PROJECT PLANNING & LIFE CYCLE ASSESSMENT OF AVIATION AND HIGH-SPEED RAIL

Recitation 7

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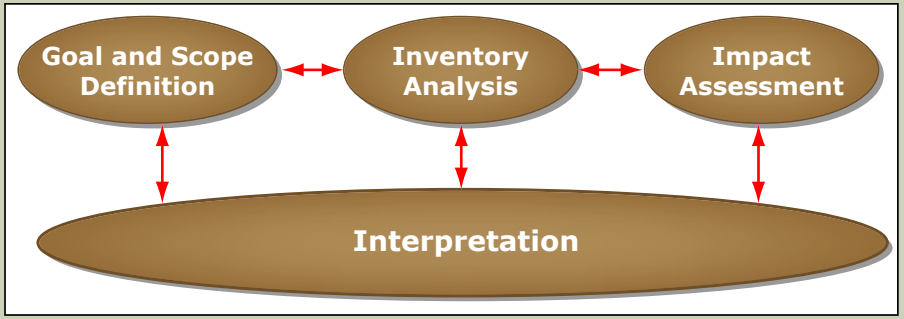
ESD.00

TODAY'S AGENDA

- Life Cycle Assessment of Aviation & HSR
  - Review basic concepts.
  - Process-based vs. EIO-LCA.
  - Discussion on goal and scope.
- Project Mid-Term Presentation

INTRODUCTION TO LIFE CYCLE ASSESSMENT

- According to ISO 14040, LCA is carried out in four main phases:
  - Goal and scope: what final results will be obtained? How much specificity? What methods?
  - Life cycle inventory: data collection and verification.
  - Life cycle assessment: evaluate contribution to impact categories.
  - Interpretation: analysis of major contributions, sensitivity analysis, and uncertainty analysis.



Source: Wikipedia, ISO

APPROACHES TO LCA: PROCESS-BASED

- Process-based LCA method.
  - Itemized inputs (materials and energy resources) and outputs (emissions and wastes to the environment).
  - Challenges:
    - Defining the boundary of analysis.
    - Circularity of effects (e.g. machinery).

Adapted from eiolca.net, Green Design Institute

APPROACHES TO LCA: ECONOMIC I/O

- Economic Input-Output method.
  - Uses information about monetary transactions between sectors.
  - Most nations create economic input-output tables every so many years (e.g. U.S. models created every 5 years).
  - To combine LCA with EIO, traditional economic I/O models are appended with information on emissions.

Sample Input-Output Table

Industry Producing	Agriculture	Food & Beverages	Textiles	Apparel	Lumber & Wood	Furniture & Fixtures	Paper & Allied Products	Total Output
Agriculture	10.86	15.70	2.16	0.02	0.19		0.01	44.26
Food & beverages	2.38	5.75	0.06	0.01			0.03	40.30
Textiles	0.06		1.30	3.88		0.29	0.04	9.84
Apparel	0.04	0.20		1.96		0.01	0.02	13.32
Lumber & wood	0.15	0.10	0.02		1.00	0.39	0.27	6.00
Furniture & fixtures			0.01			0.01	0.01	2.89
Paper & allied products		0.52	0.08	0.02		0.02	2.60	7.90
Total Outlays	**44.26**	**40.30**	**9.84**	**13.32**	**6.00**	**2.89**	**7.90**	

Figures in billions of U.S. dollars

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Adapted from eiolca.net, Green Design Institute

PROCESS-BASED LCA: AN EXAMPLE

- Aircraft Operations
  - Information about operations.
  - Select representative aircraft.
  - Collect data.
  - Develop balance equation set.

Aircraft Landing-Takeoff Cycle (Source: IPCC 1999)

Figure 7-28: The ICAO landing and take-off cycle removed due to copyright restrictions. Original image can be viewed here: http://www.ipcc.ch/ipccreports/sres/aviation/105.htm.

Aircraft emissions (Source: FAA 2007)

Table 66 – EDMS Emission Factors by LTO Stage (per kg of fuel burned) [FAA 2007]

	Fuel Flow (kg/s)	CO (g/kg)	THC (g/kg)	NMHC (g/kg)	VOC (g/kg)	NO_x (g/kg)	PM (g/kg)
Embraer 145							
Taxi Out	0.056	17	2.4	2.4	2.3	3.9	0.15
Takeoff	0.40	0.81	0.26	0.26	0.25	21	0.27
Climb	0.33	0.81	0.26	0.26	0.25	18	0.24
Approach	0.12	3.2	0.62	0.62	0.58	8.0	0.22
Taxi In	0.056	17	2.4	2.4	2.3	3.9	0.15
Boeing 737							
Taxi Out	0.13	33	2.2	2.2	2.1	4.0	0.24
Takeoff	1.00	0.89	0.043	0.043	0.041	18	0.22
Climb	0.84	0.89	0.043	0.043	0.041	16	0.19
Approach	0.31	3.7	0.077	0.077	0.073	8.5	0.20
Taxi In	0.13	33	2.2	2.2	2.1	4.0	0.24
Boeing 747							
Taxi Out	0.22	11	0.64	0.64	0.60	5.1	0.32
Takeoff	2.6	0.11	0.14	0.14	0.13	33	0.54
Climb	2.1	0.11	0.14	0.14	0.13	25	0.55
Approach	0.69	0.87	0.24	0.24	0.23	12	0.30
Taxi In	0.22	11	0.64	0.64	0.60	5.1	0.32

Source: Federal Aviation Administration, United States Federal Government.

PROCESS-BASED LCA: AN EXAMPLE

Equation Set: Aircraft At or Near Operations (Source: Chester, 2008)

$$I/O_{stage}^{air,\ aircraft\ LTO\ operations} = \frac{I/O_{EDMS}}{number_{LTO\ in\ EDMS\ inventory}}$$

$$= Aircraft\ LTO\ I/O\ Determined\ in\ FAA\ EDMS\ Software$$

$$I/O_{stage,\ aircraft\ lifetime}^{air,\ aircraft\ LTO\ operations} = I/O_{stage}^{air,\ aircraft\ LTO\ operations} \times \frac{flight}{VMT_{flight}} \times \frac{VMT_{aircraft}}{lifetime_{aircraft}}$$

$$I/O_{stage,\ VMT}^{air,\ aircraft\ LTO\ operations} = I/O_{stage}^{air,\ aircraft\ LTO\ operations} \times \frac{flight}{VMT_{flight}}$$

$$I/O_{stage,\ PMT}^{air,\ aircraft\ LTO\ operations} = I/O_{stage}^{air,\ aircraft\ LTO\ operations} \times \frac{flight}{VMT_{flight}} \times \frac{VMT_{aircraft}}{PMT_{aircraft}}$$

Image by MIT OpenCourseWare

LIFE CYCLE ASSESSMENT OF TRANSPORTATION SYSTEMS

- What components should we consider for this project? (goal and scope)

	Rail	LCA Type	Aviation	LCA Type
Vehicle	Manufacturing Operation Maintenance Insurance	Process Process Process & EIOLCA EIOLCA	Manufacturing Operation Maintenance Insurance	EIOLCA Process EIOLCA EIOLCA
Infrastructure	Construction & Maintenance Operation Insurance	Process & Hybrid Process EIOLCA	Construction & Maintenance Operation Insurance	EIOLCA & Hybrid Process & EIOLCA EIOLCA
Fuel	Production	Process	Production	Process

Adapted from Chester,
"Life-cycle Environmental Inventory of Passenger Transportation Modes in the United States," 2008

LIFE CYCLE ASSESSMENT OF TRANSPORTATION SYSTEMS: GOAL & SCOPE

- What components should we consider for this project? (goal and scope: ***suggested***)

	Rail	LCA Type	Aviation	LCA Type
Vehicle	Manufacturing Operation Maintenance ~~Insurance~~	Process Process Process & EIOLCA ~~EIOLCA~~	Manufacturing Operation Maintenance ~~Insurance~~	EIOLCA Process EIOLCA ~~EIOLCA~~
Infrastructure	Construction & Maintenance ~~Operation~~ ~~Insurance~~	Process & Hybrid ~~Process~~ ~~EIOLCA~~	Construction & Maintenance ~~Operation~~ ~~Insurance~~	EIOLCA & Hybrid ~~Process & EIOLCA~~ ~~EIOLCA~~
Fuel	Production	Process	Production	Process

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LIFE CYCLE ASSESSMENT OF TRANSPORTATION SYSTEMS: GOAL & SCOPE

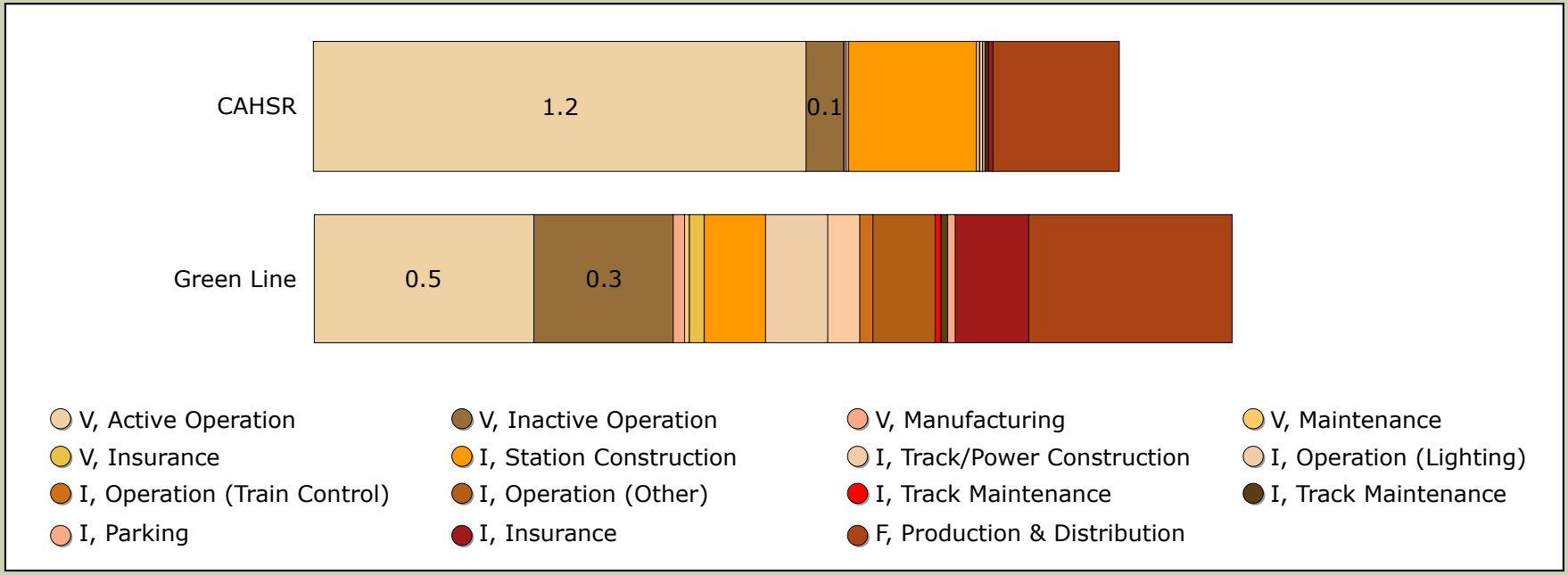

Image by MIT OpenCourseWare.

Source: Chester, "Life-cycle Environmental Inventory of Passenger Transportation Modes in the United States," 2008

PROJECT PLANNING

- Preparation for Recitation 8 project mid-term presentation.
  - Focus on:
    - Overview of the system of interest.
    - The goals of the project.
    - Preliminary data collection.
- Next steps:
  - Optional project meeting on Thursday or Friday focused on data collection and calculating 1 or 2 process-based lifecycle inventories.

ESD.00 Introduction to Engineering Systems
Spring 2011