McMaster University

Detailed Conversion Factors

Unit Conversion

→To construct an NVF to evaluate between alternatives, we need conversion factors to put the benefits and costs into the same (usually monetary) units

→Money is usually used for this because it is a very “liquid” asset (meaning it is easy for it to “change shape” and become a car, apple, physiotherapy session, etc.)

→Last class we discussed how to cost things like time and space

→Today we’ll explore even more challenging things like environmental damage and reduced safety

Environmental Considerations

Net Value Function and Unit Conversion

Environmental Impact Conversion

→**It is important to perform an environmental impact study on any engineering project you undertake**

- Recall from the intro lecture: the syllabus for the National Professional Practice Exam specifically lists that engineers must “consider environmental costs when evaluating the economic viability of projects”
- An assessment can determine whether the project should be continued, abandoned, or modified
  - e.g., doing a lifecycle assessment on the carbon footprint for the project from cradle-to-grave
  - Reactive restoration is often impossible, and almost always much more expensive than proactive minimizing of environmental impact

Externalities

→**An "externality" of a decision is an impact (benefit or cost) for people *other* than the decision makers.**

- e.g., suppose you just ate a small pizza and have a box to get rid of. Should you look for a garbage can and possibly be late for class, or maybe just throw the box on the ground in the hallway?
  - Leaving your garbage in the hallway has **negative externalities**: other people walking down the hallway later will be negatively impacted by this decision, someone else needs to work to clean it up, etc.

Externalities

→**An "externality" of a decision is an impact (benefit or cost) for people *other* than the decision makers.**

- e.g., 2, you need to get goods from a mine to the harbour, but the surrounding terrain is not very developed and has limited roads. Should you invest in more expensive all-terrain vehicles or in road construction so more efficient vehicles can work?
  - A **positive externality** of building the road is the benefit anyone else in the community has of being able to use that road themselves.

Externalities

→Decision makers almost never give the same weight to benefits or costs that are externalities (what's in it for them?). This is a failure of incentives for individuals to do what's in society's best interest.

→Governments attempt to correct this incentive failure with policy like taxes (e.g., a carbon emissions tax) and subsidies (e.g., tax rebate for better insulating your home).

→As a responsible engineer with a duty to public welfare, you have an obligation to consider externalities in decision making

- *Even where there won't be benefits or costs to your client, you must consider the broader consequences to society and not support efforts that make us collectively worse-off.*

Economic Value of GHG Emissions

→How can we price greenhouse gas emissions (e.g., atmospheric CO_2?)

→A 2022 study estimates that climate change related natural disasters caused global economic losses of $313 billion in 2022

→The International Energy Agency (IEA) has determined the total global GHG CO_{2eq} emissions grew to 36.8 billion tonnes in 2022

→Based on this info we can calculate economic impact per tonne of CO_2 this year:

- 2022 economic impact/tonne CO_{2eq} = $313/36.8 = $8.51/tonnes CO_{2eq}

→…but is this valid?

Economic Value of GHG Emissions

→**In April 2022, the federal minimum carbon tax was $50/tonne CO_{2eq}**

- And as of 2023, this has been rising by $15/tonne per year up to $170/tonne in 2030
- Why are these values much higher than $8.51/tonnes CO_{2eq}?

→**Our calculation did not account for the long-term or compounding impacts of GHG emissions over time**

Economic Value of GHG Emissions

→**The impact of climate change compounds over time (the atmospheric carbon we emit doesn't only do damage when emitted – it sticks around and increases unless it's removed at a faster rate than we're emitting it)**

- (i.e., we need to consider total past net emissions to account for current CO_2 levels, and project the impact of current emissions onto the future)

→**Many climate change experts estimate that the cost of GHG emissions is higher than $50/tonne**

- A 2021 study in Environmental Research Letters estimates the social cost of carbon at $307/tonne when including future impacts in its considerations.
- A 2022 study in Nature estimates it at $185/tonne.

→**Current estimates are limited by available information. As more information is learned about climate change impacts, the true cost of climate change is likely to be much greater than the current carbon tax.**

Example – Gas Tax

→Do you pay carbon tax for driving a car?

→According to the EPA: car CO_2 Emissions from gasoline are about 8.9 kg CO_2/gallon

- (will depend on your vehicle. e.g., will be worse if your catalytic converter is broken)

$$8.9\ \text{kg}\ CO_2/\text{gallon} = 2.35\ \text{kg}\ CO_2/\text{L}$$

Converting this to dollars using \$65/tonne of $_{CO2}$

$$\frac{2.35\ \text{kg}\ CO_2}{\text{L gasoline}} \times \frac{\$65}{1000\ \text{kg}\ CO_2} = \frac{\$0.15}{\text{L gasoline}}$$

→Actual gas tax in Ontario is \$0.09/L.

Health Cost of Air Pollution

→**Beyond climate change implications, air pollution also has negative *health* impacts**

→**How can we cost the impact of vehicle emissions on health?**

→**Example: You're thinking of driving or biking 1 km to the grocery store: what is the cost of negative health impacts inflicted on society due to the air pollution created if you opt to drive?**

- It is difficult to directly answer this question, but through some research we may be able to determine conversion factors that can help us answer the question
- The next slide will present a table summarizing that for two pollutants:
  - $\mathrm{PM}_{2.5}$ – Fine particulate matter (particles < 2.5 $\mu\mathrm{m}$ in diameter)
  - NOx – Nitrogen oxides

Health Cost of Two Air Pollutants from Driving

	$PM_{2.5}$	NO_X	Source
Health cost per year (Billions of 2015 CAD)	77	7	2019 Health Canada study
Emissions per year (million tonnes in 2015)	1.6	1.8	Health Canada Report citing ECCC 2020
Cost per tonne (thousands of CAD)	48.125	16.38889	Calculation
Light duty gas car & truck emissions per year in 2015 (tonnes)	2300	114000	ECCC 2020 report
% of total emissions from personal vehicles	0.144%	6.333%	Calculation
Health Cost from all Personal Vehicles per Year (Millions of CAD)	110.7	443.3	Calculation
Total distance driven by all personal vehicles in 2015 (billions of km)	324	324	Stats Canada
Therefore: Health Cost per km driven ($)	0.0003	0.0014	Calculation

Ethical Considerations

Net Value Function and Unit Conversion

Ethical Impact Conversion

→What is the cost of negative societal/ethical/equality/morality impact?

→Can you put a price on safety?

→Practical Engineering: ***How Much is a Human Worth? (according to engineers)***

→Moral mathematics can get complicated very quickly, but whatever conversion rate you choose, you should make appropriate justifications