Rethinking Design Scenarios through Concurrent Multi-dimensional Exploration for Sustainable Decisions

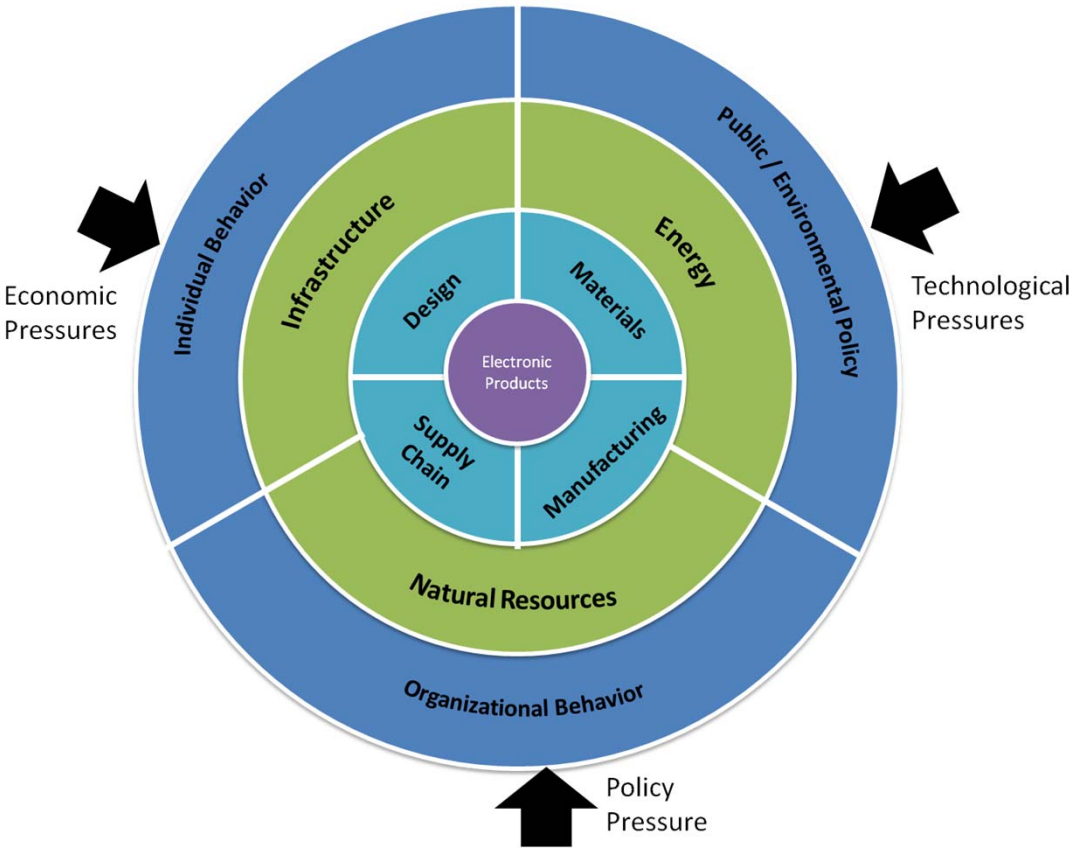
Karthik Ramani
Donald W. Feddersen Professor of Mechanical Engineering
Professor of Electrical and Computer Engineering (by courtesy)
Division of Environmental and Ecological Engineering (courtesy)
Purdue University

William Z. Bernstein
PhD Student
School of Mechanical Engineering
Purdue University

Devarajan Ramanujan
PhD Student
School of Mechanical Engineering
Purdue University

Motivation

- Built infrastructure, product and services must be rethought in a global context
- Future environmental regulations in the US are imminent
- Manufacturing, supply chains and business decisions through a design lens
- After a full-fledged LCA, it is still difficult to identify hotspots for improvements



China & US:
Comparison of superpowers

*By 2015, the cost of outsourcing manufacturing to China will be equal to the cost of manufacturing in the US.**

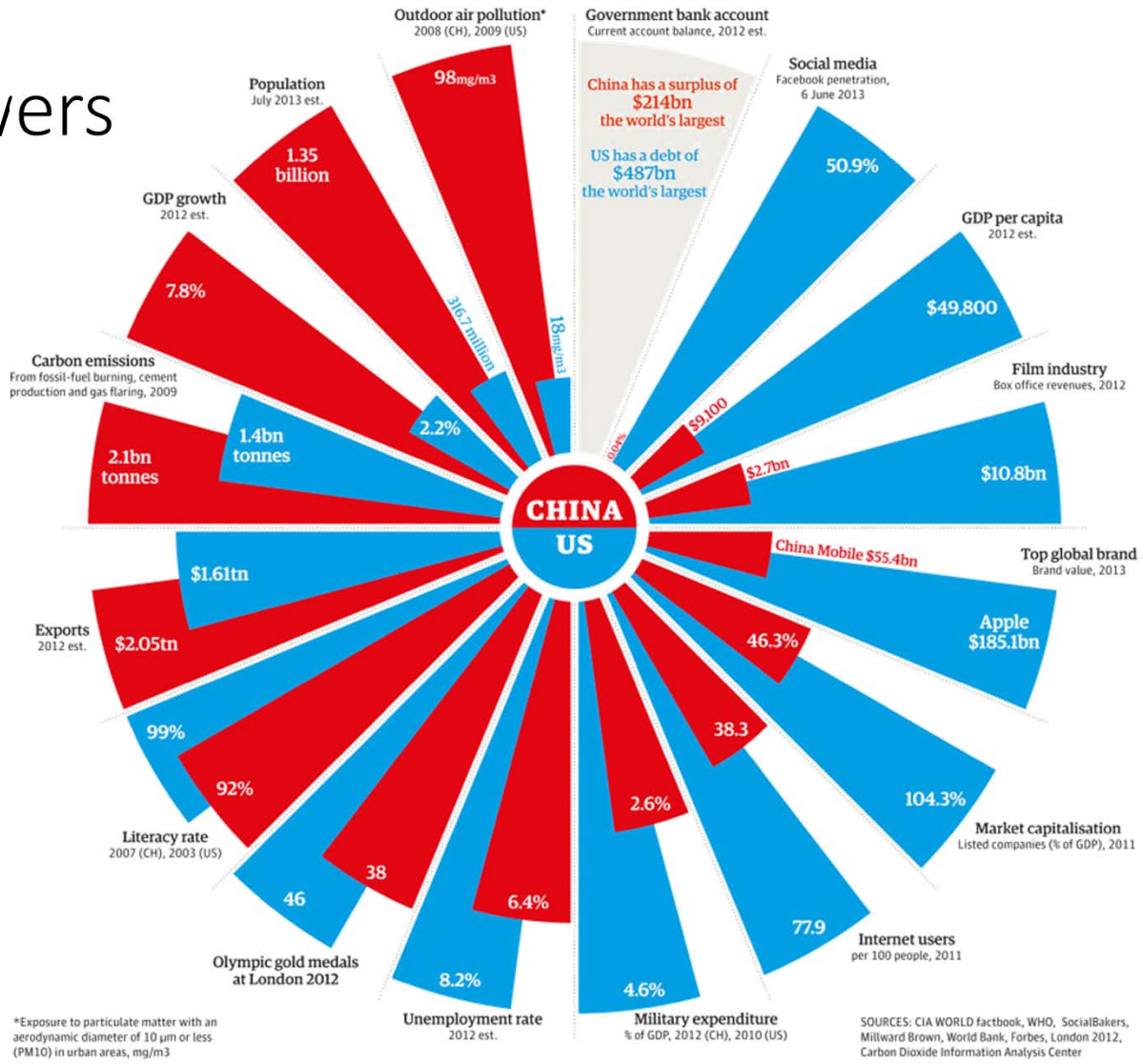
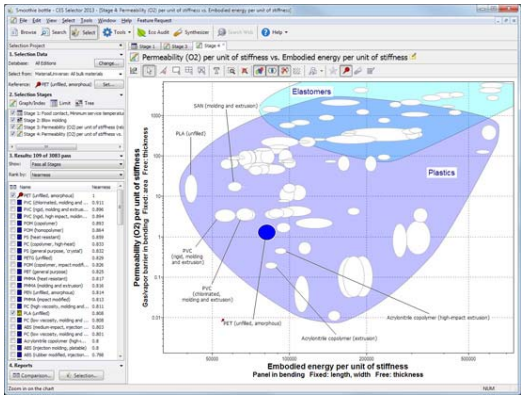


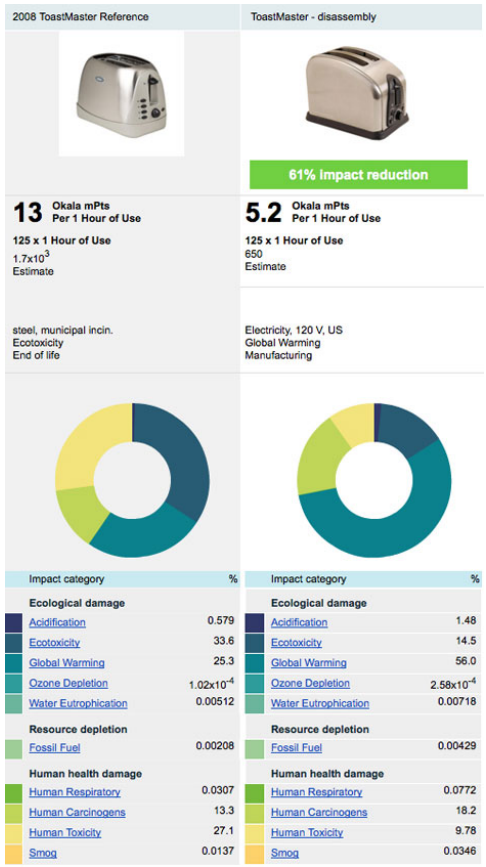
Image Source: http://www.theguardian.com/news/datablog/2013/jun/07/china-us-how-superpowers-compare-datablog
*According to AlixPartners

Current tools for sustainable design

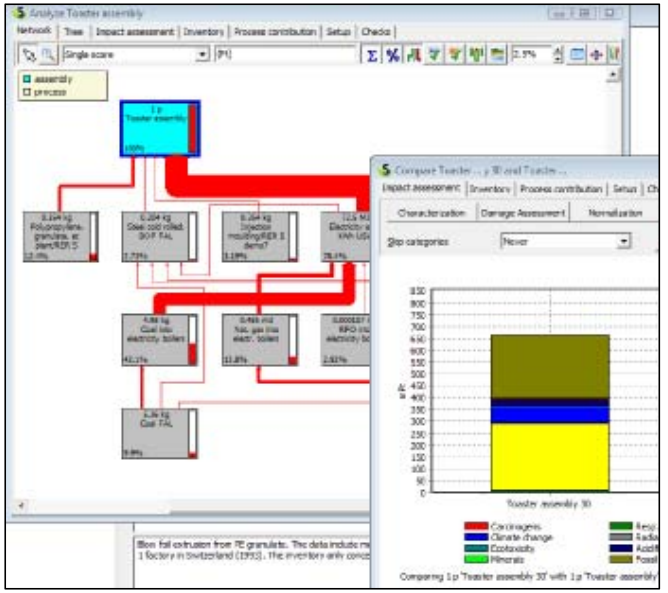


Granta Design CES EduPack Eco Seletor

SolidWorks Sustainability Express



Sustainable Minds



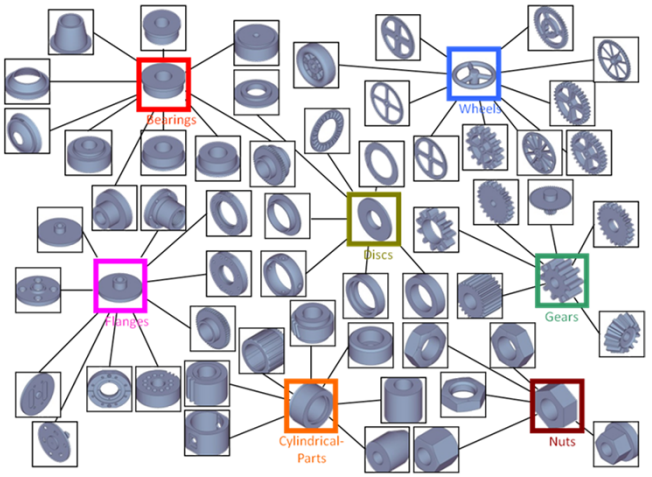
SimaPro with Ecoinvent 2.0

Requirements for future tools

- **Explore product repositories**

- **Ease of use** and **naturalness** of the interaction process

- **Cognitively prominent display** of information.



http://i.i.cbsi.com/cnwk.1d/i/tim/2011/06/17/minority-report-ui_244x183.jpg

Strategy

- Make data visible during decision-making stage
- Promote exploration towards providing new insights for decisions
- Embed sustainable thinking into existing curricula to spur educational innovation

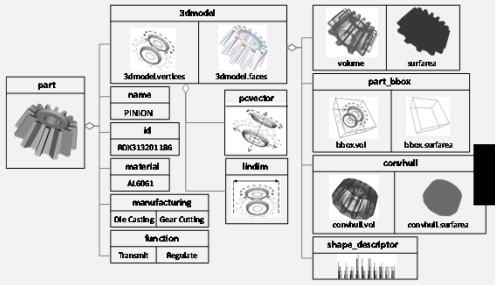
Application Areas

The potential broad applications areas for this collaborative visualization cyber-infrastructure are:

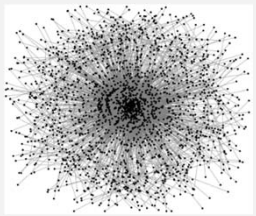
- Product development and re-design
- Manufactured products sector
- Supply chain viewing and decision making
- Building construction and management
- Environmental engineering
- Potential use of developed tools for training novice designers though data exploration
- Collaborative product engineering in geographically distributed teams

Project Overview

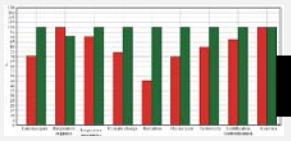
PLM DATABASE



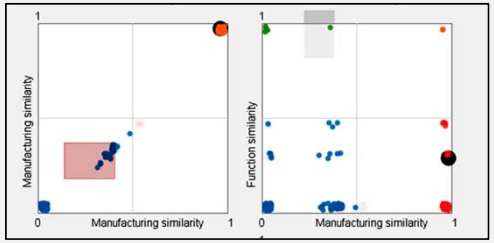
Supplier network

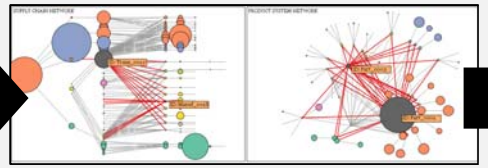


LCA DATA

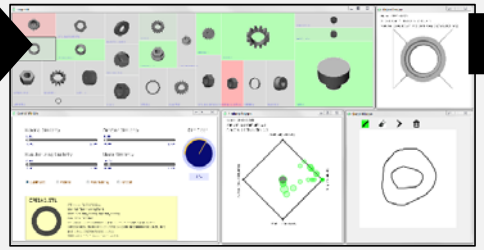


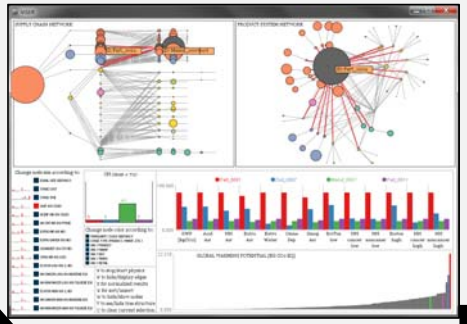
VISUAL REPRESENTATIONS FOR PLM AND LCA DATA





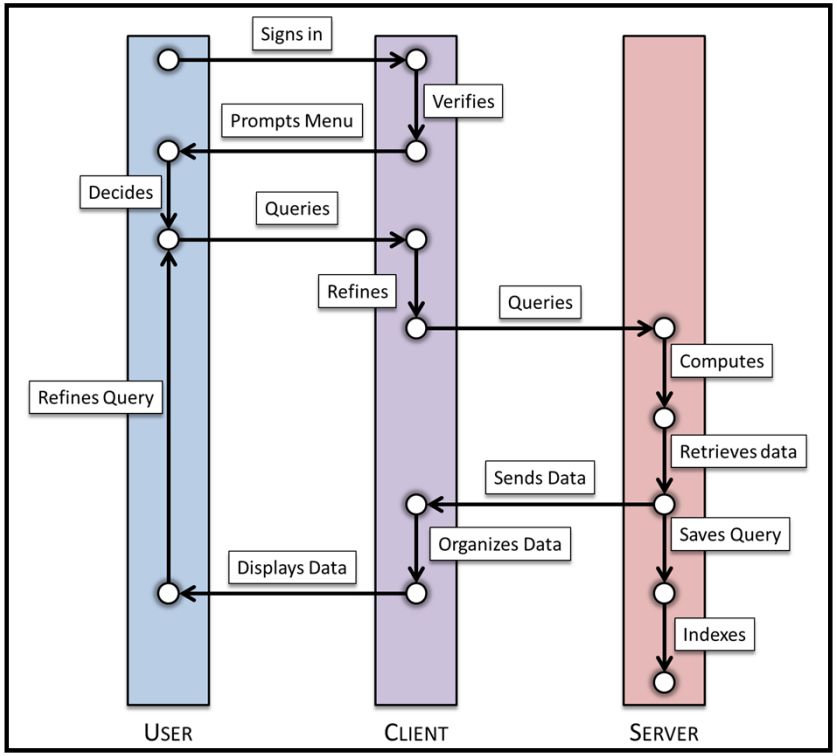
VISUAL ANALYTICS AIDING SUSTAINABILITY-AWARE DECISION MAKING

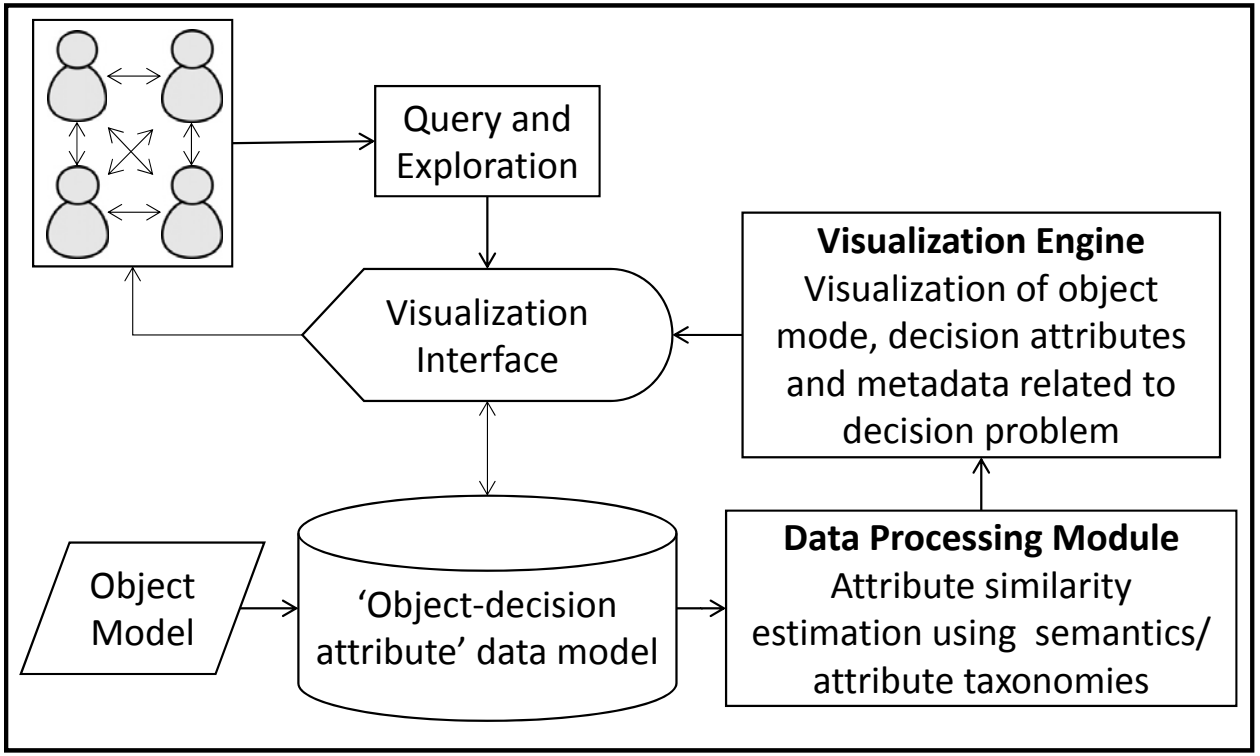




MULTIMODAL HUMAN-COMPUTER INTERFACES

Developing Interactive Prototypes





Developing Abstract Prototypes

Constructing Modular Architectures

Educational Dissemination

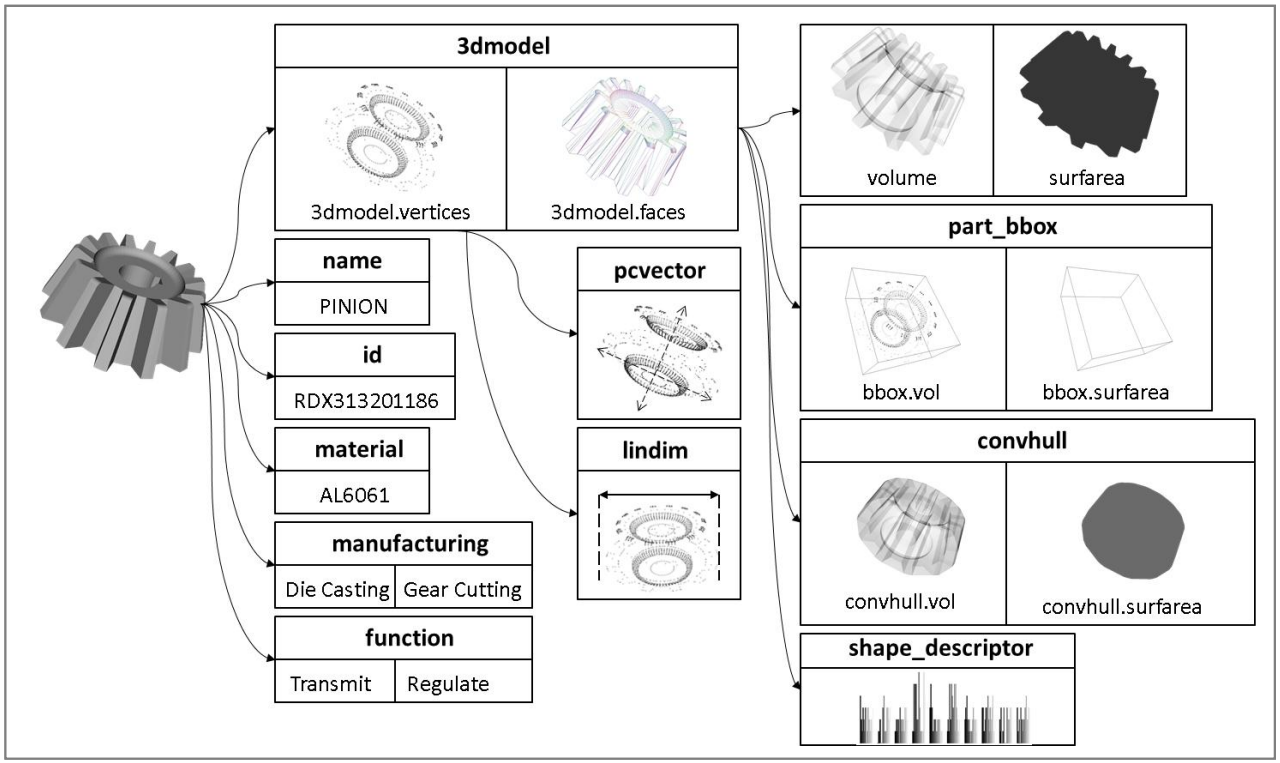
- Design critique of student projects with respect to sustainability [ME553]
- Gamification of shape synthesis constrained by environmental indicators [ME444]
- Merging ethics and empathy within design thinking targeted at extreme affordability (e.g. developing world) [ME553]

Acknowledgements

- NSF U.S. and China team
- NSF CMMI current grant in sustainable design and manufacturing
- NSF DUE sustainability related grant

Thank you

Example of a Proposed Data Representation Model



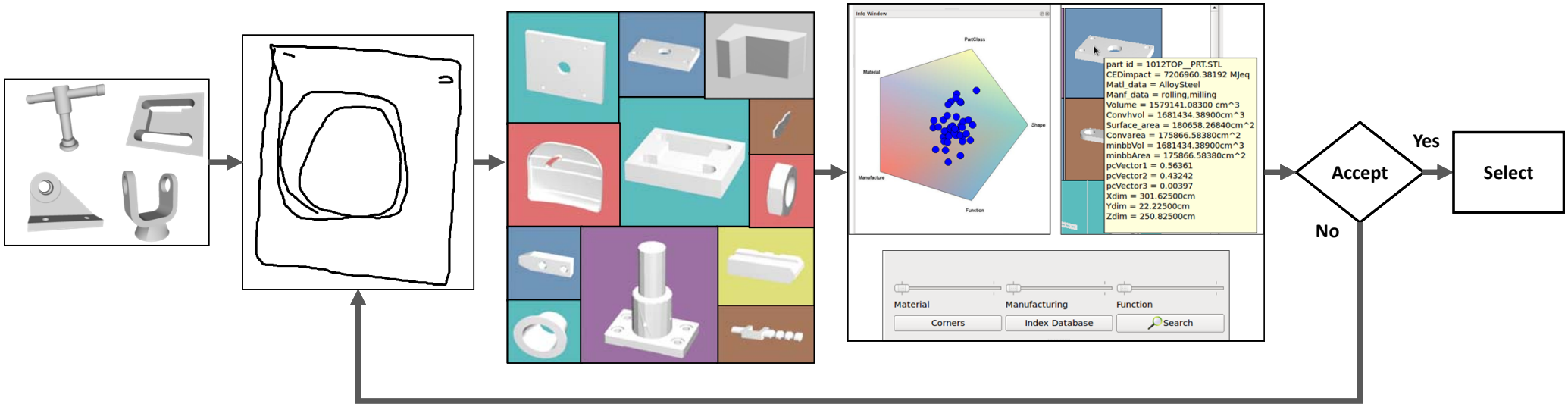
class part {

id	% unique identification number
name	% part name
shape_descriptor	% derived bag of words descriptor
function	% functions attributed
material	% material definition
manufacturing	% list of manufacturing processing
3dmodel	% mesh model of part
part_volume	% part volume
convhull.volume	% convex hull volume
bbox.volume	% volume of min. bounding box
surfarea	% part surface area
convhull.surfarea	% surface area of convex hull
bbox.surfarea	% surface area of min. bounding box
pcvector	% principal component vectors
part_linear_dim	% linear dimensions in three axes

}

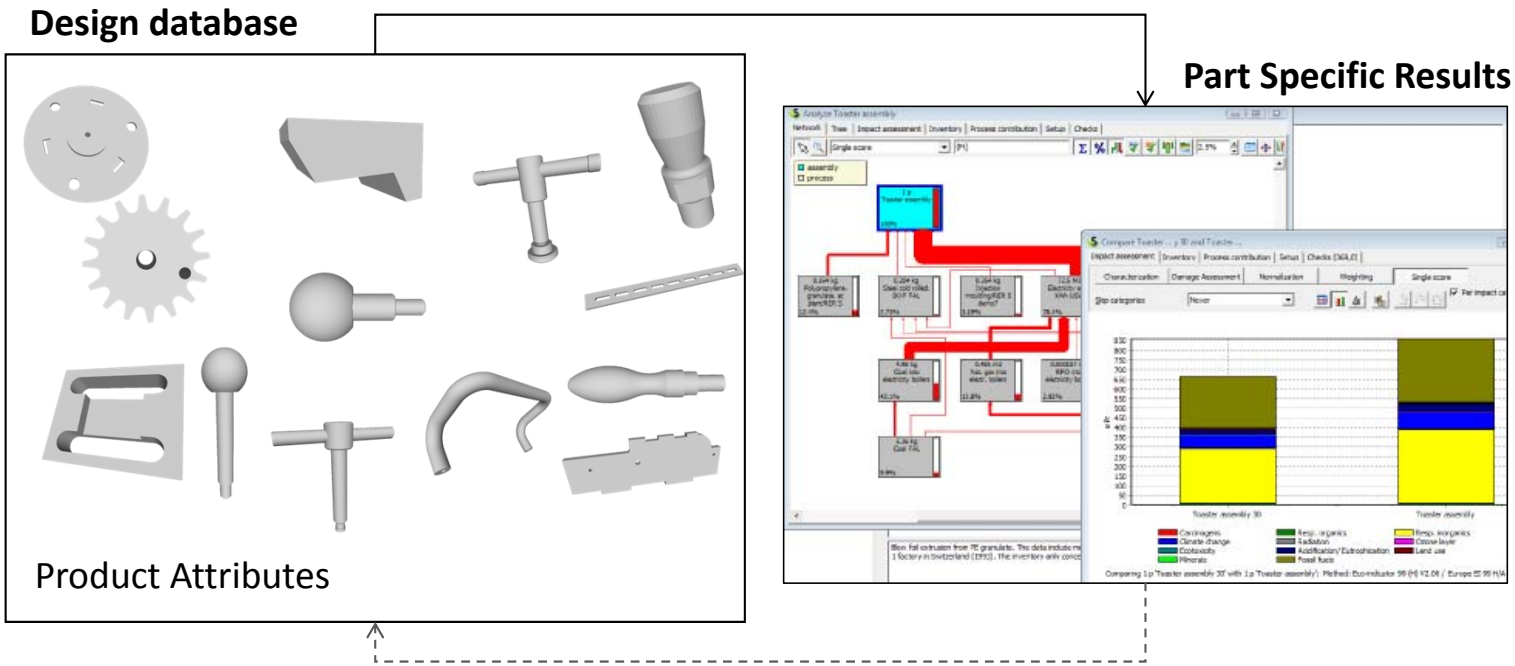
For estimating an environmental indicator of existing parts within a CAD database, we calculate a shape descriptor based on a point cloud. We can then estimate environmental impact by including material and manufacturing information from a PDM system.

ShapeSift: Sustainable options in design reuse



Ramanujan, D., Benjamin, W., Bernstein, W. Z., Elmqvist, N., Ramani, K., "shapeSift: Suggesting Sustainable options in design reuse from part repositories," *ASME 2013 IDETC/CIE, Portland, OR, August 4-7, 2013.*

Motivation

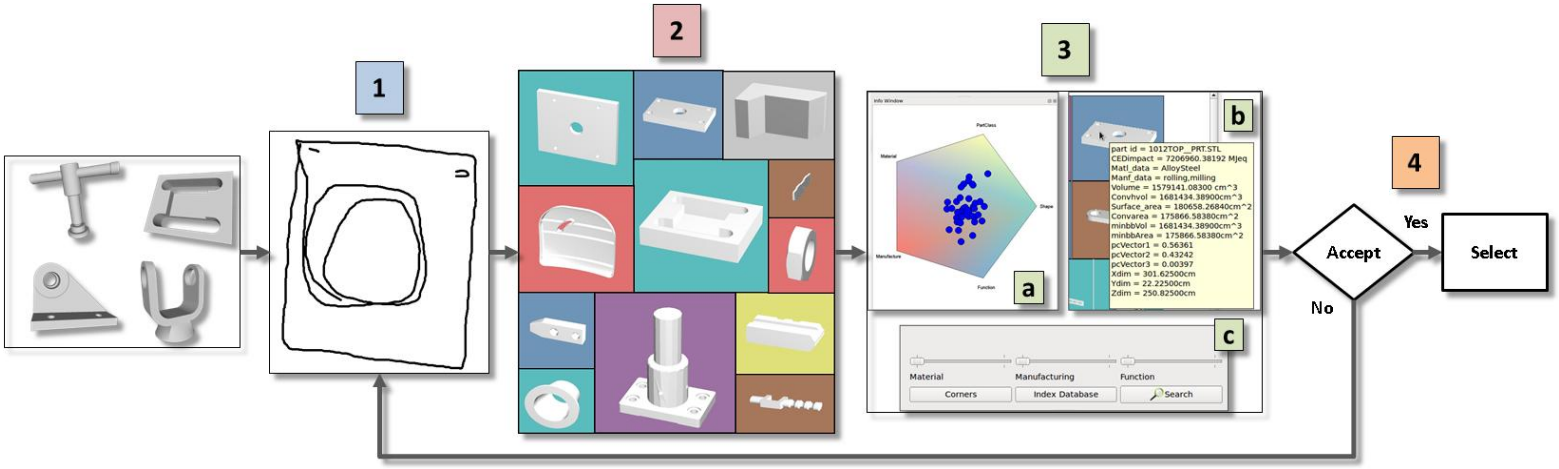

Design database
Part Specific Results
Product Attributes

Research Goals

Develop a framework for relating environmental impacts of parts with corresponding part attributes:

- How can we standardize/automate assessment of environmental indicators?
- How can we tie design exploration (based on part attributes) with sustainable design?
- How can we represent our data as visual variables and present it on an intuitive platform**?**

shapeSift Pipeline



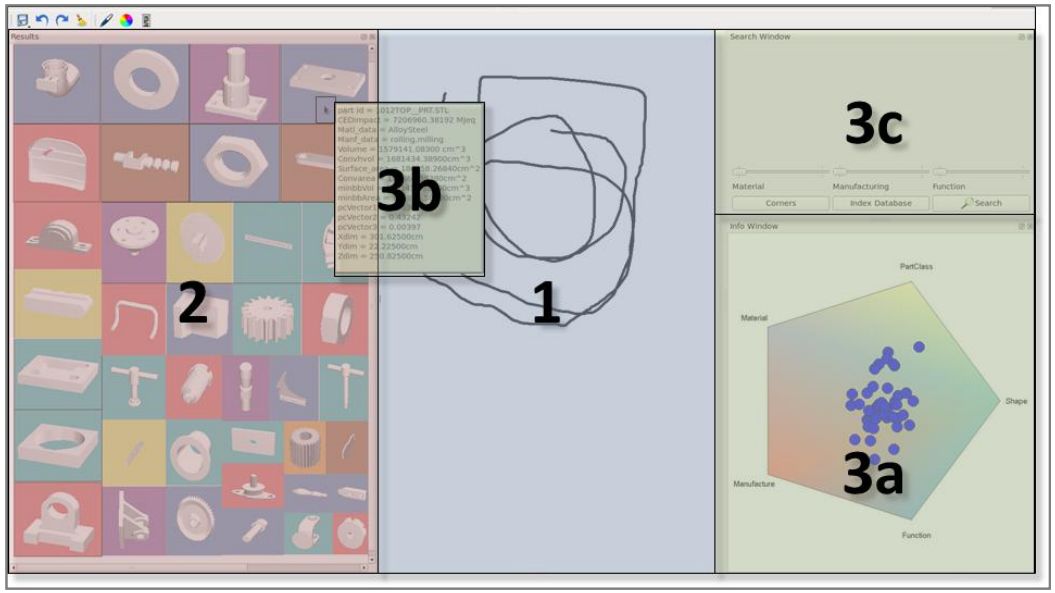
1 Query: sketch

2 Overview: visualize a set of ‘similar’ results

3 Detail & Filter: a similarity polygon b tooltips c similarity controls

4 Decision Making: accept or iterate

Prototype User Interface



1 Query: sketch

2 Overview: visualize a set of ‘similar’ results

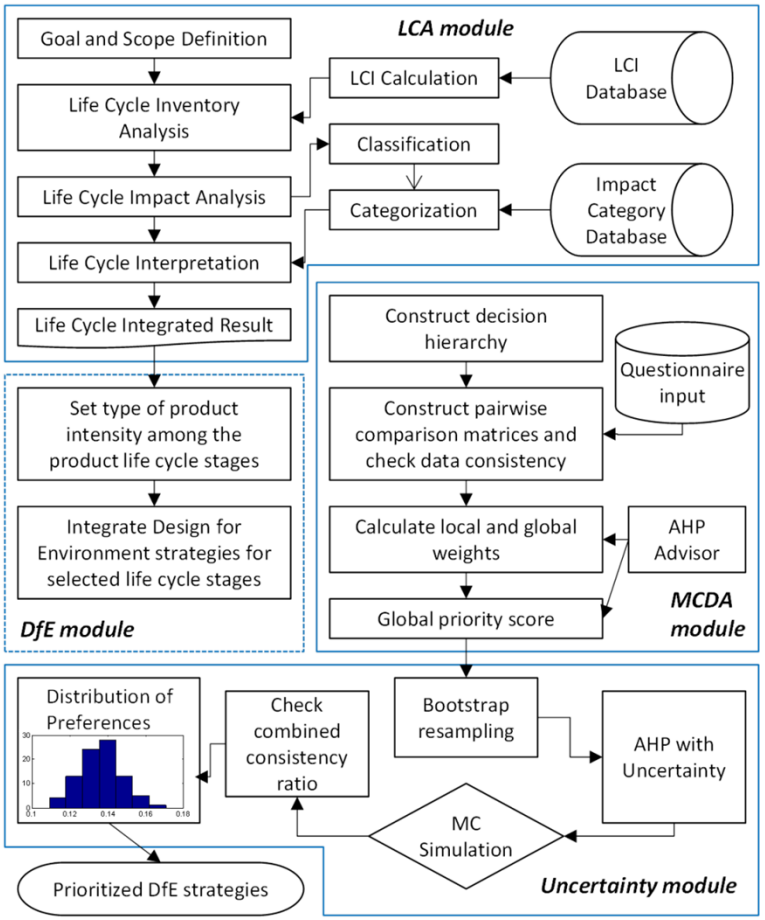
3 Detail & Filter: a similarity polygon b tooltips c similarity controls

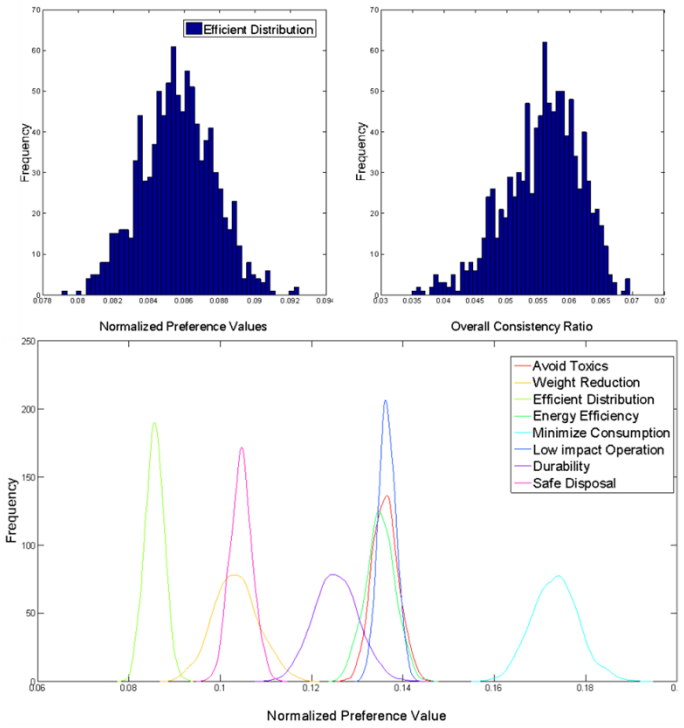
Summary

1. Information visualization provides a promising avenue for integrating sustainability based decision making with the design process

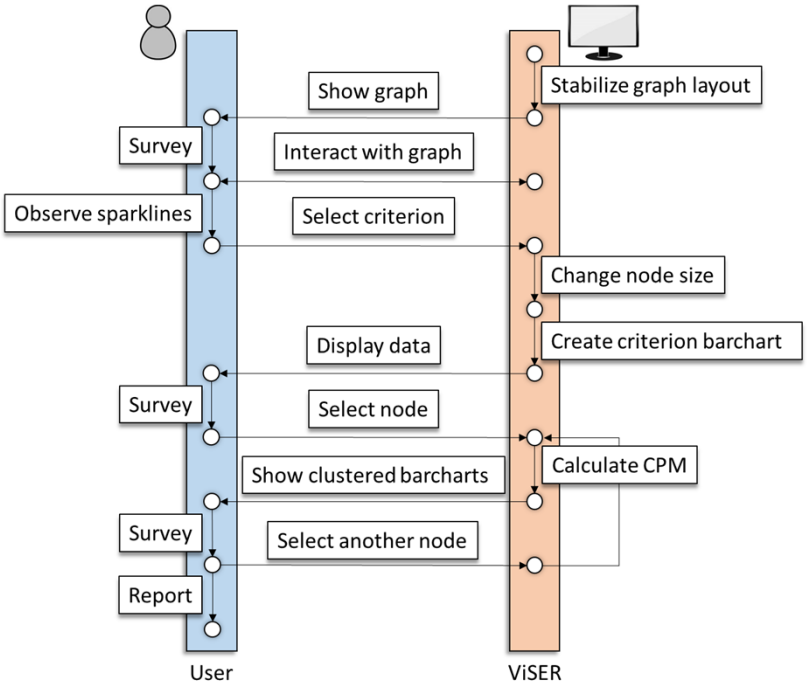
2. An exploration based framework that correlates sustainability measures with part attributes can aid designers in developing insights about their design and internalize them by forming mental models about this data.

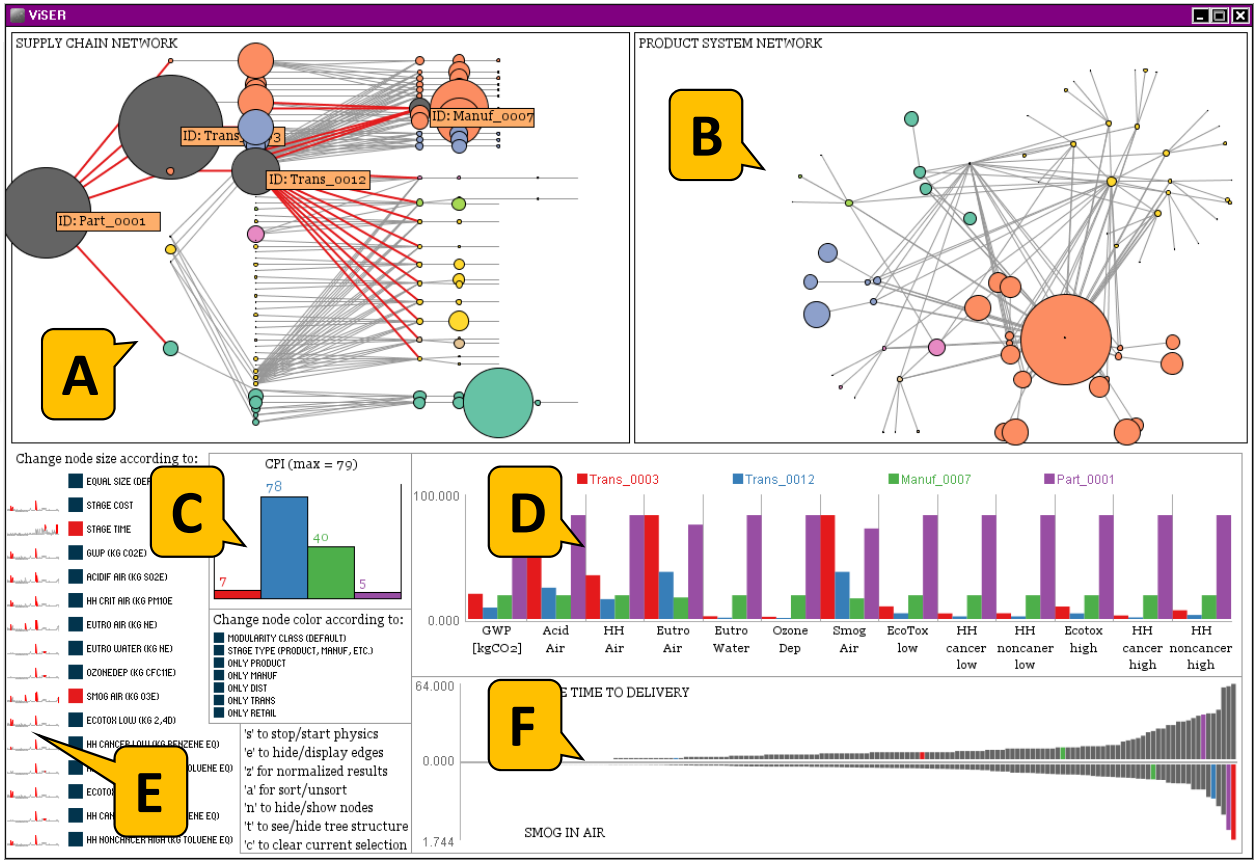
Balancing business decisions with sustainbility



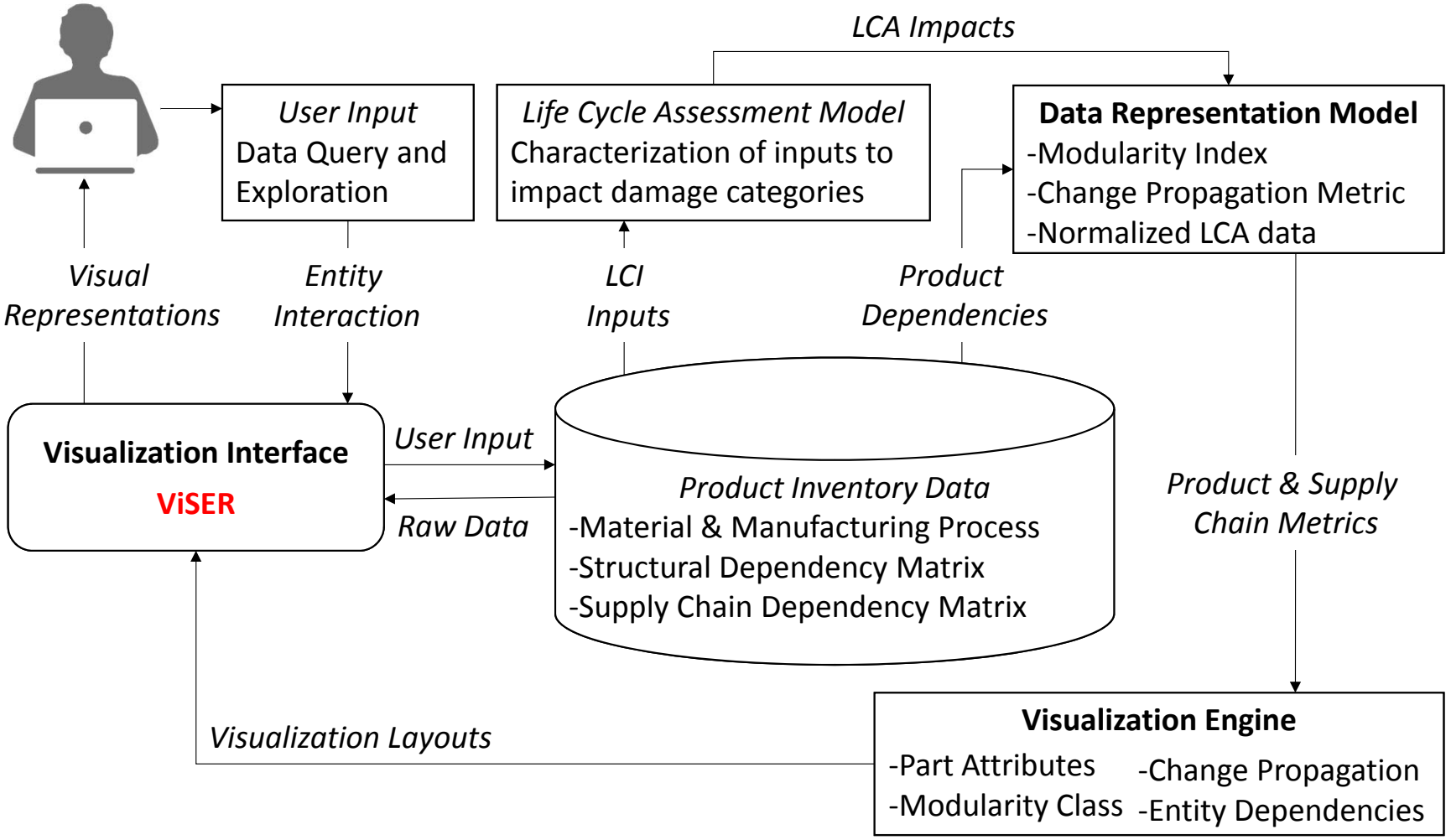


ViSER: Visualizing Supply chains for Eco-conscious Redesign



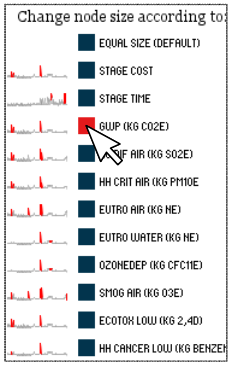


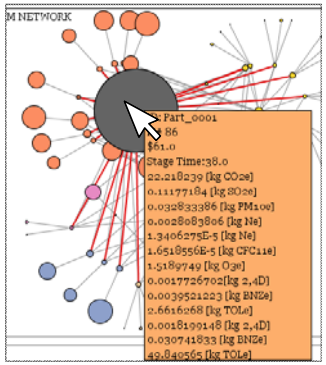
ViSER – User Pipeline

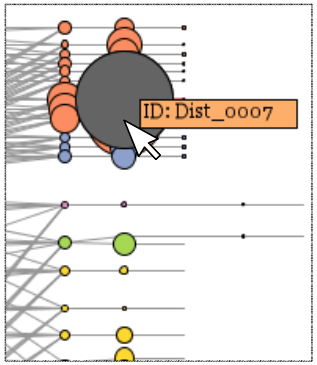


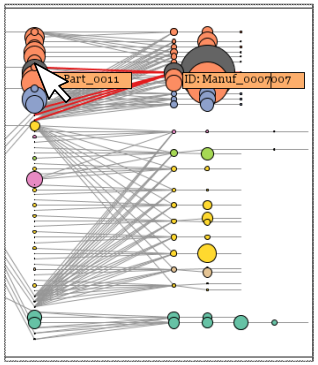
ViSER – Use Case Scenarios, User Interaction

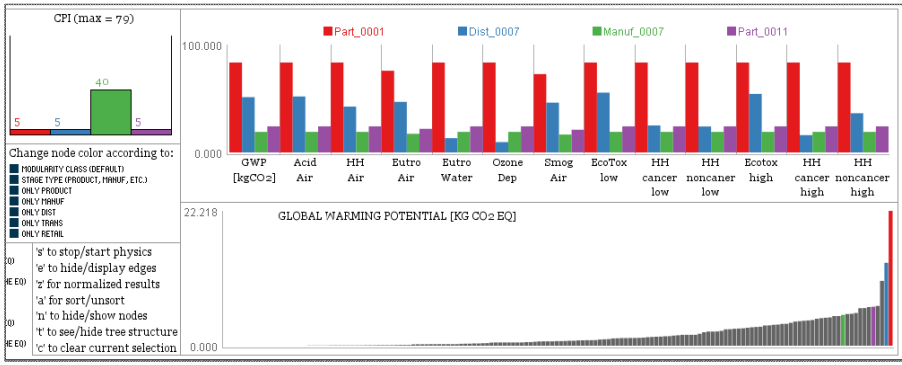
Novice User: Bart





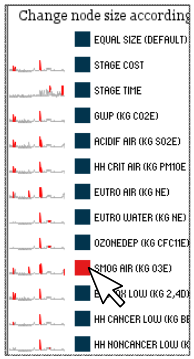


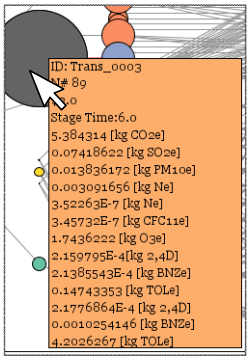


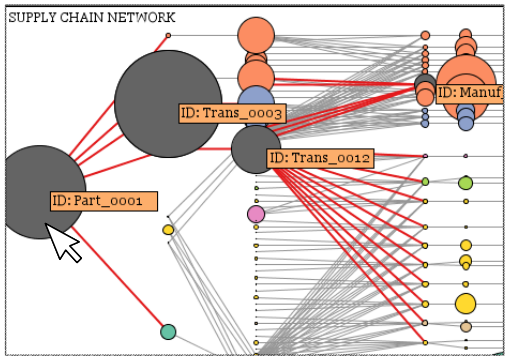


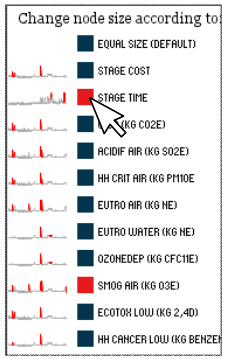
B1 B2 B3 B4 B5

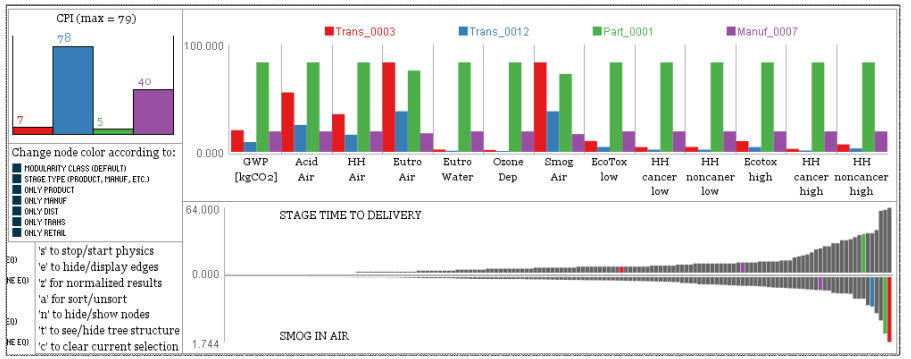
Expert User: Mark











M1 M2 M3 M4 M5

Data integration from knowledge-silos