

# Path Analysis

*Presented by*

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# Plan

- The path “problem”
- How paths are saved and recovered
- General procedure
- Path output
- Select element analysis
- Global results
- Applications

# STAN Path Analysis Capability

- A rich and powerful set of tools
- Addresses a large class of planning issues
- Based on the **assigned** paths  
i.e., paths generated during the assignment procedure
- Uses Module 6.31 *Path Analysis* together with the other network and matrix computing and analysis tools to
  - Select paths based on length, costs, combinations of user-specified link and transfer attributes
  - Visualize and report paths
  - Save global path-related results in network and matrix format

# Paths and STAN

- The assignment procedure generates paths
  - At each iteration
  - For each product (mode choice) matrix
  - For each OD pair with positive demand
- ⇒ Very large number of paths
  - On the standard demonstration data bank
  - 67 centroids, 5 products, 9 matrices
  - 20453 paths at each iteration
- One does not know *a priori* how many iterations will be performed
- ⇒ Not possible to
  - Evaluate total space required to store the paths
  - Store paths in a fixed-size data bank
- ⇒ Assignment results: link and transfer product flows

# Approaches

- Store the full path information
  - Itinerary: sequence of links and transfers
  - Product volumes and costs

Too costly in computational efficiency and memory even in external file.

- ⇒ Store the minimum information required to
- *Reconstruct* the paths
  - *Recompute* the product path flows

# Assignment Idea

*Minimize Total generalized cost*

*s.t*

*Satisfy demand  $\Rightarrow$*

$$\sum_{paths} flows = demand$$

*Non-negative flows*

# The Multimode-Multiproduct Assignment Model

Objective function:  $\text{Min} \sum_{p \in P} \left[ \sum_{l \in L} s_l^p(v) v_l^p + \sum_{t \in T} s_t^p(v) v_t^p \right]$

(subject to)

- Demand constraints:  $\sum_{k \in K_{od}^{m(p)}} h_k = g_{od}^{m(p)}, o \in O, d \in D, m(p) \in M(p), p \in P$
- Network constraints:  $h_k \geq 0, k \in K$

$$v_l^p = \sum_{k \in K^p} \delta_{lk} h_k, l \in L, p \in P$$

$$v_t^p = \sum_{k \in K^p} \delta_{tk} h_k, t \in T, p \in P$$

# The Solution Algorithm

- The multimode-multiproduct is solved by an adaptation of the linear approximation method and a **decomposition** of the problem by **product**
- Total cost =  $\sum_{p \in P}$  (total product cost)
- The main idea is to solve  $|P|$  smaller problems, where each problem considers to minimize the total product cost
- The initial solution may be:
  - “All-or-nothing” solution with free flow marginal costs
  - The current solution of an assignment carried out
- The stopping criteria may be a maximum number of iterations or a certain tolerance on the relative gap, RG

# The Linear Approximation Method

- Step 0 (Initialization)  $v^0$  initial solution;  $k = 0$

- Step 1 (Descent direction) Solve the linearized problem

$$\left. \begin{array}{l} \text{Min } F(v^k) + \nabla F(v^k)(v - v^k) \\ \text{subject to } v \in \Omega \end{array} \right\} \text{this is a shortest path problem} \\ \text{with } \mathbf{marginal\ costs}$$

$y^k$  is an “all-or-nothing” solution

Descent direction:  $d^k = y^k - v^k$

- Step 2 (Line search) Solve the one dimensional problem

$$\begin{array}{l} \text{Min } F(v^k + \lambda d^k) \\ 0 \leq \lambda \leq 1 \end{array}$$

Let  $\lambda_k$  be the optimal **step size**

- Step 3 (Update)  $v^{k+1} = v^k + \lambda_k d^k$ ;  $k = k + 1$   
Return to step 1

# The Solution Algorithm – Overview

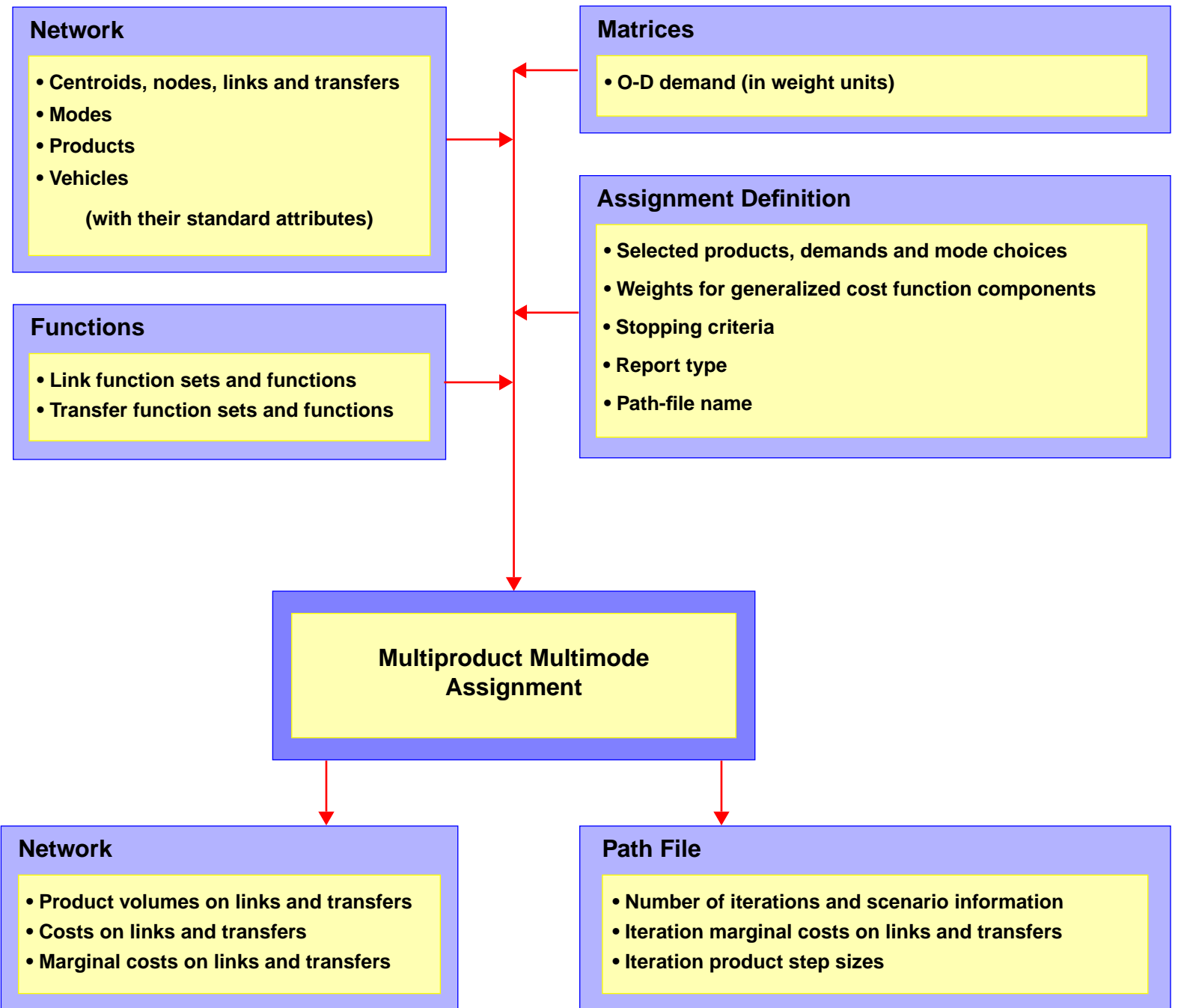
- Step 0 (Initialization)       $v$  initial solution
- Step 1 (Major cycle)      For each product  $p \in P$  do
  - Minor cycle:    1.1      Find an “all-or-nothing” solution for the linearized subproblem and the corresponding direction of descent
  - 1.2      Find the optimal step size for this direction
  - 1.3      Update product flows;  $p = p + 1$ . If  $p \in |P|$  go to 1.1
- Step 2 (Stopping Criteria)    If satisfied STOP;  
                                          Otherwise return to step 1

# Optimality Conditions

- All routes (paths) used (positive flows) are of approximately equal marginal costs, while all other routes cost more
- Assignment stops
  - Relative gap
  - Number of iterations

# Reconstruct Assigned Paths - Assignment

- Store the minimum information required to
  - *Reconstruct* the paths: **Product marginal costs on links and transfers**
  - *Recompute* the product path flows: **Step sizes**
- Storage requirements:  $O(|\mathbf{A}| + |\mathbf{T}|) * |\mathbf{P}| * n$
- Information saved in **external** file at **user request**



# Path Information

- On all paths generated at all iterations for all products and matrices in assignment
- Not case-specific
- Available for all analyses

# Reconstruct Assigned Paths - General Procedure

- For a given product  $p$  and demand matrix  $g^p$  :
- For each iteration  $k = 0, \dots, n$ 
  - For each origin  $o$ 
    - Generate the set (tree) of *shortest marginal cost paths* to all destinations  $d$
    - For each destination  $d$ 
      - Compute path **partial volumes**:  $w_{n-k}^p \ g_{od}^p$
      - Compute path attributes
      - Perform path computations
      - Report/Save results

# Computing Path Weights (Proportions) $w_k^p$

- Distribute the OD flow  $g_{od}^p$  among the  $n + 1$  (iterations) paths according to the **path proportions** computed from the optimal step sizes  $\lambda^{pk}$  ( $\lambda^{p0} = 1$ ):

$$w_n^p = \lambda^{pn}$$

$$w_{n-1}^p = \lambda_{n-1}^p (1 - \lambda_n^p)$$

...

$$w_{n-k}^p = \lambda_{n-k}^p (1 - \lambda_{n-1}^p)(1 - \lambda_{n-2}^p) \dots (1 - \lambda_n^p) \quad k = 0, \dots, n$$

# Path Partial Volumes

- The same path may be generated several times
  - Same attributes
  - Different flows (at analysis time): *Path partial volumes*
  
- The final path flow  $\neq$  iteration flow  
                                            $=$  sum of flows over all iterations
  
- Example
  - Demand for Wood products (**mf05**) by maritime modes from zone 24 to zone 15  
    $=$  **26.06t**
  - Partial volumes on 5 of 6 paths

No	from	to	iter	nlink	ntran	vol	len	cost	mcost
1	24	16	0	8	4	0	250	48.00003	48.00003
2	24	16	1	8	4	.177999	250	48.00003	48.00003
3	24	16	2	8	4	.566897	250	48.00003	48.00003
4	24	16	3	8	4	2.904244	250	48.00003	48.00003
5	24	16	4	8	4	3.717481	250	48.00003	48.00003
6	24	16	5	8	4	18.68948	250	48.00003	48.00003

# Assignment Preparation

- Specific question in Module 5.11 (last one)  
`Save information for path analysis?`
- Maximum size (2GB) of path file tested
- Controlled access to path file
- Flexible name for path file  
`paths=s%s%.pth`
- More iterations on assignment
  - Path information already saved  $\Rightarrow$  Saving continues
  - Path information not already saved
    - Too late !
    - New assignment should be considered instead

# Module 6.31 Analysis of Assigned Paths

## 6.31 ANALYSIS OF ASSIGNED PATHS

Project title: STAN STANDARD DEMONSTRATION AND TEST DATA BANK

Scen 4000(--- A-): PATH ANALYSIS

Mincost assignment: 97-07-18 14:14

Product	Demand	Modes
Ores	mf01	rnpofmhcx
Cereals	mf02	npofcx
Wood and derivatives	mf03	rfcx
	mf04	npofcx
	mf05	mhcx
Fresh & Frozen Food	mf06	rfcx
	mf07	npofcx
	mf08	mhcx
Miscellaneous	mf09	rnpofmhcx

Generalized cost: 1\*(delay cost)

Stopping criteria: maximum number of iteration(s)= 4 gap= 0.50%

Number of iterations: 4 stopped by: iter

Select: 1= output assigned paths  
2= punch assigned paths  
3= plot assigned paths  
4= save global results  
5= change module parameters  
6= end

# Validation

- Current scenario versus stored information
  - Assignment time stamps
  - Scenario number
  - Number of links
  - Number of transfers
  - Number of assigned products
  - Number of assignment iterations
  - Identifier of each assigned product
  - Matrices and mode choices for each assigned product
  - Assigned matrix time stamps

### 6.31 ANALYSIS OF ASSIGNED PATHS

mf09: TMisc (97-07-18 14:15:10)

Above matrix has been modified since 97-07-18 13:53:40!

Continue anyway?**y**

Project title: STAN STANDARD DEMONSTRATION AND TEST DATA BANK

Scen 4000(--- A-): PATH ANALYSIS

Mincost assignment: 97-07-18 14:14

Product	Demand	Modes
Ores	mf01	rnpofmhcx
Cereals	mf02	npofcx
Wood and derivatives	mf03	rfcx
	mf04	npofcx
	mf05	mhcx
Fresh & Frozen Food	mf06	rfcx
	mf07	npofcx
	mf08	mhcx
Miscellaneous	mf09	rnpofmhcx

\*\*\*\* Matrix deleted or modified \*\*\*\*

Generalized cost: 1\*(delay cost)

Stopping criteria: maximum number of iteration(s)= 4 gap= 0.50%

Number of iterations: 4 stopped by: iter

# Path Selection Dialog

- Common to all options
- Identify **assigned** product and matrix to be analyzed
- Reduce the number of paths considered
- Focus on most appropriate paths
- Sequence of questions:

## 1. **One** of the assigned products; list is given

Available assigned products:

1 Ores	2 Cereals	3 Wood and derivatives
4 Fresh & Frozen Food	6 Miscellaneous	

Enter: Product to be analyzed= **3**

## 2. **One** of the matrices specified for the selected product; the mode choice is automatically recalled

Available assigned demand for product 3:

mf03: WoodR	Wood+Products - Road (tons/week)	(rfc)
mf04: WoodT	Wood+Products - Train (tons/week)	(npofc)
mf05: WoodM	Wood+Products - Maritime Navig. (t/w)	(mhc)

Enter: Matrix to be analyzed= **mf05**

## Path Selection Dialog (2)

### 3. Reduction of number of OD pairs considered by means of usual dialog:

```
Constraint matrix
Enter: Matrix=mf05
mf05: WoodM /r Wood+Products - Maritime Navig. (t/w) (99-05-25 11:40)
Enter: Constraint interval ( 0, 0,exclude) =0.0,ex

Submatrix?y

Enter: Origins (from,to)
=24
=
  1 zones selected

Enter: Destinations (from,to)
=16
=
  1 zones selected

Up to 6 paths could be generated.
```

### 4. Estimated number of selected paths displayed: chance to reconsider!

```
Continue with selection?y
```

# Path Selection Dialog (3)

## 5. Select paths according to basic attributes

Consider paths with zero (partial) volumes?**y**

Enter: Lower, upper threshold for:

path length (-\*\*\*\*\*,\*\*\*\*\*)=

path generalized cost (-\*\*\*\*\*,\*\*\*\*\*)=

path generalized marginal cost (-\*\*\*\*\*,\*\*\*\*\*)=

## 6. Select path according to an **additional attribute**

Compute additional path attribute?**n**

# Additional Path Attribute

- Aggregation of
  - An user data or extra link attribute
  - An user data or extra transfer attribute
  - A link and a path attribute
- Aggregation through *binary* operator: **+**, **.min.**, **.max.**, ...
- Interval to restrict path access to analysis

`Enter: Lower,upper threshold(-*****,*****)=`

# Additional Path Attribute - Example

- Compute the unit transfer cost for the paths used to move Cereals (product 2) on rail (modes **n** and **p** - matrix **mf02**) from zone 55 to zone 27.
- The unit cost after assignment is copied to a transfer extra attribute
- The path additional attribute is computed by adding up the values of this transfer extra attribute for all transfers between n and p on the paths of the given OD pair.

## 6.31 ANALYSIS OF ASSIGNED PATHS

Project title: STAN STANDARD DEMONSTRATION AND TEST DATA BANK

Scen. 2001(--- A-): CANADIAN MULTIMODAL TRANSPORTATION NETWORK - PATH ANALYSIS

Mincost assignment: 99-05-22 10:40

Product	Demand	Modes
Ores	mf01	rnpofmhc
Cereals	mf02	npofc
Wood and derivatives	mf03	rfc
	mf04	npofc
	mf05	mhc
Fresh & Frozen Food	mf06	rfc
	mf07	npofc
	mf08	mhc
Miscellaneous	mf09	rnpofmhc

Generalized cost: 1\*(delay cost)

Stopping criteria: maximum number of iteration(s)= 5 gap= 0.50%

Number of iterations: 5 stopped by: iter



Enter: Destinations (from,to)

=27

=

1 zones selected

Up to 6 paths could be generated.

Continue with selection? y

Consider paths with zero (partial) volumes?n

Enter: Lower,upper threshold for:

path length (-\*\*\*\*\*,\*\*\*\*\*)=

path generalized cost (-\*\*\*\*\*,\*\*\*\*\*)=

path generalized marginal cost (-\*\*\*\*\*,\*\*\*\*\*)=

Compute additional path attribute?y

Enter: User data item (1, 2 or 3) or extra link attribute=

Enter: User data item (1, 2 or 3) or extra transfer attribute=@tp2np

T: @tp2np transfer cost between n and p 99-05-21 11:58

Aggregation over path components

Enter: Binary operator (+)= +

Enter: Lower,upper threshold (-\*\*\*\*\*,\*\*\*\*\*)=

Select: List device

1= Terminal

2= Printer

2

A N A L Y S I S O F A S S I G N E D P A T H S  
 \*\*\*\*\*

Scen. 2001(--- A-): CANADIAN MULTIMODAL TRANSPORTATION NETWORK - PATH ANALYSIS

Mincost assignment: 99-05-25 11:43  
 Product Demand Modes  
 Ores mf01 rnpofmhc  
 Cereals mf02 npofc  
 Wood and derivatives mf03 rfc  
 mf04 npofc  
 mf05 mhc  
 Fresh & Frozen Food mf06 rfc  
 mf07 npofc  
 mf08 mhc  
 Miscellaneous mf09 rnpofmhc

Generalized cost: 1\*(delay cost)  
 Stopping criteria: maximum number of iteration(s)= 5 gap= 0.50%  
 Number of iterations: 5 stopped by: iter

Analyzed product: 2 Cereals  
 Analyzed matrix and associated modes:  
 mf02: GrainT Demand - Train (tons/week) (npofc)

Constraint matrix: mf02: GrainT/r Demand - Train (tons/week) (99-05-21 13:17)  
 Constraint interval: 0 0 exclude  
 Submatrix: 1 origins 1 destinations

Paths with zero (partial) volume: excluded

Lower,upper threshold for:

path length= -\*\*\*\*\* \*\*\*\*\*  
path generalized cost= -\*\*\*\*\* \*\*\*\*\*  
path generalized marginal cost= -\*\*\*\*\* \*\*\*\*\*

Additional path attribute on transfers: @tp2np transfer cost between n and p

Binary operator for additional path attribute(s): +

Lower,upper threshold for additional path attribute(s): -\*\*\*\*\* \*\*\*\*\*

STAN Module: 6.31 Date: 99-05-22 14:58 User: E000/INRODEMO..TGC Page: 76  
Project: STAN STANDARD DEMONSTRATION AND TEST DATA BANK  
Scenario 2001: CANADIAN MULTIMODAL TRANSPORTATION NETWORK - PATH ANALYSIS

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No	from	to	iter	nlink	ntran	vol	len	cost	mcost	adatt
1	55	27	1	57	7	.015056	4301	98.78755	107.0554	.929231
2	55	27	2	46	5	.42534	4110	95.73432	105.3065	.557538
3	55	27	3	45	5	5.536621	4097	95.03233	104.2099	.557538
4	55	27	4	53	5	.312796	4046	94.40432	104.0016	.557538
5	55	27	5	42	3	11.28209	4027	93.67737	103.3154	.185846

# Output and Punch Paths - Path Attributes

- Number
- Origin and Destination
- Iteration (in assignment) when it was generated
- Number of links and transfers
- Partial volume
- Length
- Unit and marginal generalized costs
- Additional attribute

No	from	to	iter	nlink	ntran	vol	len	cost	mcost	adatt
1	55	27	1	57	7	.015056	4301	98.78755	107.0554	.929231
2	55	27	2	46	5	.42534	4110	95.73432	105.3065	.557538
3	55	27	3	45	5	5.536621	4097	95.03233	104.2099	.557538
4	55	27	4	53	5	.312796	4046	94.40432	104.0016	.557538
5	55	27	5	42	3	11.28209	4027	93.67737	103.3154	.185846

# Output and Punch Paths - Path Description

- Sequence of nodes
- Mode following a transfer

55	c	3369	n	3366	3343	3344	3342	3378	3368	p
3378		3317		3311	3349	2914	2932	2918	2929	
2994		2950		2920	2948	2947	3005	2986	n	3005
2945		2714		2712	2750	2746	2748	2739	p	2748
2169		2209		2166	2208	2223	2162	2159		2213
2153		2239		2222	n	2239	2149	2145		2188
2192		2193		2194		2142	2227	2229		2113
2216	c	27								p

55	c	3369	n	3327	3324	3334	3323	3336	3330
3378		3347		3345	2978	3002	2994	2980	2921
2953		2952		2997	2909	p	2997	2709	2743
2730		2750		2746	2748		2169	2209	2208
2223	n	2162		2206	2160		2211	2210	2239
2222	p	2239		2144	2196		2229	2216	c
								27	

55	c	3369	n	3327	3324	3334	3323	3336	3330
3378		3312		3348	2932	2929	2994	2960	2961
2989		2971		2964	2733	2743	2730	2750	2738
2750		2746		2748	2169	2209	2166	2208	2223
2162		2206		2160	2211	2210	2149	2239	n
2196		2194		2229	2113	p	2216	c	27

# Plot Assigned Paths

- One at a time
- Bare network may be plotted
- All graphic commands are available
- Origin and destination circled for enhanced visibility
- Example: Paths for Cereals moved from zone 40 to zone 28

# ANALYSIS OF ASSIGNED PATHS

**STAN**

**MODES:**

n - - - - - p - - - - -  
o . . . . . f - - - - -  
c - - - - -

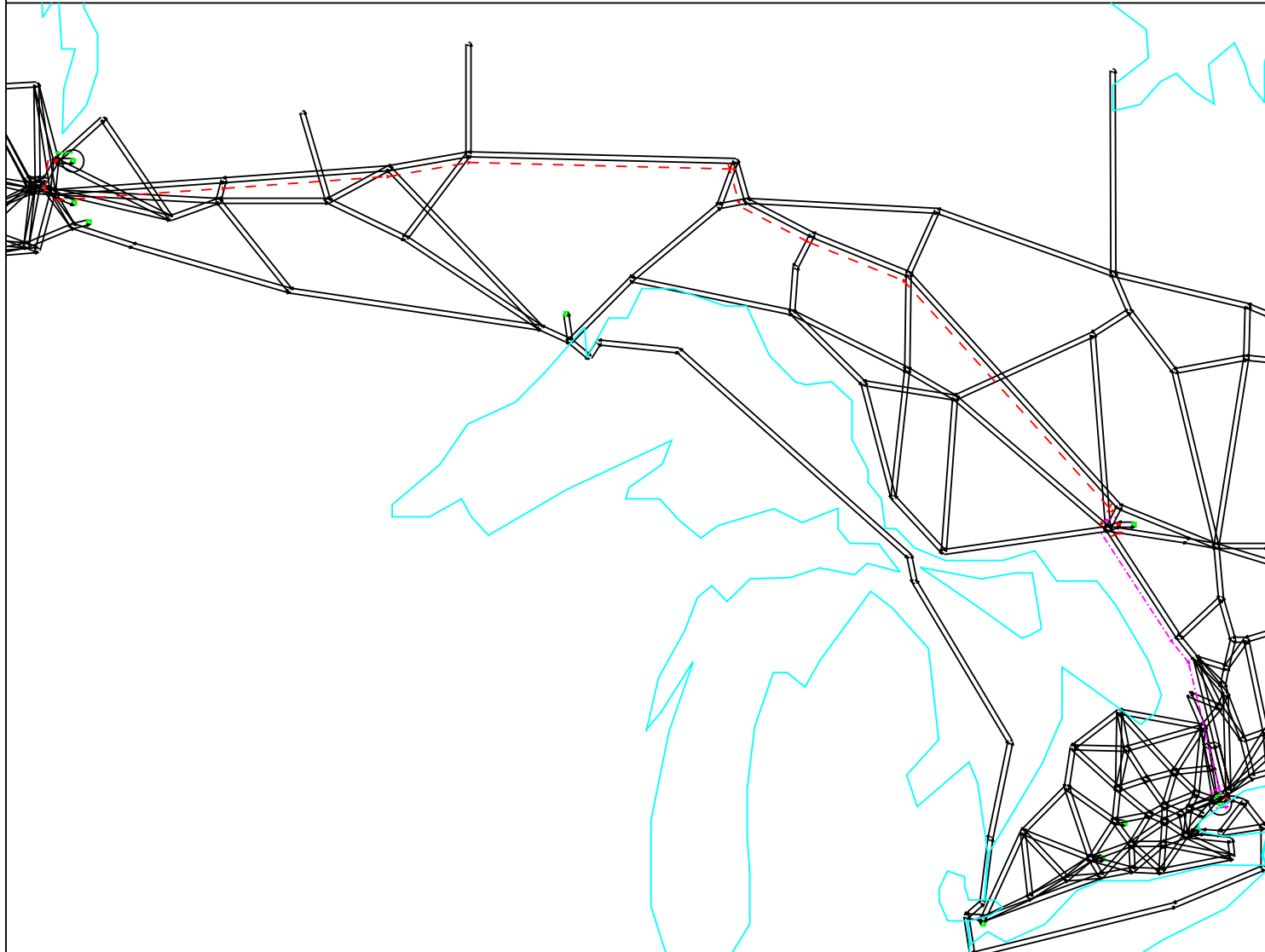
NO 1  
ITERATION 0  
PRODUCT 2  
MATRIX MF02

**CENTROID**  
FROM 40  
TO 28

NLINK: 19  
NTRAN: 3  
VOL: 0  
LEN: 1835  
COST: 44.95765  
MCOST: 51.52667

**WINDOW:**

82.323/46.2246  
101.42/60.5454



STAN PROJECT: STAN STANDARD DEMONSTRATION AND TEST DATA BANK  
SCENARIO 2001: CANADIAN MULTIMODAL TRANSPORTATION NETWORK - PATH ANALYSIS

99-05-22 17:45  
MODULE: 6.31  
INRODEMO...TGC

# ANALYSIS OF ASSIGNED PATHS

**STAN**

**MODES:**

n - - - - - p  
o . . . . . f  
c - - - - -

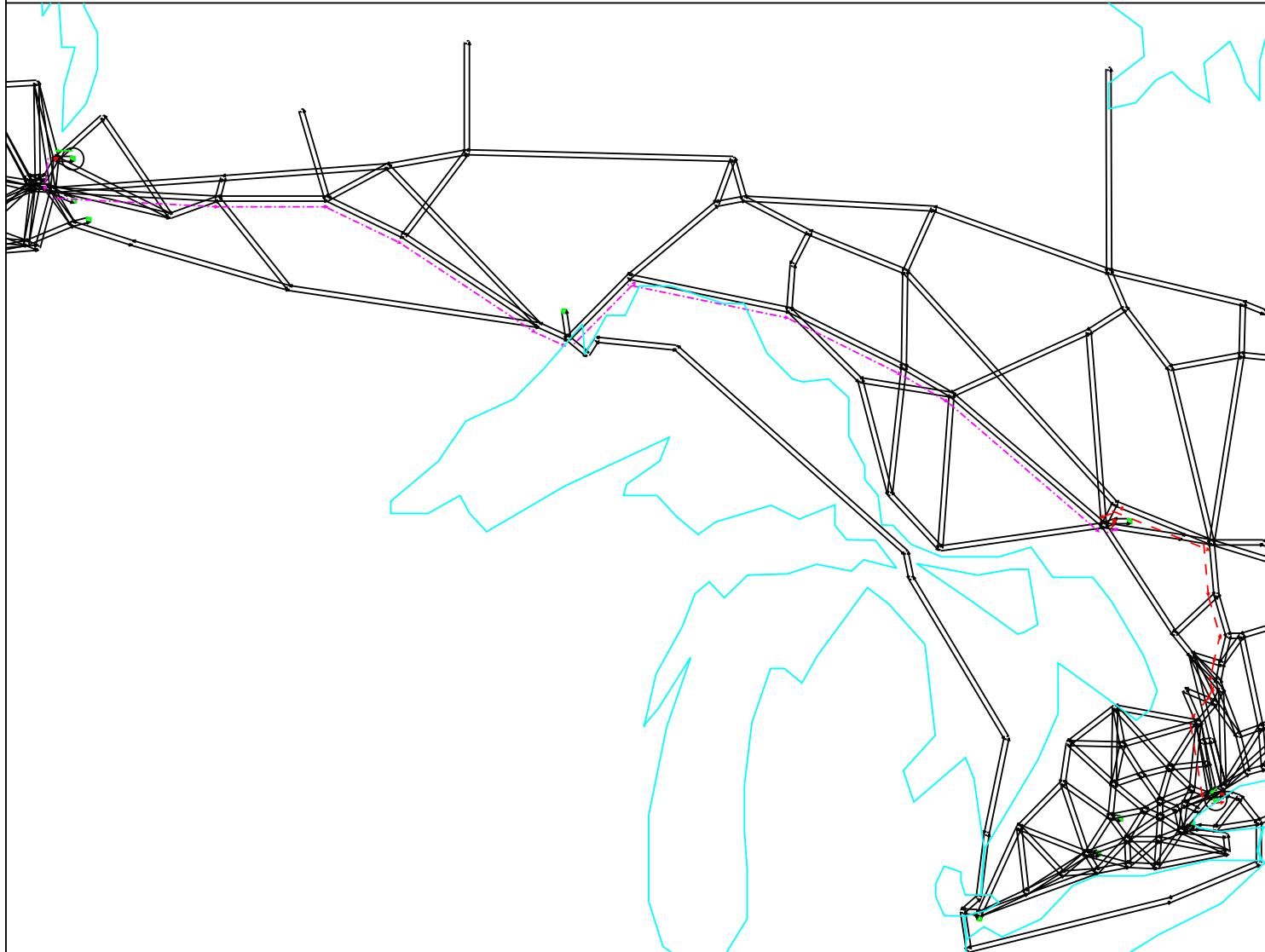
NO 2  
ITERATION 1  
PRODUCT 2  
MATRIX MF02

CENTROID  
FROM 40  
TO 28

NLINK: 26  
NTRAN: 3  
VOL: .304701  
LEN: 2134  
COST: 48.87038  
MCOST: 53.06273

**WINDOW:**

82.32/46.1463  
101.49/60.5237



STAN PROJECT: STAN STANDARD DEMONSTRATION AND TEST DATA BANK  
SCENARIO 2001: CANADIAN MULTIMODAL TRANSPORTATION NETWORK - PATH ANALYSIS

99-05-22 17:46  
MODULE: 6.31  
INRODEMO...TGC

# ANALYSIS OF ASSIGNED PATHS

**STAN**

**MODES:**

n - - - - - p  
o . . . . . f  
c - - - - -

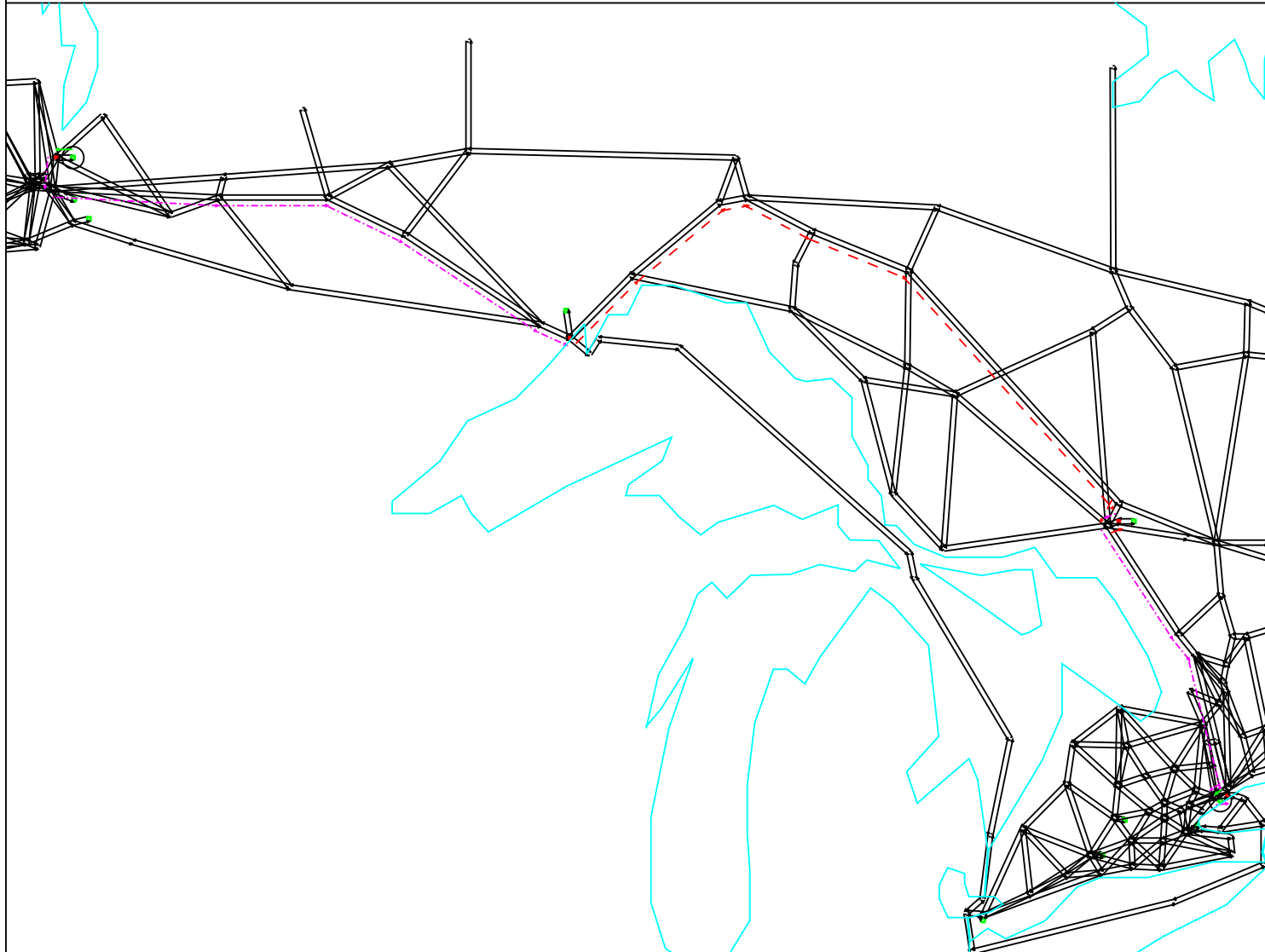
NO 3  
ITERATION 2  
PRODUCT 2  
MATRIX MF02

CENTROID  
FROM 40  
TO 28

NLINK: 22  
NTRAN: 4  
VOL: 8.608032  
LEN: 1965  
COST: 46.92439  
MCOST: 52.59539

**WINDOW:**

82.323/46.1746  
101.42/60.4954



STAN PROJECT: STAN STANDARD DEMONSTRATION AND TEST DATA BANK  
SCENARIO 2001: CANADIAN MULTIMODAL TRANSPORTATION NETWORK - PATH ANALYSIS

99-05-22 17:52  
MODULE: 6.31  
INRODEMO...TGC

# ANALYSIS OF ASSIGNED PATHS

**STAN**

**MODES:**

n - - - - - p  
o . . . . . f  
c - - - - -

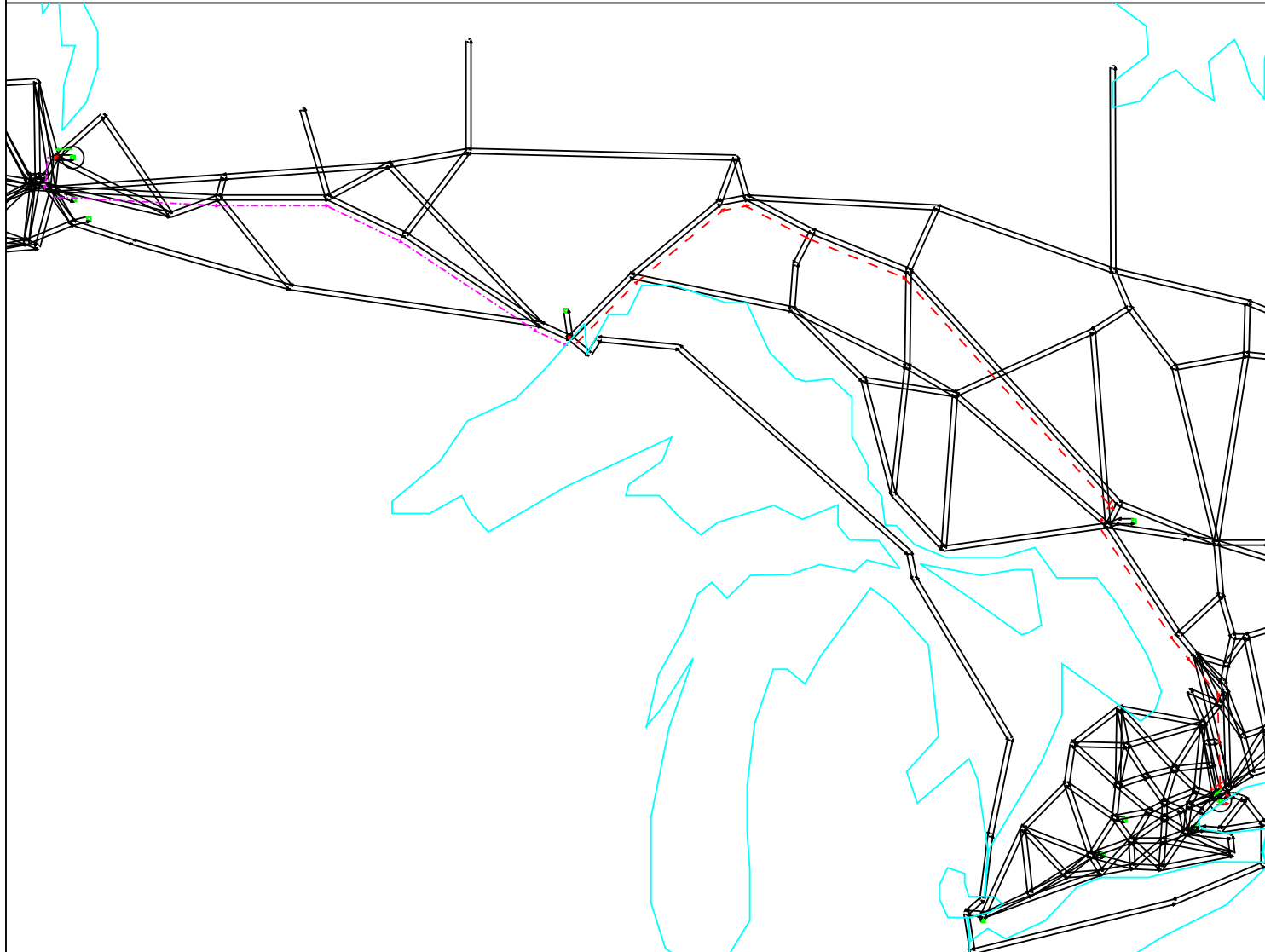
NO 4  
ITERATION 3  
PRODUCT 2  
MATRIX MF02

CENTROID  
FROM 40  
TO 28

NLINK: 21  
NTRAN: 3  
VOL: 112.0502  
LEN: 1967  
COST: 47.00239  
MCOST: 52.89521

**WINDOW:**

82.323/46.1746  
101.42/60.4954



STAN PROJECT: STAN STANDARD DEMONSTRATION AND TEST DATA BANK  
SCENARIO 2001: CANADIAN MULTIMODAL TRANSPORTATION NETWORK - PATH ANALYSIS

99-05-22 17:47  
MODULE: 6.31  
INRODEMO...TGC

# ANALYSIS OF ASSIGNED PATHS

**STAN**

**MODES:**

n - - - - - p  
o . . . . . f  
c - - - - -

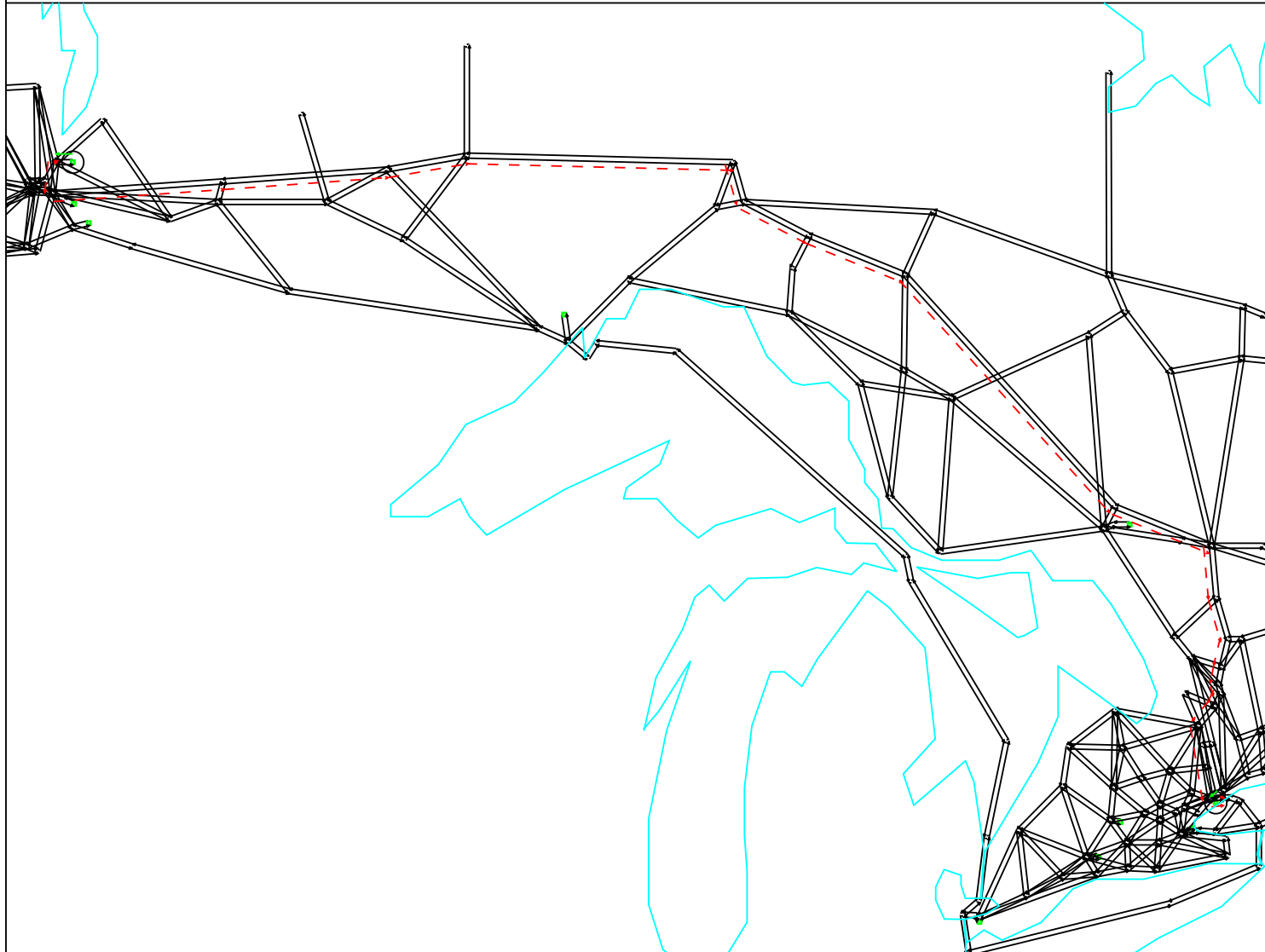
NO 5  
ITERATION 4  
PRODUCT 2  
MATRIX MF02

CENTROID  
FROM 40  
TO 28

NLINK: 21  
NTRAN: 2  
VOL: 6.330369  
LEN: 1896  
COST: 45.71387  
MCOST: 51.9592

**WINDOW:**

82.32/46.1963  
101.49/60.5737



STAN PROJECT: STAN STANDARD DEMONSTRATION AND TEST DATA BANK  
SCENARIO 2001: CANADIAN MULTIMODAL TRANSPORTATION NETWORK - PATH ANALYSIS

99-05-22 17:48  
MODULE: 6.31  
INRODEMO...TGC

# ANALYSIS OF ASSIGNED PATHS

**STAN**

**MODES:**

n - - - - - p - - - - -  
o - - - - - f - - - - -  
c - - - - -

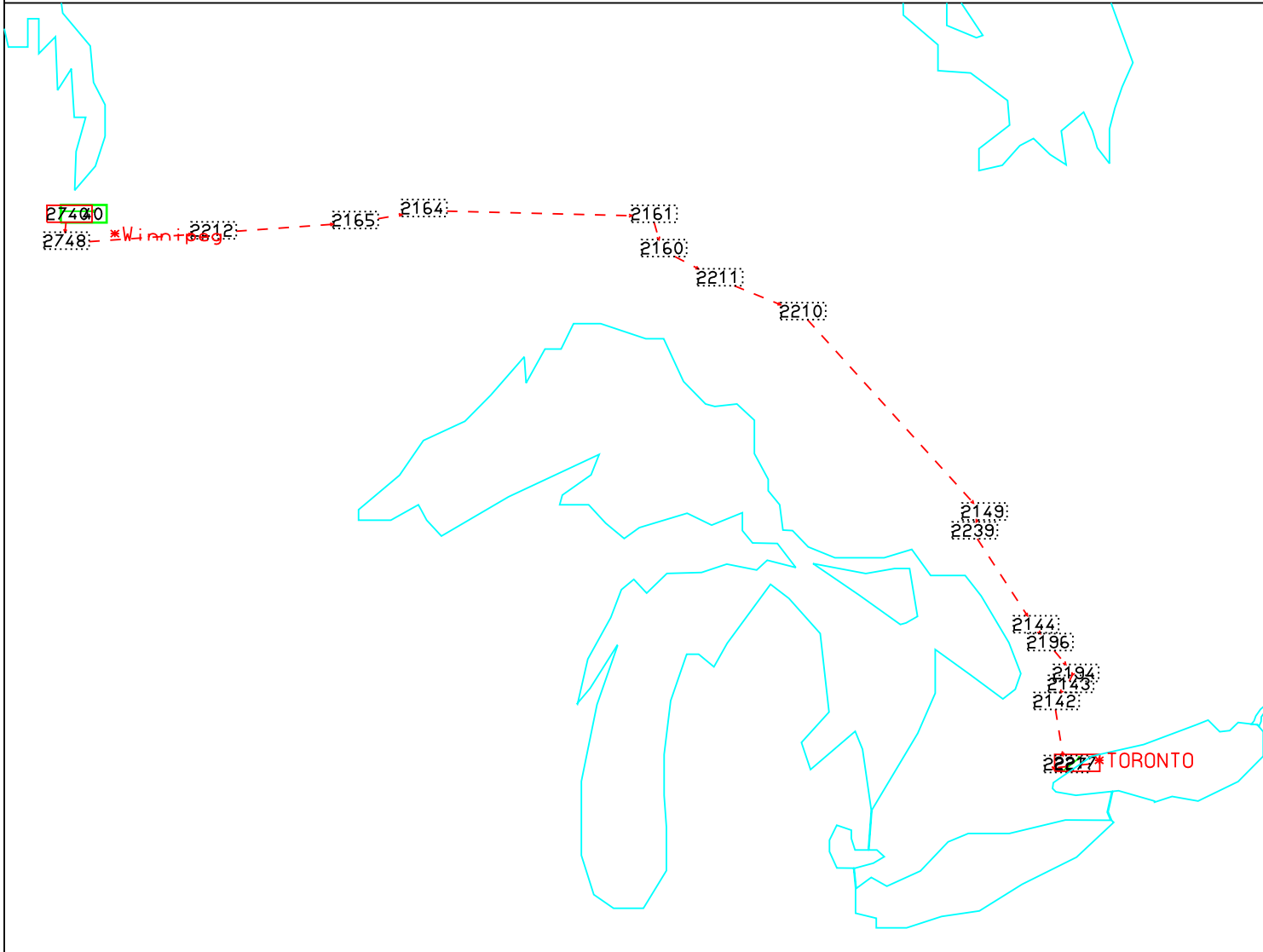
NO 6  
ITERATION 5  
PRODUCT 2  
MATRIX MF02

CENTROID  
FROM 40  
TO 28

NLINK: 19  
NTRAN: 2  
VOL: 228.327  
LEN: 1853  
COST: 45.17851  
MCOST: 51.7841

**WINDOW:**

81.94/45.2182  
104.12/61.8515



STAN PROJECT: STAN STANDARD DEMONSTRATION AND TEST DATA BANK  
SCENARIO 2001: CANADIAN MULTIMODAL TRANSPORTATION NETWORK - PATH ANALYSIS

99-05-22 17:50  
MODULE: 6.31  
INRODEMO...TGC

# Save Global Results

- **Active flows**
  - Partial volumes of the selected paths
  - Saved in link or transfers, or both, user-defined or extra attribute
- **Active demand**
  - Demand actually assigned on the selected paths
  - Saved in full **mf**-type matrix
- Values of additional path attribute
  - Saved in full **mf**-type matrix
  - Four combination options
    - *Weighted sum*: Each path attribute multiplied by its path proportion;  
Yields average attribute value of selected paths for the OD pair
    - *Sum of attribute weighted by path volume* = Total attribute value
    - *Minimum value*
    - *Maximum value*

# Global Results - Applications

- Select element (link, transfer) analysis
- Partial demand matrices
- Particular path-related measures, e.g. travel time matrices
- Implementation of various procedures: *demand matrix adjustment*
- ...
- General method
  - Mark desired links/transfers = additional attribute
  - Aggregate into path additional attribute and Select
  - Aggregate and Save into additional attribute matrix
  - Save volumes: links, transfers, matrix

# Example 1

Select the paths used to move Ores (product 1, matrix **mf01**) from all origins to Victoria (zone 62) by using the ferry (mode f) from Vancouver (node 3748) to Nanaimo (node 3726)

- Mark link 3748 f 3726: **@mark1 = 1**
- Perform path analysis - Save global results
  - product 1
  - matrix **mf01**
  - origins: all; destinations: 62
  - additional path attribute: **@mark1**
  - threshold: 1,1  $\Leftarrow$  Only paths that include the ferry link are retained
  - save volumes in **@pvoll** and **@pvolt**

## 2.41 NETWORK CALCULATIONS

```
Select: 1= network calculations and mode set changes
        2= copy network attribute from other scenario
        3= input network attribute using batch entry
        4= change module parameters
        5= end
        1
```

Save result?**y**

Enter: Attribute to save result in=**@mark1**

L: **@mark1**

99-05-25 13:38

Change description of attribute '@mark1'?n

Available attributes:

I: i xi yi ui1 ui2 ui3

J: j xj yj uj1 uj2 uj3

K: k xk yk uk1 uk2 uk3

BL: ub1 ub2 ub3

...

Enter: Expression to calculate @mark1

=1

=

@mark1 = 1

Enter: Mode(s)=f

Enter: Selected link types or attributes (from, to)

=i=3748

=and j=3726

=

Select: Type of output to be generated

1= full report

2= summary report

3= punch

4= none

5= save summary in scalars

4

Allocated memory buffer space: 3580 (max. 499810)

Number of expression evaluations: 1 (link)

Number of result values obtained: 1 (link)

Number of attribute values changed: 1

Minimum result value: 1.00000 at link 3748 3726 f

Maximum result value: 1.00000 at link 3748 3726 f

Sum of result values: 1.00000

Average result value: 1.00000

### 6.31 ANALYSIS OF ASSIGNED PATHS

Project title: STAN STANDARD DEMONSTRATION AND TEST DATA BANK

Scen. 2001(--- A-): CANADIAN MULTIMODAL TRANSPORTATION NETWORK - PATH ANALYSIS

Mincost assignment: 99-05-25 11:43

Product	Demand	Modes
Ores	mf01	rnpofmhc
Cereals	mf02	npofc
Wood and derivatives	mf03	rfc
	mf04	npofc
	mf05	mhc
Fresh & Frozen Food	mf06	rfc
	mf07	npofc
	mf08	mhc
Miscellaneous	mf09	rnpofmhc

Generalized cost: 1\*(delay cost)

Stopping criteria: maximum number of iteration(s)= 5 gap= 0.50%

Number of iterations: 5 stopped by: iter

Select: 1= output assigned paths  
2= punch assigned paths  
3= plot assigned paths  
4= save global results  
5= change module parameters  
6= end

4

Available assigned products:

1 Ores	2 Cereals	3 Wood and derivatives
4 Fresh & Frozen Food	6 Miscellaneous	

Enter: Product to be analyzed= 1

Available assigned demand for product 1:

mf01: TOres Demand for Ores (total for all modes) (rnpofmhc)

Enter: Matrix to be analyzed= mf01

Constraint matrix

Enter: Matrix=**mf01**

mf01: TOres /r Demand for Ores (total for all modes) (99-05-21 10:40)

Enter: Constraint interval ( 0, 0,exclude) =**0,0,ex**

Submatrix?**y**

Enter: Origins (from,to)

=**all**

91 zones selected

Enter: Destinations (from,to)

=**62**

=

1 zones selected

Up to 546 paths could be generated.

Continue with selection?**y**

Consider paths with zero (partial) volumes?**n**

Enter: Lower,upper threshold for:

path length (-\*\*\*\*\*,\*\*\*\*\*)=

path generalized cost (-\*\*\*\*\*,\*\*\*\*\*)=

path generalized marginal cost (-\*\*\*\*\*,\*\*\*\*\*)=

Compute additional path attribute?**y**

Enter: User data item (1, 2 or 3) or extra link attribute=**@mark1**

L: @mark1

99-05-25 13:39

Enter: User data item (1, 2 or 3) or extra transfer attribute=

Aggregation over path components

Enter: Binary operator (+)=**+**

Enter: Lower,upper threshold (-\*\*\*\*\*,\*\*\*\*\*)=**1,1**

Matrix to hold additional path attribute

Enter: Matrix( mf )=

Save link/transfer/O-D path volumes?**y**

Link attribute to hold path volumes

Enter: User data item (1, 2 or 3) or extra link attribute=**@pvoll**

L: @pvoll 99-05-21 10:48

Change description of attribute '@pvoll'?**y**

Enter: Description (max. 40 chars)=**Path Ore volumes to Victoria by ferry**

Transfer attribute to hold path volumes

Enter: User data item (1, 2 or 3) or extra transfer attribute=**@pvolt**

T: @pvolt 99-05-21 10:48

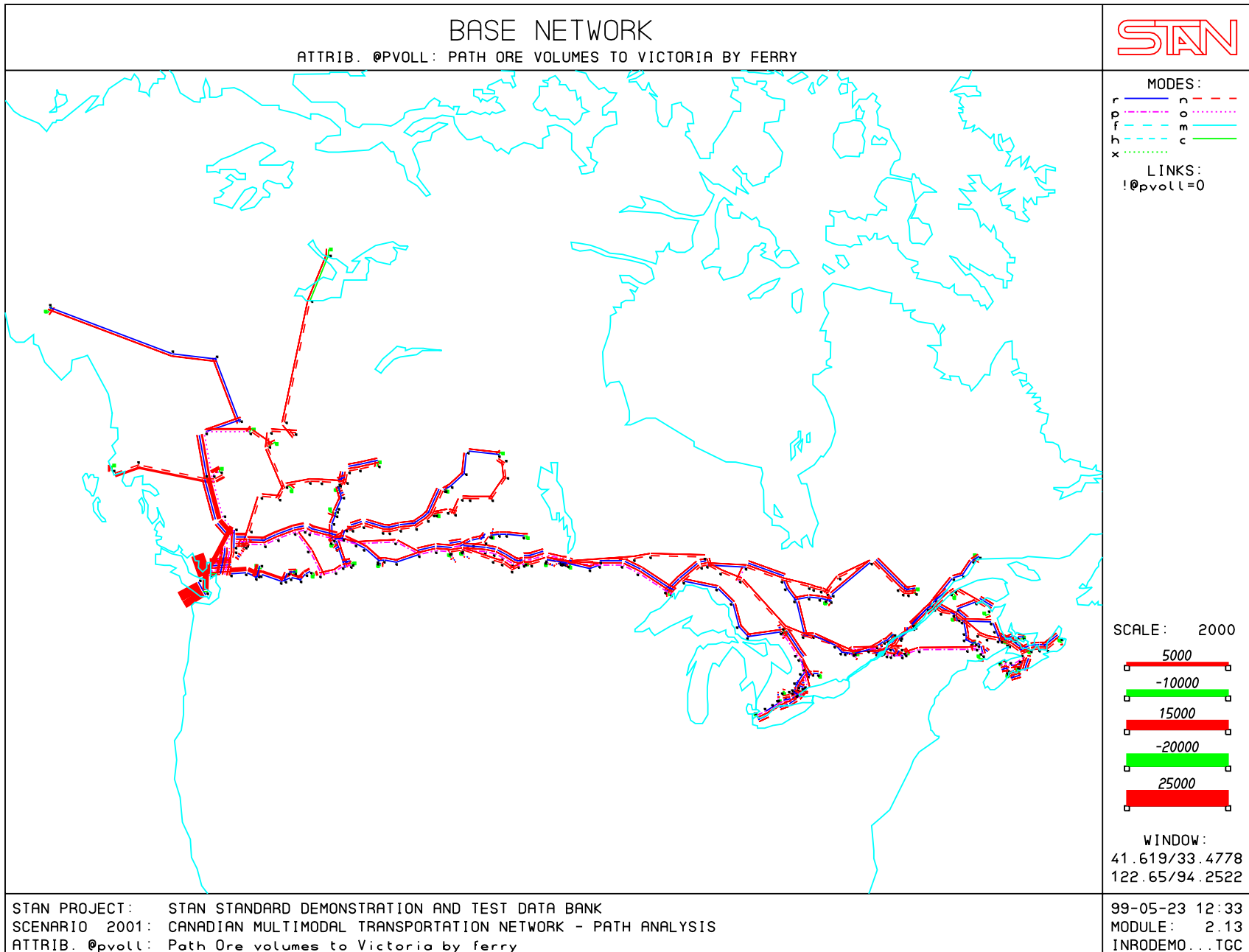
Change description of attribute '@pvolt'?**y**

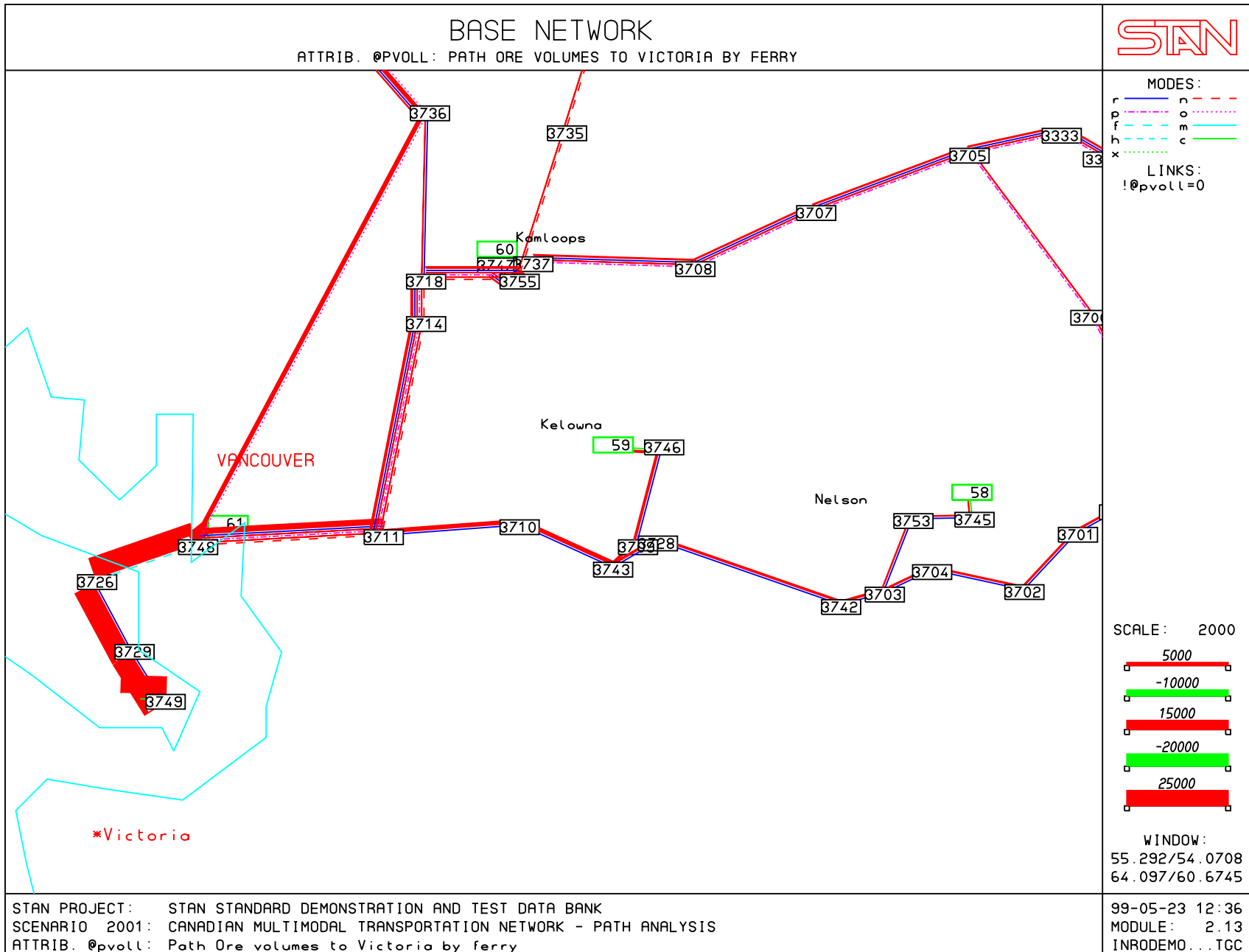
Enter: Description (max. 40 chars)=**Path Ores to Victoria: Transfer to ferry**

Matrix to hold active demand

Enter: Matrix( mf )=

Generating paths for iteration 0...  
Generating paths for iteration 1...  
Generating paths for iteration 2...  
Generating paths for iteration 3...  
Generating paths for iteration 4...  
Generating paths for iteration 5...



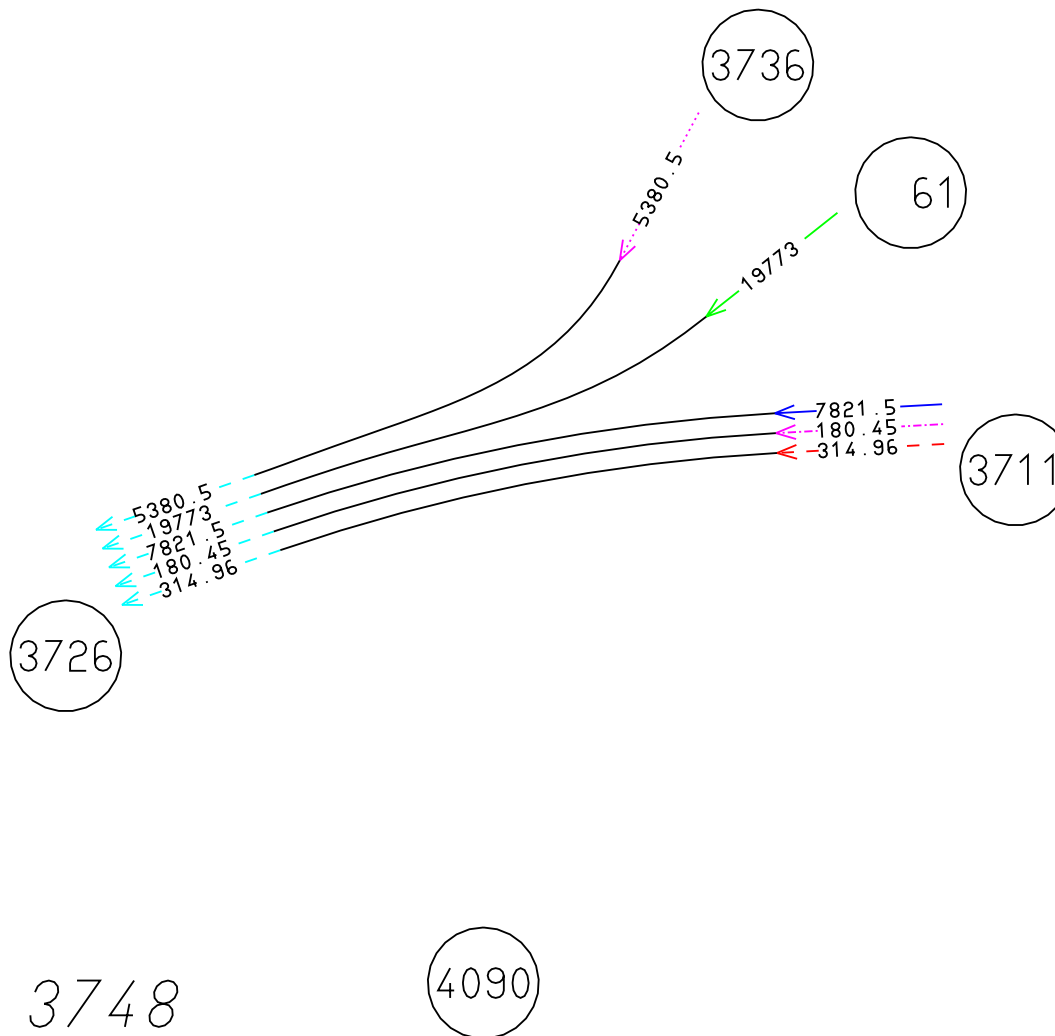


TRANSFER NODES  
 TRANSFERS BETWEEN MODES (ATTRIBUTE @PVOLT)



MODES:  
 r ——— n ———  
 p ——— o ———  
 f ——— m ———  
 h ——— c ———  
 x ———  
 TRANSFERS:  
 j=3748  
 &!@pvolt=0  
 & modn=f

OFFSET: 12



STAN PROJECT: STAN STANDARD DEMONSTRATION AND TEST DATA BANK  
 SCENARIO 2001: CANADIAN MULTIMODAL TRANSPORTATION NETWORK - PATH ANALYSIS  
 ATTRIB. @pvolt: Path Ores to Victoria: Transfer to ferry

99-05-23 12:53  
 MODULE: 2.23  
 INRODEMO...TGC

## Example 2

Compute, for each OD pair, the total transfer cost of moving Cereals (product 2, matrix **mf02**) by rail (modes **n** and **p**) from zones in Alberta (**ga09**) to zones in Ontario (**ga06**)

- Mark the transfers between modes **n** and **p** with the unit transfer cost of product 2:  
**@markt = c2t**
- Perform path analysis - Save global results
  - product 2
  - matrix **mf02**
  - origins: **ga09**; destinations: **ga06**
  - additional path attribute: **@markt**
  - threshold: 0,999999  $\Leftarrow$  all paths that include **n $\leftrightarrow$ p** transfers
  - save additional path attribute in matrix **mf15** by using the *sum of attributes weighted by path volumes* option

## 2.41 NETWORK CALCULATIONS

Select: 1= network calculations and mode set changes  
2= copy network attribute from other scenario  
3= input network attribute using batch entry  
4= change module parameters  
5= end  
1

Save result?**y**

Enter: Attribute to save result in=**@markt**

**T: @markt**

99-05-25 14:14

Change description of attribute '@markt'?**n**

Available attributes:

I: i xi yi ui1 ui2 ui3

J: j xj yj uj1 uj2 uj3

K: k xk yk uk1 uk2 uk3

BL: ub1 ub2 ub3

...

Enter: Expression to calculate @markt

**=c2t**

=

@markt = c2t

Enter: Mode(s)=**np**

Enter: Selected transfer nodes or attributes (from, to)

=mod=n

=and modn=p

=new mod=p

=and modn=n

=or set1=1

=?

Current set contains 206 transfers, selected by:

- 1: mod=n
- 2: & modn=p
- 3: [ mod=p
- 4: & modn=n
- 5: | set1=1

Continue transfer selection:

=

Select: Type of output to be generated

1= full report

2= summary report

3= punch

4= none

5= save summary in scalars

4

Allocated memory buffer space: 4056 (max. 499810)

Number of expression evaluations: 206 (transfer)

Number of result values obtained: 206 (transfer)

Number of attribute values changed: 206

Minimum result value: 0.18585 at transfer 1305 1300 n 1325 p

Maximum result value: 19.00000 at transfer 1765 1759 n 1779 p

Sum of result values: 113.54066

Average result value: 0.55117

### 6.31 ANALYSIS OF ASSIGNED PATHS

Project title: STAN STANDARD DEMONSTRATION AND TEST DATA BANK

Scen. 2001(--- A-): CANADIAN MULTIMODAL TRANSPORTATION NETWORK - PATH ANALYSIS

Mincost assignment: 99-05-25 11:43

Product	Demand	Modes
Ores	mf01	rnpofmhc
Cereals	mf02	npofc
Wood and derivatives	mf03	rfc
	mf04	npofc
	mf05	mhc
Fresh & Frozen Food	mf06	rfc
	mf07	npofc
	mf08	mhc
Miscellaneous	mf09	rnpofmhc

Generalized cost: 1\*(delay cost)

Stopping criteria: maximum number of iteration(s)= 5 gap= 0.50%

Number of iterations: 5 stopped by: iter

Select: 1= output assigned paths  
2= punch assigned paths  
3= plot assigned paths  
4= save global results  
5= change module parameters  
6= end

4

Available assigned products:

1 Ores	2 Cereals	3 Wood and derivatives
4 Fresh & Frozen Food	6 Miscellaneous	

Enter: Product to be analyzed= 2

Available assigned demand for product 2:

mf02: GrainT Demand - Train (tons/week) (npofc)

Enter: Matrix to be analyzed= mf02

```

Constraint matrix
Enter: Matrix=mf02
mf02: GrainT/r Demand - Train (tons/week) (99-05-25 11:40)
Enter: Constraint interval ( 0, 0,exclude) =0,0,ex

Submatrix?y

Enter: Origins (from,to)
=ga09
=
8 zones selected

Enter: Destinations (from,to)
=ga06
=
9 zones selected

Up to 432 paths could be generated.
Continue with selection?y

Consider paths with zero (partial) volumes?n

Enter: Lower,upper threshold for:
path length (-*****,*****)=
path generalized cost (-*****,*****)=
path generalized marginal cost (-*****,*****)=

Compute additional path attribute?y

Enter: User data item (1, 2 or 3) or extra link attribute=

Enter: User data item (1, 2 or 3) or extra transfer attribute=@markt
T: @markt 99-05-25 14:14

Aggregation over path components
Enter: Binary operator (+)=+

Enter: Lower,upper threshold (-*****,*****)=0,999999

```

Matrix to hold additional path attribute

Enter: Matrix( mf )=**mf15**

mf15 not initialized.

Do you want to initialize it?y

Enter: Name (6 char)=**tcp2np**

Enter: Description (max 40 char)=**Total tran. cost p2 between n and p**

Enter: Default value=**0**

mf15 header modified

mf15 initialized

Select: Type of path attribute combination operation

1= weighted sum

2= sum of attributes weighted by path volumes

3= minimum value

4= maximum value

**2**

Save link/transfer/O-D path volumes?**n**

Matrix to hold active demand

Enter: Matrix( mf )=

Generating paths for iteration 0...

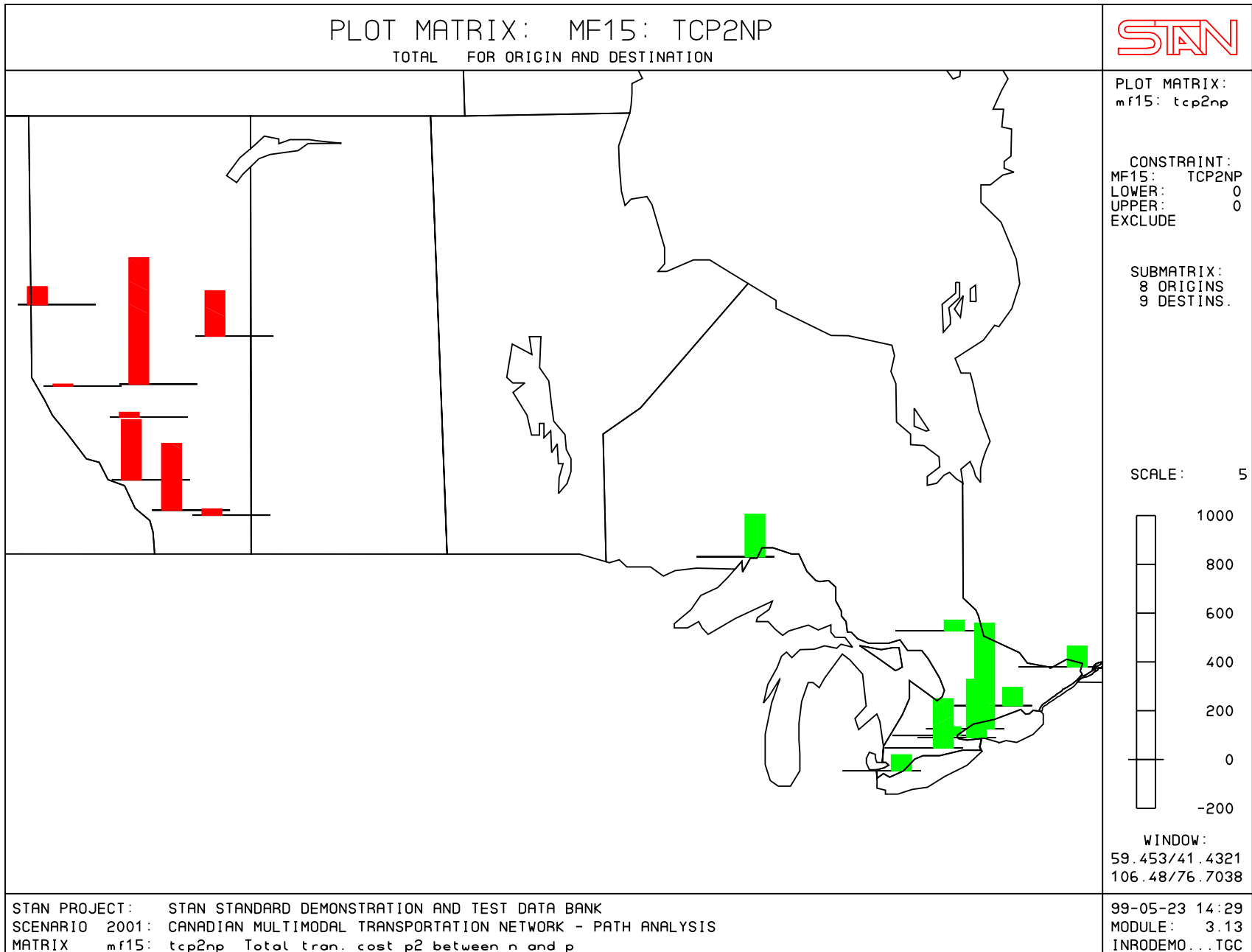
Generating paths for iteration 1...

Generating paths for iteration 2...

Generating paths for iteration 3...

Generating paths for iteration 4...

Generating paths for iteration 5...



# The Demand Adjustment Issue

- Modify the values of an O-D demand matrix such that link and transfer assigned flows be as close as possible to *observed* flows
- Do not modify the demand matrix “too” much
- Several efforts in passenger-related context
- Procedure and efficient EMME/2 implementation (Spiess, 1990)
  - Minimize differences “observed - predicted volumes”
  - Steepest descent-like algorithm
  - Additional Options assignments - the DEMADJ macro

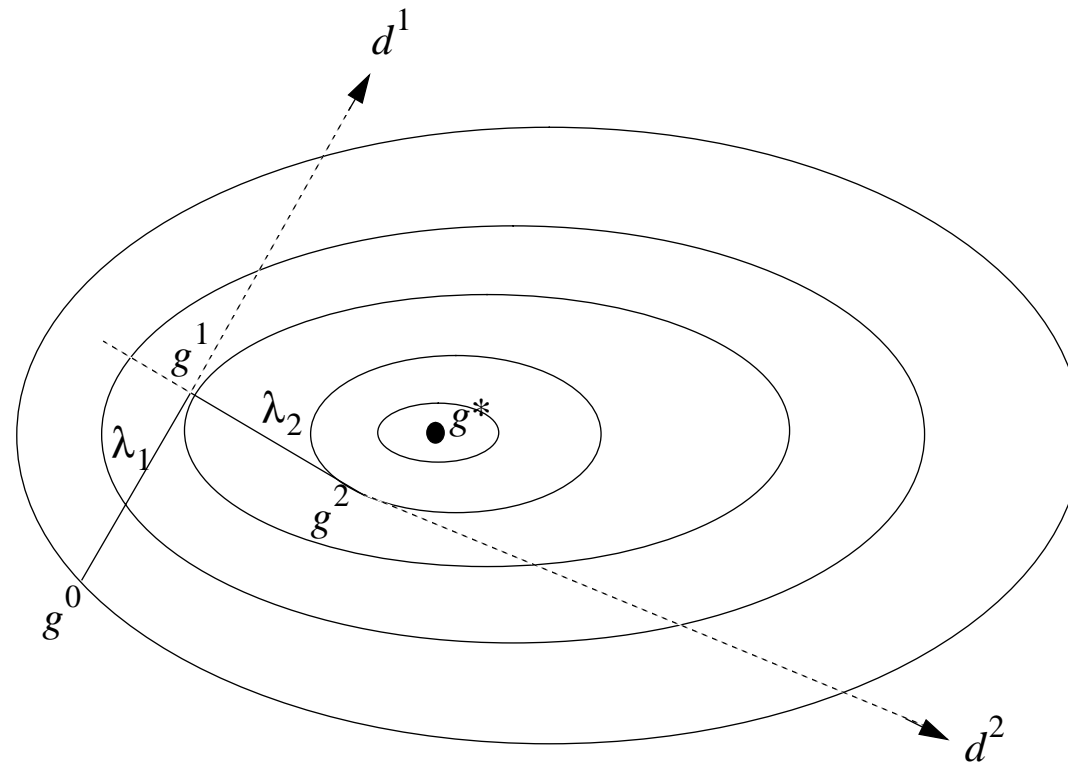
# The Freight Demand Adjustment Problem

- Several products
  - Several matrices for a product (mode choice)
  - Observations
    - by product: at entry/exit inspection stations, for example
    - aggregated: vehicle counts
  - In congested networks, products interact on links and transfers
- ⇒ Need to adjust matrices **simultaneously**

# Multicommodity Demand Matrix Adjustment

- Minimizes an objective based on differences between
  - initial and adjusted product matrices
  - observed and predicted link and transfer product volumes
- Steepest descent-like algorithm - Iteration
  - Solve assignment with current demand matrices
  - Stop ?
  - Compute (gradient and) *improving (descent) direction*
  - Compute *step length*
  - Adjust matrices:  $\text{new} = \text{current} + \text{step length} * \text{direction}$

# Descent Algorithm Idea



$$g^1 = g^0 + \lambda_1 d^1$$

$$g^2 = g^1 + \lambda_2 d^2$$

...

# Implementation

- Generally difficult  $\Leftarrow$  Explicit path proportions
- Rather easy using STAN Path Analysis capabilities
- Each iteration of the descent method:
  - One assignment: link and transfer volumes, path proportions
  - One path analysis for each (product) demand matrix: direction
  - One path analysis for each (product) descent direction matrix: step length
  - A number of network and matrix calculations

# Matrix Adjustment Cases

- Observed volumes for one product only
- Individual observed volumes for a group of products
- Aggregated observed volumes (vehicle counts) for a group of products
- ...
- Similar implementations
- Subsets of origins and destinations may be specified
  - e.g., Electronic tags/transponders may identify import/export vehicles and cargo

# One Product Procedure

## Initialization

- Assign with initial demand matrix  $g^{p0}$  (and all the appropriate matrices for the other products) saving the path information.
- Mark links and transfers with observed volumes
- $k = 1$

## Main Iteration

Given  $g^{pk}$ , predicted link and transfer volumes, and path proportions from the previous iteration

- For each marked link and transfer
  - Compute the predicted - observed differences
  - Save the result in a link and transfer extra attribute (**@diff**)
- Perform a path analysis for matrix  $g^{pk}$ 
  - **@diff** as additional path attribute
  - Save the values of the additional path attributes in a weighted active demand matrix
- Use the Matrix Calculator to
  - Compute gradient and descent direction  $d^{pk}$
  - Verify stopping criterion

- Perform a path analysis for matrix  $d^{pk}$ 
  - **@diff** as additional path attribute
  - Save link and transfer volumes
- Use the Network and Matrix Calculators to compute step length  $\lambda^{pk}$
- Use Matrix Calculator to update matrix:  $g^{p(k+1)} = g^{pk} + \lambda^{pk} d^{pk}$ ;  $k = k + 1$
- Assign with demand matrix  $g^{pk}$ , saving the path information