Challenges and a Solution in Coupling Dissimilar Models for Complex Planning Policy Analysis

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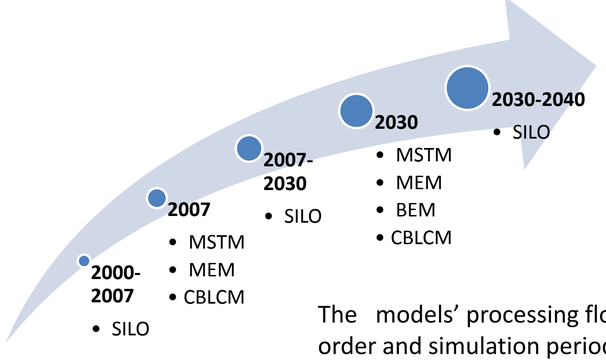
Summary

Close model integration has become the mantra among model developers. New tools under development, such as CSDMS or OpenMI, promote tight integration of very different models and ease information transfer between the same. Continuously increasing computational capacities enable ever more comprehensive model integrations. From a technical perspective, the prospects of tight model integration are excellent. However, the research presented also exemplified limitations and difficulties of model integration.

Models Used for Integration

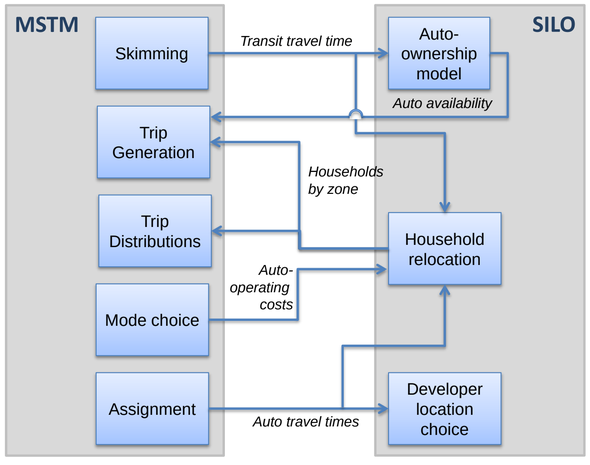
The modeling system needs to integrate models of the following domains

- **Transport**: MSTM, Maryland Statewide Transport Model
- **Land Use**: SILO, Simple Integrated Land Use Orchestrator
- **Transport Emission**: MEM, Mobile Emissions Model
- **Immobile Emissions**: BEM, Building Energy Consumption
- **Land Cover**: CBLCM, Chesapeake Bay Land Change Model



The models' processing flow order and simulation periods.

Several models require frequent data exchange, as shown between the transportation and land use model below.



Data exchange between models

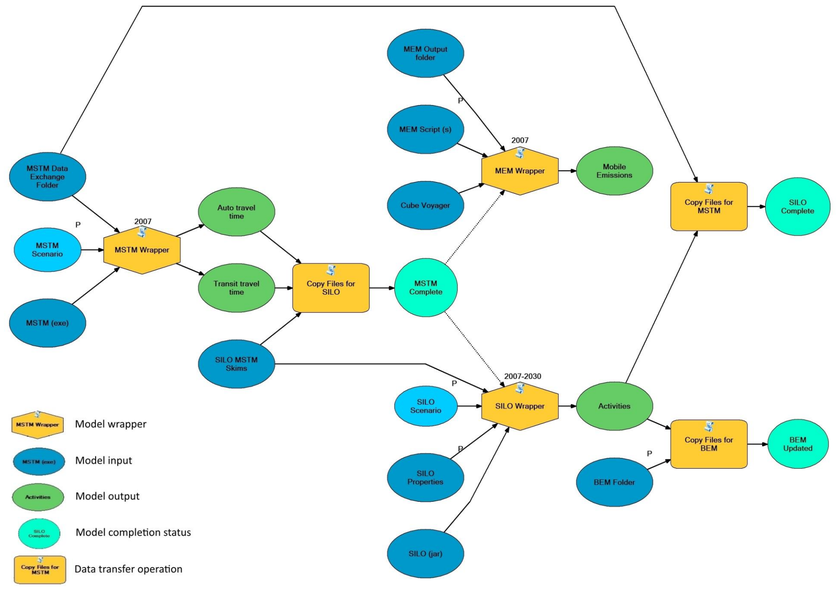
From \ To	MSTM	SILO	MEM	BEM	CBLCM
MSTM		Auto travel time between zones Transit travel time between zones Auto-operating costs	All trips within the region Average speed distribution		
SILO	Population Employment Auto availability			Building data: type, age, area, rooms, occupation, heating fuel, location, etc.	Population Employment Zonal accessibility to population by auto & transit

Main characteristics of the used models

Model	Environment	Operation System	Licensing	Simulation Period	Sim. years	Runtime
MSTM	CUBE	Windows	Scripts: Open source CUBE: CitiLabs	2007 or 2030	1	15-16 hour[a]
SILO	Java	Multi-platform	Open source	2007-2030	23	4-5 hour[a]
MEM	CUBE	Windows	USGS, CitiLabs	2007 or 2030	1	< 30 min[a]
BEM	Excel	Multi-platform	n/a	2007 or 2030	1	< 1 min[a]
CBLCM	C / C++	CentOS	USGS	2007-2030	4	3 hour[b]

[a] *20 x AMD Opteron Processor 6328 @ 3.20GHz, 42GB RAM, Windows 7 Virtual Machine*
[b] *2 x 2.56 GHz CPU's, 24GB RAM, Centos 6 Virtual Machine*

ArcGIS geo-processing model organizing the models simulation workflow



Methodology

Python wrappers were developed to loosely couple models developed in different environments. ArcGIS Model Builder was used to provide a graphical user interface and to present the models' links and workflow. With the use of Python wrappers, the implementation of the coupler is separated from the models' source codes. This gives a flexibility, which can help in terms of portability, performance and maintenance of the codes.

Benefits

- No need to change the source codes of the models.
- Runs models developed in different environments.
- Can be extended with additional models over time.
- General user interface showing process flow.
- Rich visualisation & mapping capabilities with ArcGIS.
- Easy to implement.

Limitations

- Parallel model runs and dynamic data exchange during simulation time steps are not supported.
- Model processes run independently from one another.
- Data exchanged between modules are written to and read from a hard drive. No in-memory data exchange.

Conclusion

This approach is especially efficient when the models are developed in different programming languages, their source codes are not available or the licensing restrictions make other coupling approaches infeasible. A key finding of this research is that model integration should depend on direction of information exchange and frequency of data flows, as shown below. While this simple but robust loose integration has satisfied the project's initial goals, further tighter integration within the CSDMS is currently explored to enhance model performance and data exchange as well as to widen the scope of applications.