Commercial Transport and Transport Supply Components of the TLUMIP Second Generation Model

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Integrated Land Use and Transport Models
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CT and TS Components: Overview

- CT – Commercial Transportation Component
  - Translate goods and services demand to discrete shipments for loading on multi-modal network
- TS – Transportation Supply Component
  - Load trips onto multi-modal network
  - Produce network based level of service measures
    - Inputs for other model components
    - Summary statistics used in policy analyses

CT: Overview

- Inter-sector flows (annual $) from PI to depict origins and destinations by commodity
- Use a microsimulation process to generate discrete shipments in tours
- Microsimulation captures important dynamics:
  - Trans-shipment
  - Trip chaining
- Package those tours for assignment in TS
- Resemble reality

CT: Major steps per commodity

1. Translate inter-sector flows (annual $) to daily tons by commodity and mode
2. Generate discrete shipments
3. Allocate shipments to individual establishments
4. Determine if trans-shipment occurs and where
5. Simultaneous allocation to shipper and vehicle types
6. Allocate shipments to vehicles (and tours)
7. Optimize itineraries
8. Package tours for assignment

1. Translation step

- Translate PI inter-sector flows by commodity
  - Requires explicit modal allocation before transform
  - Based on value-ton relationships from 1997 CFS
  - Transform entire matrix first, sample second
- Divide by 12 (months)
- "Deflate" the matrix
  - Eliminate shipments less than one-half of average shipment weight
  - Better than bucket rounding?
- Randomly choose one of twenty workdays

The freight mode choice problem

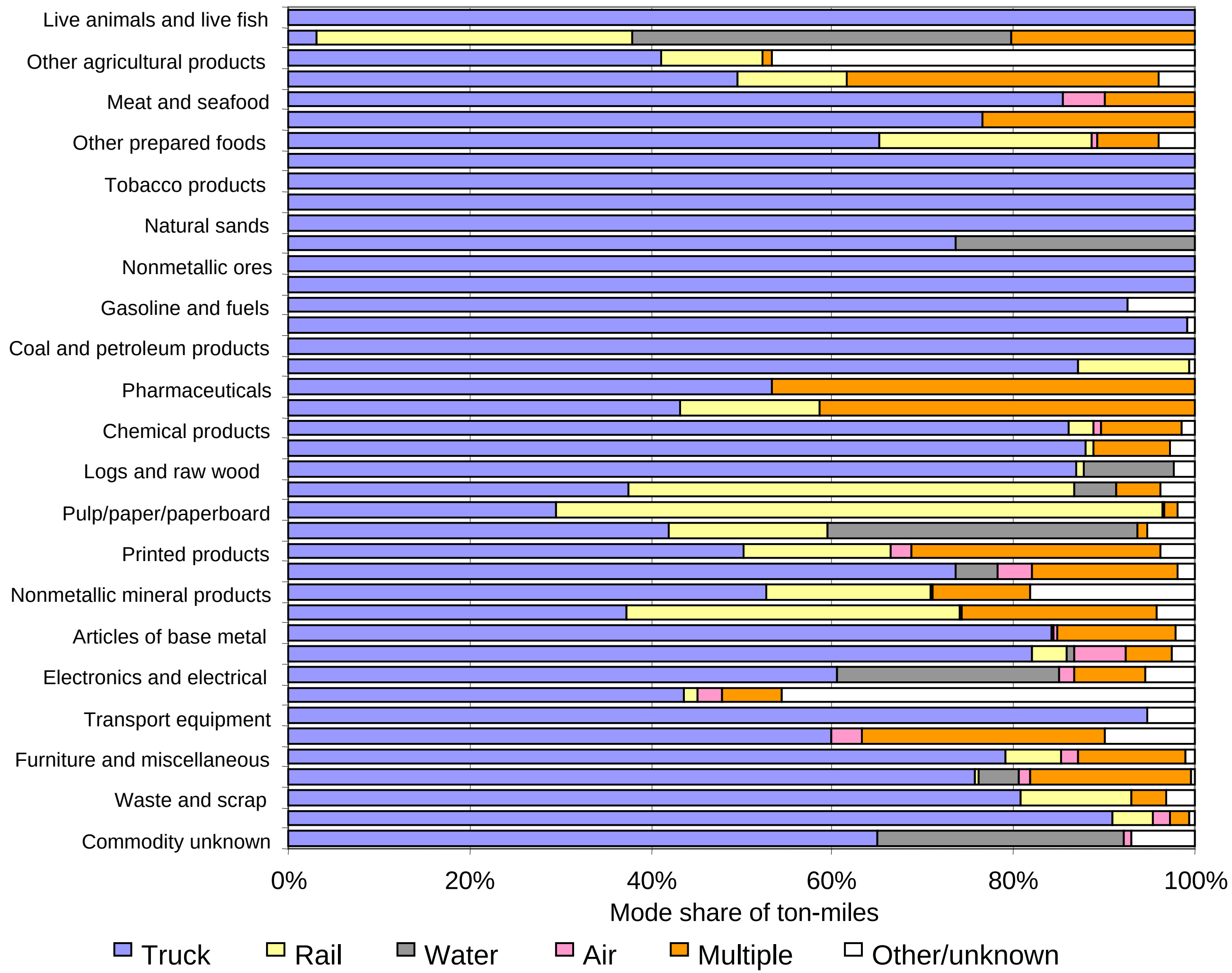
Determinant	#authors
Freight rates (costs, charges, rates)	11
Reliability (reliability, delivery time)	11
Transit time (time-in-transit, speed, delivery time)	11
Over, short, or damaged (loss, damage, claims processing, and tracing)	7
Shipper market considerations (customer service, user satisfaction, market competitiveness, market influences)	7
Carrier considerations (availability, capability, reputation, special equipment	6
Product considerations (perishability, packing requirements, new products)	4

Source: McGinnis (1989)

The freight model choice problem (Cont'd)

- Lack of data presents a challange
  - All data are aggregate
    - no information on individual tours or tour segments
  - What data is available is often suspect

Observed mode shares by commodity



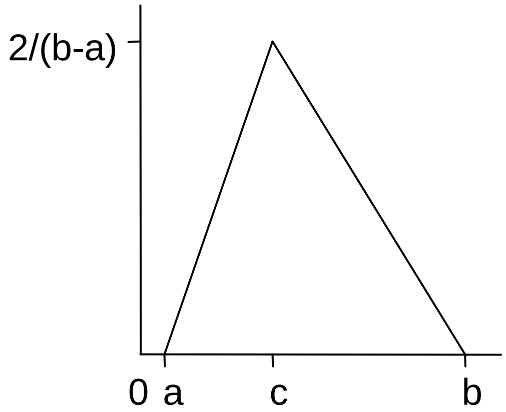
A mode choice example

Known information from CFS97...

SCTG	Average trip distance (miles)			
	Truck	Rail	Air	Water
20 (Basic chemicals)	639	1641	2715	NAS

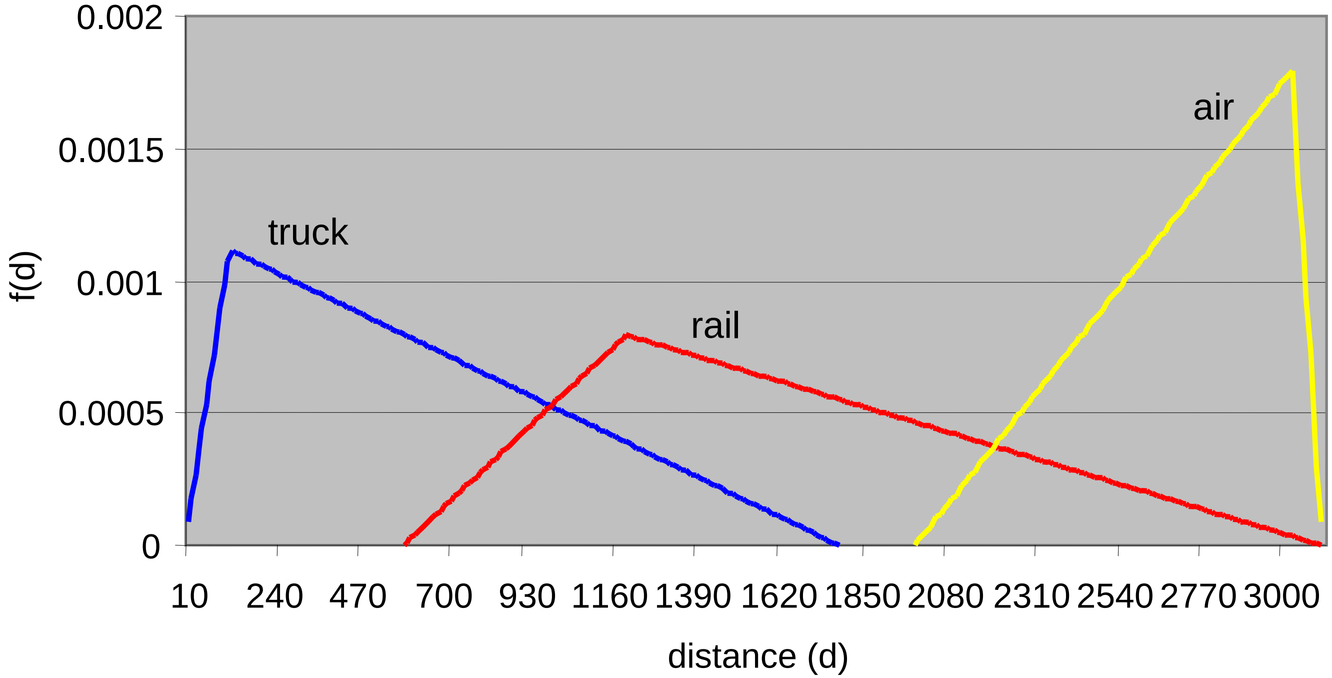
...from which we can build triangular distributions

Mode	a	b	mean	c
Truck	0	2700	639	125
Rail	600	3115	1641	1210
Air	2000	3115	2715	3030



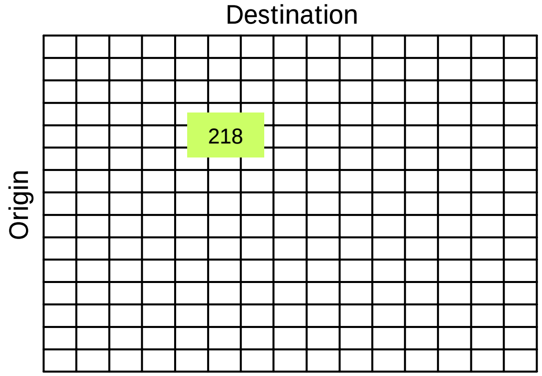
$$\text{mean} = \frac{a + b + c}{3}$$

A mode choice example (Cont'd)

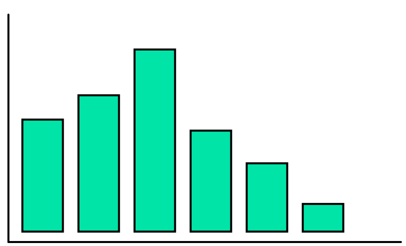


2. Generate discrete shipments

Daily tons by commodity



Payload weight (by commodity)



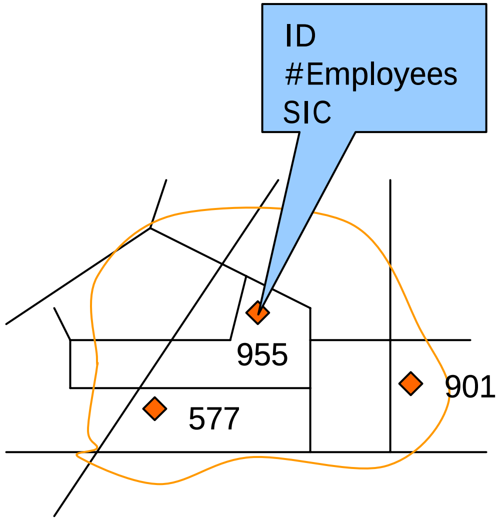
Shipment list

C	O	D	Wgt
37	5	6	14.2
37	5	6	20.1
37	5	6	97.0
37	5	6	66.7
37	6	7	1.5
37	6	21	112
37	6	22	7.9

3. Allocate to establishments

Shipment list

C	O	D	Wgt	**OID**
37	5	6	14.2	**577**
37	5	6	20.1	**577**
37	5	6	97.0	**901**
37	5	6	66.7	**955**
37	6	7	1.5	**811**
37	6	21	112	**99**
37	6	22	7.9	**99**



Note that the process is carried out at both the origin and destination end of the trip.

4. Generate trans-shipment stop

- Currently only for intercity trips
- Stop coded near the destination end
- Uses multiplicative probability:

  $P_c \times P_d$

  where P_c is the probability by commodity group and P_d is a distance filter:

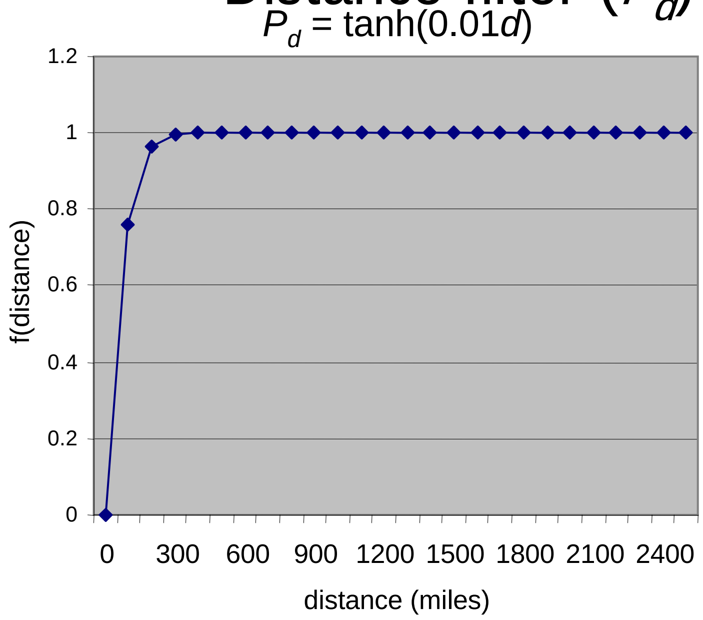
  $$P_d = \tanh(0.01d)$$
- Splits trip into two separate trips
- Randomly chosen from facilities within 40 mile radius of original destination

Multiplicative Probabilities

Probability of trans-shipment by commodity (P_c)

Group	P_c
Empty	0.137
Agriculture	0.398
Grains	0.434
Stone	0.137
Fuels	0.192
Chemicals	0.334
Wood/textiles	0.240
Metals	0.212
High value	0.199
Furniture	0.284

Distance filter (P_d)



5. Carrier and vehicle type allocation

- Light single unit, heavy single unit, and articulated trucks
- For-hire vs. private carrier
- Based on observed distributions by commodity from CFS97
- The same for all shipments originating from a given establishment
- Simple Monte Carlo process

6. Vehicle allocation

- Private carrier
  - Fill vehicle to average payload weight
  - Continue until all shipments are accommodated
- For-hire carrier (including LTL)
  - Select truck with available capacity within search range, if available
  - Otherwise generate an empty truck
  - Fill vehicle to average payload weight
  - If not filled to average, hold for additional loads from nearby establishments

7. Tour optimization

- Shipments sorted by vehicle id
- Classical traveling salesman problem (TSP)
  - Each trip independent of all others
- Optimized to minimize total distance traveled
  - Includes dwell time at each stop: constant value currently
- Uses previous period's link travel times
  - Zone-zone composite travel times (Frank-Wolfe)
- Constrained to operator time limits (10 hours)
  - Throws an exception

Current implementation

- Coded in Java
  - Uses OR-Objects package to solve TSP
- First code jettisoned
  - Second version complete
  - Still monolithic, multithreading in next re-factoring
- 10-12 minutes/year run time
- Packages tours in trip list format required by TS

CT: Validation targets

For each commodity:

Measure	Target	Outcome
Conserves inter-sector flows from PI	Tonnage by zone exact matches PI	Routinely achieved
Match observed mode shares	CR > 0.9	Usually achieved
Match average trip distance	± 10%	Usually achieved
Matches percent of trips for trans-shipment	± 10%	Routinely achieved
Distribution of carrier type	± 10% private	Routinely achieved
Distribution of vehicle type	CR > 0.9	Usually achieved
Matches payload weight distribution	CR > 0.9	Usually achieved
Matches Portland control totals	± 10%	Unknown
Matches observed daily truck counts	RMSE <40%	Unknown

TS: Overview

- Load trips on highway and transit networks
- Simultaneously determine trip mode choice
- Compute network based O/D attributes
- Compute summary statistics for validation and policy analyses

TS: Model Requirements

- Determine trip mode choice during assignment
- Avoid lumpy loading near centroid connectors
- Support traditional assignment model features:
  - Multiclass assignment
  - Multiple time periods
  - Equilibrium based
- Support traditional summary measures:
  - Select link analysis
  - VMT, VHT summaries
  - Emissions related summaries
  - Time period loadings

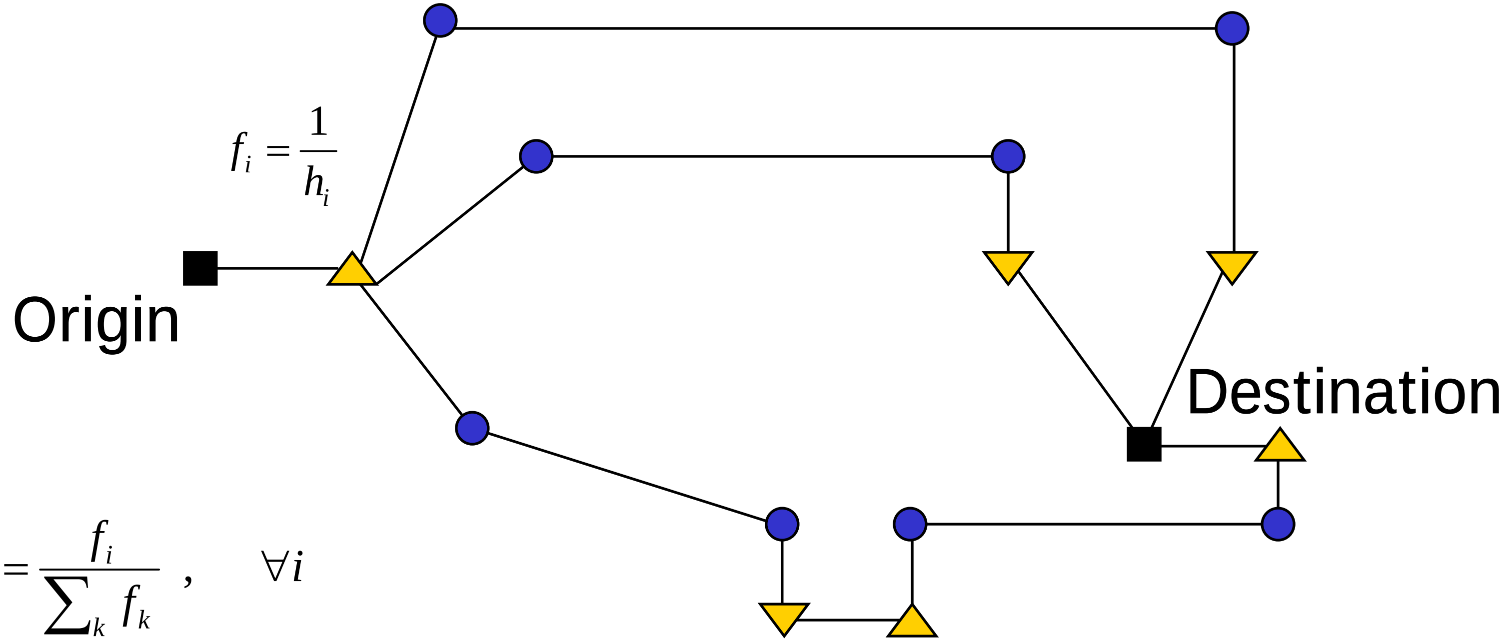
TS: Model design

- Stochastic user equilibrium framework for highway assignment
  - Individual utilities maximized
  - Multiple routes available between and O/D
  - Utility coefficients from other model components determine route choice dispersion
- Load individuals one at a time from start node to end node
  - Reduce lumpy loading
  - Individual’s mode choice determined with route choice
- Optimal strategy transit loading

TS: Transit loading overview

- Optimal strategy – Spiess, 1989
  - Same framework as used in Emme/2
- All Oregon MPO networks were coded for Emme/2
- Network based O/D attributes
  - Ivt, ovt, first wait, total wait, walk time, transfers
  - Available for input by other model components
- Transit loading summaries
  - Boardings
  - Link flows

TS: Optimal strategy example



$$f_i = \frac{1}{h_i}$$

$$p_i = \frac{f_i}{\sum_k f_k}, \qquad \forall i$$

TS: Transit loading methodology

- Determine optimal strategy for O/D nodes
- Walk access transit tours
  - Walk portion determined as part of strategy
  - Walk allowed on any highway link except freeways and ramps
- Drive access transit tours
  - Logit choice of which transit node to drive to
  - PNR tours restricted to return through PNR lot used

TS: Highway loading overview

- Microassignment of trips to network
  - Not a pure microsimulation
  - Not an aggregate assignment
  - Individuals assigned one at a time based on aggregate assignment model approach
- Aggregate Frank-Wolfe algorithm applied to estimate congested link flows and travel times
- For each individual trip from PT and CT:
  - Node to node utility maximizing path determined based on the Frank-Wolfe congested times
  - Individual trip loaded onto network
  - Congested link flows and times updated

TS: Aggregate Frank-Wolfe assignment

- Aggregate trip list to zonal O-D matrix
- Compute link utilities from user preferences
  - Presently travel cost = travel time
  - Will use utility coefficients when they're complete
- Use Frank-Wolfe method to solve user equilibrium assignment problem
- Store shortest path trees during each iteration
- Store Frank-Wolfe lambdas computed in each iteration

TS: Proportions of O/D matrix assigned

- Frank-Wolfe lambdas can be used to calculate proportion of O/D demand assigned in each iteration
- Proportions used in microassignment procedure

TS: Lambdas example

Proportions Formula	Iteration	Lambda	Proportion
$P_0 = \lambda_0(1-\lambda_1)(1-\lambda_2)(1-\lambda_3)(1-\lambda_4)$	0	1.0	0.0945
$P_1 = \lambda_1(1-\lambda_2)(1-\lambda_3)(1-\lambda_4)$	1	0.7	0.2205
$P_2 = \lambda_2(1-\lambda_3)(1-\lambda_4)$	2	0.5	0.3150
$P_3 = \lambda_3(1-\lambda_4)$	3	0.3	0.2700
$P_4 = \lambda_4$	4	0.1	0.1000
Total			1.0

TS: Microassignment

- Frank-Wolfe loading results in full O/D loading
- Node to node loading adds an individual trip
- Individual loadings should replace loadings from aggregate assignment model
  - Individual utility based paths
  - Start node to end node – less lumpy
- Need to remove a trip from the Frank-Wolfe loading for the individual O/D loaded
- Remove the fraction of the trip assigned in each Frank-Wolfe iteration from the links in the stored paths for the O/D

TS: Microassignment properties

- Deterministic properties
  - Not a true user equilibrium solution
  - Integer flows prevent a true solution
  - Closest possible solution to equilibrium
- After each trip loaded and adjusted, network flows and times still congested and representative of user equilibrium flows
- Subsequent individual trips assigned based on valid utilities from congested times

TS: Implementation

- Third refactoring of code completed
  - Multithreaded
  - Distributed
- Memory use still a problem
  - More distributed processing will fix that
- Can now solve 3 iterations of FW and store paths using full TLUMIP network
- Looking at performance and solution properties of microassignment on full network with artificial trip list (8.5 million trips)

CT and TS Summary

- CT working and being optimized
- TS being optimized to get to work on full scale model
  - Proved to work on smaller scale problems
- Next steps:
  - Integrate better with other components
  - Prepare interface to summary and analysis procedures