Linking Bio-Physical and Human Environments in 'Pathways of Effects'

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Health Canada's Impact Assessment Program supports the pathways approach to effects analysis, in recognition that health impacts of resource development and infrastructure projects (major projects) arise through inter-connected changes occurring within and across bio-physical and human environments. Gathering information to fully understand pathways of effects within the resource development and infrastructure sector and to effectively manage project effects is a burdensome process that Artificial Intelligence (AI) could help optimize. However, this requires a clear conceptual representation of the building blocks of health effect pathways as starting point.

The well-being of populations living near major project sites has been an important consideration of environmental impact assessments in Canada for decades.[1,2] With the *Impact Assessment Act* coming into force in 2019, there has been an increased focus on the broader set of contributors to health. Environmental, economic and social (including cultural) conditions at the community level can be understood as determining individuals' health-related behaviours and their biological exposures to environmental contaminants, infectious agents, psychosocial stressors and stress buffers. Health Canada's applied framework for conceptualizing generic health effect pathways illustrates how these behavioural and biological factors, as well as mental well-being, are connected to each other and to groupings of health determinants under the influence of major projects, as shown in Figure 1.[3]

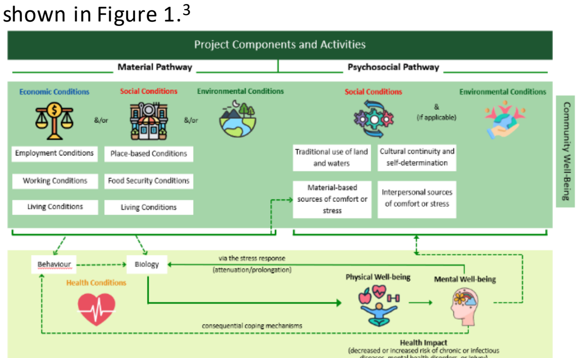

Figure 1: Generic Diagram of Pathways of Health Effects

This framework is based on the World Health Organization's conceptual framework on the social determinants of health,[4] and features three core components. The first core component has to do with influences coming from the structural level of a society, where decisions are made. For major projects, this refers to decisions being made about the design of project components and activities.

The second core component deals with intermediate factors that are influenced by these decisions, and that contribute to people's quality of life, or community well-being. These effects happen along two distinct types of pathway, labeled either "material pathway" or "psychosocial pathway". Material circumstances refer to the physical surroundings, resources and opportunities that allow or hinder people's ability to lead healthy lives for physical well-being. The psychosocial dimension covers people's material comforts and other stress buffers as well as stressors from their material circumstances and interpersonal conflicts; these are related to mental well-being and coping responses that can also affect the well-being of others.

The third core component concerns the connection between these affected intermediate factors and the behaviours and biological processes that are linked to mental well-being and physical well-being, which ultimately determine health outcomes over time.

Given that the broad topic of health effect pathways is fairly new in the field of impact assessment, this paper grew out of collaborative partnerships to advance knowledge in this important study area. It summarizes the novel tools and methodology trialed by Health Canada to adequately account for and portray the linkages among environmental, economic, social, cultural and health factors. The limitations of each approach are considered in light of the emerging opportunities and risks that AI presents. Harnessing AI may prove to be beneficial in directing the attention of project proponents, potentially affected communities and decision-makers toward key intervention points along clearly described effect pathways to mitigate harm and promote well-being.

Using the framework to explore Structural Equation Modeling using public datasets

The Structural Equation Modeling (SEM) project was a collaboration with researchers from Simon Fraser University and the University of Lethbridge.[5] It explored the use of statistical modelling to understand the relationships between environmental, socioeconomic, and behavioural determinants of health in publicly available datasets for a large region of Alberta, Canada. The first step was to identify which publicly available datasets existed with sufficient quality and quantity across the study area. Exploratory factor analysis was then applied to reduce the total number of variables into a manageable dataset.

A workshop was held with a group of expert researchers and practitioners to confirm the list of indicators proposed for the SEM project. Figure 2 shows a visual representation of the results, with the chosen indicators on the outside representing the latent concepts being tested on the inside. This project confirmed that SEM is effective in detecting established pathways of effects from large and disparate datasets.

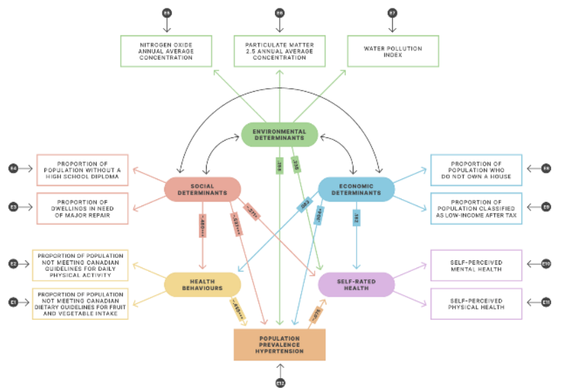

Figure 2: Pathways of Effect Model where Self-rated Health is the Health Outcome of Interest

To be noted, environmental, social and economic data are typically available at a smaller scale of analysis than that for health indicators. This means that SEM is useful for regional-scale assessments or initial scoping of issues for health, but must be complemented with local knowledge to result in effective interventions and decision-making. Implicitly, we acknowledge the need for community-informed, ethical data collection and use at the local level, especially when it comes to health data.

Additionally, this project recognizes that evidence-based conceptual frameworks already exist, such as Figure 1, as well as established links between systemic marginalization and pollution exposures. Rather than trying to prove these linkages through data, the point is to use pre-existing knowledge of cause-effect relationships to tailor indicator selection and detect effects through these models.

Integrating environmental, social, economic and health data with EnviroScreen

The EnviroScreen project was also a collaboration with researchers from Simon Fraser University and the University of Lethbridge.[6] This method uses a wide range of public datasets for indicators covering environmental, social, economic and health conditions, this time applied to Northern Ontario, Canada. Its value lies in understanding relative pressures across a geographic area, allowing for the comparison of sub-regions.

Figures 3 and 4 show the results for one public health unit, ranked against all other public health units in the area; for some indicators, it is faring better (less pressure) and for other indicators, it is faring worse (more pressure).

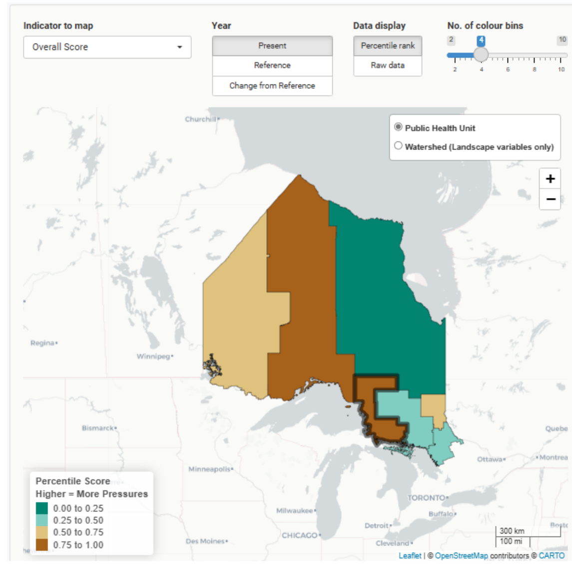

Figure 3: EnviroScreen Scores Across Public Health Units in Northern Ontario, 2020/21

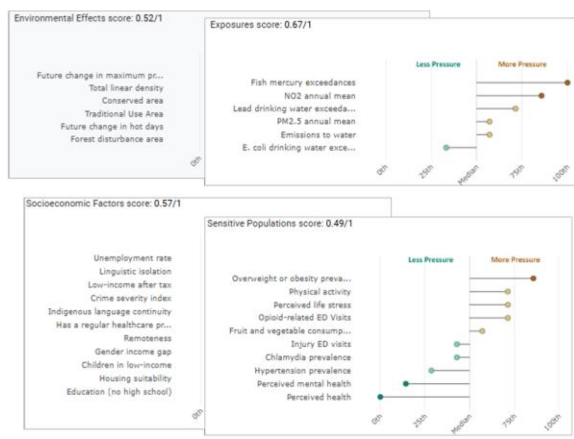

Figure 4: EnviroScreen Scores for indicators in Algoma Public Health Unit, 2020/21

The user can zoom in on one of the overall categories or even specific indicators shown on Figure 4. There is also an option to compare against historical data from 10 years prior. Or the user can toggle to see absolute values once a trend is detected. There is also the option to zoom in on smaller geographic sub-regions for the environmental indicators.

This project shows EnviroScreen as a promising tool for regional planning and scoping, and has the added benefit of a more flexible interface which allows users to manipulate the data. However, the tool is limited by the supporting data and challenges with data granularity, the type of available data and data quality. In addition, because this project covers large, sparsely populated hinterlands with a comparatively higher Indigenous population, the tool's limitations must be clearly acknowledged to avoid making decisions based on inaccurate or incomplete narratives. Participatory methods and collaboration with local Indigenous peoples are critical to address these limitations. [7]

Foundational Health Effect Pathways for Health Impact Assessments

Health Canada partnered with Northern Health, a regional health authority in British Columbia, to conduct a review of the grey and scholarly literature about major resource development projects. This review examined a variety of factors that underwent project-related changes, relevant to the Canadian context, and categorized these factors under positive or negative streams of health effect pathways. [8] Thematic analysis uncovered eight effect pathway categories centering on specific types of populations.

The first two pathway categories cover the advantages and disadvantages of both economic upturn and downturn scenarios, and related social changes. Project effects on local economic activity and corresponding in- and out-migration of people seeking employment opportunities tend to lead to changes in accessing various resources and services, community cohesion and community safety. This can in turn positively or negatively affect peoples' ability to adopt healthy behaviours, enjoy their lives and cope with psychosocial stressors, should they arise, for better health. The extent of access pressures during periods of economic upturn and economic downturn depends on how well the need for increased or sustained community supports is addressed along infrastructure and services pathways across the project's lifecycle—an integral part of the first two pathway categories that is so critical as to merit more focused consideration.

A fourth pathway category involves the effects of employment and working conditions on the physical and mental well-being of project workers, and the social and health implications, either positive or negative, that these effects may have on family members and the broader community, referred to as the "social spillover effect." Health effects on Indigenous communities *per se* point to a fifth pathway category. In recognition of the Indigenous Peoples in Canada, much importance is placed on the effect pathway category that deals with changes to Indigenous use of the land and its inextricable link to cultural continuity, at the basis of their physical, cognitive, emotional and spiritual well-being.

The remaining three health effect pathway categories concern all population types. These pathways focus on the following three areas: environmental degradation and contaminant exposures; exposures to infectious agents and disease spread; and the reassurances or stress burdens associated with the level of involvement in governance and administrative processes regarding impact assessment and management decisions about resource development projects.

Regarding limitations, health outcomes like chronic diseases are usually influenced by multiple factors, not all tied to the project. Furthermore, effect predictions become more difficult further down complex pathways. However, emphasis could be placed on health factors, like mental well-being, health-related behaviours and biological exposures, and how these factors could be linked to environmental, economic, social and cultural conditions under a project's influences. In addition, integrating all the pathway details in an impact assessment is not necessary. Simplified pathways based on the most relevant factors could guide the selection of mitigation measures that target early effects. Targeting early effects would, at the same time, benefit the interconnected factors found further down these pathways.

Potential for Adopting Artificial Intelligence to address gaps in pathways of effects

How do we unlock the promise of AI and deliver solutions that can enhance the pathways approach to effects analysis? In a 2019 blog post, Open AI stated that "[Artificial intelligence] working on a problem would be able to see connections across disciplines that no human could." [9]

The following information is a preliminary reflection of the potential and challenges of using AI for impact assessments. AI may help describe effect pathways and identify mitigation measures by:

- improving efficiencies in quantitative data harvesting and analysis, including recognizing and tracking trends and patterns;
- creating and optimizing predictive models in a time and cost-effective manner;
- automating literature review tasks, such as screening, extracting and synthesizing text; and
- handling a multitude of interconnected programs and tasks behind interfaces that are adapted to the intended audience.

However, some of the pitfalls of AI reinforce the limitations highlighted in this paper from the three research projects:

- We must address the gaps in AI training materials, including the under-representation of certain populations in online content, the paucity of monitoring data to confirm impact assessment predictions, and the lack of clear accountability for verifying the accuracy of online information.
- We need to design AI tools that safeguard intellectual property and data privacy, ensure transparency, and detect unintended information biases.
- Finally, the ethical practice of data harvesting and use is difficult to define and control with “black box” solutions like generative AI, especially when the target audience is not involved in process design and decision-making.

Ultimately, it is through relationships and exchanges within the impact assessment profession and beyond that we will arrive at the right AI solutions. Through our collective efforts and common attention on what should be improved and for what purpose, AI may eventually strengthen the usefulness and pertinence of impact assessments in the years to come.

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