Illinois Center for Transportation
University of Illinois at Urbana Champaign

Regional LCA Tool Development and Applications

Pavement LCA Symposium 2017

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"Where Excellence and Transportation Meet"

Acknowledgments

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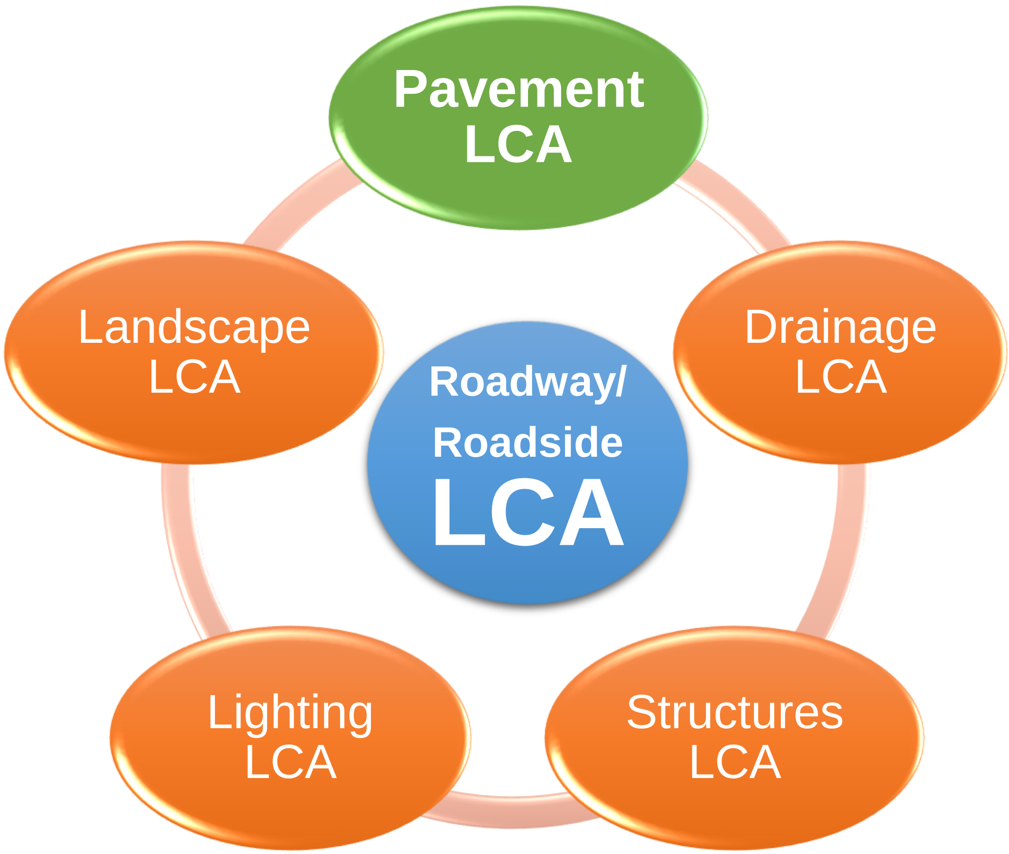
- **And Alejandro Salinas**

Illinois Tollway LCA Tool

Development of a complete roadway/ roadside LCA tool



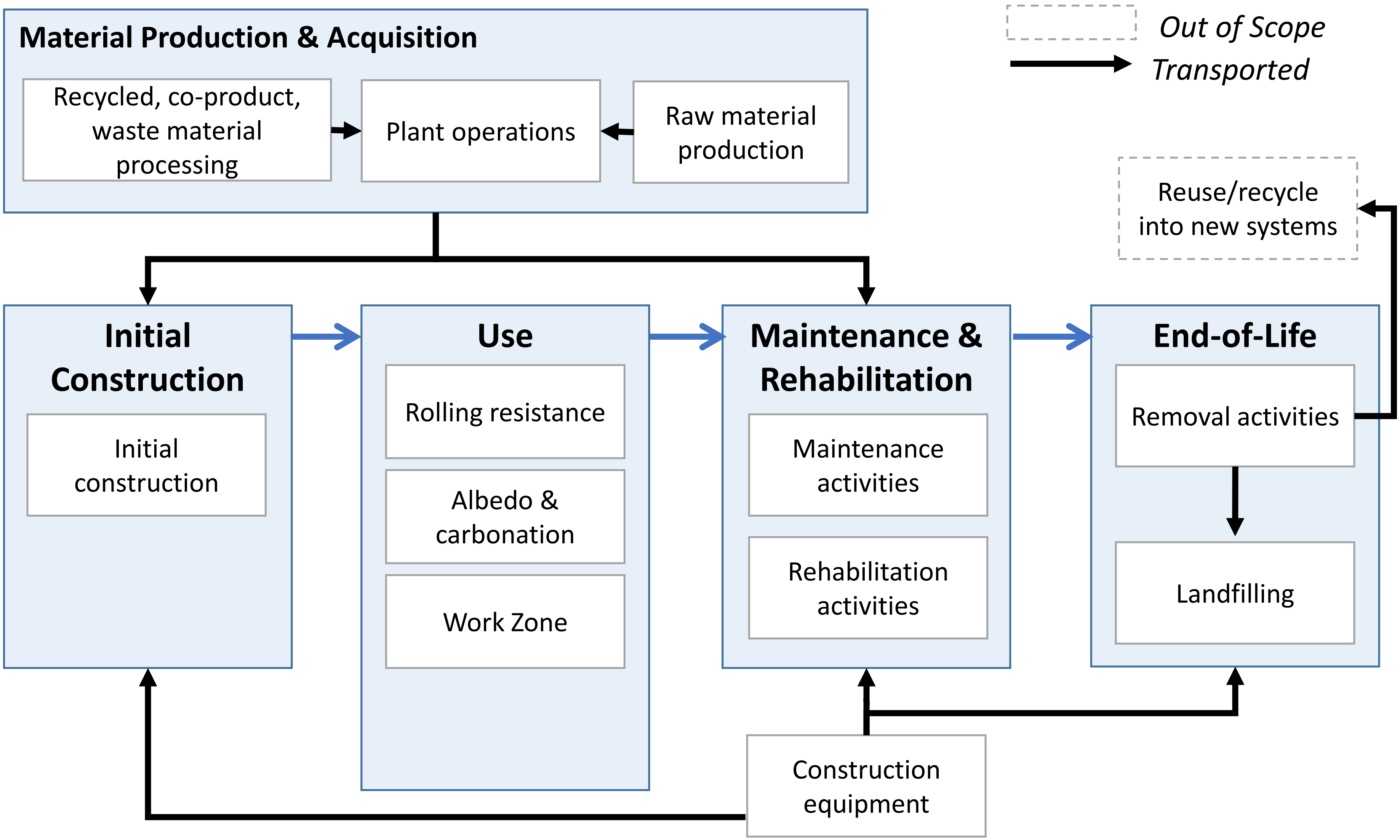
Tollway's Sustainability Goals

- **Communicate environmental performance** of roadway/roadside elements built/maintained by Tollway to all stakeholders
- **Monitor achievements** by establishing a baseline
- **Identify hot-spots** and develop **cost-effective strategies** to achieve the sustainability goals

UIUC’s Goal and Approach

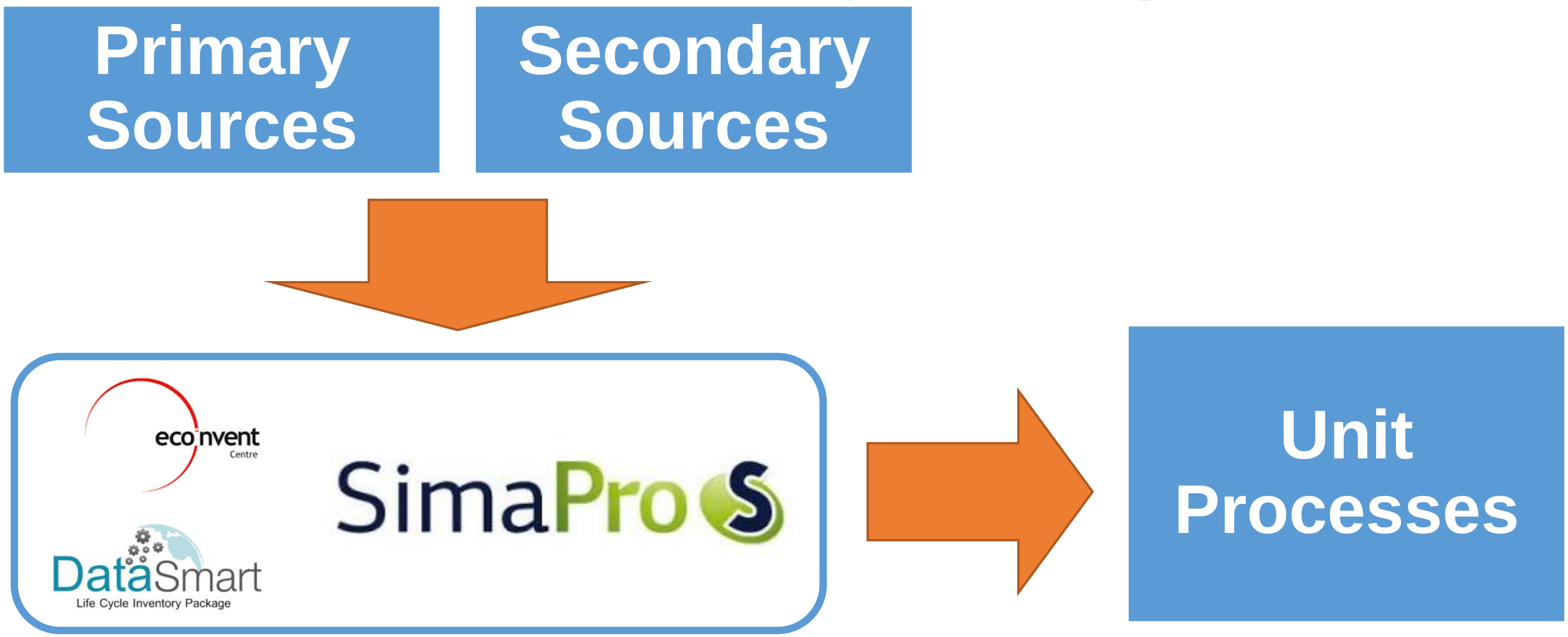
- Develop an easy-to-use and representative LCA tool to meet the needs of Illinois Tollway
- UIUC’s approach to accomplish the goal:
  - High quality and representative data
  - Inclusiveness with roadway/roadside features
  - Consistent with agency procurement practices
  - Use stage modeling and integration
  - Compatibility with ISO

System Boundaries



Inventory Analysis

- Compile data to best represent the **region and time period** of interest (Illinois, 1999-2014)
- Create **models** of major unit processes

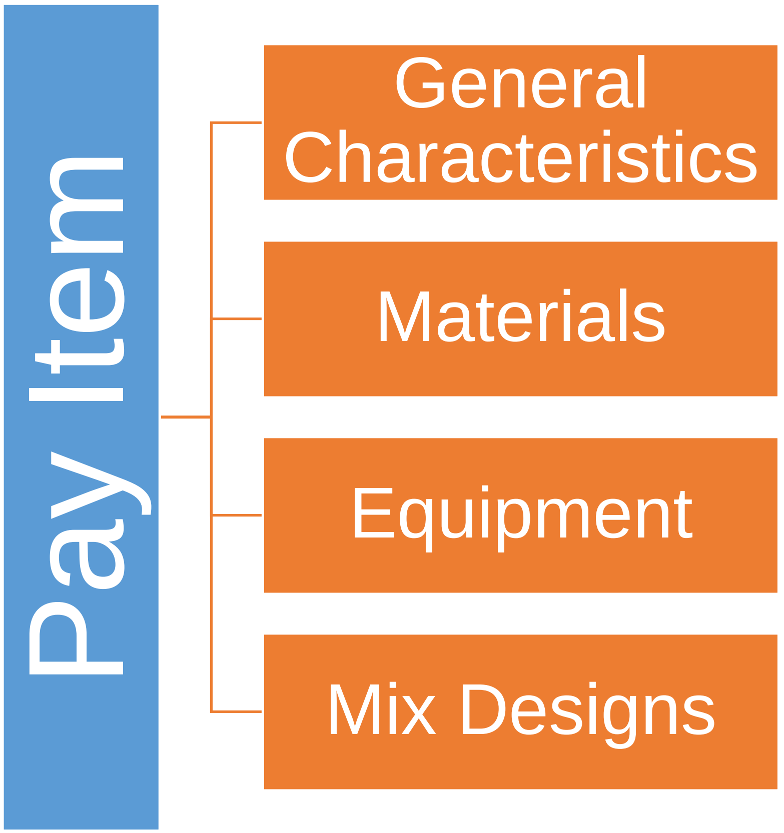


Inventory Data

- Total 591 materials are included in the inventory database
- 114 of these are related to pavements
- Primary data were sought for:
  - Aggregates
  - Asphalt binder
  - Cement and ready-mix concrete
  - Emulsions
  - Asphalt and concrete plant operations
- Secondary data for upstream processes

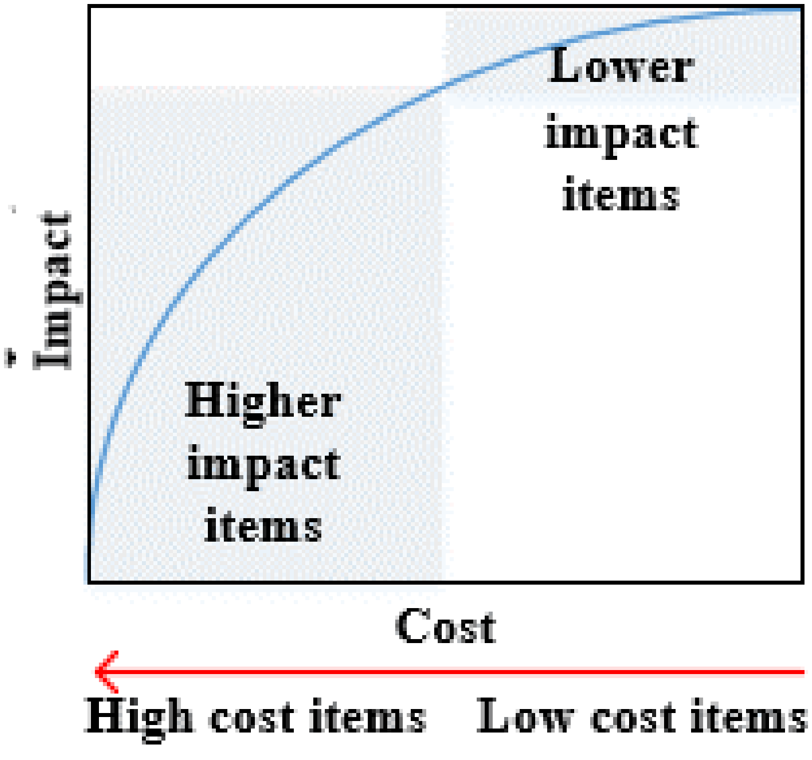
Use of Pay Items

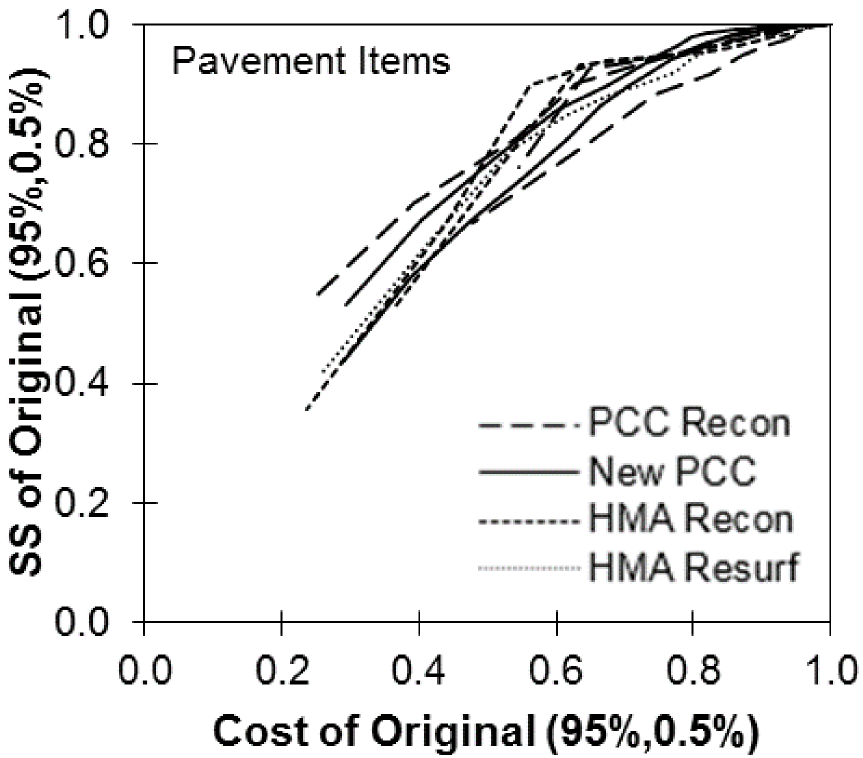
- Use of pay items as the **basis unit** in all phases except the use stage
- This **facilitates implementation** of LCA using existing procurement framework
- Improves inventory data quality



Importance of Pay Items

- Almost 2,000 pay items with 603 of them are related to pavements
- Including top pay items (95% of cost) capturing most impacts





Impact Assessment

Four major metrics

- Global Warming Potential (GWP)
- Total Primary Energy (TPE)
- Primary Energy as Fuel (PEF)
- Single Score (SS)

Weighted and normalized TRACI impacts:

- Ozone depletion
- Smog
- Acidification
- Fossil fuel depletion
- Eutrophication
- Respiratory effects
- Non carcinogenics
- Carcinogenics
- Ecotoxicity
- Global warming

Other relevant metrics

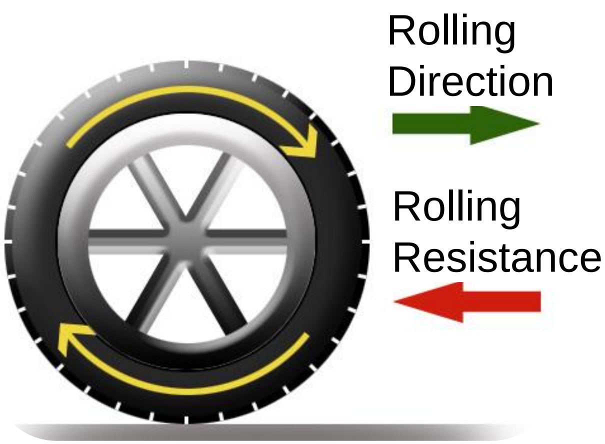
- Recycled Content (%)
- Renewable Content (%)
- Transportation Intensity (ton-mile)

Data Quality Assessment

Time-Period	• Data collected from 2012 • Time-sensitive equipment and electricity databases
Geography	• Northern Illinois region • Inventory models for electricity mix, asphalt binder, hauling trucks
Technology	• Includes warm mix technology • Recent IDOT/Tollway standards
Representa-tiveness	• Actual pay items, mixes, standards • Surveys to Tollway contractors/plants
Completeness	• Use of pay items allows for supporting items (i.e., markings, signs, etc.)

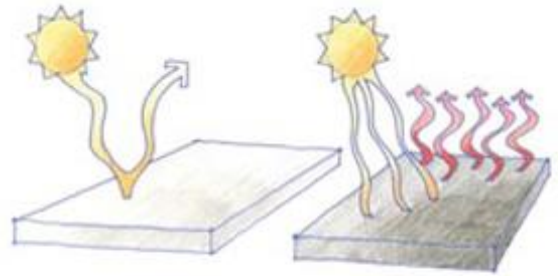
Use Stage Models

- Developed models for rolling resistance and included albedo and lighting in the use stage



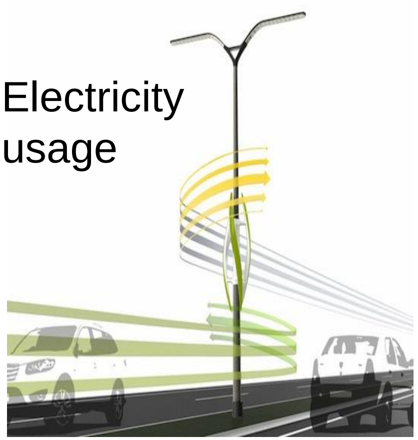
Pavement-tire interaction

Rolling Resistance



Higher Albedo Lower Albedo

Albedo



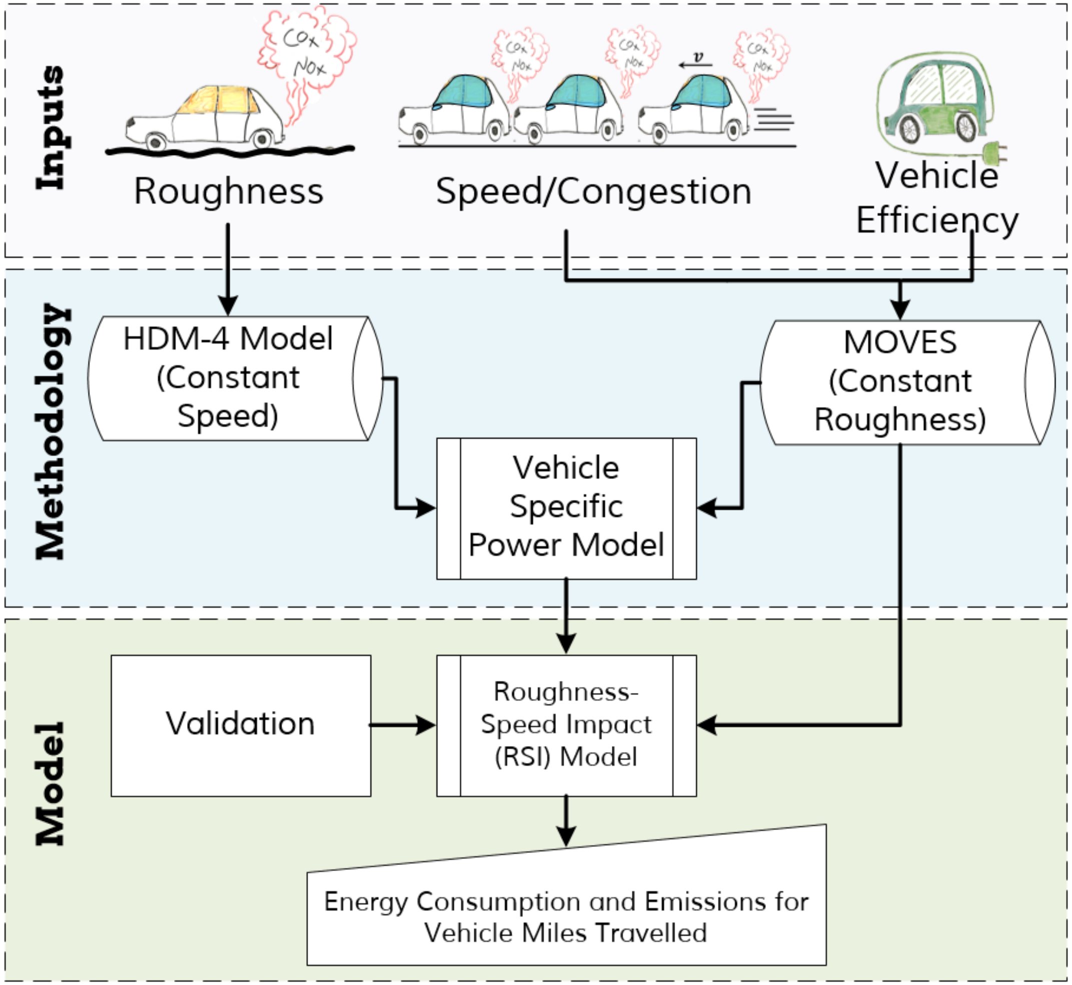
Lighting

Use Phase

Roughness-Speed-Impact Model

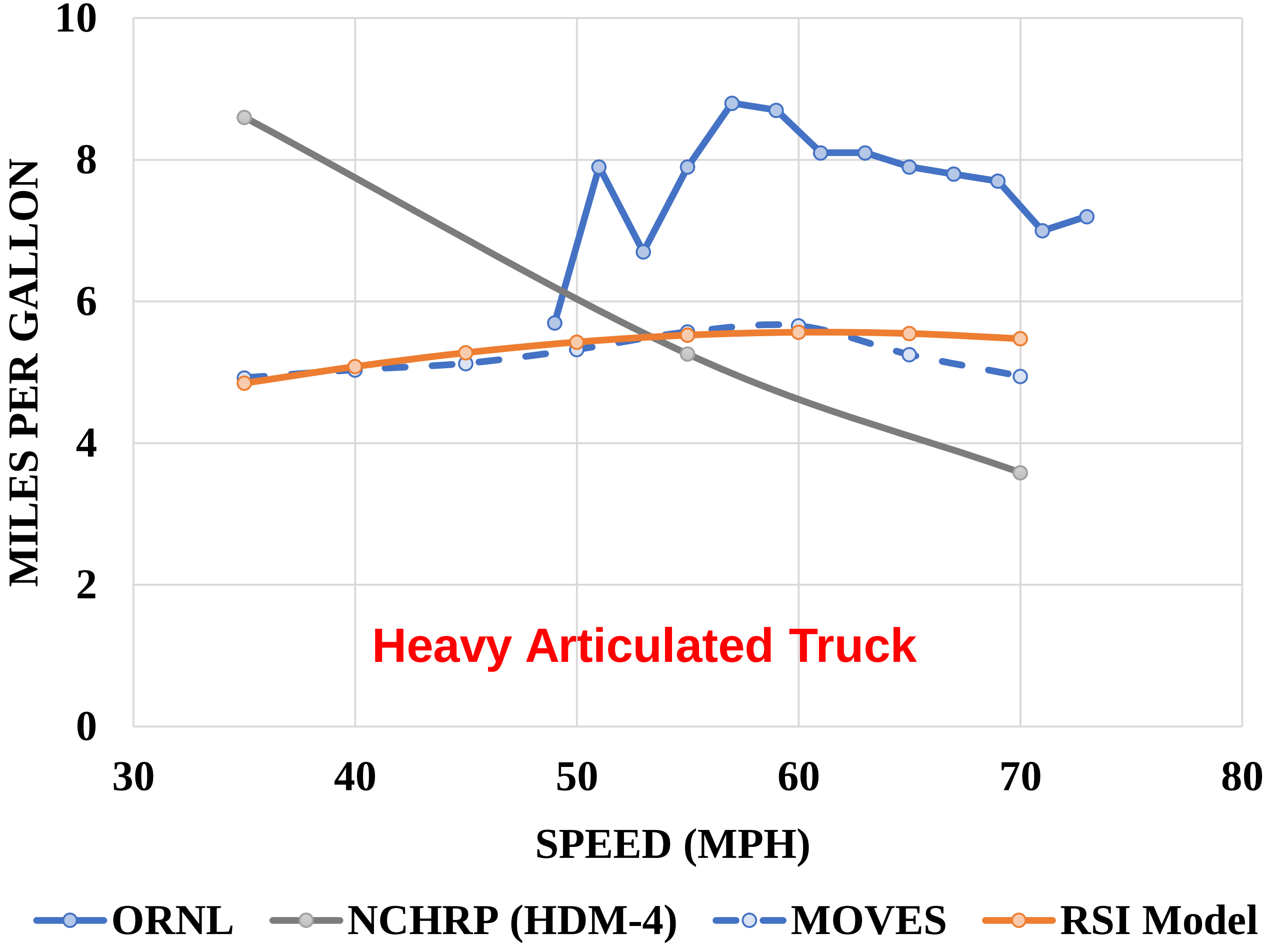
- An analytical standalone model was needed
- Impacts are based on vehicle type, speed, roughness
- RSI model can be easily integrated to any LCA software

Model Development Approach



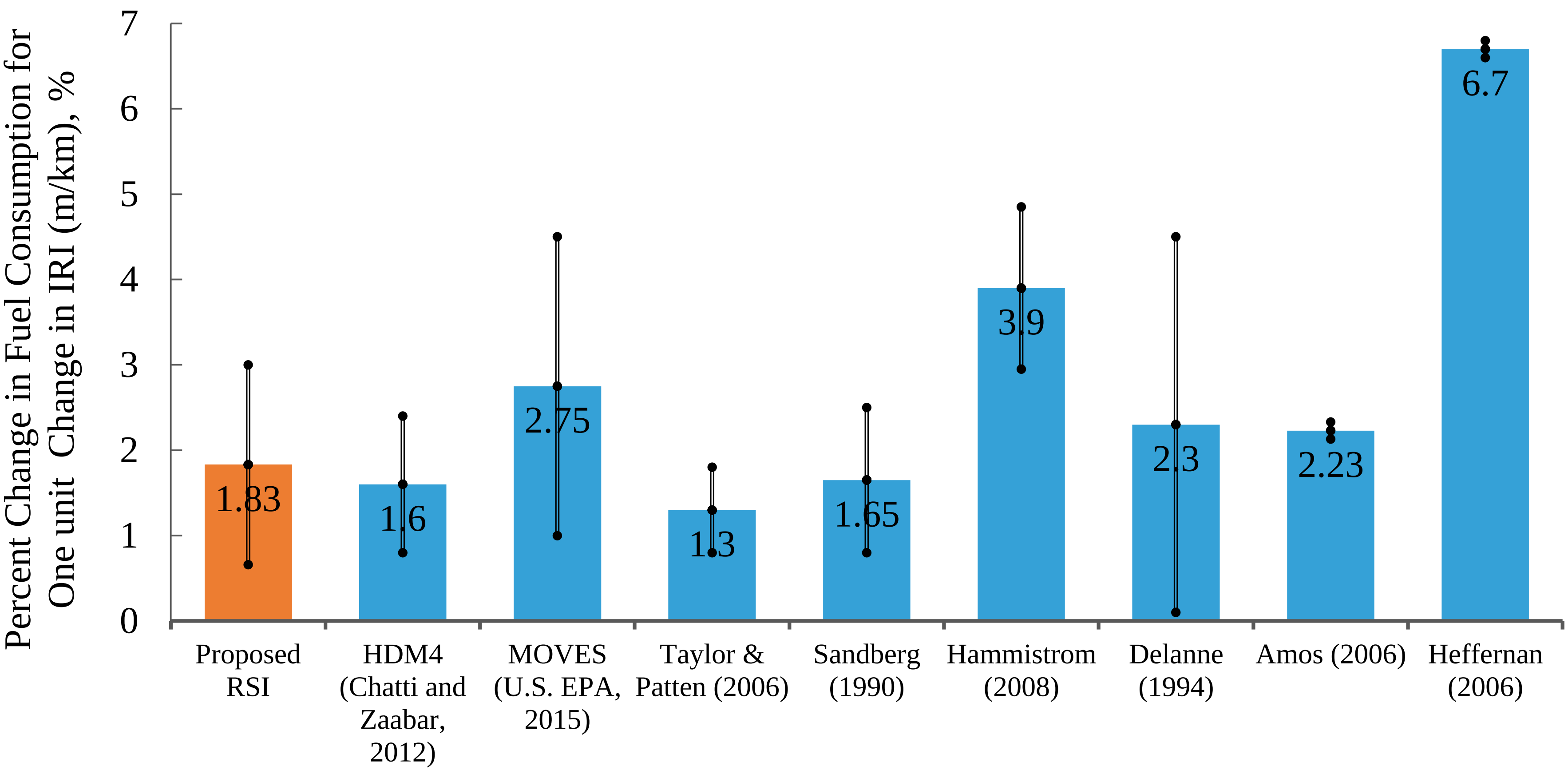
RSI Model Verification

- Total fuel consumption according to the RSI model as a function of speed is in the range



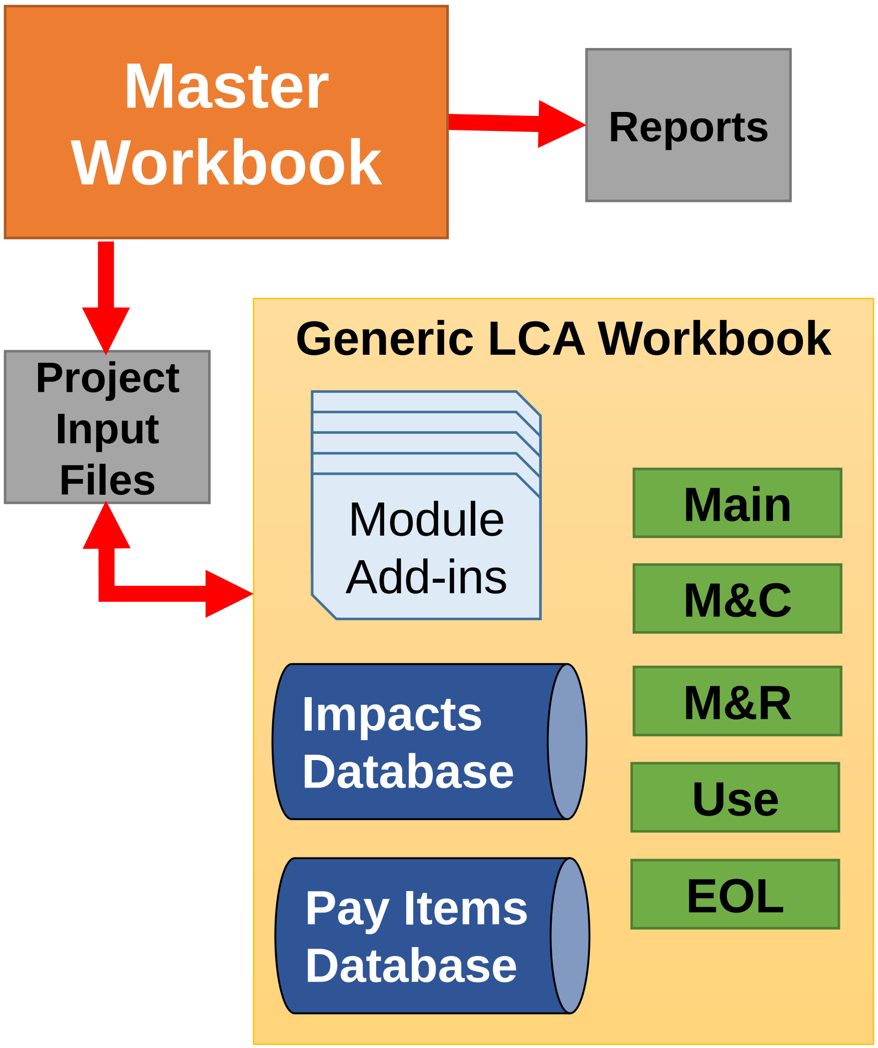
RSI Model Verification

- RSI can report incremental impacts per change in IRI

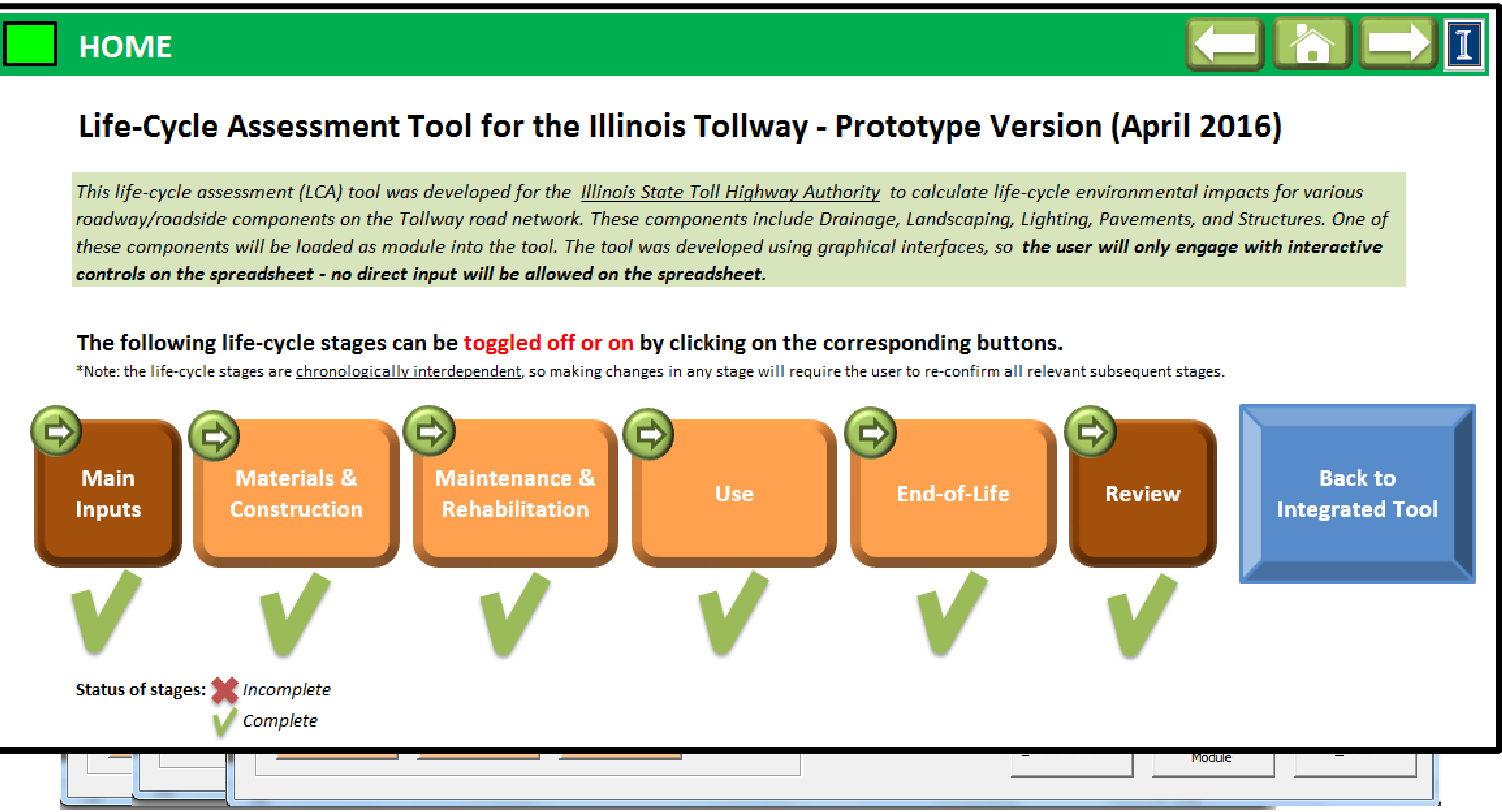


LCA Software

- MS Excel/VBA
- Follows life-cycle stages
- Modular design for consistency to allow for other roadway/ roadside elements
- Pay items are used throughout to facilitate agency use



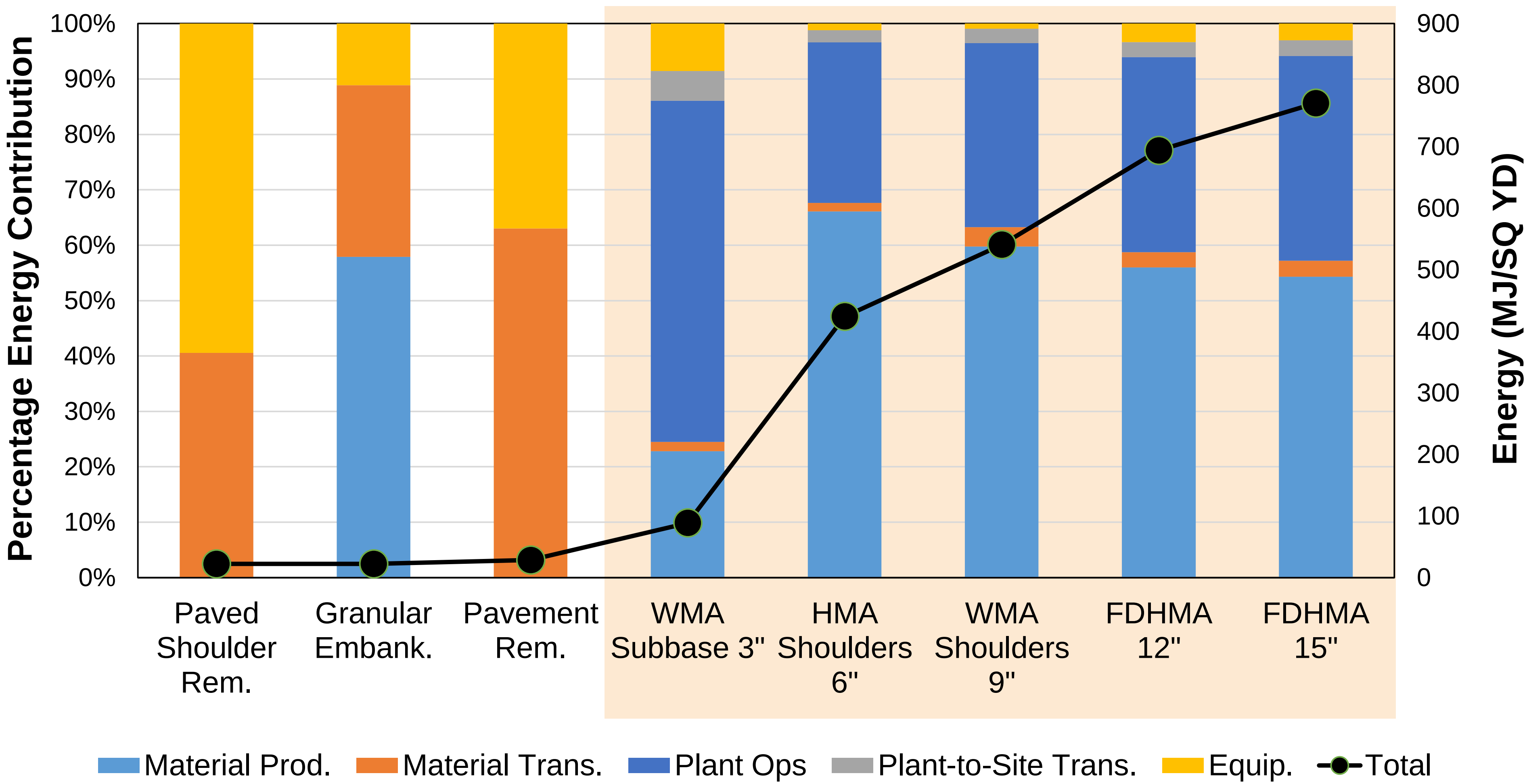
Complete LCA Tool



Mix Level and Pay Items Analysis

Contri[redacted]y Items

Total



Project Level LCA and Interpretation

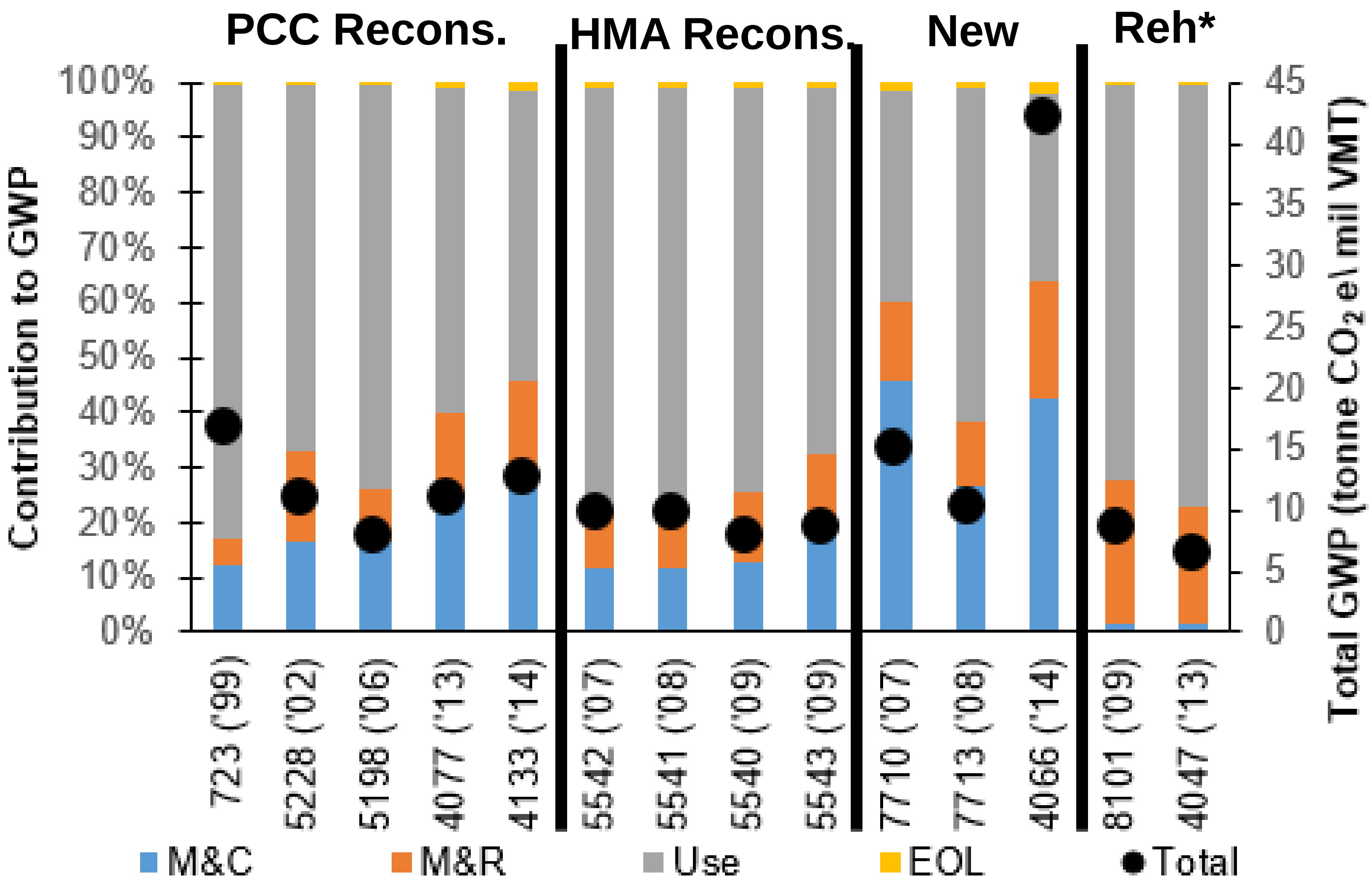
14 Case Study Projects

Parameter	Range of Values in Projects
Year	1999 – 2013
Pavement type	12” JPCP, 12” CRCP, 12 – 15” HMA, 11.25” JPCP composite, HMA overlays
Project type	Widening, reconstruction, resurfacing, new construction, new ramp construction
Traffic level	20,000 to 70,000
% Truck	7% – 29%
Cost	$6.7M – $50M
Length	1.5 mi – 12.8 mi
Analysis Period	44 – 78 yrs

Key Assumptions

- Tollway LCA software is capable of performing **comparative analysis** between projects and modules
- **Unique attributes** in projects make it challenging to draw comparisons or trends
- Reports results based on **total project impacts** as well as the **functional unit** chosen as vehicle-miles-travelled
  - More on Thursday presentation…

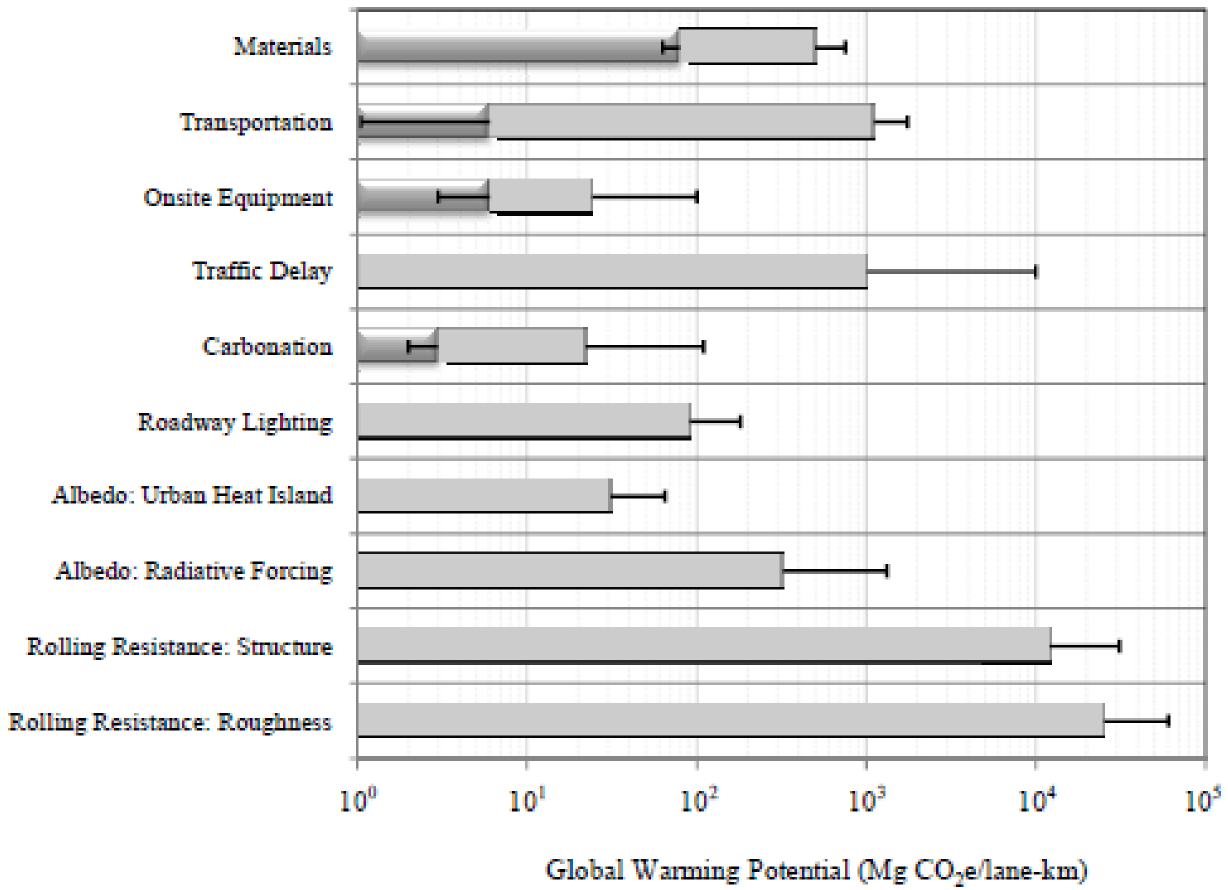
Summary of Projects - GWP



*Rehabilitation/Resurfacing

A Bit of Nostalgia!!!

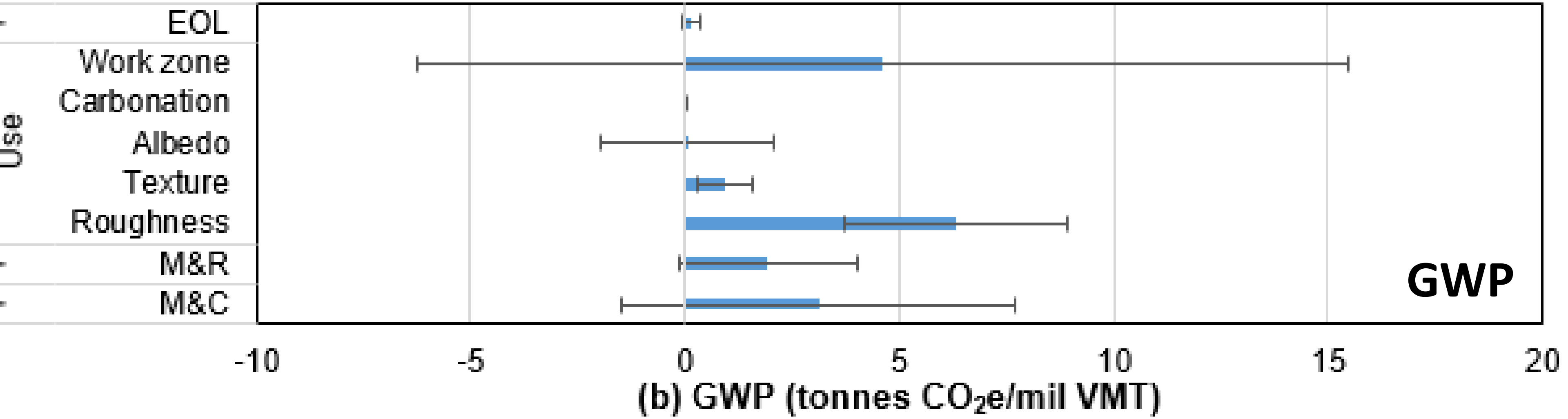
- Let's check where we are at since 2009!



Santero and Horvath (2009). GWP of pavements. Environmental Research Letters

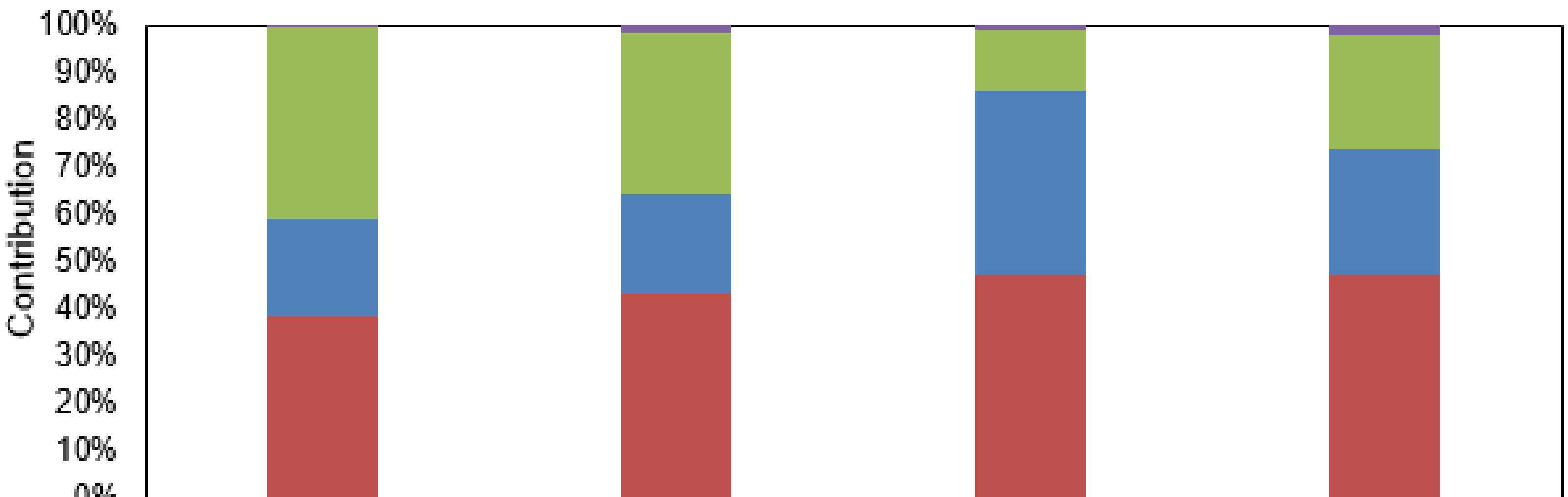
Impact Ranges Based on Actual Data

- **Material and construction** stages are not always as small as we think (~5-50%)
- **Roughness and work zone** are the largest contributors
- **Large variations** in all impacts from projects to projects



Case Study – Low Volume

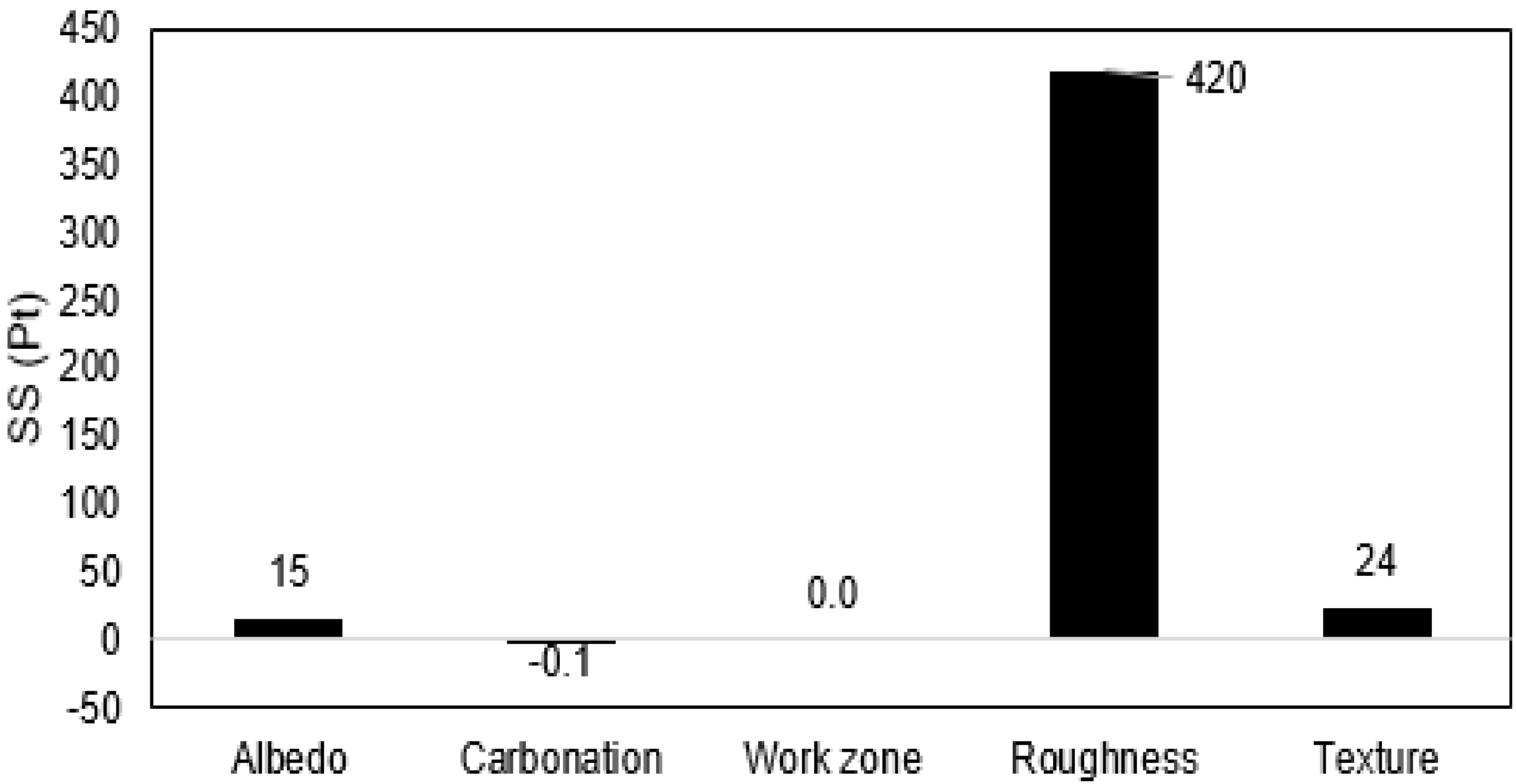
Project Year & Cost	2013-2014 & $29.5 million ($4.9 million for pavement)
Type	New JPCP Ramp I-57
Analysis Period	62 years
Length/Lanes	1.2 mi
Traffic	**4,100** ADT with 22.1 % truck (2013)



	SS	GWP	TPE	PEF
EOL	0.4%	1.8%	1.1%	2.1%
Use	40.8%	34.1%	13.2%	24.6%
M&R	20.6%	21.3%	38.3%	26.3%
M&C	38.2%	42.7%	47.4%	47.0%

Use Stage Breakdown

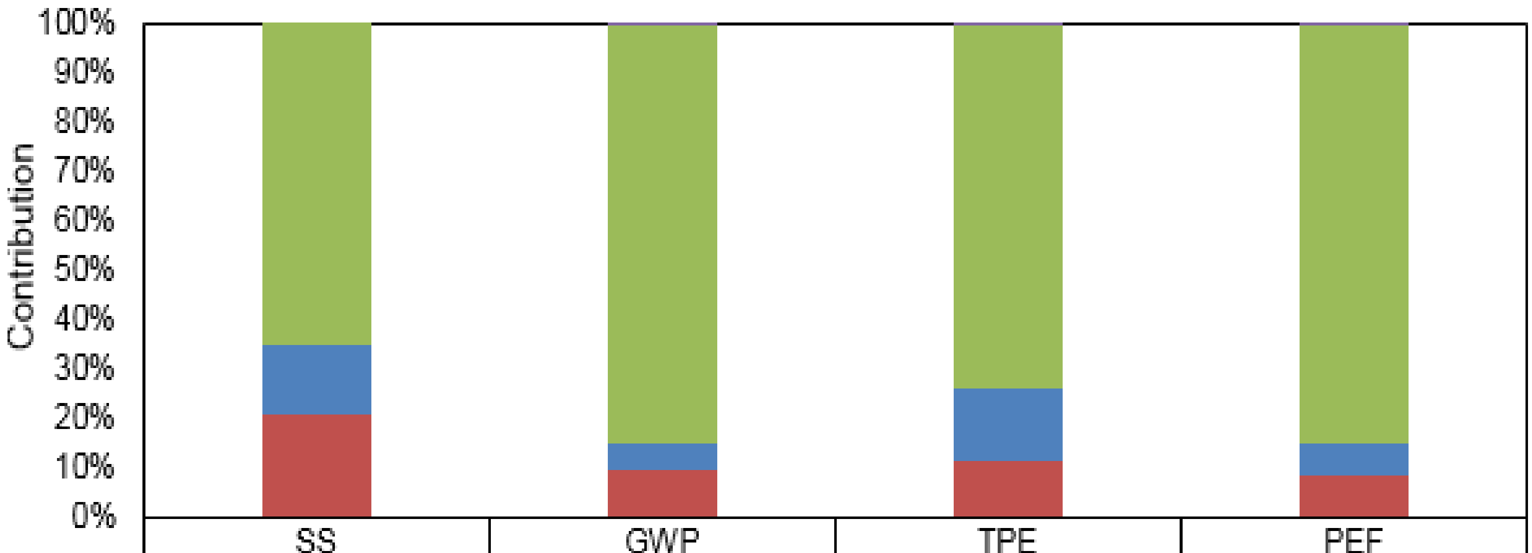
- Roughness governs the use stage impact



No work zone closures due to new construction

Case Study – High Volume

Project Year & Cost	2004-2006 & $36.7 million ($31 million for pavement)
Type	Widening with CRCP
Analysis Period	78 years
Length/Lanes	4.6 mi
Traffic	**70,000** ADT with 7.6 % truck (2006)



	SS	GWP	TPE	PEF
EOL	0.2%	0.3%	0.3%	0.4%
Use	64.8%	84.8%	73.6%	85.0%
M&R	14.5%	5.4%	14.9%	6.2%
M&C	20.5%	9.4%	11.3%	8.5%

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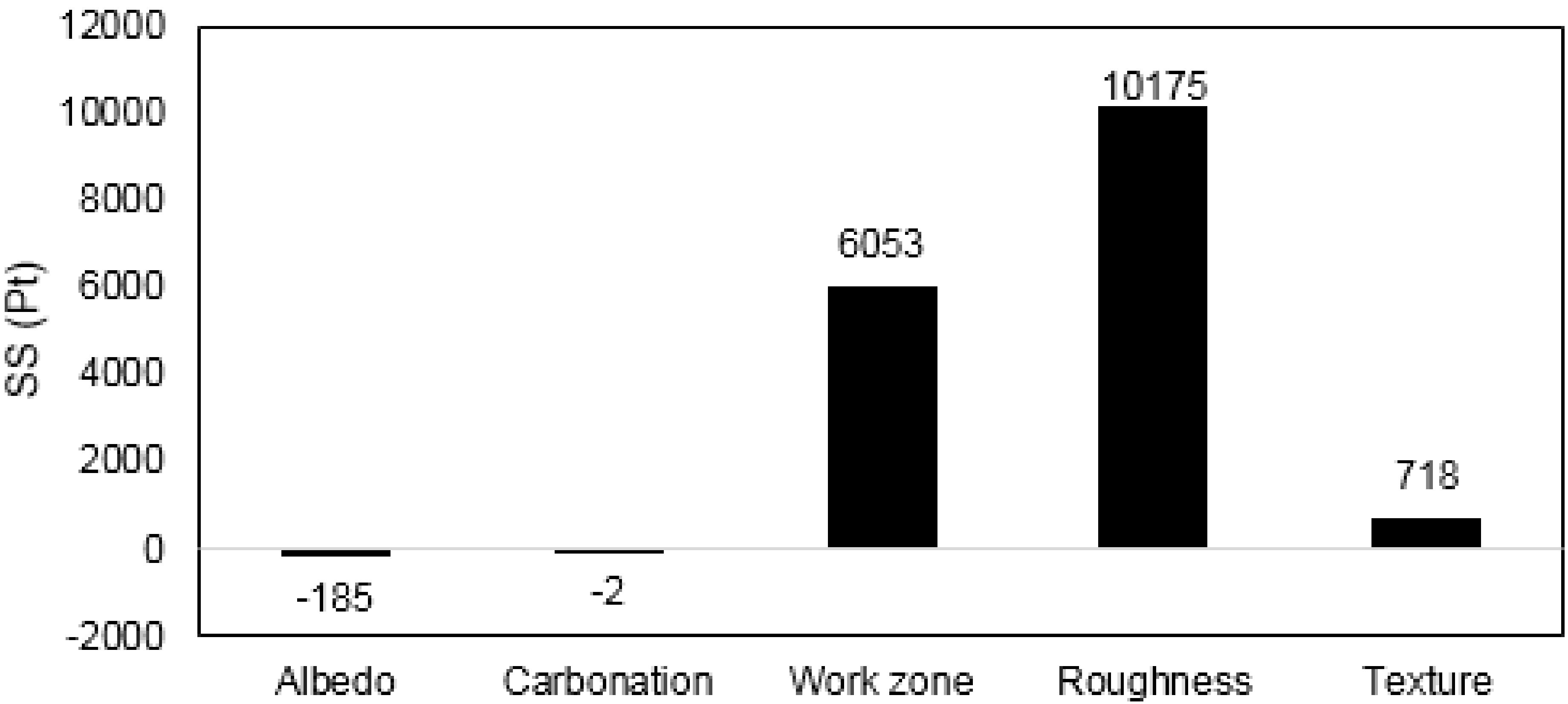
Use Stage Breakdown

- Work zone and roughness may be competing with each other



Final Remarks

- A **ready-to-use tool** was developed for an agency use
- Required data quality can be achieved using **inventory modeling**
- Completeness of an LCA analysis is critical to report most accurate impacts (importance of **pay items**)

Final Remarks

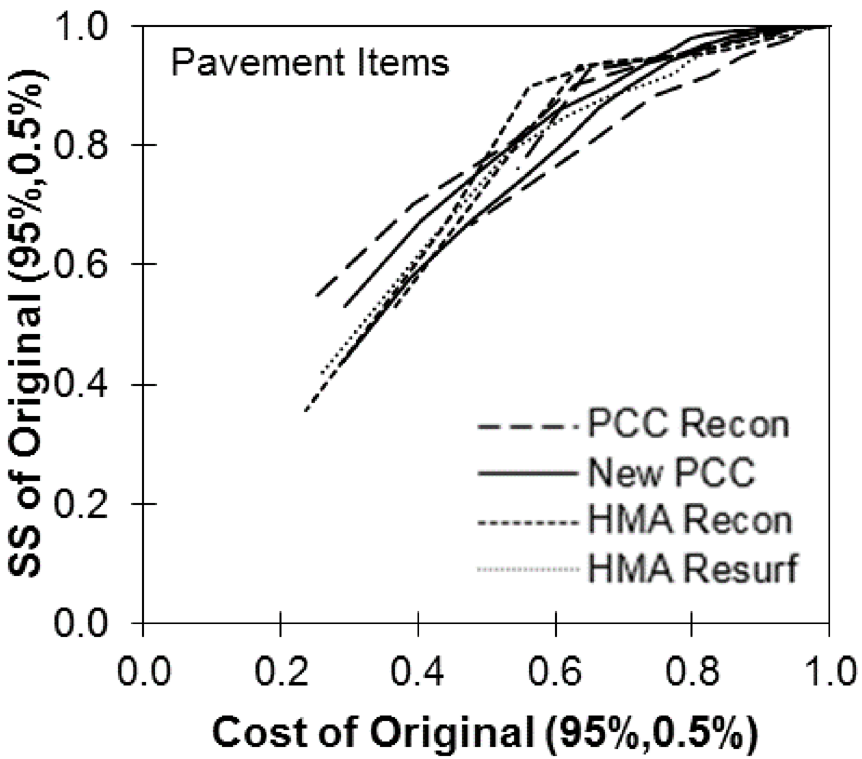
- **Materials and construction** stages can be as **important** as use stage for low volume roads
- **Roughness** impact should be captured with **proper models** and traffic volume/ composition
- **Work zone** contribution to LCA **may not be ignored**; especially for high volume roads

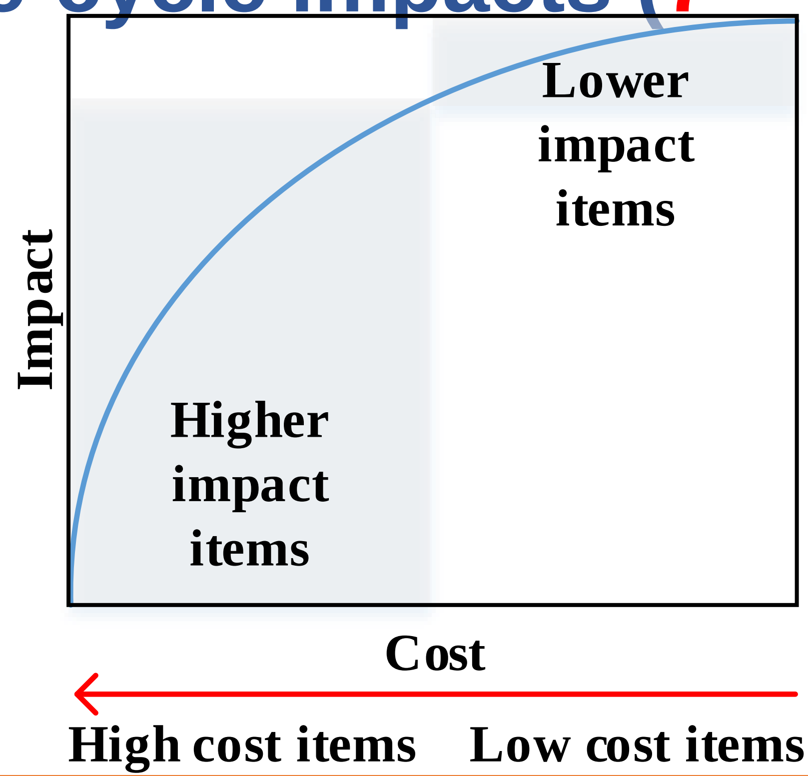
Thank you for your time!

UIUC's Main Quad

Sensitivity: Cut-off Criteria

- Including **top pay items** capturing most impacts
- Considering only top 70% vs. 95% pay items omits 2-3% life-cycle impacts (7-





Sensitivity Analysis

- **Systematic evaluation of the effect of methodological choices on life-cycle impacts**

Issue	Effect on Life-Cycle (LC)	Individual LC Stage
M&C cut-off criteria	2 – 3%	7 – 12%
Substitution allocation for EOL	small	39 – 76%
M&C round trip hauling	--	10%
Random traffic growth	+/- 20% STDEV	--
Impact assessment	35%	--

Sensitivity Analysis

- Systematic evaluation of the effect of important **parameters** on life-cycle impacts

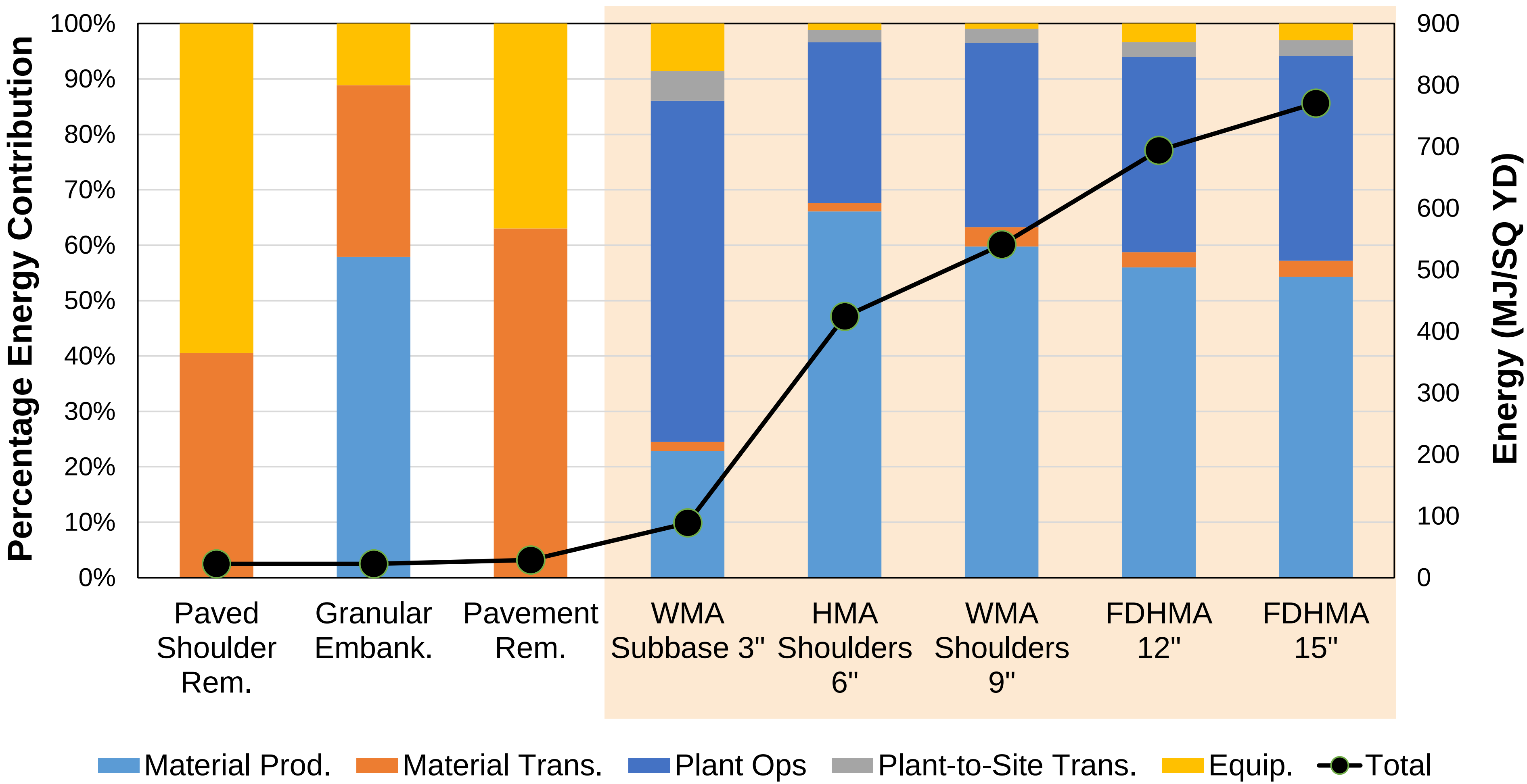
Issue	Effect on Life-Cycle	Excluding Use-Phase
Binder allocation	0.8 – 2%	2 – 8%
Progressive material LCI	small	2 – 6%
Progressive equipment LCI	small	0 – 3.4% REP*
Improved technology	50%	--

*Respiratory Effects

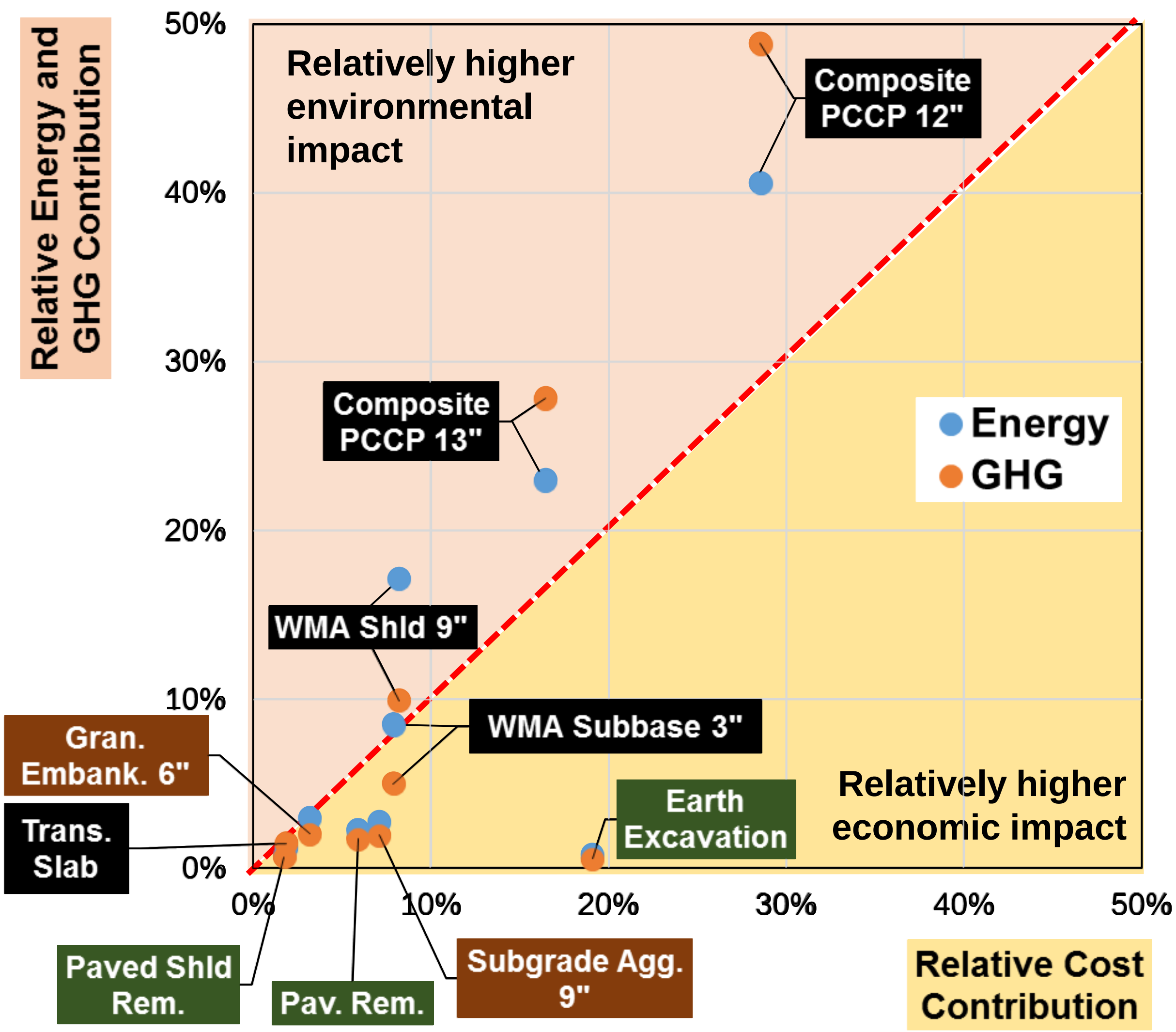
Mix Level and Pay Items Analysis

Contri[redacted]y Items

Total



Pay Items: Project-Level* View



- **Cost-environment relationship for pay items**
- **Potential tradeoffs to optimize multi-objectives**

*Composite PCC reconstruction project