e., the potential for harm). Consequently, the two categories of indicators are considered: maturity indicators and risk indicators.

Indicators of Maturity

Indicators of maturity are organized by Stage in the SEC. These indicators are intended to help Regulators assess the stage of an engineering area and determine when the area has progressed from one stage to another. The use of indicators, rather than firm criteria, is intentional. It recognizes that there is not a "one size fits all" approach to engineering regulation and that different indicators might be more useful for different engineering areas and jurisdictions. Further, it is not necessary for all indicators to be satisfied for an engineering area to transition from one stage to another. Regulators applying EFRM should interpret the indicators in combination with the stage definition to judge the stage of an engineering area.

A suggested set of indicators, organized by stage of the SEC for which they are applicable, are provided in the Section titled “Applying EFRM” below. Overall, indicators for maturity are consistent with the following trends:

- As an engineering area emerges, the number of practitioners working in the area increases, which can be measured by surveying a Regulator’s professional registrants/firms or surveying employment/business trends in the area (regardless of professional registration status).
- As an engineering area emerges, the demand for education and training in the area increases, which can be measured by the existence of various professional development events and programs offered by higher education institutions.
- As an engineering area emerges, the knowledge in the area matures moving from industry/application specific knowledge to more generalized practices, which can be measured by the existence of technical standards, publications, syllabi, and training programs.
- As an engineering area emerges, the area appears more often in public (e.g., government) projects or discourse.

Indicators of Risk

Effective “right touch” regulation requires striking the *right balance* between harm avoidance and mitigating the potential for unintended consequences of regulatory actions, such as stifling innovation, inhibiting growth of a practice community, and the cost of compliance to regulatory standards. The decision on how to find this *right balance* should be informed by societal views and public priorities. Therefore, the proposed indicators of risk have three sub-categories of indicators:

1) indicators for potential harm arising from an emerging engineering practice;
2) indicators of the potential for unintended consequences (of regulation); and
3) indicators for the “risk appetite” of the public the regulators are tasked to protect.

These indicators of risk can be used to classify the risk of an engineering area. For applying EFRM, it is necessary to classify the risk into one of three levels: low risk, medium risk, or high risk. The level of risk informs, when combined with the maturity indicators, the actions that the Regulator might take to manage risk.

Importantly, since risk is highly dependent on many contextual factors, the level of risk must be assessed with a specific application in mind. For instance, it is difficult to assess risk for Mechanical Engineering as a whole discipline since some applications of Mechanical Engineering are relatively low risk whereas others can be extremely high risk.

Since an essential role of Regulators is to manage risk to the public and environment, it is recognized that Regulators might have established their own means of evaluating risk for engineering areas. The intent of this Paper is not to (re-)invent risk assessment. Rather, this Paper shows how to apply the results of a risk assessment to emerging engineering areas. If a Regulator already has an established method of evaluating risk, it is expected that EFRM could be adapted to use outputs of that method. Alternatively, the section "Indicators of Risk" below contains suggestions for indicators of risk that align the three sub-categories introduced above.

Maturity, Risk, and Uncertainty

Assessing risks associated with earlier Stages (e.g., Stage 1, less mature) tends to be more difficult than assessing risks in later Stages (e.g., Stage 2 or 3, more mature) because there is more uncertainty about the nature of the engineering work being performed. Figure 3 illustrates this concept by indicating decreasing confidence intervals for risk assessments over time while an emerging engineering area matures. The diagram shows three exemplary risk trajectories (in red, blue, and green) of an emerging field, all starting out with much uncertainty about the associated risks. As maturity increases, the green trajectory converges towards low risk while red towards a high-risk valuation. It is important for Regulators to be aware of the impact that uncertainty might have on risk assessment for an emerging engineering area.

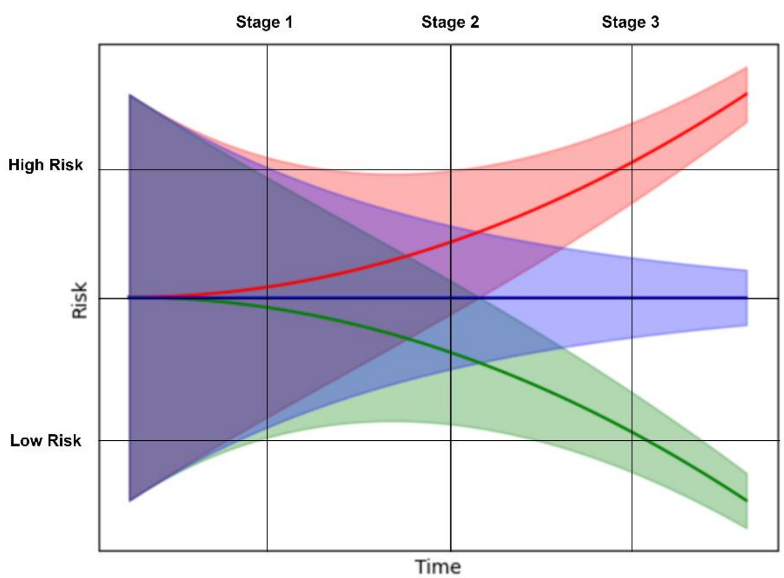

Figure 3 – Impact of uncertainty on risk and maturity.

Actions

Given an SEC maturity stage and level of risk for an emerging engineering area, as determined by the indicators described above, "actions" may be selected to manage risk of practice in the area. Different actions are applicable for different combinations of maturity and risk. However, there are overall trends in some categories to consider, which are discussed below. Concrete suggestions for Actions are provided below.

It is recognized that each Regulator operates in a context with unique industrial, legislative, and judicial constraints. The trends discussed below, and suggested actions below are intended to provide suggestions for how Regulators might apply "right touch" regulation based on the maturity and risk of practice in an emerging engineering area. For this reason, a wide range of actions have been suggested with the intent that Regulators select those that are the most appropriate for their context.

Actions Trends for Education & Knowledge

Actions in the "Education & Knowledge" category are focused on establishing and sustaining the foundational scientific and engineering knowledge that supports the engineering area.

For engineering areas with lower maturity (i.e., Stage 1), education-oriented actions undertaken by Regulators should focus on creating awareness of the engineering area and the associated risks. As the area matures (e.g., Stage 2 and 3), actions should shift towards establishing and communicating standards of professional practice. Additionally, especially in earlier stages, it may be important for Regulators to engage in "self-education" to improve their understanding of the practice. Conceptually, this will have the effect of reducing uncertainty about maturity and risk in the area, i.e., reducing the "confidence interval" in Figure 3 above.

For more mature engineering areas (i.e., Stage 2 or 3), Regulators may consider education-oriented actions that focus on sustaining and incrementally growing the knowledge in the area, such as participating (e.g., reviewing, consulting on, etc.) in the development of syllabi and engaging with higher education institutions to ensure graduates of training programs are aware of professional requirements in the area. For medium or high-risk areas, Regulators should also consider authoring practice guidance documents that describe the standard of practice in the engineering area.

Actions Trends for Registration

The ability of Regulators to effectively regulate in an engineering area, and as a result protect the public, in the long term depends on actions taken by regulators early in an engineering area's development. Using only "reactive" approaches to regulation for emerging areas will result in emerging areas to developing "out of sight" of Regulators, and as a result the area is unlikely to develop foundational practices around professional regulation. To avoid this scenario, Regulators might need to undertake strategic initiatives, focused on registration and advocacy, that highlight the role of professional regulation in an emerging area. To this end, actions in the "Registration" category are focused on growing and sustaining the professional practice community.

For engineering areas with lower maturity (i.e., Stage 1), registration-related actions should focus on establishing an initial community[1] of license/regulated professionals who practice in the engineering area. This might entail collaborating professionals who already hold licenses that have evolved their practice scope to work in the emerging area. Additionally, Regulators might consider more flexible criteria to prospective registrants to grow a "base" of licensed professionals that the community can grow from. As the engineering area matures (i.e., Stages 2 and 3) and the practice community grows, stricter[2] educational and experiential requirements should be applied.

Especially in higher risk areas, proactive registration initiatives might be required to seek out firms and practitioners who are practicing but not registered. Such initiatives are important for ensuring that as the practice community for high-risk areas matures, it does so in a manner that is consistent with the Regulator's expectations.

Action Trends for Regulation

Actions in the "Regulation" category are focused on regulating the practice of professionals who are already license/registered.

For engineering areas with lower maturity (i.e., Stage 1 or 2), regulatory actions should be approached in a constructive manner with the intent of mutual learning. For instance, if firm audits are carried out, they should be performed with an understanding that standards of practice and conventions in the emerging area might differ (but not necessarily be "wrong") from those in more established engineering areas. Applying overly forceful regulation to "early adopter" professionals might have unintended consequences for how the practice community develops, and Regulators might need to adjust the force of their regulation to limit unintended consequences.

As maturity or risk increases, more forceful regulatory actions may be applied. For instance, audits might strictly hold practitioners to a standard of practice. Further, if there is a large practice community, having dedicated "expert" resources within the Regulator for addressing practice concerns in the area might be beneficial.

Action Trends for Enforcement

Actions in the "Enforcement" category are focused on preventing misuse of engineering title and unauthorized practice in the engineering area by unlicensed persons. Overall, as the level of risk increases, regardless of the stage of maturity, enforcement efforts should increase. For

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[1] For this paper, "community" refers to a population of registered professionals practicing in the emerging area. These professionals might also contribute to regulatory activities such as sitting on advisory committees or reviewing incoming license applications.

[2] Stricter relative to a more flexible set of criteria used while an engineering area is in an earlier Stage of maturity.

instance, in low-risk areas enforcement might focus on misuse of engineering title whereas in higher risk areas enforcement might focus on unauthorized practice.

Process Improvement

The emergence of engineering areas (and their regulation) occurs over relatively long time periods, on the order of years and decades. The core components of EFRM (SEC, indicators, and actions) used by Regulator "today" might be inappropriate many years in the future, as societal needs and priorities shift. Further, after applying EFRM, Regulators might have learnings that can be used to improve or tailor EFRM. Therefore, an "outer" feedback loop concerned with process improvement is included in EFRM.

Process improvement might consider the following questions:

1. Are the stages of maturity in the SEC still an accurate reflection of how engineering areas emerge?
2. Are the indicators applicable to the current societal context? For example, perhaps the model of higher education for engineers has changed and there are modes of education (other than undergraduate degree programs) that train practitioners.
3. Are the indicators feasible to apply at scale in the long run?
4. Are the actions consistent with the current societal context? For example, perhaps a jurisdiction has changed the legal authority of a Regulator, which requires considering different action(s).

Applying EFRM

This section contains concrete suggestions for indicators and actions, which may be used by a Regulator to operationalize EFRM. These suggestions follow the trends for indicators and actions described in above. These suggestions are not intended as an exhaustive or prescriptive list. It is recognized that Regulators operate in unique contexts that mean that some suggestions might be inapplicable or more or less effective.

Suggested Indicators for Maturity

The following suggested maturity indicators are organized by stage of the SEC. If indicators for a given stage are satisfied, then it is likely that the engineering area is at that stage of maturity.

Stage 1 (Industry Recognition)

Category	**Indicator**	**Measured By…**
REGISTRATION	Registered firms have staff whose job titles and responsibilities involve work in the engineering area.	Data collected during firm audits or firm renewals.
REGISTRATION	Persons applying for professional licences identify industrial activities that are part of the engineering area.	Reviews of competency assessments submitted by applicants OR results of survey questions posed to applicants.
EDUCATION & KNOWLEDGE	There are requests for, or offers to present, continuing education events (e.g., webinars) in the engineering area.	Reviews of requests for, or offers to present, continuing education events.
EDUCATION & KNOWLEDGE	There are methods focused on solving a set of problems encountered in a specific industrial context; these methods are repeatable by different practitioners in the same industry and yield consistent and predictable results.	Surveys of engineering practice and methods within the emerging area.
EDUCATION & KNOWLEDGE	There are specialised graduate level “topics” courses taught at higher education institutions that describe or teach topics in the engineering area.	Surveys of senior undergraduate and graduate courses offered by higher education institutions.
INDUSTRY	There are industrial research grants awarded to organizations undertaking research and development in this engineering area.	Surveys of grants issued by Canadian funding agencies.
INDUSTRY	Multiple organizations have personnel whose job title refers to the name of an engineering area.	Surveys of job titles on social media sites or posting on job boards.
INDUSTRY	There are few (possibly only one) persons or organizations that offer products or services related to the engineering area.	Surveys of organizations and persons on sites, social media, or association registrations OR surveys on activities performed by existing registrants as part of their practice.
GOVERNMENT	Legal cases in the judicial system refer to systems that were created by activities that fall within the engineering area.	Surveys of relevant legal proceedings.
GOVERNMENT	Requests for proposals published on public bid/job boards describe activities related to the engineering area.	Surveys of public bid/job boards.

Stage 2 (Practice Recognition)

Category	Indicator	Measured By...
EDUCATION & KNOWLEDGE	A recognized body of scientific knowledge exists that is the basis for an engineering area.	Existence of specialized academic journals, academic and industrial conferences, or textbooks.
EDUCATION & KNOWLEDGE	There are recognized methods to solve problems related to the engineering area that are repeatable and yield consistent and predictable results when applied by different practitioners in different industrial settings.	Surveys of engineering practice and methods within the emerging area.
EDUCATION & KNOWLEDGE	There are graduate training programs or credentials offered by institutions that address topics related to the engineering area.	Surveys of graduate training programs or post-graduate credential programs offered by higher education institutions.
EDUCATION & KNOWLEDGE	There are specializations offered as part of established undergraduate degree programs that address the engineering area (e.g., “AI Speciality” as a specialization of “Software Engineering”).	Surveys of undergraduate engineering programs at higher education institutions.
EDUCATION & KNOWLEDGE	Technical standards organizations (e.g., ISO) have published standards describing the standard of practice for activities in the engineering area.	Surveys of standards published of standard organizations.
REGISTRATION	A threshold number of registered firms indicate they undertake activities in the engineering area.	Data collected during firm registration renewals.
REGISTRATION	A threshold number of existing registrants indicate they practice within the engineering area.	Data collected during annual licence renewals.
REGISTRATION	A threshold number of new licence applications identify the engineering area as an area of practice.	Data collected from new license applications.
INDUSTRY	Industry associations exist that represent the interests of those practicing in the engineering area (e.g., IEEE for computer engineers).	Survey of industry associations in the engineering area.
INDUSTRY	Organizations working in the engineering area have established policies and procedures for performing activities related to the engineering area.	Data collected during firm audits.

INDUSTRY	Many persons or organizations provide products or services related to the engineering area.	Surveys of products or services provided practitioners or companies.
GOVERNMENT	Public organizations (e.g., crown corporations, government agencies, governments) undertake activities in the engineering area.	Surveys of public bid/job boards to identify activities being performed by public organizations OR data collected during firm registration renewals for public organizations.
GOVERNMENT	Legislation or regulations exist that refer to topics related to the engineering area (e.g., cybersecurity legislation for health data/systems).	Surveys of recently created legislation or regulation.
GOVERNMENT	There are government sponsored regulatory agencies dedicated to monitoring and regulating products or systems produced by those working in the engineering area (e.g., Transport Canada for Aircraft).	Review of mandates of government sponsored regulatory agencies.

Stage 3 (Discipline Recognition)

Category	**Indicator**	**Measured By...**
EDUCATION & KNOWLEDGE	There are whole undergraduate engineering programs offered by higher education institutions that address the engineering area (e.g., "Bachelor of Engineering - Electrical").	Surveys of undergraduate programs offered by higher education institutions.
EDUCATION & KNOWLEDGE	There are established scientific or engineering principles that support generalized methods for solving a wide range of problems encountered in the engineering area; these methods are repeatable and yield consistent results when used in a wide range of applications, including by non-experts (e.g., students).	Surveys of key scientific and engineering principles in the engineering area.
EDUCATION & KNOWLEDGE	There are engineering syllabi published by Engineers Canada for the engineering area.	Surveys of engineering syllabi published by Engineers Canada.
REGISTRATION	There is a threshold number of license applications from internationally trained engineers who have formal education in the engineering area.	Data collected from license applications.
INDUSTRY	There is a significant number of regulated firms whose internal policies and procedures recognize the engineering area as an	Data collected during firm audits.

	engineering discipline alongside other established areas of practice.	
EDUCATION & KNOWLEDGE	The engineering regulator has full-time staff who are professional engineers with formal education qualifications and demonstrable industry experience in the engineering area.	Areas of practice identified by annual reporting by staff.

Suggested Indicators for Risk

The following indicators may be used to assess the level of risk of practice in an emerging engineering area. As discussed above, it is possible that Regulators have established methods/frameworks of assessing the risk associated with areas of engineering practice, which could be used in place of the indicators below. The risk indicators are organized into the categories discussed in above.

Category	Indicator	Measured By…
HARM	Number of people who might experience serious physical harm or death because of potential incidents related to the engineering area.	Severity scales and risk studies.
HARM	Scale of environmental damage because of incidents related to the engineering area.	Severity scales and risk studies.
HARM	Financial/economic value of assets lost or damaged because of incidents related to the engineering area.	Severity scales and risk studies.
HARM	Incident reports about losses and near misses for relevant industries, systems, and processes	Number and severity of incidents as measured by incident reports from industry-specific regulators (e.g., Transport Canada).
HARM	Estimated number of practitioners, including those not licensed/registered with a Regulator, working in the engineering area.	Surveys of registered professionals combined with surveys of the broader job market in the engineering area.
UNINTENDED CONSEQUENCES	Potential impact on growth in related industries compared to other jurisdictions (i.e., “will we fall behind”).	Number of start-ups, number of companies, number of patents, services, products as measured by surveys of industrial activity in the area.
UNINTENDED CONSEQUENCES	Cost of compliance compared to practitioners and organisations in other jurisdictions and other fields	Cost of maintaining professional licenses in other jurisdictions OR cost of engineering activities/effort required to comply with existing regulations, as measured by surveys of practitioners and firms.

RISK APPETITE	Direction of government(s) in relation to the mitigating risk associated with the engineering area.	Surveys of government initiatives, legislation, and policy agenda(s).
RISK APPETITE	Direction of government(s) in relation to economic development related to the engineering area.	Surveys of government initiatives, legislation, and policy agenda(s).
RISK APPETITE	Outcomes of judicial proceedings involving the engineering area.	Surveys of recent court decisions.
RISK APPETITE	Public opinions and priorities related to risk in the engineering area.	Surveys of recent news media related to the engineering area OR surveys of public opinion.
RISK APPETITE	Consistency of risk tolerance/appetite for the engineering area with ethical and legal principles.	Study of ethical and legal principles in relation to the engineering area.

Suggested Regulatory Actions

The suggested regulatory actions below are organized by maturity stage and risk level.

Stage 1 (Industrial Recognition)

Risk Level	Category	Action
Low Risk	EDUCATION & KNOWLEDGE	Facilitate continuing education events (e.g., webinars) with the objective of creating awareness of the engineering area within the wider engineering practice community.
	EDUCATION & KNOWLEDGE	Hold internal briefings/seminars (e.g., “lunch and learn”) for regulator staff members to become aware of the engineering area and the current regulatory strategies for the area.
	REGISTRATION	Offer limited professional licenses to practitioners who work in the engineering area but might not have qualifications to merit a full license.
	REGISTRATION	Adopt more flexible qualification and experiential requirements for full P.Eng. licensure to recognize that practitioners might have diverse education or experiential backgrounds.
	ENFORCEMENT	Handle discipline of registrants working in the engineering area as they arise, based on complaints or incidents, while recognizing that standards of practice in the area might differ from those in more mature areas.
	ENFORCEMENT	Proactively pursue enforcement actions focused on the title protection in the engineering area.
	All Low Risk actions and…	

Medium Risk	EDUCATION & KNOWLEDGE	Provide continuing education events (e.g., webinars) focused on educating the practice community about the risk(s) associated with the engineering area.
	EDUCATION & KNOWLEDGE	Facilitate (on an “as needed” basis) practitioner focus groups or interviews that will inform regulators about the unique needs and risks to the engineering area.
	REGISTRATION	Undertake initiatives to increase registration of non-registrant persons or firms practicing in the engineering area (e.g., public information sessions, speaking at industry events, etc.).
	REGULATION	Audit practitioners or firms working in the engineering area in a constructive and collaborative manner that recognizes that practices and conventions in the engineering area might differ from those more mature areas.
	ENFORCEMENT	Proactively pursue enforcement actions focused on unauthorized practice in the engineering area.
High Risk	*All Low Risk and Medium Risk actions and …*	
	EDUCATION & KNOWLEDGE	Publish short guidance documents describing the standard of practice for activities in the engineering area.
	REGISTRATION	Seek out unregistered persons or firms practicing in the engineering area and notify of their obligation to register with the regulator.
	REGULATION	Audit practitioners or firms working in the engineering area with a focus on risk management while recognizing that risk management activities in the engineering area might differ from those in more mature areas.

Stage 2 (Practice Recognition)

Risk Level	**Category**	**Action**
Low Risk	EDUCATION & KNOWLEDGE	Facilitate continuing education events (e.g., webinars) with the objective of educating practitioners on the standard of professional practice in the area.
	EDUCATION & KNOWLEDGE	Engage with other engineering regulators and associations to discuss approaches to regulation for the engineering area.
	EDUCATION & KNOWLEDGE	Visit HEIs offering dedicated courses or programs in the engineering area to educate participants about the role of the regulator in the area and legal requirement(s) for registration.
	REGISTRATION	Establish limited license registration pathways for practitioners who work in the engineering area but might not have qualifications for full licensure (e.g., competency templates for limited licenses).

	REGISTRATION	Adopt more flexible qualification and experiential requirements for full P.Eng. licensure to recognize that practitioners might have diverse education or experiential backgrounds.
	REGISTRATION	Create registration paths for internationally trained practitioners who work in the engineering area to obtain professional licensure.
	REGULATION	Undertake review(s) of existing quality management guidelines and professional practice guidelines to determine if they meet the needs of practitioners working the engineering area.
	ENFORCEMENT	Handle discipline of registrants working in the engineering area as they arise, based on complaints or incidents, taking into account the standard of practice for the engineering area as documented in practice guidelines and advisories.
	ENFORCEMENT	Proactively pursue enforcement actions focused on the right to title in the engineering area.
Medium Risk	*All Low Risk actions and...*	
	EDUCATION & KNOWLEDGE	Establish practice advisory groups that consist of representatives from academia and industry that periodically meet with regulators to discuss topics related to practice in the engineering area.
	EDUCATION & KNOWLEDGE	Engage with other regulators and associations (e.g., technologists) who regulate or represent professionals with overlapping or related practice scopes to the engineering area.
	REGISTRATION	Seek out unregistered persons or firms practicing in the engineering area and notify of their obligation to register with the regulator.
	REGISTRATION	Engage with accreditation organizations to request syllabi for the engineering area, as applicable.
	REGISTRATION	Establish mentorship programs that provide support for EITs or non-registrants who work in the engineering area to become fully registered.
	REGULATION	Appoint an "expert" practice advisor (or similar staff role) within the regulators who handle matters related to the engineering area; alternatively, acquire access to this expertise as a shared resources between Canadian regulators.
	REGULATION	Audit practitioners or firms working in the engineering area in a constructive and collaborative manner that recognizes that practices and conventions in the engineering area might differ from those more mature areas.
	ENFORCEMENT	Engage public organizations (e.g., governments, crown corporations, government agencies, etc.) and notify them of obligations to include registered professionals in projects related to the engineering area (e.g., requirements for P.Eng. qualifications in public bids).

	ENFORCEMENT	Proactively pursue enforcement actions focused on unauthorized practice in the engineering area.
High Risk	*All Low Risk and Medium Risk actions and …*	
	EDUCATION & KNOWLEDGE	Publish longer form practice guidance that address the engineering area in broad terms.
	REGULATION	Audit practitioners or firms working in the engineering area with a focus on risk management activities as outlined in published practice guidance or the standard of practice for the engineering area.

Stage 3 (Discipline Recognition)

Risk Level	Category	Action
Low Risk	EDUCATION & KNOWLEDGE	Hold regular continuing education events (e.g., webinars) with the objective of educating practitioners of the standard of professional practice in the area and keeping abreast of changes in the area.
	EDUCATION & KNOWLEDGE	Visit higher education institutions offering dedicated undergraduate programs in the engineering area to educate participants about the role of the regulator in the area and legal requirement(s) for registration.
	REGISTRATION	Establish limited license registration pathways for practitioners who work in the engineering area but might not have qualifications to merit full license (e.g., competency templates for limited licenses in the area).
	REGISTRATION	Establish full P.Eng. registration pathways for graduates of formal education programs in the engineering area.
	REGISTRATION	Create registration paths for internationally trained practitioners who work in the engineering area to obtain professional licensure.
	REGISTRATION	Seek out unregistered persons or firms practicing in the engineering area and notify of their obligation to register with the regulator.
	REGISTRATION	Engage with accreditation organizations to request updates to syllabi for the engineering area, as applicable.
	REGISTRATION	Establish or maintain mentorship programs that provide support for engineers-in-training or non-registrants who work in the engineering area to become fully registered.
	REGULATION	Create an internal "expert" group of practice advisors (or similar staff role) within the regulator to handle matters related to the engineering area.
	REGULATION	Periodically review existing quality management guidelines and professional practice guidelines to determine if they meet the needs of practitioners working the engineering area.

	ENFORCEMENT	Handle discipline of registrants working in the engineering area as it arises, based on complaints or incident.
	ENFORCEMENT	Pursue enforcement actions focused on the right to title in the engineering area.
Medium Risk	*All Low Risk actions and…*	
	EDUCATION & KNOWLEDGE	Establish and maintain practice advisory groups that consist of representatives from academia and industry that periodically meet with regulators to discuss topics related to professional practice in the engineering area.
	EDUCATION & KNOWLEDGE	Engage with other regulators and associations (e.g., technologists) who regulate or represent professionals with overlapping or related practice scopes to the engineering area.
	EDUCATION & KNOWLEDGE	Publish longer form practice guidance that address specific subtopics of the engineering area.
	REGISTRATION	Establish mentorship programs that provide support for EITs or non-registrants who work in the engineering area to become fully registered.
	REGULATION	Appoint an "expert" practice advisor (or similar staff role) within the regulators who handle matters related to the engineering area; alternatively, acquire access to this expertise as a shared resources between Canadian regulators.
	REGULATION	Audit practitioners or firms working in the engineering area with a focus on risk management activities as outlined in published practice guidance or the standard of practice for the engineering area.
	ENFORCEMENT	Engage public organizations (e.g., governments, crown corporations, government agencies, etc.) and notify them of obligations to include registered professionals in projects related to the engineering area (e.g., requirements for P.Eng. qualifications in public bids).
	ENFORCEMENT	Pursue enforcement actions focused on unauthorized practice in the engineering area.
High Risk	*All Low Risk and Medium Risk actions and …*	
	REGULATION	Create an internal "expert" group of practice advisors (or similar staff role) within the regulator to handle matters related to the engineering area; alternatively, acquire access to this expertise as a shared resources between Canadian regulators.
	REGULATION	Engage with government(s) to discuss "demand side" legislation or regulations for specific the engineering area.
	ENFORCEMENT	Pursue (more aggressively than for Medium Risk) actions focused on unauthorized practice areas in the engineering area.

Prioritizing Use of the EFRM

There are conceivably many dozens of engineering-like activities that might be identified as emerging areas of engineering practice by Regulators or the broader community. Applying the EFRM simultaneously to every activity that has been identified as an emerging discipline is likely to exceed the capacity and resources of a Regulator. Instead, Regulators could prioritize the use of the EFRM according to various factors such as potential for harm, gaps not covered by established engineering disciplines, relationship with the regulation of other professionals outside engineering, number of applicants identifying such activities as their practice area, and significance to economic activity within the jurisdiction of the regulator. The maturity indicators described earlier in this Paper might also be useful for the purpose of this prioritization task, although priority should not necessarily be based on maturity alone.

Worked Example: “AI Engineering”

Machine Learning (ML), Large Language Models (LLM), and other forms of Artificial Intelligence (AI) have rapidly been integrated into products, systems and services that have a strong potential to cause harm to people, property and the environment. One example is the use of ML in self-driving automobiles, which have been involved in several fatalities whose cause is traceable to the AI-enabled functionality. Other uses of AI associated with risk may be less obvious, such as, the use of AI in engineering tools used by engineers while designing a bridge.

A significant portion of the world’s economy depends on products, systems and services that rely on AI. The use of AI already has a very important role in transportation systems, critical infrastructure, health care, and other domains that directly impact safety and well-being of the public. Some uses of AI may be surreptitiously introduced to existing products, systems and services replacing traditional non-AI rule-based software or even human decision making. Society will increasingly look to engineering regulators to safeguard engineering activities that involve the use of AI.

It would be naive to suggest that engineering regulation for traditional areas of practice, such as mechanical engineering or electrical engineering, could be directly applied in any specific way to the use of AI in products, systems and services. It would even be a stretch to expect guidelines for software engineering to serve as a basis for regulation of AI-enabled software. While AI is implemented by software, the development of AI-enabled software is very different than conventional (non-AI-enabled) software. As well, highly skilled individuals who have an integral role in the development of AI-enabled software sometimes have little or no background in the traditional methods and tools used for the development of conventional software.

In this worked example, it is imagined that an unnamed Canadian engineering regulator, APEX, has recognized that AI is an emerging engineering area for which APEX has a responsibility to provide regulation. We imagine for the purposes of this example that APEX has decided to use the Emergent Field Regulation Model (EFRM) proposed by this Paper.

The remainder of this case study is written from the perspective of APEX, as they carry out the guidance from this Paper. The details provided in the remainder of this case study are meant to illustrate the use of the EFRM. While these details are believed to be reasonably accurate, they should not be relied upon exclusively for the purpose of assessing the maturity of an emerging engineering area or the risk associated with engineering activities in this area.

Knowledge Maturity of “AI Engineering”

This Paper identifies three stages of maturity along with indicators for determining the maturity of an emerging engineering area. Following consultations with qualified professionals, APEX has determined that the maturity of AI Engineering, as an emerging engineering area, is at Stage 2 (Practice Recognition) and that it is likely to reach Stage 3 (Discipline Recognition) within the next five years. Key findings in support of the determination that the maturity of this emergent discipline is at least Stage 2 include:

1. At the time of this assessment, more than a thousand job advertisements for “AI Engineers” were currently posted in Canada on the social media site LinkedIn, many of which are for positions within organisations that perform engineering activities that could pose risk to the public or environment and a significant number who are regulated firms.
2. As of writing, there are specializations of established undergraduate degree programs focused on AI Engineering offered by major universities in Canada including:
    a. University of Toronto, Applied Sciences, Minor in AI Engineering [5].
    b. Western University, Engineering, Concurrent Program in AI Systems Engineering [6].
3. In June 2022, the federal government introduced C-27 which includes the Artificial Intelligence and Data Act (AIDA) [7].
4. There have been lawsuits for serious accidents, including fatal accidents, attributed to the use of Artificial Intelligence in life-critical systems, such as several lawsuits against Tesla and other driverless car manufacturers.
5. There are well established published safety standards that provide detailed guidance on managing safety risk for systems that depend on the use of Artificial Intelligence [8, 9].

While AI Engineering, as an emergent discipline, likely also satisfies some of the indicators for Stage 3 of the EFRM model, it does not yet exhibit sufficient characteristics to deem its maturity at Stage 3. For example, an engineering syllabus for Artificial Intelligence has not been published by Engineers Canada.

Risk of “AI Engineering”

It is necessary to assess the risk of AI Engineering in the context of a specific application/industry. Since APEX is aware of several firms in their jurisdiction who are already using AI in advanced automotive and robotics applications, APEX has decided to assess risk with those industries in mind, using EFRM's risk indicators as follows:

- APEX performs a study of potential harms of AI-enabled automotive and robotics systems. They find that incidents involving AI-enabled automotive, or robotics technology could cause severe harm (injury, death) to a small number of persons per incident. However, automobiles depending on AI to provide supportive driving features (e.g., emergency braking, lane keeping, etc.) are increasingly used on public roads, so there is potential for many incidents to occur over time.
- APEX surveys government initiatives and policies in AI-enabled automotive technology. They find that Federal and Provincial governments have made large investments in developing AI-enabled technology, suggesting growth in this engineering area is a priority.
- In June 2022, the federal government introduced C-27 which includes the Artificial Intelligence and Data Act (AIDA) [7]. While this (draft) legislation is focused primarily on data privacy, it suggests the federal government has interest in regulating the use of AI in Canadian society.
- APEX surveys regulatory initiatives and positions of other regulators in nearby jurisdictions. They find that the United States National Highway Traffic Safety Administration (NHTSA) and similar regulators in various States have imposed restrictions on self-driving vehicle technology, which is heavily dependent on AI.
- APEX recognizes that there are several firms within its jurisdiction that are developing AI-enabled automotive and robotics technology, some of which are large multinational firms. APEX also recognizes that there are many similar firms in the United States and in adjacent Canadian jurisdictions, which have different regulatory positions in terms of licensing professionals. They identify an unintended consequence of heavy-handed regulation in this area as "pushing out" firms from their jurisdiction.

Based on these risk indicators, APEX determines that AI Engineering in automotive and robotics applications is a high-risk engineering area and that there is appetite for regulation in this space.

Right Touch Actions for AI as an Emergent Discipline

APEX leadership has decided that the priority for application of the EFRM is to develop guidance for "right touch" actions in the case of high-risk applications of AI. Based guidance in the Actions of the EFRM for Stage 2 engineering areas, APEX has established an objective to complete the following actions to be completed within 24 months:

1. APEX will develop and publish full practice guidelines for regulated activities that involve the development of AI-enabled software and systems for high-risk application areas.
2. APEX will review existing professional practice and quality management guidelines to determine if they are compatible with practices in AI Engineering.

3. APEX will audit firms involved in the development/maintenance of AI-enabled software in high-risk application areas, with a specific focus on published practice guidelines/advisories or the standard of practice for AI.
4. APEX will prepare for stronger enforcement by identifying reasons why individuals or firms might believe (or claim) that the use of AI is outside the scope of engineering regulation so that regulators are better equipped to counter such beliefs and claims.
5. APEX will establish a practice advisory group with membership from AI experts in both academia and industry.
6. APEX will identify specific associations that regulate other professionals outside engineering with overlapping areas of interest in AI. This might include, for example, the Royal College of Physicians and Surgeons of Canada in the context of the use of AI in the deployment of robotic surgical devices that incorporate AI.
7. APEX will designate a specialized practice advisor with expertise in "AI Engineering" and either hire to fulfil this role or provide professional development to existing staff to support this area.
8. APEX will seek an opportunity with other regulators and Engineers Canada to develop a national syllabus for AI Engineering.
9. APEX will proactively engage with firms practicing AI Engineering in high-risk areas and notify them of their obligation to register with APEX or pursue appropriate enforcement action(s).
10. APEX will engage public organizations (e.g., health authorities/agencies, transportation authorities) and notify them of their obligation to include requirements for licensed professionals in projects and bids related to AI Engineering.

Furthermore, with the expectation that the maturity of Artificial Intelligence as an emergent discipline will advance to Stage 3 within the next five years, APEX will aim to establish an internal "expert" group of practice advisors (or similar staff role) within the regulator with sufficient knowledge and experience in the use of Artificial Intelligent to support regulation of individual and firms working in this area of practice. APEX will also notify government(s) of the need to engage in discussions about legislation and/or regulation for the use of AI in products, systems, or services that have a potential to cause harm.

Recommendations

Advances in science and technology are rapidly changing and expanding the scope of engineering activities. This Paper offers regulators an actionable strategy to keep pace with this evolution by means of a "right touch" approach to regulation for emergent areas of engineering practice. The central idea of this approach is the selection of regulatory actions based on consideration of both risk and the maturity of an emerging area.

Moving forward, it is recommended that Regulators:

1. Undertake initiatives to identify engineering-like activities that might be emerging areas of engineering practice that require monitoring and regulation using EFRM.
2. Maintain a prioritized list of emerging areas using criteria such as those suggested in this Paper, including periodic review of this list.
3. Subject to available resources and capacity, apply the EFRM to the highest priority emerging areas of engineering practice.
4. Ensure that leadership within the Regulator is informed of the need to provide resources for monitoring emerging areas and undertaking regulatory actions.

Further, it is recommended that Regulators and Engineers Canada:

5. Meet to determine how the findings of this paper can be implemented, either individually or in collaboration with Engineers Canada. For instance, Engineers Canada might undertake on-going surveillance activities described by the Indicators in this paper and develop a national dashboard for emerging engineering areas that is accessible to Regulators.

Abbreviations and Definitions

Term	Acronym	Definition / Interpretation
Action	-	An activity, initiative, process, or similar that a Regulator might undertake to manage risk associated with an emerging engineering area.
Artificial Intelligence	AI	The capability of a computer system to perform tasks that are typically associated with human-level intelligence, such as classification, synthesis, and reasoning.
Canadian Engineering Qualifications Board	CEQB	A group within Engineers Canada that develops guidance and syllabi to support Canada's engineering Regulators and practitioners.
Emerging Field Regulation Model	EFRM	A conceptual framework for regulating emerging areas of engineering practice ("fields"). Includes three Stages of maturity, indicators for assessing the stage of an area and the level of risk associated with it, and actions that Regulators might take at each stage of maturity.
Engineering Area	-	A term that broadly captures a collection of practices, knowledge, and conventions carried about by a community of practitioners (who might not be licensed).
Engineering Discipline	-	A specific branch of engineering studies that focus on a distinct body of knowledge of technical and scientific principles addressing specific categories of problems.
Engineering Practice Area	-	A specialized field of applying engineering principles to specific technical problems (e.g., robotics control and automation).
Engineering Industry of Practice	-	A specific industry (e.g., rail, aerospace, medical devices, automotive, marine, etc.) that engineers practice within.
Indicator	-	An observable or measurable phenomena, trend, or fact that can be used to determine the level of maturity or risk of an engineering area.
Practice of Engineering	-	Any act of planning, designing, composing, evaluating, advising, reporting, directing or supervising, or managing any of the foregoing, that requires the application of engineering principles and that concerns the safeguarding of life, health, property, economic interests, the public welfare or the environment [2].
Staged Emergence Cycle	SEC	The Staged Emergence Cycle (SEC) is a conceptual model that characterizes the emergence of an engineering area in three stages: 1) Industry Recognition, 2) Practice Recognition, and 3) Discipline Recognition.

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